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Part IV - Aquaculture Development Trends

Foreword

The Network of Aquaculture Centres in Asia-Pacific (NACA) and the Food and Agriculture Organization of the United Nations (FAO) are pleased to make widely available Aquaculture in the Third Millennium, the Technical Proceedings of the Conference on Aquaculture in the Third Millennium. It is the third major report from the Conference; the others are the Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000 that was published in April 2000 and the Report of the Conference, published in December 2000. As with the previous two reports, these Technical Proceedings are available on the Websites of NACA and FAO.

Together, the three reports present a potent source of knowledge of the past, present and future status of world aquaculture, in-depth discussion of experience and ideas on how to reach the desired goals for the future of aquaculture, and inspiration to achieve this potential. Preparing and organizing the Conference was an undertaking buoyed significantly by the enthusiasm and cooperation that marked everyone's efforts and input on an international scale.

The Conference was held in actions suggested in the Bangkok Declaration and Strategy. Among the tasks achieved was the formulation of NACA's Work Programme for 2001-2005, which incorporates salient recommendations of the Declaration and Strategy. Likewise, FAO convened a meeting at its regional headquarters in Asia-Pacific immediately after the Conference. This included aquaculture experts from many parts of the world, who proposed constitution of a sub-committee on aquaculture within the FAO Committee on Fisheries (COFI), and outlined ways to implement the Conference recommendations, particularly those with inter-regional implications.

These modest first steps are intended to pave the way for many more initiatives to be taken to get the objectives outlined in the Bangkok Strategy "on the road" and "into the water". In the one-year period during which these Technical Proceedings were being edited, many more steps have been initiated. As with the implementation of the Millennium Conference, NACA and FAO, in cooperation with other concerned organizations, institutions and agencies, have started to forge ahead to assist aquaculture

Bangkok between 20-25 February, 2000, and generously hosted by the Government of Thailand with major support from six organizations and agencies whose names and corporate logos appear on the back cover of this and the previous two publications. In addition to our official hosts and supporting agencies, many others, too numerous to mention individually, helped in countless heartwarming ways. We reiterate our deep appreciation for all the assistance given by each and every person, group and organization that enabled the Conference to be held successfully, and are grateful to everyone who took part. Your participation made it possible to achieve its immediate purpose of launching the pursuit of the long-term objectives outlined throughout these Technical Proceedings.

Regardless of the length of time it may take to realize our goals for aquaculture in the third millennium, the journey starts with the first step. NACA and FAO have taken those initial steps. The day after the Conference, Asian government representatives to the Governing Council of NACA met to map the immediate and long-term stakeholders, especially the governments and people who depend on aquaculture for their livelihoods, to achieve the social, economic and environmental sustainability goals embodied in the Bangkok Declaration and Strategy. Our optimism, that these goals are realistic and attainable, is firmly founded on the dedication and drive shown by all sectors involved: farmer cooperatives and agencies, regulators, policymakers and planners, scientists, workers of non-governmental organizations, and other aquatic resource users. This optimism is further reinforced by a new wave of international collaboration, which clearly reflects increased recognition that sustainable use of our aquatic resources can only be achieved through vigorous and combined efforts.

These Technical Proceedings reflect this unity of effort. They also emphasize the openness of communication, singularity of purpose, and wisdom to adapt to dynamic aquatic systems and social conditions. It will be this flexibility, guided by principles founded on the common good, that will allow us to make optimal and sustained use of the aquatic environment, to which we are linked and on which we, and all who follow us, depend.

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From the Editors

We, the editors of Aquaculture in the Third Millennium, the Technical Proceedings of the Conference on Aquaculture in the Third Millennium, would like to acknowledge the tremendous undertaking - and satisfaction - that this responsibility entailed for both the authors and us. Concept to compilation took a mere two years, but this final product embodies years of experience and a vast range of expertise on the part of all contributors. An "Advance Copy" was produced for limited pre-publication circulation at the 24th Session of the Food and Agriculture of the United Nations (FAO) Committee on Fisheries (COFI) meeting in Rome, from 26 February to 02 March 2001. Following one more proof and style review, this final document was published in June 2001.

The Editorial Team was faced with the task of compiling information and manuscripts submitted by the authors, in many cases comprising writing teams whose members are working in various parts of the world. Editorial style was based on standard FAO editorial guidelines, however, Keynote Addresses and some Plenary Lectures are published as submitted, due to the narrative presentation of the talks given at the Conference. The Every effort was made to protect the sense and opinions expressed by the author(s), and editorial changes and questions were made in consultation with them. Every manuscript has been proofed by its authors or at least by the senior author. We thank everyone for their prompt and gracious responses to the numerous, repeated and often insistent requests for more information or clarification. Despite the close and repeated scrutiny described above, however, errors may still emerge for which we, the editors, take full responsibility and apologize in advance.

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Thematic Reviews were edited for language, style and technical consistency. The Regional Reviews and the Global Synthesis were subjected to the same editorial review, in addition to standardising production data and statistical presentations. Tables, figures and graphs were also standardized for better visual quality and ease of comparison. Production figures and analytical methods were based on FAO FishStat Plus Version 2.3 (2000)1. The editors were assisted in this task by many staff at FAO Fisheries Department and the Network of Aquaculture Centres in Asia-Pacific (NACA). Significant acknowledgement is due to: Uwe Barg, Devin Bartley, Matthias Halwart, Jiansan Jia, Manuel Martinez, John Moehl, Melba Reantaso and Zhou Xiaowei. Felix Marttin of FAO Fisheries Department helped with producing standardized graphs, tables, and figures. Juancarlos Trabucco helped in page formatting. The cover page was designed by Delfin Laforteza and the credit for final page formatting, layout design and desktop publishing goes to Sylviane Borghesi of the Inland Water Resources and Aquaculture Service (FAO/FIRI).

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Introduction

These Technical Proceedings represent the most comprehensive and authoritative review assembled to date of the status of aquaculture development in the world. This volume, the third major publication arising from the Conference on Aquaculture in the Third Millennium, contains the information essential to conduct well-informed discussion of sustainable aquaculture development - both at the Conference, as well as after. The conclusions and recommendations were derived from the following discussion fora:

- ***Two keynote papers***, one reviewing the progress of aquaculture since 1976, when the first technical conference on aquaculture was held in Kyoto, and one looking ahead to where sustainable aquaculture should be in 20 years time, including possible ways to get there;
- ***One global review*** of the status, progress and future role of aquaculture;
- ***Nine regional aquaculture development trends and reviews***, including one dedicated to China, which provided the basis for the global review;
- ***Five plenary lectures***
- the regional workshop to formulate the Asian aquaculture development strategy for 2000-2020 conducted by the Network of Aquaculture Centres in Asia-Pacific (NACA) in September 1999;
- the review of South Pacific aquaculture by the Secretariat of the Pacific Community (SPC), with the assistance of the International Center for Living Aquatic Resources Management (ICLARM);
- the reviews on the state of, and trends in, aquaculture development in six other regions, facilitated and conducted by FAO with the participation of various regional organizations;
- the review of Chinese aquaculture developed by the Bureau of Fisheries of China (BFC) with inputs from various centres under the Chinese Academy of Fishery Sciences (CAFS), as well as the NACA Secretariat;
- fourteen specialized expert-led thematic reviews;
- a workshop on regional reviews and global synthesis of trends in aquaculture development, held at the FAO Regional Office in Asia-Pacific in October 1999;

providing the information settings for the thematic and technical reviews; and

- ***Fourteen thematic (policy-related and production-based) reviews.***

These all provide basic reference points on the progress, direction and magnitude of aquaculture changes, and the factors associated with these changes, within global, regional, sectoral, thematic and technical perspectives. As a collective, these offer a holistic view, thorough analyses and multi-dimensional perspectives on the progress of aquaculture, upon which stakeholders can base decisions for future development requirements.

The reviews were prepared in various fora by individuals or groups of expert authorities. The intensive preparatory work included: organization of expert consultations, national studies and workshops; regional workshops; and an international expert meeting that refined the draft regional reviews and initiated the development of the global synthesis on trends in aquaculture development. Specifically, these included:

- the preparation of the two keynote papers, the first by Dr T.V.R. Pillay, who was the architect of the Kyoto Aquaculture Conference of 1976, the second by Mr Jiansan Jia, Chief of the Inland Water Resources and Aquaculture Service of the FAO Fisheries Department; and
- the development of the five plenary lectures.

Additionally, technical and experience papers were submitted voluntarily, many of which were presented as posters.

For the purposes of the Conference, the presentation of the reviews was arranged in a sequence and manner that enabled the Conference participants to develop a broad understanding of the status of aquaculture and a systematic recognition of the key issues associated with its status. The program enabled a deliberate, iterative and participatory process that allowed every participant ample opportunity to contribute constructively to the deliberations, formulation of conclusions and recom-mendations, and the framing of the Bangkok

Declaration and Strategy for Aquaculture Development Beyond 2000[1].

The two keynote papers complemented each other. The first reviewed the progress made in development of aquaculture, and how this has been achieved over the 24 years since 1976, when the first conference on aquaculture was held in Kyoto; the second keynote reviewed the prospects for aquaculture development over the next 20 years, the potential for sustainable aquaculture development, and the mechanisms by which this potential can be achieved. Following the keynote papers, during the first day of the Conference, eight regional reviews of aquaculture development status, trends and issues were presented, along with those within China and a global overview which was largely, but not wholly, the synthesis of the regional reviews. The plenary lectures were delivered prior to the thematic sessions, their purpose being to provide the context and setting for issues to be described and analysed by the reviewers undertaking the thematic reviews. The platforms for discussion were divided into eight thematic sessions

In addition to the Bangkok Declaration and Strategy, the recommendations of the thematic sessions were brought together in the Reportof the Conference on Aquaculture in the Third Millennium[2]. The recommendations were developed by the members of the session panels and other specialists present at the conference, presented in plenary workshops, redrafted, and refined through post-conference consultation by correspondence among the panel members and interested participants. These provide a comprehensive set of recommendations on key issues to address for the future development of sustainable aquaculture.

The three publications produced from this Conference are complementary. Together, they provide a useful reference for anyone with an interest or stake in aquaculture development. Moreover, they underline the need for direction towards higher production within the bounds of sustaining the aquatic resource base upon which aquaculture depends (habitat, water quality, stock resources). The Conference also emphasized the benefits from covering policy-related issues, such as legal frameworks, stakeholder involvement etc., and six sessions addressing technical issues, such as health, nutrition and genetics. The results of these discussions, specifically the conclusions and recommendations, were presented in plenary workshops and subjected to further deliberations. These conclusions and recommendations were further synthesized by a multi-national, multi-sectoral and multi–disciplinary Technical Drafting Committee into a draft Bangkok Declaration and Strategy. The Draft was discussed and adopted at the final plenary session. After being subjected to a post-conference public review over a period of one month, it was refined and published.

equitable distribution of the income and products generated by aquaculture. These have to support not only those who work directly for the sector, but also the rural communities and socio-economic dependants upon which aquaculture is developing. Sustainability is not only founded upon, but also best supported by, well-nourished and educated workforce communities.

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[1]http://www.fao.org/fi/statist/fisoft/fishplus.asp

[1] NACA/FAO. 2000. Aquaculture Development Beyond 2000: the Bangkok Declaration and Strategy. Conference on Aquaculture in the Third Millennium, 20-25 February 2000, Bangkok, Thailand. NACA, Bangkok and FAO, Rome. 27pp. http://www.fao.org/fi/default.asp, www.eNACA.org

[2] NACA/FAO. 2000. Report of the Conference on Aquaculture in the Third Millennium. Conference on Aquaculture in the Third Millennium, 20-25 February 2000, Bangkok, Thailand. NACA, Bangkok and FAO, Rome. 120pp.

Part I - Keynote Addresses

Aquaculture Development: From Kyoto 1976 to Bangkok 2000 Keynote Address I

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Pillay, T.V.R. 2001. Aquaculture development: from Kyoto 1976 to Bangkok 2000, Keynote Address I. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp.3-7. NACA, Bangkok and FAO, Rome.

ABSTRACT: During the intervening period of 24 years between the Kyoto Conference and the Bangkok Conference, aquaculture has gone through major changes in many areas, ranging from a small-scale homestead-level activity to large-scale commercial farming. Against the erstwhile perception of aquaculture as an insignificant subsistence activity, aquaculture production in some areas has, in fact, exceeded landings in capture fisheries. The Kyoto Conference adopted the Kyoto Declaration on Aquaculture that underlined the real potential for future development into a major industry. Its specific recommendations, addressed to those that were responsible for the development of the sector, covered the areas of increasing production and raising the profile of aquaculture in government development plans and private-sector investment priorities, investment and aid for aquaculture development, transfer of technologies and pilot projects, and coordination and integration of research. The Kyoto strategy was to infuse more science into traditional aquaculture practices, spread improved technologies and develop manpower through cooperation among developing countries. The strategy thus included the establishment of regional networks of aquaculture centres in developing regions to be subsequently converted into intergovernmental organizations. One of those networks was the Network of Aquaculture Centres in Asia-Pacific (NACA).

KEY WORDS: Aquaculture, Kyoto Conference, Aquatic production, Development, Global trends, Regional trends, Asia

Introduction

The two landmark events in the recent history of aquaculture are the holding of the FAO Technical Conference on Aquaculture in Kyoto, Japan in 1976 and the Conference on Aquaculture in the Third Millennium in Bangkok, Thailand, in the year 2000. During the intervening period of 24 years, aquaculture has gone through major changes, ranging from small-scale homestead-level activities to large-scale commercial farming. Over-production has also occurred, leading to dumping in foreign markets and the imposition of tariff barriers. Against the erstwhile perception of aquaculture as an insignificant subsistence activity, aquaculture production has exceeded landings from capture fisheries in many areas. Both Conferences were designed to take stock of elements that are relevant to the future of the sector and to recommend action plans to be implemented by identified public-sector entities.

The regional workshop reports and subject matter reviews were intended to lead to vision statements and action plans to solve envisaged problems.

The Conference was convened at a time when many organizations had an interest only in capture fisheries, in the belief that only well-managed natural stocks can support fishery industries. Aquaculture production was perceived as an insignificant contributor to food security. It was believed that aquaculture would survive only as a small-scale industry, contributing to rural development in developing countries. Although the Conference was essentially focused on the potential of aquaculture in meeting the objectives of rural development, it was decided to adopt a general Declaration that underlined the real potential for future development into a major industry. This Declaration came to

The first and only FAO Technical Conference on Aquaculture was held, along with an international festival of educational and documentary films, in 1976 in Kyoto. Over 463 delegates nominated by member governments participated in the Conference. It brought together all interests directly concerned with aquaculture development: scientists, administrators, industrialists, financiers and representatives of academic and private institutions in member countries. The main documentation of the Conference, which was held in 12 consecutive sessions, consisted of 38 review papers and 82 experience papers, copies of which were made available to participants before each session to enable in-depth discussion in panel sessions. The distinguishing feature of this Conference was that there were no oral presentations by the authors. Instead, each session facilitated interaction between the audience and the selected panel members. Recommendations from these sessions, as far as possible, were directed to the agencies concerned for implementation. The accepted papers were published in a volume entitled Advances in Aquaculture (Pillay and Dill, 1979).

Regional workshops that preceded the Conference discussed plans for be known as the Kyoto Declaration on Aquaculture, to distinguish it from subsequent Kyoto declarations or protocols.

Kyoto Declaration on Aquaculture

Since the Declaration formed the basis of the Action Plan that followed, I may take the liberty of quoting in toto the Declaration that was adopted by the Conference (FAO, 1976). It declared:

- That aquaculture has made encouraging progress in the past decade, producing significant quantities of food, income and employment; that realistic estimates place future yields of food at twice the present level in ten years, and five times the present level in thirty years, if adequate support is provided.
- That aquaculture, imaginatively planned and intelligently applied, provides a means of revitalising rural life and supplying products of high nutritional value, and that aquaculture, in its various forms, can be practised in most countries, coastal and landlocked, developed and developing.
- That aquaculture has a unique potential contribution to make to the enhancement and

development of aquaculture in each of the member countries, and identified those that could be accomplished by national efforts and those that required regional cooperation to ensure speedy implementation with the available resources.

maintenance of wild aquatic stocks and thereby to the improvement of capture fisheries, both commercial and recreational.

- That aquaculture forms an efficient means of recycling and upgrading low-grade food materials and waste products into high-grade protein-rich food

- That aquaculture can, in many circumstances, be combined with agriculture and animal husbandry with mutual advantage, and contribute substantially to integrated rural development.
- That aquaculture provides intellectual challenge to skilled professionals of many disciplines, and a rewarding activity for farmers and other workers at many levels of skill and education.
- That aquaculture provides now, and will continue to provide, options for sound investment of money, materials, labour and skills.
- That aquaculture merits the

million mt as the 1976 world production, based on the available information from government sources. In less than two decades, the recommended figure was exceeded. Production reached an impressive 27.2 million mt in 1995, and subsequently, over 36 million mt in 1998. Aquaculture thus became the main growth sector of the fishery industry, contributing nearly 30 percent of the world production from fisheries by 1998.

Investment and aid for aquaculture development

Recognising that over-capitalization and increased fishing effort are problems facing the fishing fullest possible support and attention by national authorities for integration into comprehensive renewable resource, energy, and land and water use policies and programmes, and for ensuring that the natural resources on which it is based are enhanced and not impaired.

- That aquaculture could benefit greatly from support and assistance from international agencies, which should include the transfer of technology, actively planned and executed, with research carried out in centres representative of the various regions concerned.

Recommendations and their implementation

In furtherance of the policy implicit in the Declaration adopted by the Conference, the Conference made a number of specific recommendations to those who were responsible for the development of the sector.

Increasing production

Noting that there are a number of proven aquaculture systems that could be expected to expand production, governments were urged to give high priority to aquaculture development in industry, many national governments, including those of major fishing nations, have accorded higher priority to aquaculture development, especially in order to reduce fishing pressure on exportable species. Inclusion of aquaculture in rural development has achieved considerable importance in aid projects. Strengthened extension services, organized independently, or as part of agriculture extension, have helped in promoting aquaculture in rural areas. National and regional centres have provided training of core personnel, such as extension workers, as also recommended by the Conference.

Till recently, before environmental issues gained prominence, private investments, as well as institutional financing from national development banks and donor agencies, gave considerable support to aquaculture projects. The statistics of external support, however, are very sketchy. In the six-years from 1988-1993, more than US$910 million is reported to have been committed in loans and grants for aquaculture from external sources. Thus the average annual input of aid is estimated to be about US$152 million during the same period. Investment in aquaculture from national sources is obviously much greater.

national planning, and governments and the private sector were recommended to promote aquaculture-production projects to increase harvests to a minimum of five-fold over the next three decades.

Even though regular compilation of aquaculture statistics started in the Food and Agriculture Organization of the United Nations (FAO) only in 1984, the Conference had taken a figure of 6.1

Transfer of technologies and pilot projects

Another recommendation emanating from the Kyoto Declaration relates to the expected expansion of aquaculture production through transfer of existing technologies, improvements of technologies and development of new technologies. Based on reviews of aquaculture world-wide, the Kyoto Conference noted that considerable basic information on new aquaculture species and farming systems was available, but a lack of pilot-scale model projects to test technical and economic viability hampered commercial applications.

Several pilot-scale and commercial projects had been carried out, however, on shrimp farming; cage farming of valuable fish species like salmon, trout, seabass and seabream; pond farming of turbot, strains of selected tilapia, and giant freshwater prawn; raft systems for growing oysters and mussels; scallop farming in lantern-type cages; and seaweed farming.

Bangkok Conference

In a number of regional meetings, including those of the Governing Council of NACA, it was recognized that it was time to hold a conference similar to the FAO Technical Conference, in order to take stock of the changed scenario of aquaculture in the last few decades and identify future

Coordination and integration of research

Recognising the relevance of systems-oriented multidisciplinary research, the Conference recommended that the diffused research efforts underway in many institutions could be made more productive through coordination and integration. In implementing the recom-mendation with regard to this, it was decided to combine research, practice-oriented training and information dissemination. FAO with the support of the United Nations Development Programme (UNDP), attempted to establish regional networks of Lead Centres and National Centres to carry out applied research, training and information dissemination. The strategy was to provide external funding for initiating the network in each developing region, to be later converted into inter-governmental organizations. Long-term training was recognized by the national universities as equivalent to their master's degree courses.

The first network established, the Network of Aquaculture Centres in Asia-Pacific (NACA), was in the Asia-Pacific, with China, India, Thailand and the Philippines specialising in the areas of their major interests. NACA, as per the original provision, became an inter-governmental opportunities and challenges that it may have to face to achieve its optimum potentials. Since FAO did not have such a conference in its agenda, the Governing Council of NACA asked its secretariat to take the initiative in this regard as part of its five-year program of work, if possible with FAO cooperation. FAO Fishery Department proposed that this Conference be made a world conference and agreed to cooperate in its organization.

A preparatory regional workshop was held for the formulation and discussion of national development plans for the countries of the Asia-Pacific Region. FAO agreed to arrange for the preparation of review papers on the state of, and trends in, aquaculture development in other regions in order to achieve a global coverage. These plans and reviews are meant to delineate the global opportunities and constraints that have bearing on the development of the aquaculture sector.

This Conference is being organized together with the Aquaculture and Sea Food Fair, to focus on the participation of the private sector in the development of aquaculture and allied industries. It is conceived as a futuristic exercise to envision the state of aquaculture in the next millennium and to formulate strategies for national, regional and organization when the UNDP support ended. Networking in Africa and Latin America had started with the establishment of lead centres in the regions. The African lead centre was established in Nigeria and the Latin American lead centre in Brazil. Because of changed circumstances, efforts to expand and regionalize the two centres had to be suspended. The Freshwater Fish Farming Institute in Szarvas, Hungary, which received UNDP support for its expansion, agreed to function as an inter-regional centre for long-term fundamental research.

inter-regional actions. The Kyoto Conference concentrated, though not exclusively, on aquaculture as a small-scale enterprise integrated with rural development.

Even though aquaculture the world over is still a small-scale enterprise, the compulsions of ensuring food security for the increasing world population and the need to utilize the opportunity for international trade and investment will likely make large commercial farms become more common, which may involve greater use of intensive farming methods to increase production and profitability. Consequently, environmental concern and sustainability problems can be expected to intensify in this new millennium. The growth of environmental-activist groups and public-interest litigation may retard progress, unless the concerned institutions and agencies give high priority to the development of appropriate and tested technologies.

The correct information has to be made accessible to aquaculture practitioners and the general public. The revolutionary development of information technology expected in this new millennium can facilitate dissemination of such authentic information. This is important, because much of the present-day opposition to development is caused by lack of correct information, or by misinformation.

Technological progress in the next millennium has to go hand-in-hand with the social and ethical acceptability of development measures. Research and assessment policies have to be evolved to suit different socio-economic conditions.

The reference to overall economic climate and its impact on the aquaculture sector would become evident if investment requirements and opportunities are adequately dealt with by the Conference. Adoption of intensive farming methods may lead to greater disease outbreaks. Crop insurance procedures, regular farm inspections and maintenance of disease diagnosis centres will all become imperative. Though still a small-scale enterprise, aquaculture has emerged as the major growth sector in the fishery industries. Since one cannot see much scope

This applies not only to the environmental sustainability of development, but also to the use of genetic modification in farming. Though the maintenance of biological diversity in ecological management of aquatic farming is of special importance, aquaculture and resource enhancement often require the transplantation of non-indigenous species or strains, and this is likely to increase in the future as efforts intensify to rebuild diminishing stocks of commercially important species.

I do not wish to forestall the discussion at this Conference and the agenda of action plans that may be adopted. I have tried to pinpoint some of the challenges of the next millennium that I consider to be of relevance to this Conference. I am sure the speakers that follow will deal with these in greater detail. I have attempted to underline the major considerations needed to arrive at an adequate vision of the aquaculture sector in this new millennium, so that appropriate action plans can be identified and implemented.

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for the expansion of capture fisheries to meet market requirements, there is an inevitable need to develop sustainable systems of aquaculture production. It is essential to maintain and, if possible, increase the rate of growth of aquaculture to ensure food security, as well as meet the demand for farm-fresh products by the affluent sections of society. Large commercial firms using intensive farming methods would lead to environmental concerns and sustainability problems.

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Aquaculture Development Beyond 2000: Global Prospects[1] Keynote Address II

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Jia, J., Wijkstrom, U., Subasinghe, R.P. & Barg, U. 2001. Aquaculture development beyond 2000: global prospects, Keynote Address II. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 9-12. NACA, Bangkok and FAO, Rome.

ABSTRACT: Over the past three decades, aquaculture has developed to become the fastest growing food production sector in the world; it has expanded, diversified, intensified and technologically advanced. Its potential contribution to local food security and livelihoods can be very significant, especially in remote and resource-poor areas. To attain its full potential to contribute to human development and social empowerment, the aquaculture sector may require new approaches. These could vary with countries, and the challenge is to develop approaches that are realistic and achievable in the context of current social, economic, environmental and political circumstances. Such approaches should not only focus on increasing production; they should focus on producing a product that is affordable, acceptable and accessible to all sectors of society. The concerns and needs to be addressed will include increasing the emphasis on aquaculture and aquafarmers in national development plans to enhance institutional and financial support to the sector; providing an enabling environment with appropriate policy, legal and institutional framework to facilitate access to key development resources such as money and knowledge; stimulating investments in aquaculture development; producing products in the acceptable manner for specific consumer preferences and complementing the efforts of other food production sectors; involving the participation of all stakeholders in decision making and policy planning; and broad and closer cooperation among stakeholders, countries and regions. In sum, the prospects for aquaculture development are bright and envisaged expectations are achievable. Their achievement can be ensured by creating the appropriate environments for improved support to producers, enhanced participation, strengthened networking, better information and regional and global cooperation.

KEY WORDS: Aquaculture development, Global trends, Regional trends, Future outlook, Sustainable aquaculture.

Professor Sena De Silva and Dr Laszlo Varadi – Joint Chairpersons, Members of the Panel,

Fellow Participants.

It is my pleasure to be here today, at this Conference on Aquaculture in the Third Millennium, to deliver this Second Keynote Address entitled "Aquaculture Beyond 2000: Global Prospects".

During the last Keynote Address, Dr. Pillay elaborated the journey from Kyoto to Bangkok. Dr. Subasinghe's Introduction covered the scope and purpose of the Conference. In my Keynote, I do not intend to provide you with a detailed analysis of specific trends in the aquaculture sector. They will

Thus, this sector contributes to food security, poverty alleviation and social well-being in many countries. The contributions of aquaculture to trade, both local and international, have increased over the past decades, and its share in the generation of income and employment for national economic development has increased in many countries.

The world population is on the increase, as is the demand for aquatic food products. Production from capture fisheries at a global level is levelling off, and most of the main fishing areas have reached their maximum potential. Global fish supply could be increased through reduction of discards and better use of by-catch be covered by the regional and global trends reviews and the thematic reviews that will be presented over the next few days.

Rather, in this Keynote Address, I will attempt to look at some broad global trends, key issues and constraints, and important challenges and development prospects for the future, in realising the full potential of aquaculture for humankind. I would like you to debate, discuss and consider these "Food for Thought" ideas over the next few days, in order to achieve our objectives of the Conference.

In my presentation, I attempt to cover, briefly, within the given 25 minutes or so, the following:

- Short introduction and an overview of the aquaculture sector today;
- Major trends and issues – where do we stand?;
- Future aquaculture development – prospects and outlook; and
- Conclusions.

Introduction and overview

Over the past three decades, aquaculture has developed to become the fastest-growing food-producing sector in the world. Aquaculture has expanded, for human consumption, e.g. use of at least part of the catch now going for reduction to fishmeal and fish oils. Better management of fishery resources and enhanced efforts to protect fishery resources from accelerating environmental degradation, particularly in inland waters and estuaries, may well contribute to sustained, if not enhanced, fish supplies in the medium to long term.

However, aquaculture appears to have stronger potential to meet the increasing demands for aquatic products in most regions of the world. Potential contributions from aquaculture to local food security and livelihoods can be highly significant, especially in many remote and resource-poor rural areas. However, it appears that the full potential of the aquaculture sector to contribute to human development and social empowerment is yet to be realized, and the sector may require new approaches to realize its goals beyond 2000. These approaches will undoubtedly differ between different countries, and depend on country-specific circumstances and national development plans, goals and aspirations. The challenge is to develop such approaches, which are realistic and achievable, within the context of current social, economic, environmental and political circumstances. Such diversified, intensified and advanced technologically and, as a result, its contribution to aquatic food production has also increased significantly. Aquaculture is highly diverse and consists of a broad spectrum of systems, practices and operations ranging from simple backyard, small-household pond systems to large-scale, highly intensive, commercially oriented practices. A large proportion of aquaculture production comes from small scale producers in developing countries and Low Income Food Deficit Countries (LIFDCs).

approaches should not focus only on increasing production; they should also focus on producing a product that is affordable, acceptable and accessible to all sectors of society.

Major trends and issues – where do we stand?

Aquaculture is an activity that produces nutritious, high-value species using sophisticated systems; a mechanism for local food security, rural livelihoods and poverty alleviation; and a sector that provides both income (local and foreign exchange), employment and food security.

Aquaculture is an income-generating activity. However, rapid sector growth has, in some instances, outstripped planning and regulatory activities. As a result, many areas have seen a regulatory rebound, with disproportionate requirements as resource use conflicts have occurred, resource scarcities have become more constraining, and demand for product quality and safety has increased significantly. Increasingly, some markets will consider additional product attributes, like environmental and social impacts of production. It may be necessary to redefine and/or reassess the respective roles of government and private sector, including producers' associations and organizations, in managing aquaculture development.

In some regions, aquaculture faces a considerable problem with public perception. Yes, in some cases, aquaculture development has failed to keep up with, or meet, many environmental and socio-economic issues and expectations. Future aquaculture development needs to produce a product that is not only acceptable to the public and consumers in terms of price, quality and safety, but also in terms of environmental cost.

Development prospects

The essential challenge for future aquaculture development will be to ensure that the full potential of aquaculture is realized, and that a nutritious, safe, high-quality product that is affordable, acceptable and accessible to all sectors of society, is produced. In doing so, we need to address the following needs and opportunities. We have to assist in feeding people in this millennium. This means investing in food security. Aquaculture can play a significant role in this respect.

We have to assist in social development, poverty alleviation and improving the livelihoods of people. In doing so, there is a need to increase emphasis on aquaculture and aqua-farmers in national social and economic development plans, with the view to enhance institutional and financial support for the sector. This can only be achieved through investing in human resources, including existing and future aquaculture practitioners, as well as government and non-government agencies and institutions. Investing in training, education, extension, information and communication are important in this respect. Use of modern information and communication tools and methods such as the Internet and other state-of-the-art communication methodologies will

and outlook

The constraints in farming can be highly complex and often of a technical/technological nature. However, the overall success of farming may depend largely on economic and social issues. The challenge will be to focus on meeting social needs – i.e. food security, poverty, livelihoods, community development etc., rather than solely trying to produce aquatic animals. While doing so, the sector should be well integrated into the overall development programme so that conflicts can be minimized. It is also important that necessary technical/technological means/solutions and capacity building needs are met for the future success of the sector. Aquaculture will continue to grow, but has to address the costs of production, quality and safety of products, international trade obligations and requirements, environmental concerns etc. More emphasis on investment, research, information and public education is needed. Challenges for increasing aquaculture's contribution to food security, poverty alleviation and rural livelihoods will have to be met.

have to be given due consideration, as will the essential requirement to ensure broad-based public access, especially for farmers, to these sources of information.

We must create and provide an enabling environment, with appropriate policy and legal and institutional frameworks to facilitate access to key development resources, such as financial resources and knowledge. There is a strong need for greater emphasis on institutional support, that is, support not only to government ministries and public-sector agencies dealing with administration, extension and research and development, but also to organizations and institutions representing the private sector, consumers and other stakeholders.

Aquaculture development, especially if it is to be sustainable for food security goals, may need to be stimulated, at least in the beginning, so there should be a key point on increasing access to credit for farmers, producers and local marketing. It is important to understand the investment opportunities in the sector. In an era of globalization, it is imperative to emphasize national and international trends of trade. Trade of aquaculture produce, input supplies, capital and information are all important to mention and acknowledge.

Aquaculture is dependent on key natural resources such as water, land, seed and nutrients. There is strong pressure for production and marketing systems that are more efficient and more effective in terms of resource utilization. In this respect, we should invest in research on developing production and marketing systems with better resource utilization and more efficient performances.

During production, there should be emphasis on targeting the consumers. We must emphasize the difference between mass production and production for the masses. For example, formerly expensive produce such as salmon and shrimp are increasingly becoming affordable to larger segments of the population. We should compete with, and complement, other food-producing sectors and providers. Aquaculture produce should be acceptable to all sectors of society. Tremendous gains will be possible through improved biotechnology, genetic

Stakeholder participation and consultation in decision-making and policy planning for aquaculture development should be duly considered. Aquaculture's potential for social empowerment should be harnessed, and the involvement of more women in aquaculture development should be given due respect. Trust between producers and consumers needs to be improved, and avenues must be found to achieve this. Public relations campaigns and labelling issues will have to be addressed. The role of regional and interregional cooperation in achieving the future development goals for aquaculture should be reviewed and strengthened. There are considerable opportunities to increase the impact on aquaculture development through continued regional and interregional cooperation. As agreed in 1995 by our Member Governments, in particular through the implementation of the FAO Code of Conduct for Responsible Fisheries (CCRF), further strengthening of modification, improved nutrition, probiotics, and disease diagnosis and treatment. However, the problem of consumer resistance to perceived risks stemming from "unnatural" products, ethical problems and fear of unknown technologies will affect potential gain. Environmental and human health issues will slow development or reduce market access. Strategic solutions are required. We should emphasize biosafety issues, development and promotion of biotechnology that conserve the environment. We should promote policies that support ethical issues of welfare and autonomy, and emphasize labelling and transparency for production process and beneficiaries. There is a need to increase the impact of research to understand technical and other constraints and to enhance the applicability and use of research results in the development of strategies to overcome these challenges.

such cooperation is highly recommended.

Conclusions

The challenge for the new millennium should be sustainable aquaculture development for enhanced food security and economic development. Prospects for future aquaculture development are good! The envisaged expectations can be achieved! To ensure this, we must create appropriate environments for improved support to producers, enhanced participation, better networking and information exchange and strong regional and inter-regional cooperation.

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[1] This presentation did not intend to provide a detailed analysis of specific trends in the aquaculture sector. Instead, it attempted to look at some broad global trends, key issues and constraints, important challenges and development prospects for realising the full potential of aquaculture. These ideas or "Food for Thought" were debated, discussed and considered during the Conference. The views expressed in this manuscript are personal to the authors and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations (FAO).

[2] The Keynote Address was delivered by Mr. Jiansan Jia. Jiansan.Jia@FAO.Org

Part II - Plenary and Guest Lectures

Policy Making and Planning in Aquaculture Development and Management Plenary Lecture I

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Ladies and gentlemen, and friends:

It is indeed a pleasure to be here at this Conference, a great opportunity to meet friends of yesterday and to make new ones. I should thank Dr Pillay for this. He brought me into the Aquaculture Development Coordination Project (ADCP) and aquaculture. I should thank former colleagues, many of whom are here: Chen Foo Yan, Chua Thia Eng, Jim Kapetsky. Many I miss – foremost among them Joseph Kovari and Michel Vincke. All have been great friends and

They all, with very few exceptions, will do their best to improve the livelihood they derive from fish farming. They will attempt to improve returns. They will try to reduce costs. They will try to make the animal or plant they raise more acceptable to those who buy it. For some, this continuous striving to improve will lead to a substitution of species.

I believe these actions constitute the essence of the farmer's policy and provide the context within which he/she plans and manages teachers.

First of all, what I will tell you during the next half-hour or so is my view, as a long-time staff member of the Food and Agriculture Organization of the United Nations (FAO), about policy and planning in aquaculture. It is what I would try to convince my colleagues to accept as an FAO position on these matters, if asked to do so. However, they have not had the chance to endorse or reject what I will tell you. This will permit them to intervene in the debate, and I expect they will, as I know they do not all agree with me on several points below. We should all benefit from the exchange.

Is it useful to address this subject globally? I believe it is useful to do so. There are three main reasons:

Fish farmers – one motive

As we all know, there are an immense variety of fish farmers. They vary in the technology they use and in the species they culture, and are active in a range of differing economic and social contexts. However, they do have something in common.

his/her activities. I do not believe much can be said usefully in a general manner about how he/she goes about this task, and so I will say no more about how the individual farmer should, could or will manage and develop his/her farm. But, established fish farmers may want to take action as a group, and I will return to this subject.

So I will talk mostly about “public sector” policy making and planning for aquaculture development and management. I said I had three reasons for believing that it is feasible to talk meaningfully about policy development and planning in a global perspective, so what is the second one?

Public administrations – uniform assignment

The way I see it, in almost all countries the public administration should promote an economic and social environment that is optimal for the fish farmer while ensuring that his/her activities do not cause undue costs for others. Thus the public sector intervenes to promote efficient production; to protect the environment, including ensuring biodiversity; and to ensure that the evolution of the sector is socially acceptable.

Thus we have a situation where fish farmers as a group have fundamental concerns in common - and so do the civil servants tasked with supporting and guiding them - thus a global discussion of public aquaculture policy may have some merit.

Globalization

The third reason has to do with globalization. The "open market economy" tends to be a part of globalization. Governments increasingly adopt open-market economies as a framework for their economies. Even the poorest economies are drawn into international economic relations. No economy can remain isolated, and issues in economic management rapidly involve most countries. This is the third reason why I believe countries can learn from each other in policy development and planning, also within the narrow area of aquaculture.

But, the topic is still enormously large. Not much can be said in half an hour. However, the conference programme states that plenary

History

What does experience tell us? That many countries – with no sector or at the time when they did not have any sector – at one time or another adopted policies aimed at positively trying to create a sector. They conducted surveys to identify which species/culture systems would be possible to pursue, then conducted both research and training aiming to get the industry going, at times trying to speed up developments by economic incentives.

In some countries, aquaculture developed. In others, it did not, or the results were modest compared to expectations or targets. In those cases I am familiar with, I believe the reason is basically one of an inadequate balance between costs and revenue for the concerned enterprises or farmers. Revenues did not, or were not expected to, cover costs. That is, in my view, a minimum condition for the sector to take off.

However, for some sectors of the industry in some countries, the initiatives have come from the lectures "are meant to draw a scenario of the state and prospects of aquaculture and outline the requirements for its development." I will try to do that from the perspective that has been given me: that of policy formulation and planning for development and management of aquaculture.

To guide myself I have added a subtitle: "What can the public administrator do to facilitate the life of the fish farmer in the coming decades – or help him get started if he has not yet begun?" I will start by saying a few words about the situation and possible role of the public sector in countries or regions where aquaculture has not yet started or taken off in any meaningful way. I will then look at policy development and planning in countries or regions within countries in which aquaculture is an established sector of the economy. I will try to pay attention not only to issues which are still with us, and those which seem about to appear from within the sector, but will also look out for those that will arrive from outside the aquaculture sector proper.

Regions/countries with little or no aquaculture

I will start by going back to basics: do we need a policy at all?

private sector. In fact, I do not believe there are many countries left where enthusiasts have not attempted to start culture of some form or another, with or without the support of governments. Sometimes they succeeded, on other occasions they found they did not have sufficient capital, or that the market was willing to pay a lower price than expected, etc. However, sometimes they did succeed and externalities were contained, or they did succeed and results – while being acceptable to the fish farmers – were negative for others; that is, externalities were not contained.

Lessons

I draw two lessons from the above. The first lesson is that it is not possible to substitute long-run, positive economic farming results with a large amount of public-sector efforts dedicated to developing policy and plans. I have some personal familiarity with Gabon, Sweden and Tunisia. In these countries, governments have not put considerable efforts into developing policies and plans, and relatively little has come in terms of aquaculture production. There are probably more examples. I rest convinced that, if the economic conditions are not there, there is very little that can be usefully done by public administrations.

Generally, they have neither the means nor, in fact, the task to create such conditions.

The second lesson is that unless some form of legal structure is in place, considerable harm can be done through unregulated, uncontrolled aquaculture development.

That is a reflection on the past. What is next in these regions where aquaculture has not yet established itself? First of all, globally, aquaculture is set to grow. We believe in FAO that capture fisheries will expand only slowly during the coming decades; so the aquaculture enthusiasts will come back. Thus it would seem to be imperative for public-sector administrations in countries with no or only a very small aquaculture sector to make certain that they have at least an appropriate minimum legal framework for the industry. I see three components of the legal framework: basic legal texts, procedures for issuing aquaculture permits and zoning for aquaculture.

The difficult scientific/political issue here is to determine the amount of alteration that is acceptable to the marine milieu and the landscape. The great attraction is that the issues are addressed once, and hopefully for all, for the zone as a whole and are not decided on the merits of any individual prospective fish farmer.

Thus, a partway conclusion of mine at this point is that this legal framework should be a priority in all countries where it does not exist and where there is a likelihood that aquaculture can develop.

But, some of you will say, should we not do more? A legal framework is not good enough – will not by itself generate a full-scale aquaculture sector. So let’s take a more positive approach. I am sceptical, and believe public administrations should be hard-nosed and selective at this point. There are a couple of reasons for

A few words about these. I expect Annick VanHoutte will tell you more.

The basic legal texts should make certain that aquaculture is a recognized economic activity enjoying – particularly in respect of the use of renewable natural resources - the same rights and obligations as farming, fishing and forestry activities. Furthermore, these texts should be clear about how the sector should be managed.

The procedure for issuing permits should identify the species that may be cultured and the technologies that may be used, specifying limits inter alia related to possible externalities derived from practices employed in the search for fish health and in the management of aquaculture waste. The procedure should also specify the administrative procedures and the information requirements linked to applications, as well as establish procedures to be followed in the interest of transparency and consultation with those directly concerned by the granting of an aquaculture permit.

Zoning: The main purpose of delimiting geographical areas within which aquaculture will be allowed is to address the issue of equity. This would seem to be particularly this.

Technology transfer: In today's world - and even more so in tomorrow's - technologies are moved around the globe rapidly by entrepreneurs in search of low-cost locations for production. This is happening, and will happen with increasing frequency. It seems to me that this is the most likely avenue for the spread of new technologies and the practice of commercially oriented aquaculture to countries where it is not yet widely practised in Europe, Latin America, Africa and Asia.

In the poorest of the countries that do not have an established aquaculture, I do not believe there is much of an alternative. I believe, in fact, that economically self-sufficient aquaculture will take off by producing for urban markets, most of them, foreign urban markets. The local markets will not be wealthy enough and consumers, for reasons of economy, will be carefully considering substitutes.

Thus, in my view the fastest way of starting a sector is by inviting already established entrepreneurs; but before doing so, the minimum legislative package should be in place, at the very least.

Infant-industry argument: What are the alternatives to inviting important for marine areas. The general notion in most countries is that the sea belongs to all. The issuance of aquaculture permits is contrary to this belief, and the very idea runs into opposition, and not only from direct users of the water areas concerned. When establishing a zone these issues must be addressed squarely.

foreign entrepreneurs? Some of you will argue that the "infant-industry argument" applies. That is, that there is a "potential" but the potential will not be realized because the potential producers cannot make the initial investment or cannot compete against established entrepreneurs supplying possibly foreign markets. Therefore, some economic support should be given to those who are willing to start aquaculture.

The support should permit the sector to overcome initial economic difficulties, and it should be withdrawn after a brief period.

This argument is not generally valid in wealthy economies. In less wealthy ones, it has more validity but should be inspected on a case by case basis. In fact, with growing globalization and the relatively large share that international trade has for several aquaculture products, there will be a growing international opposition to direct governmental transfers in favour of aquaculture producers, or of other forms of shielding domestic

Economic activity: Also, for the poor, fish farming is an economic activity. There is no doubt about this; the poor can ill afford hobbies. The poor will get involved in fish farming or aquaculture activities only if they believe that it will improve their income (in cash or kind) and will only continue the activity if that proves to be the case.

Cheap fish for poor people: At times in the past, the stated objective of these policies has been to make the poor people produce cheap fish for other poor people to buy. If such a policy is pursued, it producers against foreign competition.

Government obligation: Others will argue that it is the duty of the public sector to provide "basic support" to the industry. Potential producers should be supported through aquaculture research, training of aquaculture technicians and extension of technologies.

Most poor countries do not have the resources required to develop commercially viable technologies for local species not yet subject to culture. To my mind, to do so ahead of the establishment of a sector should require exceptional conditions. Much of the work needed for technology development and adaptation is costly. It would benefit from international cooperation, perhaps of the kind initiated by the International Center for Living Aquatic Resource Management (ICLARM) for the use of traditional animal breeding technologies also in the field of aquaculture.

But, let us end on a somewhat more positive note. I would say that government policy in developed economies, at a minimum, should focus on informing potential entrepreneurs and financiers. It is important that they receive up-to-date information on technologies, markets and the should be recognised that it is, in principle, contrary to what the farmer in his role as producer wants to produce. He/she wants to produce expensive products so that his income increases. If the policy is seriously pursued, it is likely to need increasing subsidies.

Subsidies – indefinitely? The first issue to settle is to see that aquaculture – usually some form of fish farming – is indeed the best alternative, given the objectives of better nutrition and food security. Once that is done, direct subsidies should be avoided as far as possible. If they need to be provided, it is essential to maintain them as long as necessary. It would be cruel to withdraw them before the activity has become self-sustaining.

Diversification vs. specialization: The second issue to remember is that introduction of pond culture, with or without association with other livestock, often represents a diversification. However, with economic growth, specialization is more likely than continued diversification. Thus it is likely that in any given farming population, as economic growth occurs, the number who continue to be active in fish farming will decline. Some will remain and probably expand their operations; others will abandon this activity.

best intelligence about possible future developments.

Exception – reducing poverty and improving nutrition: There is, of course, an exception to all of what I have just said -that is the case where aquaculture can serve as a means of reducing poverty and improving nutrition. The fact that aquaculture has, and will continue to have, also this role is the main reason for FAO to be closely involved in this activity. However, experience tells us that also, in these regions, it is essential to proceed with care.

However, this does not mean that it has been a failure. The opposite may be the case. Aquaculture can have served as a stepping stone to a higher living standard.

Finally, I would like to draw your attention to the fact that in economically underdeveloped regions, the challenge for the poor is how to obtain a chance to have an occupation from which they can derive sufficient income to provide a decent life. Where most aquaculture is practised today – you have that chance if you have access to land and water, that is, if you have access to natural resources, you have a base with which to earn a livelihood.

The information revolution and globalization of markets will cause change in rural areas to be much faster during coming decades than it has been. The technologies used in agriculture, forestry, fisheries and fish farming will change with increasing speed. This will be reflected in changing values of land. In order not to be displaced, the poor need to acquire the

It would be useful to develop implementation plans for this framework. Such plans should consider inter alia the following issues:

Up-to-date: First of all, the framework needs to be kept up to date. After all, it was designed to handle the latest technology at the time of its development. It should, knowledge needed to realize the income from the land.

In my view, the task of the public sector should be one of attempting to anticipate change by preparing rural producers to become part of the change. If not they run the risk of being pushed aside by it. Information about developments in aquaculture should also be provided to them. They should be encouraged to form producer associations and to improve their technical know-how.

I conclude for regions without a sector, by saying that it is important to elaborate a policy for the management of the sector that will help ensure its development. A policy that favours development (in the sense of providing support to producers) and forgets management may be heading the wrong way. Finally, it is important to remember that the poor also count their money.

Countries, regions with well-established aquaculture sectors

In these regions, the minimum legal texts are often in place. Where they are not, it is urgent to get them into place along with institutions and staff to make them therefore, evolve as technology and economy evolve. A joint government, civil society, producer group should be established to review these issues.

Costs: The public costs associated with implementation should be kept as low as is reasonable. The level should reflect the costs to society of not monitoring the adherence to the framework by the farming sector. These costs should be added to the direct costs of implementation and a minimum sought.

Incentives versus other instruments: The plan should specifically review the possibilities of gradually replacing some of the command-and control-measures by economic incentives.

Role of producers: The introduction of incentives may go hand in hand with a larger role for producers, probably as producer associations, in the management of the sector. The plan should review and establish a schedule for the gradual transfer of management responsibility from public administrations to producers.

Civil society: Also, more or less formal groups in civil society may demand a role in the management of the sector. Their role should be agreed with producers and the effective. The industry and the government then need to keep them up-to-date; that is, to see that they reflect economic and technological realities, inside and outside the aquaculture sector.

However, we all know that the laws do not solve all the problems of the sector, and in particular, there is no guarantee that they will be effective in handling future ones. I will address some of those I see, from the policy and planning framework. I will classify them under: technology, markets and "spill-over". I do not presume to identify how they should be resolved; I highlight them simply because I believe they need to be dealt with.

However, before discussing these, a few words about the regulatory framework and its implementation.

public administration.

Technology

The sector faces a number of technology issues: feed; new species, including genetically modified organisms (GMOs); and health.

Technological developments outside the aquaculture sector in communication, transportation and food preservation will lead to better knowledge of distant, often foreign, markets and provide the economic possibilities to supply them with high-quality products. Technological developments in various maritime industries will feed into the aquaculture equipment sector, and technologies involving offshore, submersible, automated culture units will come into increasing use. These developments will make it essential to modify parts of the legal framework.

Aquaculture feeds: The issue is global; it is one where the individual producer has little possibility to play a role. Informed observers believe that by the end of this decade the aquaculture industry may absorb as much as 70-80 percent the world fish oil production and at least 50 percent of the white fish meal production. Fishmeal will also continue to be demanded by the livestock industry.

Interests in the industry differ and therefore, also the approach used in dealing with the issue. The producers of fishmeal and oil, of course, would like to see the demand grow even further, while users look for substitutes. Research in support of both strategies is carried out in the industry and by university-based scientists. The role of the public sector is foremost, to ensure that research results come to good use, by keeping aquaculture producers up-to-date on developments.

Other factors of production: Land and water - will they be available in the quantities needed? Yes, but not perhaps at a price that can be afforded. They are basically difficult to move, so in technologies where they are needed in large quantities, production sites will be selected accordingly, that is, essentially to sites where human

Genetically modified aquatic species: My colleague Devin Bartley tells me that so far only a few genetically modified aquatic species have been brought into commercial aquaculture operations. But, the know-how to develop genetically modified fish is spreading. So far, consumer reactions to genetically modified foods have been – at least in Europe – hostile. The aquaculture industry would probably find it to be in its interest to join forces and agree, jointly with governments and consumer organizations, on a protocol to be followed by anyone intending to develop commercial cultures using genetically modified aquatic species. Once agreed, the protocol would become part of national legislation. To me, it seems important that such a protocol be in place before the industry develops genetically modified organisms (GMOs) that satisfy the desires of the consumer more than the economic needs of the producer, which is now the case. The reason is that there is no reason to believe that such modifications are more benign to humans than modifications that makes life easier for the producer.

Markets

Natural limits: As for any other agricultural or livestock product, the consumer also imposes population densities are low. Or, technologies will be modified. Where fresh water is increasingly in short supply, closed recirculating systems, then relying on intensive feeding, may be used. However, in the more distant future it is not easy to see what will happen. If desalination technology becomes very efficient, we may be in a situation where we have more fresh water available then we thought, especially if simultaneously gene technologies permit grain (wheat, barley, rice etc.) to be grown in salt water.

New species: It is indeed rare that the individual producer manages to domesticate new species on his own. It seems often to be a drawn-out and costly undertaking. Considerable work is done on this, particularly by industries in wealthy economies, and especially amongst those for which the fishery sector is of vital economic interest. It is in these industries and countries that most new domestications will occur. In countries with large aquaculture production, but spread out amongst a large number of small producers, the sector faces a bottleneck, and this is an area where it would seem to me that governments should concentrate their resources available for research and development. The fisheries aquaculture administration should pursue a policy that limitations on the aquaculture sector. The salmon industry has experienced this and confronted it inter alia with generic advertising. The Mediterranean marine aquaculture industry is getting ready to do the same. In America, the catfish industry has faced such limits; so has the culture of milkfish in the Philippines and rainbow trout in Europe. Also, in the future the industry will face market saturation.

Created limits: Besides quality and price, other considerations may affect the size of the market. In large parts of Europe and North America, products from capture fisheries and aquaculture have a bad name with many consumers. Both industries are seen – fairly or unfairly – as doing harm to nature. This is not only a constraint on the aquaculture licensing process, but it also reduces the size of the market. Where industry associations are strong, they need to do something, and where the public understanding is decidedly mistaken, the public administration could intervene and support the industry in its search for a balanced view by the general public of the industry relationship to nature.

facilitates such research in the public and private sectors.

There is also the possibility that capture fisheries will, through eco-labelling schemes and other means, create niche markets. They would do so, as one of the better avenues to increasing income is by increasing unit value, as the near-term possibilities to achieve sustained increases in volume are limited. One strategy for creating niche markets is to emphasize the healthy quality of its wild product – in contrast with the "unnatural" products of aquaculture. Again, it could be a task for the public sector to try to forestall any "marketing-war" between aquaculture and capture fisheries, as it would probably be detrimental to both industries.

Spillover issues

There are several: substitutes, subsidies, cost-recovery, the information explosion and increasing globalization.

The first spillover I will say a few

Subsidies: The practice of providing financial transfers in the fishing industry is a subject of much controversy amongst World Trade Organization (WTO) members. The issue was one of the very difficult subjects in the negotiation of the recent International Plan of Action for the Management of Fishing Capacity. The salmon aquaculture industry, both in Norway and Chile, has already experienced international controversy related to alleged subsidies. As subsidies to the capture fisheries have been significantly reduced during the last 15 years, it seems more than likely that the concern – essentially of large fish-exporting countries – will turn to the aquaculture sector. Strong arguments will be made for the elimination of all subsidies also in the aquaculture sector. If subsidies to fisheries become part of a future trade negotiation in WTO, I suppose that aquaculture produce will be included.

words about is that of ***substitutes.*** First the almost perfect one – fish caught in capture fisheries. The thinking in the Fisheries Department of FAO on this point now is that by the middle of the next decade there will have been some expansion of capture fishery landings. Production is likely to oscillate around at least about 100 million mt per year from capture fisheries in marine waters, some 85 million mt destined for human consumption. Thus a reduced portion of small pelagic species would be used for reduction. These figures are tentative and will be revised in the course of this year.

Consumption of terrestrial meats: The livestock industry is predicting a rapid growth of production; average consumption reaching in developing countries some 30 kg/capita by 2020 (according to International Food Policy Research Institute (IFPRI)/International Center for Living Aquatic Resources (ICLARM)/FAO), and importantly, this would happen under stable, or even slightly falling, relative prices for both meat and grains. This will impose a constraint upon retail prices for fish in developing countries. The less well-off part of the populations will have a viable alternative to fish. As I said before, this will put a lid on possibilities of local aquaculture production for

Cost recovery: Closely related to the issue of subsidies is that of cost recovery. Some countries are starting to request that the capture fishing industry refund to the public budget the cost of the public-sector management of the sector. Where this is the practice fishers will, of course, argue that all those who sell to whatever market they sell to, should do the same. Compatriots in the aquaculture industries will be first to feel the pressure; those abroad will be included as this argument is extended to all those who share the same export markets. Industry organizations would probably do well to consider how to tackle this issue.

Conclusions

It seems to me, that in the presence of developed aquaculture sectors, the public administration vis-à-vis these sectors should have a somewhat different policy than that advocated vis-à-vis areas where no aquaculture exists, assuming that the legal framework is in place and operational. The policy should be to establish an early warning mechanism and consultation procedure facilitating public-sector response to the number of issues likely to befall the sector from outside itself.

local markets. The stage will be set for continued growth of fish exports.

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Technologies for Sustainable Aquaculture Development Plenary Lecture II

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Twenty-four years after the Food and Agriculture Organization of the United Nations (FAO) Technical Conference on Aquaculture in Kyoto, Japan, where my Asian experience started, I am particularly happy to present this lecture dealing with Research Priorities for Sustainable Aquaculture Development, a talk which is based on the keynote lecture I presented last year in Sydney at the World Aquaculture '99 Conference.

I would like to repeat my appreciation to many colleagues and friends from all over the world (in fact, many of them are

Allow me to simplify things by classifying present-day aquaculture into two types: traditional food aquaculture, mainly practised in Asia with a few species of freshwater and brackishwater fish, shellfish and sea weeds, and the more recent business aquaculture of shrimp, catfish and salmon, just to list the key groups. Although food aquaculture still represents the dominant output, this type of aquaculture has evolved along minimal research inputs. Trial and error practices, developed over several decades, even centuries, have resulted in well-balanced, extensive production systems. Continuous expansion of production attending this conference). Thanks for all the ideas and suggestions you provided me.

I would like to make a critical remark at the start of this presentation. Many reports propose that in the decades to come aquaculture should bridge the gap between market demand for aquatic products and supply from capture fisheries. I want to underline that there is great consensus in the research community that, following present-day aquaculture approaches, this is a very simplistic goal. It would not be the right decision to try to achieve this goal by applying current technology and business methods. Risks of major environmental and human-health problems need to be weighed against achieving a more cautious rise in production that is, in the longer term, sustainable. We should all see this not only as a challenge to do it well and responsibly, but also as a commercial opportunity for the industry.

Aquaculture is clearly at a crossroads and can come, in fact, should come of age in the twenty-first century. However, this will require more responsible researchers and more integrated R&D approaches than we apply at present.

area and further improvements in culture systems have been responsible for the fast growth over the last decades. Many agree, however, that productions cannot increase at the same pace, simply because of limitations of suitable water resources. Furthermore, the recent interest to "modernize", which in fact means to intensify freshwater fish production, will imply very serious threats to sustainability.

Fast progress in business aquaculture has benefited most from R&D inputs, especially in western countries, although we need to admit that it has often been following very empirical approaches. Short-term oriented research had to find ways:

- to grow the animal;
- to maximize profitability; and
- to assure long-term sustainability.

This three-step process has been accelerated by high profits, and accompanied by abuses in some regions (although at the start, often by ignorance) and vocal opposition to these types of industrial farming in some sectors of the nongovernmental organization (NGO) community. Still, in other wording, the approach has been to develop monocultures, and apply intensification, which brought about diseases.

Their treatments often resulted in more problems (e.g. bacterial resistance, not to speak of the environmental problems), until one realised that disease prevention is the new procedure to adopt.

It is interesting to see how both types of aquaculture begin duplicating some of each other's approaches: business aquaculture starts to adopt the principle of polyculture widely applied in food aquaculture, whereas China is intensifying its traditional freshwater pond cultures and is using formulated feeds. Such approaches open very interesting opportunities, but serious constraints as well.

Further development of the aquaculture industry must take a holistic approach to culturing technologies, socio-economics, natural resour-ces and the environment, so that sustainability can be achieved. The momentum of the sustainability dialogue in

Various funding agencies are finally giving high research priority to "integrated coastal zone management studies", which are not restricted to ecosystem studies involving biologists, oceanographers and aquaculturists, but consider the socio-economical and legal aspects as well. Our Asian colleagues, for example, have identified the need for more socio-economic studies for integrated farming systems in poor coastal communities, for example, by developing sustainable coastal production systems that integrate aquaculture and fisheries under community management. Conclusions from the research results of these studies in developing, as well as developed countries, may well be straightforward. However, it is clear that special motivation will be required to see proper implementation of the true cost of certain farming practices. New tax systems or - better even - a system of incentives should be considered aquaculture has increased dramatically in recent years.

Despite increasing institutional focus, the amorphous nature of the sustainability concept continues to constrain progress towards objective definitions and applications. It is here that researchers need to fill in by developing criteria and documenting test cases. At present, “codes of conduct” and “development criteria” often lead to over-generalizations and to qualitative goals with little or no specific means of measure or application.

One of these new concepts which deserves further study and application is the “ecological footprint”, which reflects the land and water areas necessary to sustain current levels of resource consumption and waste discharge by a given aquaculture practice. Cultures that combine species from different trophic levels, both terrestrial and aquatic, application of ecocyclic production, and generation of multiple services and outputs all can reduce the ecological footprint substantially.

All agree that freshwater resources are limited and, thus, priority is to increase production in the presently available volumes of water, not necessarily by further here.

In the case of aquaculture activities in the coastal zone, the purpose is to reach a balance between “extractive” aquaculture and “fed” aquaculture. Extractive aquaculture refers to seaweed and mollusc farming, which can play a significant role in nutrient recycling, in fact of any waste nitrogen and phosphorus, not only from aquaculture farms. R&D projects in Europe are exploring the potential of extensive mariculture for “anthropogenic nutrient recycling”. Seaweeds are efficient nutrient scrubbers that could assist in the management of nitrification of coastal waters. Other ideas are based on the fact that the cost of mussel farming, if used only for nitrogen removal, is about the same as in a conventional purification plant.

Fed aquaculture systems are, for example, the cage farming of carnivorous marine fish such as salmon, bream and grouper. These systems might have to be removed from the more sensitive inshore waters to more offshore systems, eventually integrated with further nutrient trapping by seaweeds and molluscs. Shrimp farming is another example of such “fed” aquaculture systems, the impact of which on coastal ecosystems needs to be better remedied by intensification but rather by polyculture and integration with terrestrial productions.

With regard to the coastal and marine environment, one has come to realize that these ecosystems must be managed as a whole, and that we need to model these systems for the nutrient carrying capacities of the different water systems involved, and for the various human activities and the different ecological conditions at any one location.

integration with proper nutrient trapping and/or recirculation.

The next level to explore in the research priorities is the farmed species. There is general consensus that species diversification, especially of carnivorous types, is not a research priority.

Broad species diversification leads to an exponential growth of research requirements that are difficult to meet in view of limited resources. Clear exception is made for a few key species such as the genus Anguilla and the bluefin tuna, for which controlled breeding would mean a major breakthrough. In the case of eel, it would alleviate the pressure on wild stocks of glass eel in Asia as well as in Europe. Hatchery availability of bluefin tuna would reduce pressure on tuna fisheries and thus reduce the by-catch problem significantly. Still, to introduce effective genetic improvement programmes using selective breeding. We are decades behind developments in the agricultural sector, where genetic research has resulted in huge gains in productivity. In recent times, milk production is up 150 percent, daily weight gains in pigs has doubled, and time to produce marketable broilers cut in half. The Norwegian salmon industry, where a lot of research money has been targeted in the past, has seen overall gains of 60 to 70 percent. Productivity of most other farmed little effort is devoted to search for, and to cultivate more species of shellfish, sea urchin, sea cucumber and especially, herbivorous fish, the primary consumers that are able to utilize the primary productivity most efficiently. They have been listed on many occasions as a priority to improve overall energy budgets. It is clear that for several species market demands, consumer preferences or restrictions are the driving force here. A good example is the milkfish, which is considered a staple in the Philippines but is not appreciated at all in many other Southeast Asian countries. Market researchers claim that there is room for improvement here, and this research challenge should be taken up very seriously, especially in Asia. The same applies to the molluscs, where further handicaps are health risks in consuming contaminated product, as a result of which interest is down in several species and regions (e.g. mussels in the Philippines). Suggestions are made to consider new approaches to increase the value of low-in-the-food-chain products, if not as food products maybe as dietary ingredients.

Fresh water becoming more and more a limited resource, air-breathing fish (clariid catfish and snakehead) are proposed as a valuable extension of the species species has remained almost constant, close to that of the wild founder stocks. Research is proceeding with several species of fish (carp, tilapia, trout, bream, bass) and molluscs (oysters, clams, abalone) and with others, like shrimp, work is barely starting, as very few species can be regarded as domesticated. The technical challenge is to close complex life cycles, not only with empirical culture techniques, but especially to understand how the nervous and the endocrine systems coordinate with the changing external environment. Once fully domesticated breeds are available and all factors for good genetic management of broodstock are fulfilled, the selection work can start. The importance of such a strategy of selective breeding is two-fold: first, it provides a sound population within which incremental improvements can be begun; second, much of this work is practical, and the sooner the industry people are involved the better the technology transfer and the closer to return on investment. Another point is that no other genetic approach offers continuing incremental improvement. The formation of improved selected lines provides a base population upon which, sooner or later, the additional advantage of other genetic approaches can be applied, on top of the incremental change.

list of freshwater fishes. Among the primary producers, seaweeds are clearly identified as still having a very important potential, not the least because their domestication is still at the very pioneering stages. As mentioned earlier, several research groups are exploring their possible role in large-scale nutrient recycling and even in increasing the capacity of the sea as a carbon dioxide sink. However, the search for, and development of, new utilizations of seaweeds, either as a source of fine chemicals and/or as an ingredient in formulated feeds, will be crucial here.

Let us turn now to research in genetics. All believe that for the next decade the real challenge is to get the aquaculture industries First priority is thus developing domesticated broodstock, still an art with some key species such as the penaeid shrimp, then followed by selective breeding schemes, allowing the production of certified seed.

The ability to use techniques in molecular biology to mark and identify stock by genetic fingerprinting will enable a much faster selection of advantageous traits. Highest priority in selective breeding programmes involves disease-related aspects. Two approaches are considered: disease-free as well as disease-resistant lines. Although no miracles are to be expected either, as good farming practices, optimal health management and appropriate measures of quarantine should not be neglected. Other factors of interest in selective breeding programmes are growth rate, market size and quality, food conversion ratios, fecundity and ease of domestication.

Although selection on a wide genetic base will give continued improvement, the development of monosex and polyploid strains can yield large gains.

The logical approach is to work for a combination of gains as is successfully done with genetically-male-tilapia (GMT) and genetically improved farmed tilapia (GIFT). Several of these strains have already proven their benefits; however, their impacts on the environment are not well-enough documented yet. Finally the use of transgenics or genetically modified organisms (GMOs) is a very sensitive issue indeed, especially since opinions are so extreme, with work ongoing and supported in some countries, completely halted in others. On one hand, public concern is at such level, at least in the western world, that the products will have to be proven safe for consumption and for the environment three times over. Let me warn you, however, that perceptions of safety are equally as important as safety itself. Proper testing is essential here. It seems likely that public debate will increase on this front and that the well-publicized precautionary approach with strict application of "performance standards" developed as a guide for researchers, will be adopted with absolute priority. The main danger seen is less one of

One could explore the potential to increase primary and secondary productivity, for example, by providing extra substrate as with the new idea of aquamats used in fish and shrimp farming. In fact, a very similar approach has been applied for decades in some traditional estuarine and coastal fisheries: the acadjas in Cote d'Ivoire and the katha fisheries in Bangladesh and India, where extra substrate suitable for colonization by periphytic flora and fauna results in increased food supplies. It is very likely that more research on pond-culture systems could improve the economics of the production and especially, ensure better environmental sustainability.

In view of the need to move mariculture more off-shore, extra research is needed on open sea-cage farming: equipment and materials, knowledge of fish behaviour, use of submersible lights to adjust photoperiod to control cycles of growth and maturation, and integration with seaweed and mollusc farming, as practised, for example, in Chile.

Recirculation technology will receive much more attention, as it offers lots of opportunities for captive markets and for safe applications with GMOs, as absolute guarantees can be provided to prevent escapees. Systems need to health, but more of the maintenance of biodiversity through effects of escapes into the wild. In this respect, the often proposed need for gene-banking of aquatic organisms should receive a higher priority.

In any case, the development of transgenic aquaculture organisms is not expected to proceed so fast as some are claiming. The utility of any transgenic work is dependent upon inserting genes into individuals and having the insertion stable so that it is inherited. The expression of genes is dependent upon the genetic background into which they are inserted. That, and their continuance in a breeding population, means that there has to be a sound domesticated population into which they can be introduced for them to be effective. That is another reason for ensuring that industries establish sound selective improvement programmes first.

Let us now turn to research priorities in culture systems and techniques. Although pond cultures make up by far the most dominant form of aquaculture, still very little is understood about pond ecosystem functioning. It is time to plan more studies on nutrient dynamics in the water, the soil and their interactions, as well as the role of microbes in these processes. be further improved in order to make the production more efficient to be able to deliver competitive products for the market.

Consider restocking and stock enhancement: beneficial effects are well documented for confined areas such as lakes and reservoirs and for benthic organisms. However, more research is needed with pelagic species in the marine environment. Focus needs to be on how to make fish juveniles more fit for life in the wild, on releasing strategies and on their possible impact on wild populations. Most needed are validation studies, which can be better planned now that appropriate tagging and genetic marking techniques have become available. Also, the matter of artificial reefs and offshore drifting nets requires more attention. Can we better document increased primary productivity, or is it the sole effect of an aggregation of the fishable stocks?

As aquaculture feeds often make up 50 percent and more of the production cost, it is clear that research in this field will remain a priority. The nutritionist is to develop economical feeds, and here the concerns around the availability of fish meal and fish oil are paramount. Although some claim that we are OK for another one to two decades, many others are not as optimistic. Who can guarantee that global meal production will remain high? What about the sudden increase of fish meal consumption in aquafeeds in China?

As I explained earlier, a gradual conversion is taking place in China of extensive freshwater fish production to semi-intensive systems using pelleted feeds. The search is on for alternative protein and lipid sources. Plant-based protein sources are highest on the list; rendered products could be valuable, although the human health concern will require careful study. Single-cell proteins and by no means least, the recovery proteins from the waste of seafood processing and from fisheries by-catch are also important alternate protein sources. Disease issues that might be involved with this approach also need to be understood. Of course, these substitutions will require supplementation to fulfil the essential amino acid balance and essential fatty acid requirements.

Microbial products might alleviate

Disease control in aquaculture should focus first on preventive measures related to good management practices that maintain good water quality, with better/certified seed, less stress, high-quality feeds etc. In many, maybe most, farming practices, there is still plenty of room for improvement on many of these counts. More applied research should better document these effects. We still need to acquire a lot more basic knowledge of the microbial, viral and parasitic diseases and their epidemiology in aquatic organisms. Access to a large arsenal of molecular techniques will certainly assist in quick progress in this area.

Development and validation of appropriate diagnostics has high priority. However, whilst PCR-based kits are very sensitive and can detect very small quantities of demands for selected amino acids and fatty acids of the n-3 and n-6 series. Before this can become a reality, production must be increased, supplies must be stable and prices must fall to a competitive level. Improved nutrient availability should optimize the digestible protein to energy balance, but also be effective for maintaining good health and improving disease resistance. Finally, the so-called eco-friendly feeds, more nutrient-dense diets that allow for the reduction in phosphorus and nitrogen waste output, will further gain in importance. Progress in diet formulation is a must, but improved feed management is another field where research could contribute to more environmentally friendly productions: development of regimes that lead to reduction in losses from unconsumed feed and use of interactive feeding systems, to mention a few approaches. Consumer preferences will have to be better considered, as diet and feeding practices influence attributes of the farmed fish - their nutritional quality, texture and flavour. Further progress is also required with the starter feeds: use of less live food could be further improved and made more predictable. One could consider better-selected and eventually, manipulated strains of algae, rotifers and Artemia. Another need organisms, in the wrong hands they are very dangerous, as false positives and negatives are common from non-standardization of techniques, contamination etc. Lack of time does not allow me to further elaborate on research needs for vaccine development, quarantine systems and basic immunology research, especially in invertebrates.

Because of our preliminary research experience with microbial manipulation in larviculture systems, I would like to mention here that I expect important progress in the study of microbial processes and their regulation in many aquaculture systems. Competitive exclusion is one of the ecological processes that allow manipulation of the bacterial species composition in the water, the sediment and the animals' digestive tracts.

It is a shame that I don't have enough time left to cover regional differences in research priorities. However, one continent I want to at least mention is Africa, considered by many as the sleeping giant in aquaculture. Experts agree that the approach of the past - to adapt foreign technology - has failed. The way forward would be to research the indigenous knowledge base in Africa which has been largely neglected. Furthermore, one is more diversity in Artemia resources. Also required are improved formulations and manufacturing of micro-diets for use in co-feeding and full substitution of live food.

With annual losses of several billion US dollars caused by diseases in aquaculture, it is clear that this is another area of high research priority. However, first we should realize that we need to leave behind the decade of disease treatment with all the negative environmental and other consequences, and move to a future of disease prevention.

should develop economic options that are needs based and demand driven.

I mentioned earlier that extension of research results has to be better considered, as there are too many failures in technology transfer. We need more adaptive research: partnerships between the farmers and various service providers. Researchers need to realize that we have the responsibility to prove our research findings.

Furthermore, researchers often might not realize that, depending on specific circumstances, social and economic factors may be more important than technological factors. More interdisciplinary interaction will pay off, as is illustrated by recent aquaculture progress in the Mediterranean through various schemes of support by the European Union (EU) for joint initiatives between the private sector and the research

Today, we live in a small world with unique opportunities for communication and inter-action. I am also convinced that, in the field of aquaculture, humanity has an opportunity to better benefit from the historical differences. The diversity of our cultures and ways of thinking (for example, with regard to identifying research priorities and performing research and extension), the diversity in aquaculture farming practices and community. Furthermore, North-South and especially South-South R&D interactions and networking are to be much more stimulated. the differences in consumer interests - all can help us to understand aquaculture principles better and to consider better the challenges for the century to come.

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Regional and Inter-regional Cooperation for Sustainable Aquaculture Development[1] Plenary Lecture III

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ABSTRACT: The resources available for designing and implementing aquaculture development projects are no more immune from the current “down-sizing” trends than are those of most other publicly funded development initiatives. There is also an increasing onus on recipients to demonstrate greater accountability for their wise use. The aquaculture sector must now move towards development strategies which favour greater cooperation in collectively addressing the issues important to achieving sustainable development, not just in developing countries, but in all regions of the globe where aquatic animals and plants are farmed. To achieve a level of cooperation which emphasizes complementarity rather than duplication and competition, improved processes need to be identified to partition responsibilities fairly and equitably amongst existing agencies.

Cooperation first requires a focal point to give it life, and then a strategy to sustain it. It is suggested that the most effective focal points for regional development are the Regional Indigenous Organizations (RIOs). They are seen to be particularly important in taking the lead in regional development,

since they have been established to serve their constituent member states, and thus have a strong sense of ownership, commitment and responsibility for development in their respective regions. Moreover, they already have a government-mandated framework upon which to structure programmes and projects. They can, therefore, be viewed as being the logical lead agencies around which sustainable development can be pursued. Accordingly then, as the focal point for functional cooperation, they can also be considered for taking on the coordinating role for regional programme participants, which may include: regional intra-governmental representation, universities and research institutes, private-sector interests, industry associations, regional chambers of commerce, nongovernmental organzations (NGOs) and others who have interests in aquaculture development. These same arguments hold true when considering inter-regional cooperation. There is much to be gained through inter-regional cooperation. Specific climatic, cultural or other features usually prevent "wholesale" transplantation of development programmes from one region to another. There are tremendous benefits to be derived from the greater understanding and cooperation made possible by expanding the development process to consider the inter-regional level.

KEY WORDS: Aquaculture, Development, Regional Cooperation, Inter-regional Cooperation

Introduction

On a global scale, the resources available for designing and implementing aquaculture development projects are no more immune from the current "down-sizing" trends than are those of most other publicly funded development initiatives. This, despite the fact that aquaculture is being increasingly looked to by nations of the world to replace the

Elements of cooperation

Establishing Development Priorities

One of the key elements in measuring how effective we are at achieving cooperation relates to the process of how we go about setting priorities for development. This holds true at all levels: locally, nationally, and both intra-regionally and inter-regionally. With declining resources of our oceans and inland waters. The impacts are being felt at all levels; donor and recipient governments alike are being told to "do more with less". So too are intergovernmental organizations, such as specialized agencies within the United Nations (UN) system, intergovernmental organizations outside the UN system, nongovernmental organizations (NGOs), financial institutions, the private sector and others who have traditionally contributed to development of the aquaculture sector. While it is not the message one wants to hear, it is nevertheless the operating principle that is likely to be with us for several years to come.

The message also has a corollary: not only are the resources shrinking in magnitude, but when and where they are made available, there is an increasing onus on recipients to demonstrate greater accountability for their wise use.

For the aquaculture sector, at least, we have come face-to-face with the reality that the "narrow view" is no longer acceptable, and that we must now move towards development strategies which favour greater cooperation in collectively addressing the issues important to achieving sustainable development, not just in developing countries, but in all regions of the diminished resources available to us, the process through which development priorities are established must necessarily be rigorous and easily defendable from technical and economic, as well as political perspectives. As such, governments and agencies involved in aquaculture development initiatives are being increasingly vigilant to ensure that their decision-making processes satisfy these criteria. Inevitably, the numbers of worthy projects far outweigh the resources to support them. Clearly, stronger debate and greater wisdom are required to ensure that resources are not applied too thinly nor ineffectively in the hopes of broadening coverage, instead of allocating them to key constraints to development.

Long-term vs. short-term goal setting

Where the process of debate may have once focused on the short-term benefits to be achieved from development projects, in particular tangible assets such as new equipment, buildings and overseas visits to gather information - in effect the narrow view - this track is no longer in keeping with achieving the goals of sustainable development. In seeking to address the longer-term view, attention needs to be diverted from the more globe where aquatic animals and plants are farmed. For years, decades even, we have spoken about a regional programming focus. While there are vivid examples of how regional programming can be effective, there is still a reluctance on the part of many nations to move from the more familiar and comfortable bilateral project perspective. Nevertheless, there is increasing pressure to do so and we must, therefore, respond.

This paper considers some of the elements important in achieving strong regional and inter-regional cooperation in aquaculture development. It reviews some features of existing regional approaches, offers suggestions for new approaches, and will hopefully provoke Conference participants to consider how they can promote and achieve greater cooperation within their own particular spheres of influence.

immediate tangible benefits to those achievable within a broader view. This requires a higher level of cooperative thinking and decision making, to ensure that the longer-term goals remain clearly in focus and that scarce internal resources are not side-tracked into achieving short-term objectives which, though they may momentarily appear attractive, are in reality, inconsistent with achieving the major goals.

Internal vs. external priority setting

Further, in formulating aquaculture development programmes, greater recognition needs to be given to the importance of ensuring that those priorities which are established are internally driven, and not ones that serve some external agency’s agenda, especially if that agenda is not consistent with the recipient’s established priorities for development.

This, in itself, is often difficult, since no one wishes to turn down assistance; however, if over the longer term, it means a delay in addressing the important priorities, great care needs to be exercized in proceeding along this path.

Development agencies - the UN system

On the regional scene, there are a number of levels of cooperation to consider. In Asia for example, there are the various specialized agencies of the UN system which have involvement, at some level, in aquaculture (including inland fisheries) development. These include the Food and Agriculture Organization of the United Nations (FAO), the Asia-Pacific Fishery Commission (FAO/APFIC), the Intergovernmental Oceanographic Commission Sub-Commission for the Western Pacific (IOC/SC-WESTPAC), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the United Nations Children's Fund (UNICEF), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and others.

Regional indigenous agencies (RIOs)

There are the regional indigenous organizations (RIOs), such as the

Areas for cooperation in aquaculture development

When considering topical areas for cooperation in aquaculture development, the following come to mind:

- Exchange of coastal zone management strategies - how can we achieve sustainable aquaculture development while also protecting the quality of our coastal waters? Are there national or regional strategies which could serve as models for other areas?
- Development and implementation of aquaculture policies - do all RIOs have an aquaculture development policy that recognizes specific needs and opportunities for aquaculture development? Or are aquaculture development activities included as an appendage of fisheries or agriculture? Are there existing models for national aquaculture policy which could be adapted into a regional format?
- Marketing has strong proprietary implications for the private sector; nevertheless there is opportunity for generic marketing activities on a regional level that are in support of individual company

Association of Southeast Asian Nations (ASEAN), the Network of Aquaculture Centres in Asia-Pacific (NACA), the Southeast Asian Fisheries Development Center (SEAFDEC) and the South Pacific Forum (SPF), which are funded by their member states and, as well, attract programme and project funds from external sources. Included in the equation are the various country dialogue partners, who provide funding to bilateral and regional development projects; the regional financial institutions; education, training and research institutions; and private-sector interests, all of which are involved in development processes.

Complementing vs. competing

During the evolution of development agencies in Asia, or in any region, it is to be expected that, amongst them, there are some over-lapping, perhaps even competing interests. To achieve a level of cooperation which emphasizes complementarity rather than duplication and competition in positioning activities on their respective priority agendas, improved processes need to be identified to partition responsibilities fairly and equitably amongst existing agencies.

efforts. Such activities as identification of new export-market opportunities, regional market promotion endeavours and other related activities would be acceptable to most companies.

- The balance between food security for the domestic market and the need to earn foreign exchange currency through export of higher value products such as prawns and shrimp can be viewed in a regional context.
- Control of transfer of exotic species - there is an obvious need to minimize the transfer of pathogens and diseases which may accompany movement of live aquatic animals and their products intra- and inter-regionally. Maintaining biosecurity also needs to be considered in terms of the policies of the World Trade Organization (WTO), as well as in terms of the practicalities and considerable costs associated with establishing and maintaining biosecurity zones.
- While most nations have their own extension programmes developed and implemented internally, the commonalities of aquaculture within regions, and in some cases between regions, would suggest that there are real advantages to

focusing on more cooperative approaches. This would apply to the training and education of extension workers, as well as to the delivery of their services.

- For aquaculture chemicals, therapeutants and other treatment products, there is a strong need for regional cooperation in establishing acceptable treatment strategies which meet the needs of the grower, as well as recognize the requirement for environmental sustainability. There needs to be cooperation on which products are acceptable; what limits should be permissible in target and non-target organisms, and in the surrounding environment; how to monitor and enforce compliance; and on how to develop policy and legislation that support the technical requirements. Cooperation involves regional authorities

Inter-regional cooperation

It is now also clear from previous gatherings, such as the 1997 CIDA Regional Oceans Programmes Workshop (Hinds, 1998), that there is much to be gained through inter-regional cooperation. Specific climatic, cultural or other features usually prevent "wholesale" transplantation of development programmes from one region to another. However, it is acknowledged that there are tremendous benefits to be derived from the greater understanding and cooperation made possible by expanding the development process to consider the inter-regional level. While geographic distances remain considerable, the advent of the World Wide Web has done much to shrink distances from the exporting states, as well as authorities from the importing states or region. In many cases, there are already existing limits imposed by importing countries. Even so, there is a need for regional cooperative strategies to determine how to meet these limits, especially since rejection or detention from one member state of the region may place others under suspicion. Representatives of the companies manufacturing the products should also be considered in the equation, since they should be included when it comes to supporting the costs for demonstrating efficacy. Clearly, because of the cost of the equipment and activities involved, it makes more sense to have one regional centre to address these types of problems, rather than leaving it to each country to establish its own centre(s).

- For other areas of research and development, including husbandry and farm systems, education and training, communications and information dissemination, postharvest technology and social dimensions, it has already been demonstrated that regional cooperation offers significant economies of "virtually" and permit opportunity for "south-south" sharing of knowledge, relative to the opportunities and constraints facing people and organizations engaged in aquaculture development in all regions of the globe.

While this particular workshop focused on seven regional projects not specifically devoted to aquaculture, the aim was to arrive at some generic "lessons learned" in regional programme development, and then to examine how these could be applied to the development of subsequent regional projects. This was the first time in which participants from five of CIDA's regional projects were gathered together to formally present their experiences with their projects and how, from a recipient's perspective, the process could be improved. There were 160 participants from over 40 countries - over one-third of whom were women - representing a considerable range of experiences, ideas and approaches.

The five projects represented West Africa (Dioh, 1998), the Caribbean (Saul, 1998), Southeast Asia (Tan, 1998; Jusoh, 1998) and the South Pacific (Maiava, 1998). In addition to the project participants themselves, there were representatives of multilateral and bilateral donor agencies, agencies scale.

- When committed to regional cooperation, there are also benefits to be gained in terms of maintaining focus on the political and priority agenda levels. Once agreed to at the regional level, it is more difficult for a member state to unilaterally declare a separate agenda that is inconsistent with the region as a whole.

of the UN, NGOs, the private sector and the universities.

Coming out of this forum was a fresh view of the importance of establishing a strong understanding of how partners develop synergy through cooperation in project design, implementation and measuring progress. The bringing together of the delegates was viewed as the beginning of a process of advancing communications and understanding of how to improve the cooperation required to achieve better designed and delivered projects.

- With the emphasis on cooperation, most of the lessons learned (Hinds and Bacon, 1998) are directly

- While events such as this CIDA workshop are not inexpensive, the argument can be made that periodic gatherings of regional project participants are a wise development strategy. Direct discussions amongst regional project participants are more likely to achieve inter-regional cooperation than if it is imposed by external dialogue partners or agencies.

Cooperation - how do we "programme" it?

applicable to sustainable aquaculture development, since they relate to how donors and recipients can interact between and amongst each other to achieve stronger projects. Some of these lessons for the future include:
A key ingredient for project success is ensuring input from all stakeholders, particularly the target audience (growers) during all phases of a project, but especially during the design phases. Experience has indicated that when the target audience is excluded from the design process, the project usually encounters considerable difficulty in implementation. When this occurs, there is tremendous loss of development momentum, since the project either needs to be halted for redesign purposes, or in the worst cases, the project fails to achieve its objectives.

- During project formulation, there needs to be strong regional cooperation in selecting activity centres. There also needs to be regional agreement concerning postproject support for operation of the centres. If regional support is withdrawn at the conclusion of the project, and if the host country alone is left to

Clearly, cooperation does not happen uni-laterally; it first requires a focal point to give it life, and then a strategy to sustain it. Looking first at the focal point, there are a number of options that could be considered, depending on which agency takes the lead. These could include specific dialogue partners, specialized agencies of the UN, regional financial institutions and perhaps others. However, other than the regional financial institutions, none of these has an exclusive focus on a particular region. As for regional financial institutions, they are lending agencies and their primary focus is not necessarily directed at the detailed strategies involved in sustainable development.

Regional indigenous organizations as the lead agencies for regional and inter-regional cooperation

It is suggested here, that the most effective focal points for regional development are the RIOs. RIOs are seen to be particularly important in taking the lead in regional development since, having been established to serve their constituent member states, they have a strong sense of ownership, commitment and responsibility for development in their respective

support the operations, chances for successful continuation of the centre’s activities will likely be threatened. Conversely, host countries need to ensure that project centres visibly project a “regional persona” and are not seen as having a national focus.
- Greater cooperation and coordination need to be exhibited when, as often occurs, several projects are being designed or implemented simultaneously in a region. There is a tendency for projects to become compartmentalized with linkages restricted to between specific donors and recipients rather than amongst them. In many instances, the opportunities for synergism are overlooked because the coordinating agencies are not fully aware of other projects or are too narrowly focused on the activities of a single project.

regions. Moreover, they already have a government-mandated framework upon which to structure programmes and projects. They can, therefore, be viewed as being the logical lead agencies around which sustainable development can be pursued. Accordingly then, as the focal point for functional cooperation, they can also be considered for taking on the coordinating role for regional programme participants, which may include: regional intra-governmental representation, universities and research institutes, private-sector interests, industry associations, regional chambers of commerce, NGOs and others who have interests in aquaculture development.

These same arguments hold true when considering inter-regional cooperation. While it is acknowledged that some RIOs are more developed than others, this only emphasizes the need to include greater inter-RIO dialogue when considering the strategy for achieving sustainability.

Elements of "Sustainability"

Technical imperatives and associated resources

Key elements in the formulation of a sustainable aquaculture development strategy focus on the technical imperatives that need to be addressed, and on marshalling the human and other resources needed to build the elements of the strategy. It is important to recognize that the technical aspects of development cannot be achieved with any lasting effect unless consideration is first given to the institutional architecture needed to support them. All of this needs to be considered within an organizational framework that favours institutional strengthening, capacity building and service delivery with a long-term view. There are plenty of examples of projects that were implemented with too much emphasis placed on the technical contributions of

- From a project design and implementation perspective, traditional thinking needs to be revised. Where capacity-building projects previously measured achievement of objectives somewhat subjectively, a results-based management (RBM) approach requires that such projects have a strong objective component and that the results achieved are linked to demonstrable improvements in the state of aquaculture development.
- This "new order" implies that project designers must be able to rely on having the appropriate policies in place to support this process of institutional building, and as such, must also have the human intellectual skills available to develop, implement, measure and analyse success towards achieving sustainability.
- Effective policy decisions are the institutional basis for sustainable aquaculture development. As such, when developing policy there is a need for strong communication, cooperation and coordination amongst the RIOs, the education and research institutions and the business community. In assigning the mandate for

foreign experts, rather than on transferring their expertise and experience to counterparts who have the long-term responsibility for ensuring sustainability. Wherever failure occurred in development projects, it is usually apparent that the technical initiatives were not accompanied by development of the indigenous capacity and capability which would ensure continuation of the project benefits after the departure of foreign experts. The result is that subsequent "trips to the well" were required to 'sustain' the previous project. This clearly is not an acceptable definition of "sustainability".

Institutional strengthening and capacity building

In identifying the key elements of a human resource strategy for achieving sustainable aquaculture development, the focus needs to be on institutional strengthening and capacity building. These are clear prerequisites for better resource management and physically improving the regional development process. Paraphrasing Watson (1998), who discusses institutional strengthening in terms of environmental management, one could suggest the following for sustainable aquaculture development:

project development and management to reside with the RIOs, they will then look: i) to the research and education institutions to provide the intellect and innovation needed to improve the technology and methodology, and ii) to the business community to translate it into sustainable aquaculture production.

As a strategy for sustainable capacity building, institutional strengthening requires advisors and counterparts to prepare a comprehensive action plan that is specifically targeted at the resolution of important aquaculture development constraints, or at taking advantage of development opportunities. This process can be considered in two phases:

- Phase I is an outwardly looking "situation assessment" where needs are assessed; priorities for development agreed upon; objectives for capacity building established; and anticipated improvements identified, assuming the objectives are achieved. Strategically, resources need to be targeted at filling institutional gaps rather than being dispersed over a range of secondary activities which cannot be achieved without the critically important institutional strengthening being considered first.

- Phase II is the inwardly looking "baseline assessment" in which institutional constraints facing people and organizations responsible for development are identified. In addressing this phase, the role of the advisors is to assist their counterparts in improving their capabilities through analysis, planning, training and providing opportunities to gain hands-on experience in situations that can be monitored and evaluated objectively using some previously established and accepted performance standards.

A rigorous approach to institutional strengthening is a prerequisite to preventing so called "strategic drift", i.e. fading of original clear-cut objectives and dissipation of targeted resources over a broader

This issue, together with others relating to environmental degradation linked directly to aquaculture development, has gained considerable profile and is thus well placed on priority agendas for consideration.

Policy and legislation support technical initiatives

A second aspect of "sustainability" relates to the policies and legislation that are created to support scientific and technical developments. The establishment of regional environmental, aquatic animal health, transportation and other criteria for aquaculture operations is only truly useful if they are given some effect in law. In formulating sustainable aquaculture strategies, it is important to recognize the downstream legislative process as an integral, though perhaps range of activities. “Successful implementation of strategy requires that the long-term project objectives are kept in view, activities and outputs are linked to expected outcomes and that frequent journeys down side-tracks without clear objectives, priorities or endpoints are avoided” (Watson 1998).

Framework to support technical activities

In terms of the technical imperatives, “sustainability”, in itself, can be viewed from at least three perspectives:

- The first relates to all of the technical components of aquaculture development.
- The technical components must be set in a framework which promotes economical production, considers social obligations to development, and of course, ensures environmental sustainability.
- The last perspective has both an internal and external component; first, aquaculture operations need to adopt practices that are at least environmentally neutral; and secondly, surrounding industrial and domestic activities must themselves be environmentally neutral to prevent detrimental impacts

subsequent, component of the process. The argument can be made that the technical developments may be the easier of the two to accomplish, since legislative development is likely to have many external competing factors that could delay promulgation. This, then, makes a strong case for the focus on RIOs, since they can provide a responsible forum for building credible regional development strategies to promote and protect aquaculture development. RIOs can serve as effective vehicles for consensus building that includes “bottom-up” input at the national level, integrated with an effective “top-down” management function when extended to the regional level.

Sustainability and international profile

The third aspect of “sustainability” relates to its international profile. As indicated earlier, development funds are limited, and competition for them is vigorous. Most nations within a region share similar problems and opportunities in aquaculture development. The bilateral approach is now viewed as economically inefficient, as well as being too time-consuming if one considers sequential nation-by-nation, project-by-project aquaculture development.

on nearby farms.

Linkage - environmental sustainability and sustainable aquaculture development

Inexorably, sustainability in aquaculture development is linked to environmental sustainability. Much has been studied and written about the need for more vigilance in maintaining an equilibrium between the needs of the shrimp growers and the need to protect coastal mangrove areas as critical nursery habitat for marine species and as an important ecological buffer between tropical marine and terrestrial ecosystems.

Accordingly, cogent arguments can be made for focusing on RIOs which have been assigned strong mandates from their member nations for aquaculture development, and which have equitable arrangements for division of responsibilities among themselves and individual member states, as well as amongst other RIOs within the same region that may have overlapping interests.

As a regional instrument of a group of cooperating governments, a RIO projects a strong image which is the summation of all its member states. Enabled by their charters, RIOs can serve as effective focal points for the development and implementation of regional policy and regulation to support a coordinated approach to sustainable aquaculture development. In doing so, they can

Participants were from government depart-ments, a university and a research institute representing the Philippines, Indonesia, Malaysia, Thailand, Singapore and Brunei Darussalam. Project outputs included:

- through the delivery of more than 100 workshops, technical studies and case studies to over 830 participants, a also develop, project and sustain a strong regional image of aquaculture as a responsible activity with demonstrated commitment to achieving "best practices", even when some member states, which may be less well developed, are having difficulty in attaining regional performance targets. With the encouragement and support of other members of the RIO, less well-developed states have a greater chance of achieving sustainable development than if they were left to do so on their own.

a successful regional development project - an example for model consideration

An example of a successful regionally implemented project focusing on sustainable development is the ASEAN-Canada Cooperative Program On Marine Science (CPMS-II) 1992-1998 (Vigers, pers. comm.). This project also embodies many of the features which have been identified above as being important elements in a successful strategy for regional cooperation. Paraphrasing Vigers (pers. comm.), some of the highlights of the project are as follows:

strengthened ASEAN understanding, technical knowledge and institutional capacity in marine environmental management leading to greater recognition of the need to work regionally;

- strengthening of human resource skills, knowledge and technical capabilities through the placement of graduate student trainees, short-term training attachments and study tours;
- establishment of a cadre of ASEAN specialists, and the development of a networking system amongst them;
- formulation of a common set of ASEAN marine environmental quality criteria for key environmental parameters;development of toxicity testing and analytical protocols that are contributing to data comparability and reliability within the region;
- regional agreement on standard methods, procedures and quality analysis/quality control (QA/QC) methods for sampling and analyses;
- identification of regional marine environmental quality targets and establishment of regional baseline data sets;
- establishment of a red tide surveillance and advisory network;

- The goal of CPMS-II was to support ASEAN's own regional effort to cooperatively optimize its marine resource-based benefits while also maintaining resource integrity and promoting human health protection.
- The broad objective was to upgrade ASEAN marine science capabilities through a programme of training initiatives and through the hands-on execution of three major technical activities:
  - development of tropical marine environmental quality criteria,
  undertaking pollution monitoring and baseline studies, and
  - investigation of toxic red tides, which cause contamination of shellfish, marine fish kills and human deaths.
- an increasingly harmonized approach to regulatory implementation monitoring, enforcement and policy development in marine environmental management that recognizes the conflicting needs of industrial development, population and economic growth, as well as ecological sustainability; and
- closer technical cooperation between Canada and ASEAN.

One of the key features of this project, which has particular relevance to sustainable aquaculture development, concerns the management strategy for the project. Specifically, the Canadian Executing Agency (CEA) adopted an advisory role to the Project Steering Committee and Technical Working Groups.

The CEA, working in a consultative manner, administered funds on behalf of CIDA, sourced technical specialists to be made available to the project, maintained overall project momentum, and provided an assistant project coordinator to help in managing and administering the many project activities occurring in the region from the Project Execution Centre located within the Department of Fisheries, Government of Malaysia, Kuala Lumpur.

However, the Project Coordinator was selected by ASEAN, and the direction of the project and the forces impacting on its focus were very definitely ASEAN. This was in keeping with the project design philosophy of having ASEAN assume the lead role when it came to responsibility for the conduct of the project. This approach was possible because ASEAN, as a well-structured RIO, has the strength needed to assume this level of responsibility. As it turns out, this approach was successful. Moreover, when analysing the inputs to human resource development and physical resources dedicated to the project, it was evident that for every two dollars Canada contributed to the project, ASEAN contributed three dollars.

A regional sustainable

In Asia, there are currently three RIOs (NACA, SEAFDEC, ASEAN) with strong ties to aquaculture development. Of these, NACA with its regional network of centres, is seen as being the focal point for a strong regional approach to aquaculture development. There are several reasons to support this suggestion, including NACA's:

- exclusive focus on aquaculture development through regional cooperation;
- approximately 20 member and participating nations encompass most of the people of Asia;
- ability to provide the "bottom-up" elements from an R&D perspective;
- endorsement by FAO and the confidence of other agencies; and
- experience in designing and delivering effective R&D programmes.

It makes sense then, that with this profile and level of regional representation, favourable consideration needs to be given to NACA as a lead agency.

However, consideration needs also be given to the other two RIOs. SEAFDEC has a well-developed aquaculture programme and a strong history of institutional strengthening in partnership with

aquaculture development strategy for consideration

It is fitting, though not coincidental, that we are discussing models for regional sustainable aquaculture development, here in Asia. After all, it is generally agreed that aquaculture had its beginnings in Asia, probably at least two millennia ago. Moreover, in terms of RIOs, it is generally agreed that Asian organizations have probably achieved a higher level of development to date, than those in other parts of the globe. Accordingly, looking eventually at inter-regional strategies as a means of promoting greater sustainability in aquaculture development, it makes sense to first ensure that there is a solid model in at least one region upon which to build future initiatives.

Synthesising the elements from the foregoing discussion, we would suggest that the following are the major considerations in designing a regional strategy for sustainable aquaculture development:

A RIO as lead agency

For all of the reasons indicated earlier in this discussion, a suitable RIO to take the lead in the development process is a primary consideration.

the governments of its member states. Moreover, SEAFDEC also has considerable experience in technology transfer initiatives. Specifically, many of SEAFDEC's pilot-scale projects have involved bridging the gap between the R&D institution laboratory bench level, and commercialization through an industry partner. As a facilitator of aquaculture industrial development, SEAFDEC too, clearly has an important role to play as a lead agency for development.

ASEAN is a formal political organization representing governments of seven countries, has close ties with other countries in the region, and has well-established connections to multilateral and other development organizations. As such, ASEAN will be important in providing the political leadership to keep aquaculture development high on the priority agenda. To subsequently enable specific development initiatives, ASEAN will also be important in ensuring that funds are sourced, either internally or in partnership with other NACA members, or in broader partnerships involving bilateral and multilateral development agencies.

It is concluded then, that while all three RIOs are currently pursuing aquaculture development in Asia, that a more synergistic approach focused on complementing each other's strengths could be achieved through a partnership involving the technical and institutional strengths of NACA and SEAFDEC, combined with the political expertise resident within ASEAN. One could envisage the aquaculture development initiatives undertaken by these three organizations being integrated and consolidated in a manner which would give a more effective regional voice to sustainable aquaculture development issues.

It is suggested that initially there needs to be a forum in which senior representatives of NACA, SEAFDEC and ASEAN can meet to explore possibilities and hopefully develop a common front on approaches to sustainable aquaculture development in Asia. Also included in the forum could be traditional dialogue partners, FAO and other

The principal task will be designing and implementing the process by which development initiatives can be moved from scientific and technical design, through the bureaucratic level, to the political level where they can garner greater profile and compete more effectively with other issues on the political agenda. This proposed strategy, which also provides for appropriate monitoring and evaluation, is illustrated in Figure 1. It is envisaged that the chain of events in the process may resemble the following: The private sector identifies the need for a particular research and development initiative, which has generic implications for the industry as a whole, or for some subsector of it. For example, a particular disease issue in a farmed species may require better diagnostic and treatment strategies, or some other issue that, when addressed adequately, can improve the standard of aquaculture in general. The need is communicated to the RIOs.

specialized agencies who would be viewed as critical to the process of establishing the priority agendas for regional development. Such a high profile forum, aimed at consolidating regional efforts in aquaculture development, should also emit positive signals to attract regional and global support for initiatives emanating from this cooperative approach.

Assuming that an agreement can be reached, the next step could be a five-year pilot programme designed to permit the integration and consolidation process to proceed on an experimental basis. This would provide an adequate timeframe in which to work through the various issues associated with the move in this direction. The intention here is that NACA, SEAFDEC and ASEAN would carry on their normal work programmes, but would also focus on determining how they can optimize combined expertise to accelerate development, as well as reorganize activities amongst themselves to avoid duplication of effort. For example, there could be "trade-offs" in the form of one agency taking the lead for a specific technical initiative, with others adopting support roles. This would not only reduce duplication in the system, but could enhance complementary activities, in place of competition.

- NACA/SEAFDEC, with their expertise in undertaking R&D programmes, identify the technical elements required to address the issues; compare these to the inventories of specialists within their member centres, and prepare the project design. If external expertise is required, this would be identified at this stage. A commercialization strategy would also be included, using private-sector participation to ensure that results from the R&D component are translated into commercial benefits.
- SEAFDEC, with its expertise in the commercialization of R&D initiatives, would play a lead role in this aspect of the programme.

  ASEAN's political expertise would be enlisted to move the technical plan forward for consideration by the appropriate bureaucratic levels (usually by economic planning units of representative regional governments).
- When senior bureaucratic approval is received, ASEAN would be enlisted to move the process to the political level for approval. In doing so, consideration would also be given to strategies for

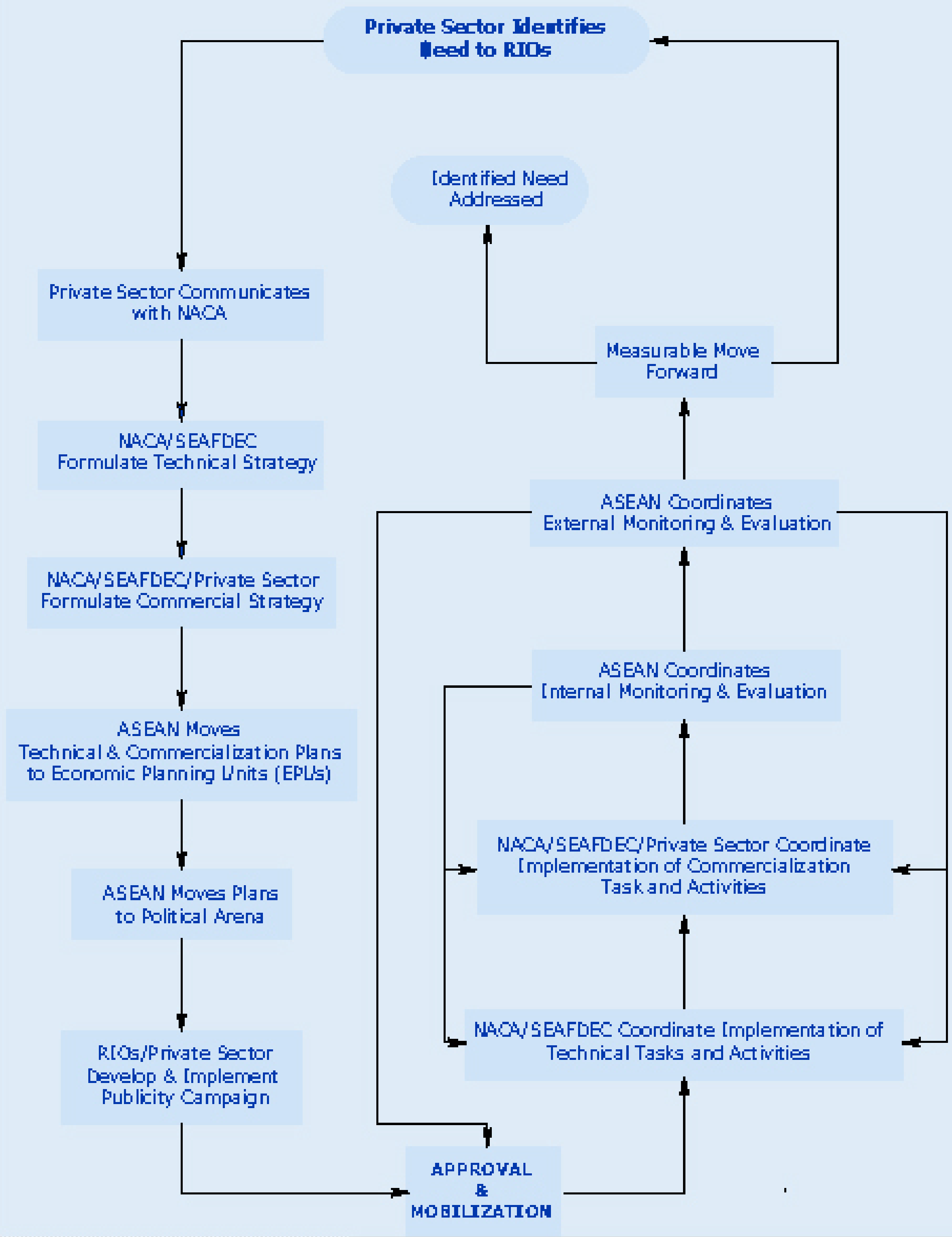
Setting priority agendas

Placing aquaculture high on the priority list of regional development initiatives will be a rigorous exercise in consensus building. Nevertheless, the proposed NACA/SEAFDEC partnership with support from ASEAN would have considerable experience and expertise in this regard.

publicising the initiative in a way which is likely to favour a positive political decision. For instance, assuming that there are to be spin-off benefits to the aquaculture service sector and others, the support of regional chambers of commerce could be enlisted to help promote or endorse the agenda.

- Following approvals, project implementation of the technical components through NACA/SEAFDEC, and then the commercialization components through NACA/SEAFDEC and the private-sector partner(s) would proceed.

Figure 1. Regional Sustainable Aquaculture Development Regional Indigenous Organization (RIOs) Model for Asia



- At appropriate points throughout the project, ASEAN coordinates internal and external monitoring and evaluation activities.
- It is expected that the project, when completed, will demonstrate a measurable advance in development, and address the specific needs identified at the start.
- The model is cyclical in nature and thus provides for sequences of project initiatives all directed at moving sustainable development forward.

In moving the priority "through the system" in this manner, there is good opportunity for integrating the bottom-up concerns, prominent at the local and national levels, with a more benevolent top-down management approach necessary for a successful regional approach to cooperation.

Institutional strengthening and capacity building

As indicated earlier in this paper, successful programmes have focused on these elements as a means of ensuring sustainability. The latter is to ensure that they develop the capacity to evaluate and integrate attractive technical innovations into a company's operations, within the limits allowed by the company's financial strength.

Extending the model regionally and inter-regionally

NACA's member and participating states include several nations outside Southeast Asia. Thus, while the first step in building a stronger regional approach to sustainable aquaculture development may be on the "sub-region" of Southeast Asia, the ultimate intent is that the structural elements of the new partnership can be extended to other states in the region, through NACA's central coordinating role.

Following the development of this "Asia model", it is conceivable that a forum could be held in which RIOs from other areas of the globe would gather to consider how this particular model could be shaped to address other regions' needs for sustainable aquaculture development. Here, it is envisaged that the process utilized is as important as the results achieved.

While most human resource development has focused on providing graduate and postgraduate training to incumbents in specific programmes, consideration should also be given to more formal university and technical institutional curricula focusing on aquaculture development. If there is stronger formalized grounding provided in the fundamentals of aquaculture development, counterparts would be better prepared, and existing operations would be better able to absorb new project activities into their line operations.

While there is a need to continue to develop the academic ranks of aquaculture specialists who will undertake R&D projects in universities, research institutes and government laboratories, there is also a need to focus on the training required for aquaculturists whose career path will be towards operations and management of commercial ventures. Accordingly, while their curriculum will include many of the same subjects as those of the scientific and technical specialists, they would also focus attention on the practical aspects of aquaculture operations, including resource engineering, geotechnical topics, environmental sciences, aquatic animal health and nutrition management, husbandry, and

Specifically, assuming that such a model comes to life, it would be particularly useful for other RIOs to be able to share the experiences encountered as it develops. This would allow them to develop some context of how analogous models could be developed in their own regions.

Even better than waiting for successful development of the currently proposed model, would be to share the experiences inter-regionally, as they are encountered. This would provide for more inter-regional dialogue, more rapid dissemination of useful information, and serve as a catalyst for the overall thrust of greater inter-regional cooperation in aquaculture development.

Ultimately, a more efficient and productive approach to cooperation in sustainable aquaculture development will translate into visibly positive actions with respect to addressing the existing global protein deficit problem.

especially business management.

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Human Resources Development for Sustainable Aquaculture in the New Millennium
Plenary Lecture IV

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ABSTRACT: Human resources development (HRD) is pivotal to aquaculture development in the new millennium, particularly so in the changing global pressure for all development to be environmentally and socially acceptable, irrespective of the economic status of nations. In the above context, HRD in the aquaculture sector has to have a more holistic approach, and the type of training provided has to be changed accordingly. Most nations in which aquaculture plays a significant role in poverty alleviation recognise that HRD is a key to sustained development of the sector. The types and levels of training required in the sector in the foreseeable future are discussed. The need to increase specialised training, particularly for researchers, in some of the developing nations likely to play a dominant role in the aquaculture sector in the ensuing years, is also underlined. Examples are presented to indicate that current development programmes do not cater to HRD to the extent that is desirable to have a long-term impact.

KEY WORDS: Aquaculture, Human Resources Development, Extension, Education, Research

Introduction

The development of human resources, both in quality and quantity, is pivotal to sustaining the aquaculture industry in the new millennium, especially so in the climate of changing paradigms affecting the sector (De Silva, 2001). Some of the key trends and challenges facing the industry reflect an ever-increasing global call for development, irrespective of the economic status of the nation, to be socially and environmentally acceptable. As a follow-up to this, aquaculture is unlikely to sustain itself based on economic viability alone, but will need to ensure social and

Improved hygiene standards: Access to knowledge and information is public domain and increasingly so in all corners of the world, and a very desirable consequence of this has been an increasing awareness on hygienic standards, nutrition-health links and related food quality issues.

Finally, as emphasised in the Bangkok Declaration and Strategy prepared by this Conference, it is increasingly recognised that aquaculture has to contribute more effectively to human development goals in many countries - poverty alleviation, food security and improvement of rural peoples' livelihoods.

environmental sustainability as well (Kutty, 1997). The potential milieu of the sector in the new millennium can, therefore, be summarised as follows:

Reduced growth rates in the aquaculture sector: There has been a reduction in the rate of growth of aquaculture production in some parts of the world, e.g. Asia. Only South America has shown an overall increase in the rate of growth over the last 10 years (De Silva, 2001).

Controversies and issues of public concern: There is concern over some aquaculture developments, for example, the increasing use of fishmeal in some aquaculture sectors (Naylor et al., 2000) and shrimp farm development in India (Murthy, 1997). It is crucial that aquaculture takes note of such controversies and any potential repercussions, if it is going to meet its development targets.

Changing aspirations of the industry: Like all primary production industries, aquaculture has to keep pace with the needs of a growing global middle class and economic upswing in most developing countries and/or regions. The sector has to increase the proportion of production of high value aquatic animals, e.g. the increase of the production of Chinese perch, Siniperca chuasti, in China. The bulk of this production is now consumed locally compared with the predominant export market of a decade ago.

Increasing demand for land and water resources: Aquaculture now has to compete for primary resources, such as land and water, on an equal basis with all other stakeholders, whereas it was previously a marginal land/water site user.

Increasing competition among aquaculture products: With increasing living standards, the aspirations of the consumers are destined to change; consumers will become more choosy, and this will inevitably result in increasing competition amongst produce.

Envisaged development of the sector

Within the above milieu, the sector's development can only be sustained through the prudent adoption of key measures, which can be categorised as follows:

- technological development,
- minimal environmental perturbation,
- efficient use of primary resources, and
- greater effort towards meeting human development goals.

These are complementary. The perceived technological developments in the sector in the new millennium are dealt with in detail by Sorgeloos (2001) and are likely to focus on:

- genetic improvements, selective breeding and application of other genetic technologies;
- feed technology and feed management;
- minimisation of waste production;
- effective completion of life cycles (e.g. shrimp);
- re-use of water; recirculation technology;
- health management, disease prevention and control; and
- new species.

The sector can, therefore, be sustained through technological developments etc., which proceed hand in hand with changes in the knowledge, skills and attitudes of practitioners, extension workers, researchers, developers etc.; in essence, through all key stakeholders. Thus the era of each stakeholder working in isolation is a thing of the past, and will not develop the synergies that are required to sustain the sector in the new millennium.

In this regard, an Expert Consultation on Aquaculture Education (July 2000, Hanoi) considered the target groups, the desired knowledge and skills for each target group, and the type of education that would deliver the desired results. The results of the findings are summarised in Table 1.

Importance of human resource development

In general, the immediate returns for investments in HRD are not always obvious. Accordingly, development institutions, governments and donor agencies tend to give a relatively low priority to HRD, even though most nations consider HRD as a priority area for development of the sector. For example, a recent Network of Aquaculture Centres in Asia-Pacific (NACA)/Food and Agriculture Organization of the United Nations (FAO) survey in Asia revealed that 93% of the countries considered HRD as a major problem facing aquaculture, and 71% of the nations noted that a lack of skilled personnel was a major impediment to further development(NACA/FAO, 1996). A recent review on aquaculture development in Africa identified eight strategies as pivotal to the development of the sector, and not surprisingly, five of these involved HRD, particularly in relation to small-scale farmers and extension workers. (Machena and Moehl, 2001). On the issue of HRD, it is also important to recognise the specific needs of nations and regions. Past experience in the aquaculture sector and elsewhere has shown that mere transfer of technologies is not always effective and can even be counter productive. Obviously, training needs vary significantly amongst regions and are related to the degree of development of the sector, thus the gross needs of Africa may be significantly different from those of Asia (Machena and Moehl, 2001).

Requirements for human resource development in the new millennium

In the past, extension workers were expected to have specialised knowledge in technological aspects, such as the artificial propagation of an aquatic species. The training for this, however, tended to be specialised and relatively short term, lacking a holistic approach. Such training was frequently driven more by technology interests than by development needs or the needs of the farmers. A holistic approach to aquaculture training is, and will continue to be, an essential ingredient in HRD of the sector. Only this will ensure sustainable aquaculture development.

Group			Farmer	Manager	Technician	Extensionist	Trainer[1]	Teacher[1]	Research Scientist	Policy Maker
Skills	Knowledge	Facts	+[2]	++	++	++	++	++	+++	+
		Principles	+	+	+	+	++	++	+++	+
	Skills	Practical aquaculture	+++	++	+++	++	++	++	+	-
		Problem solving	++	+++	++	+++	++	++	+++	-
		Teaching skills	-	+	+	+++	+++	+++	-	-
	Attitudes	Environmental ethics	++	++	++	++	++	++	++	+++
		Social ethics	-	-	-	++	++	++	++	+++
Type of education	Informal	Short courses	+++	+	+	+	++	+	+	+
	Formal	Vocational	+	++	++	++	+	-	-	-
		BSc	-	+++	+++	+++	+++	+	-	+
		Masters	-	+	+	-	+	++	++	++
		PhD	-	-	-	-	-	+++	+++	+++
Content		Basic sciences	-	+	++	++	++	+++	+++	+
		Engineering	+	+	++	+	+	++	++	-
		Aquaculture science & technology	++	+	+++	+++	+++	+++	+++	+
		Social science	+	+	+	++	++	++	++	++
		Business management & economics	+++	+++	+	++	++	++	+	+
		Ecology & environmental science	+	+	++	++	++	++	++	++
		Resource planning & management	+++	++	+	+++	+++	++	+	++
		Information technology	+	++	+	++	++	+++	++	+
		English	-	+	+	+	+	++	++	++
		Teaching skills	-	-	-	++	+++	+++	+	-

[1] Trainer and teacher are defined as persons who conducts short-term and specific training needs and impart knowledge in the conventional sense, respectively.

[2] + to +++ represents the level of need (+++ = maximum)

	English	-	+	+	+	+	++	++	++
	Teaching skills	-	-	-	++	+++	+++	+	-

[1] Trainer and teacher are defined as persons who conducts short-term and specific training needs and impart knowledge in the conventional sense, respectively.
[2] + to +++ represents the level of need (+++ = maximum).

One other important factor that needs to be taken into consideration in HRD is the diverse nature of the aquaculture sector. Currently, it is estimated that nearly 150 species are cultured, ranging from invertebrates to reptiles (FAO, 1999), including marine, brackish- and freshwater, temperate and tropical species. Culture practices range from extensive, to semi-intensive to intensive systems, and involve the use of ponds, raceways, pens and cages etc., in open, flow-through or closed systems. Aquaculture is practised in widely diversified ecological and socio-economic condi-tions, and the handling of the postharvest product also varies consi-derably. Not surprisingly, this diversity exacerbates the complexity of providing skill development and know-ledge transfer at all levels of expertise needed. This differs significantly from other food production sectors. In such circum-stances, it is difficult, if not impossible, for one (or even a limited number) of institutions to provide the expertise in all of these aspects. Therefore, a key to HRD in the new millennium will be cooperation amongst institutions.

If aquaculture is to develop in a sustainable manner in the new millennium, there needs to be an increase in research capabilities at the centres of emergent aquaculture, e.g. Vietnam and Ecuador. Continued dependence on training and expertise from temperate and developed regions should be re-evaluated and resources enhanced for within-region training, where expertise is based on local aquaculture systems.

To illustrate the need for enhanced HRD in research Figure 1, indicates the age and qualification distribution of researchers in an emerging aquaculture nation’s government research institutions. In this nation, of the 224 researchers in govern-mental aquaculture institutions, only 20.1 percent had postgraduate training, of which 6.3 percent had a Ph.D. or equivalent qualification.

This does not imply that to be an effective researcher one needs a Ph.D., but it has to be conceded that a critical mass of people with suitable postgraduate training is needed to maintain and generate the research designs required to meet aquaculture development needs.

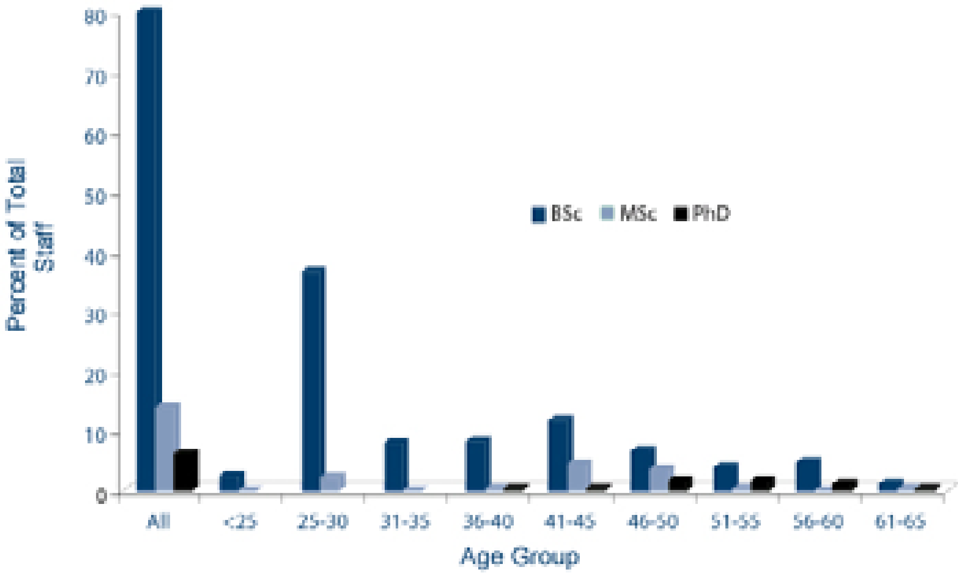
Mechanics of human resource development

One common factor operating at all levels of HRD is the sharing and effective dissemination of information. A recent survey of 54 institutions involved in aquaculture education in the member economies of the Asia Pacific Economic Cooperation (APEC) showed that institutions providing aquaculture education and training fall into three broad categories:

- vocational training institutions providing training for farm hands and lower managerial levels,
- governmental institutions specialising in short-term courses (non-diploma), and
- some research training at tertiary institutions that provide diplomas (24%), bachelor’s degrees (44.4%) and higher research degree training (22.2%) (De Silva et al., 2000).

There is very limited formalised private-sector training operating at the present time. The survey also showed that the degree of collaboration amongst international institutions and national institutions is: (a) in research (29.6% vs. 53.7%), (b) in development (5.6% vs. 14.8%) and (c) in education (7.4% vs. 33.3%) (De Silva et al., 2000). Furthermore,

Figure 1. Age and qualification profile of aquaculture research staff in an emerging nation's governmental institutions



the following were evident from the survey:

- most training is not market driven,
- part-time study was available only in about 18.5% of the institutions, and
- long distance or remote study was available only at one institution in the region.

Fresh approaches in human resources development

Inadequate aquaculture extension services have been recognised as a major constraint in many developing countries, and this needs to be rectified if the sector is to develop further in a sustainable manner. Training of extension workers has to be modified to incorporate and reinforce information delivery methods and mechanisms, as well as practical farming techniques. There is also a need for greater interaction between extension trainees and farmers during training ("on-site" training). Furthermore, extension training will certainly have to exceed the traditional "government extension" models of the past. New models and players in extension are needed - media, farmer associations, development nongovernmental organizations (NGOs), private sector suppliers and others will all likely come into more prominence, broadening

Unfortunately however, research funding provided by governments and/or the private sector in developing countries is relatively little. The private sector needs to be encouraged to invest in research, and governments need to consider providing appropriate incentives to the private sector to facilitate such a trend.

Hitherto, developing countries have tended to depend to a significant extent on donor agencies for training and research funding. Tables 2 and 3 provide the breakdown of funds allocated in a regional and international context.

It is evident that only a small amount of donor funds were dedicated to HRD by the above organisation. Admittedly, each of the major areas of expenditure may have included a certain amount of funds for workshops and short-term training, but the question remains whether or not funds spent on capacity building are adequate for sector development in a sustainable manner. Certainly the proportion of funds spent on training within one regional project valued at US$600 000 was only 6.7 percent (Table 3), and the bulk of these funds was spent on consultants.

It is important that donor agencies take note of the above and encourage capacity building in emerging training experience.

The ultimate goal should be to improve extension services and ensure a more effective use of resources. This can be achieved through:

- strengthening cooperation among extension training providers, including government, NGOs and the private sector;
- closer involvement of farmers in extension project planning, and development and dissemination of appropriate farming technologies;
- improved institutional linkages for better transfer of research findings to extension workers; and
- providing opportunities for extension workers to share their problems and experiences at the national and regional levels, similar to that enjoyed by researchers.

The centres of aquaculture development in the southern hemisphere are concentrated mainly in developing countries. It was stated earlier that there is a need for emerging aquaculture nations to develop their research capabilities and gear the research to meet the ever increasing needs and challenges imposed on the sector and minimise the dependence on research from outside the region.

aquaculture nations by channelling a larger amount/proportion of funds into on-site or regionally based training.

Conclusions

It has to be conceded that if aquaculture is to develop sustainably in the context of changing paradigms of development in the new millennium, there has to be more emphasis on HRD to address this need. Equally, there have to be changes in the nature of the training provided, and personnel encouraged to adopt a more holistic approach. There needs to be HRD in the research sectors, particularly in developing nations with aquaculture potential, and the research dependence on countries outside the region should be reduced accordingly. Governments within developing aquaculture countries and international organizations need to place more emphasis on HRD at all levels, and the private sector, particularly in developing nations, should be encouraged to participate more actively in funding research.

Table 2. Areas of expenditure of donor funds within a major regional organisation 1990-1998. (De Silva et al., 2000).

Major areas of investment	Expenditure US$ (x 1000)	Percentage of total
Coastal shrimp culture	2 215	44.4
Disease/quarantine	1 133	22.7
Capacity building	95	1.9
Environmental assessment/sustainability	1 275	25.6
Farming systems	45	0.9
Information technology	45	0.9
Processing	180	3.6

Table 3. The breakdown of expenditure of a regional R & D project conducted by an international organisation

Major areas of expenditure	Expenditure (US$)	Percentage of total
Personnel	185 000	30.8
International travel	60 000	10.0
Research expenses	245 000	40.8
Training /workshops	40 000	6.7
Contingency	70 000	11.7

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funding research.

Livestock Production: A Model for Aquaculture? Guest Lecture

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ABSTRACT: The broiler industry has been a vision of success to those producing and marketing other animal proteins of terrestrial, fishery or aquaculture origin. The broiler industry has evolved over the past 30 years to be a major source of animal protein in the human diet. Growth has been massive in recent years, having increased some 42 percent since 1992 alone. The United States has led the way in broilers, and now produces over 34 percent of the world's supply of 56 million mt of live broiler. The formula for success in broilers has been an abundant and affordable supply of corn and soybean meal and a business organization where birds are produced and finished meat products are marketed by the same company. Commercial fish production, in contrast, consists of many fragmented marketing arms for a wide array of finfish, molluscs and crustaceans involving both wild catch and managed culture. Of the total estimated 142 million mt of fish produced globally in 1999, the capture fisheries accounted for 102 million mt, with 30 million mt of that converted to fishmeal and oil. Aquaculture is estimated to have produced nearly 40 million mt in 1999, with over 90 percent of the production in Asia. China is by far the leader, with an estimated 1999 production of 27 million mt. China produces mainly carp and tilapia grown on a sustainable basis in small holdings with little or no feeding. Fish are collected and sold in traditional wet markets by third parties. Although Chinese aquaculture lacks capital and organization, the use of processed feed has recently caught the attention of the more progressive growers as a way to increase profit.

Shrimp and salmon on the other hand, because of their relatively high value among the cultured fish species, stand out for their potential to be grown the way broilers are, that is, in vertically integrated businesses. In Taiwan Province of China and Southeast Asia, several large feed and poultry companies made significant strides in the late 1980s and early 1990s toward vertical integration in shrimp production. This led the way to upstarts in South and Central America, the Indian subcontinent and now Africa. In most locations, however, early successes have been punctuated with disease failures. The outbreaks of disease, more often than not, have been the consequence of a deteriorated environment caused by the farms themselves and poor practice of biosecurity. Technical advances in disease control, genetics, nutrition and ecology all have the potential to overcome many of these problems. The value and demand of these food products in the market warrant strong development effort. Business integration and technological development will lead the way for cultured aquatic species to become major protein sources in the human diet. Opportunities and obstacles in aquaculture are considered in this paper relative to the parallels and differences in livestock production.

KEY WORDS: Agriculture, Animal Production, Aquaculture, Feed, Feed Conversion, Shrimp Production

Introduction

Aquaculture is contributing to an increasing share of the world's seafood supply. Figures provided by the Food and Agriculture Organization of the United Nations (FAO) show that aquaculture has increased in importance, with a global growth rate outstripping that of livestock meat production by a factor of two to four. In Asia, particularly in countries like China (1.23 million mt in 1979 to 15.31 million mt in 1996), Bangladesh,

Recent advances in selective breeding and sex control technologies for tilapia, for example, have had a considerable impact on tilapia production. (G.C. Mair, pers. comm.).

However, it is in the production of high-value species such as salmon and shrimp that parallels may be more clearly drawn in the large-scale production of livestock such as broilers. Without downplaying the importance of rural aquaculture in food production and provision of

India, Indonesia, The Philippines, Thailand and Vietnam, the growth of aquaculture has greatly outpaced growth in livestock production. As the scope for increasing the supply of seafood from traditional fisheries is limited, aquaculture is seen as having an important role to play in feeding the growing populations of many developing countries.

Despite the high international profile of aquaculture products such as shrimp and salmon, world aquaculture production is dominated by freshwater fish, particularly in Asia, which is estimated to produce over 90 percent of the world's aquaculture output. Much of this is produced by small-scale rural aquaculturists. Small-scale rural aquaculture, like its terrestrial counterpart, is likely to benefit indirectly from developments in technology. Improvements in the characteristics of farmed ish as a result of genetic improvements, and in health management and disease control will filter through to the small-scale farmer.

rural livelihoods, it is this type of commercial, large-scale aquaculture that may benefit most from a comparison with trends in agriculture production.

In the United States, per capita consumption of broiler meat has surpassed that of beef, lamb, fish and pork. Since 1976, the per capita consumption of fish increased by a modest 12 percent and pork by 41 percent, while beef decreased by 33 percent and lamb decreased by 41 percent (Graves, 1999). Broiler chicken and turkey meat were the star performers, with increases of 93 percent and 100 percent over the same period. Table 1 shows the United States consumption patterns for these animal proteins. Broiler production has followed similar trends in other countries, as shown in Figure 1, with large increases in China, Brazil, Mexico, France, the United Kingdom and Thailand. In most countries, a majority of the production is consumed domestically.

Coupled with the increase in consumption of broiler meat has been a fantastic increase in profit performance of the chicken companies involved. What caused this shift in consumption pattern favouring chicken? What made these companies so successful?

Figure 1. Top Broiler Producing Countries

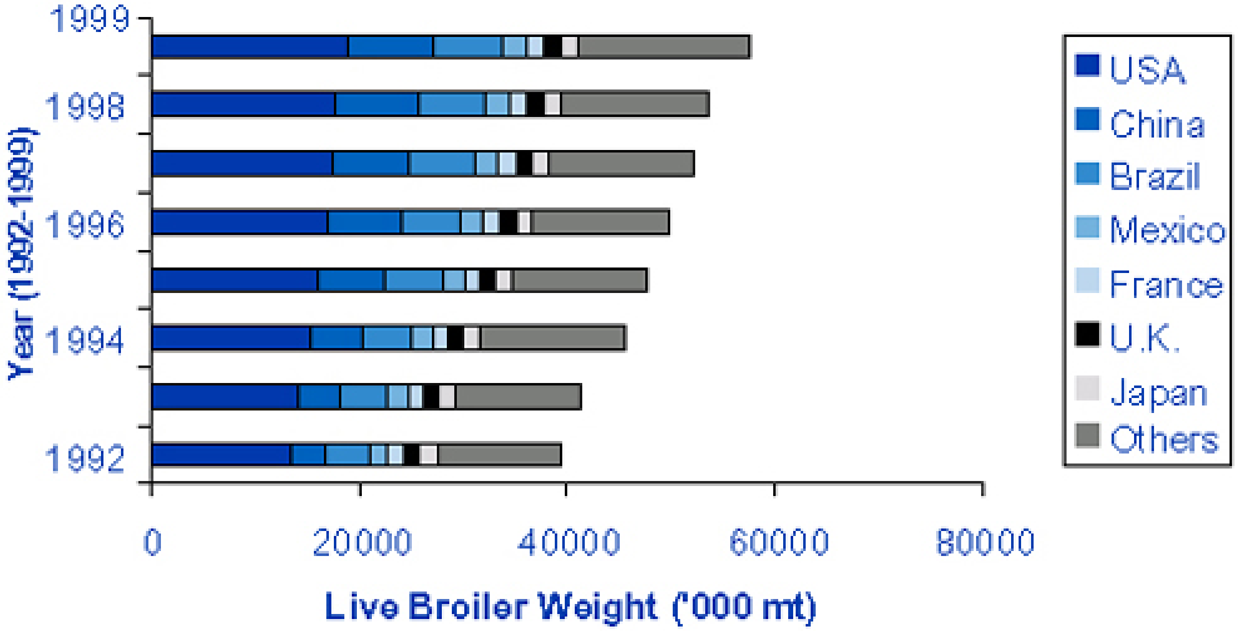

Table 1. Change in meat consumption in the United States (kg of boneless meat per person per year)[2]

	1976	1988	1999	23 Year Change (%)
Beef	44.1	31.2	27.1	-39
Pork	16.3	22.2	23.0	41
Lamb	1.2	1.0	0.7	-41
Chicken	12.9	18.2	24.7	93
Turkey	3.2	5.6	6.4	100
Fish	5.8	6.7	6.6	12
Total	**83.5**	**84.9**	**88.5**	**6**

[2]Adapted from Graves (1999) and the United States Department of Agriculture (USDA, 1999)

What is the take home message for the other livestock and aquaculture industries? The answers are: 1) successful marketing of attractive, high quality, branded finished products; 2) vertical business integration that resulted in decreased costs with improved quality; and 3) technological breakthroughs and innovations in production. The single major factor that increased profit in these companies was being able gain control over many if not all of the aspects of chicken production and marketing. In its most evolved form, this integration involves control of primary breeding, hatching, growout, feed production, processing, shipment of raw materials, delivery of finished meat products, marketing, restaurant chains, retail outlets, grain farming and soybean processing. Teams of highly trained technical and management specialists are required to manage operations under one entity. Figure 2 shows the estimated production of the top five integrated broiler companies in the world. The largest, Tyson Foods, produces more broiler meat per year than the countries

Integration allows companies to produce what consumers prefer without losing concentration on the cost aspect. The balance of product quality versus cost is a constant, never ending, internal battle for an integrated company.

The contract growing system has been considered one of the most important core aspects for successful operation of an integrated broiler company (Aho, 1988). Broiler husbandry is an occupation that requires a 24-hour dedication to the task. This is the main reason why the contract system has been found to be more successful than company-owned farms. Such dedication is easier to find in a farmer-owner with a stake in the profit outcome than in a salaried worker. A large bank loan has a way of concentrating the mind to proper priorities at 3.00 a.m. when the weather is bad. While there are many variations to the theme, in most contract-grower operations, the independent farmer owns the land, buildings and equipment, and the integrated broiler company supplies the day-old chicken stock, feed, fuel, vaccination and technical assistance and guarantees buy-back of hatching eggs or broilers at a set price. Integrators continually rate the performance of their growers regarding superior performance and penalise those that are below average. Good management and feed conversion is rewarded with a cash bonus, while the poorest growers are dropped from the company. The integrated company may provide loans for improvements and new buildings provided they are built to company specifications. This has been a win-win situation for both the growers and integrators. By employing vertical integration, a company can effectively control cost, reduce outbreak of disease and improve of Mexico, France, the United Kingdom or Thailand.

Integration and contract growing

As broiler companies expand by both acquisition and new facilities, economies of scale are increased and costs are decreased. Business relationships with suppliers of raw materials and equipment necessary to operate are such that they are made part of the business chain and are responsible for their actions and products. The most highly developed and profitable integrators know the value of on-time delivery, product quality and consistency, and are willing to pay for and recognise value. They continually work with their suppliers to improve quality.

Broiler integrators have developed extensive marketing campaigns and strongly tout the features, advantages and benefits of their product in various forms of media. This allows companies to differentiate themselves not only from other available meat products, but also from

overall quality of finished product.

Figure 2. 1999 Estimated Production of the Top Five Integrated Broiler Companies of the World

ordinary wet-market or commercial grocery store chicken. The integrators have been successful in eliminating or reducing the profit of middlemen involved in the marketing chain of their products. Marketing is focused on the consumer, with the spotlight on freshness, cleanliness, taste, eye appeal and product utility.

Some companies have also started vertical integration in aquaculture operations. Salmon producers have embraced this concept, but there are major differences in the structure of the salmon industry (in particular, the fact that salmon farm concessions are granted by governments and are not privately owned freeholds) that limit the extent to which this model can be applied (Forster, 1999). Farmed shrimp shows a greater similarity to the situation with chickens, as shrimp farms are usually located on private property or on land for which a long-term freehold is available. As a result, shrimp exporters in some countries have developed farm and

Economic estimates comparing broiler and shrimp production “on the farm” in the United States and Thailand are interesting (Table 3). On a live weight basis, the market price received for broilers in the United States is cheaper than the feed cost to produce the same weight in Thailand. Live shrimp command a market price roughly ten times higher than live broilers. The gross margin for “on the farm” shrimp produced in Thailand is several orders of magnitude greater than the “on the farm” profit for broilers in the United States or Thailand. These numbers suggest that unlike shrimp, much of the profit in broiler production is not hatchery operations to ensure supplies of good quality product and, in some cases, have developed further integration with marketing operations in major markets.

Contract farming in aquaculture is less common, partly due to the high cost of entry into the farming operation itself. Many integrated operations are based on corporate farming, and where contract farming has been tried, it has shown mixed results. Several groups have attempted to establish contract-farming operations for shrimp, especially in Southeast Asia. One of the problems experienced, however, is that the shrimp industry is not yet at a stage of development where risks are understood and can be spread across the production chain. The supply chain is still fragmented and, as in the early days of chicken production, there is an "every man for himself" attitude in which each level in the supply chain has to look after its own profits. The market lacks predictability, further impacting on continuity. There are signs that this may change but, with disease still having a major impact on product availability and price, there is still some way to go before the conditions will be conducive to efficient contract-farming operations.

Economics of broiler and aquaculture production

derived from farm growout but rather, by adding value as in further processing. The data also demonstrate the large potential for reducing the price of shrimp. That would increase both consumption and economies of scale in shrimp production and processing.

The major costs in salmon farming are usually smolts (juvenile fish, or seedstock) and feed, with labour, insurance and other costs making up the rest of the production cost. Feed is the largest expense, ranging between 35 to 50 percent of total cost. It is anticipated that continued improvements, especially in feed utilisation (food conversion rate), will contribute to a reduction in production cost. Smolts are another large expense, but the cost has come down in recent years because of better survival at sea and lower costs of smolt production. Further technical improvements will continue to move costs down, but savings will become harder to achieve (Forster, 1995).

As with the poultry industry, farmed salmon has already come some way towards reducing costs, with production costs declining substantially and likely to continue to do so as a result of increasing efficiency (Forster, 1995). Feed costs are still a substantial cost component in salmon production, and have been estimated at 2.8 times the cost of feed to produce an equivalent weight of chicken. However, if yield and the

Intense competition by broiler integrators has created an extremely efficient industry. Some indicative costs for production, processing and sale of broilers in the United States during November 1999, given in Table 2, show just how competitive this system has become. The fact that it should cost only $1.78 per kg, including profit (the price spread), to process, transport, wholesale and retail a whole chicken is remarkable, and salutary when compared with generally accepted costs of doing these same tasks in the seafood industry today (Forster, 1999; USDA, 1999).

cost of holding breeding stocks are taken into account, this can be reduced by half, with further reductions expected as a result of future improvements in nutrition and genetics.

Marketing

A comparison of the broiler and beef industries in the United States is useful to explain how important the consumer and vertical integration might be to the shrimp or other aquaculture industries in the future. In the early 1970s, beef was king in America. Today, beef represents an unbranded and non-integrated protein source with falling market share.

The industry largely ignores its consumers and continues to offer raw pieces of beef flesh described anatomically using an antiquated grading system that favours a high fat product. Each segment of the industry operates as if it were an island. The cow-calf breeding operation, feedlot, meat packing plant, truck lines, merchandising and retailing are all independent businesses, each

Major acquisition and consolidation has taken place, similar to what happened in the poultry industry 15 to 20 years ago. Consumers’ preference for lean meat and creative processing is being heard by pork producers, and consumption is on the upswing.

Aquaculture, especially shrimp and salmon, appears to be well suited to vertical integration and well suited to responsible for making as much profit as possible. Once the product is off the truck or out the door and the money changes hands, all care and much of the responsibility is finished.

In contrast, since the 1970s, large chicken companies such as Tyson Foods, Charoen Pokphand, ConAgra and Perdue Farms have become relentless in developing products such as chicken nuggets, processed meat, precooked turkey ham and other specialities. Innovative ideas such as chicken shops, franchise restaurants, and retail outlets have become part of these integrated broiler operations. Branding and brand recognition of poultry products has been an essential element, allowing these companies to gain control of the entire business from grain plow to dinner plate. Consequently, more consumers have switched to chicken and have decided to eat less beef. The swine industry in the United States in the past five to eight years has begun to follow the lead of the poultry industry.

producing attractive food products for the consumer. In the search to improve genetics, disease resistance and pollution control, the aquaculture industry must not lose sight of the end consumers and their preferences. Consumers will be loyal to a product that is wholesome, healthy, tasty, consistent, versatile, provided in attractive packaging and is available consistently throughout the year.

Marketing in the shrimp industry is different than in the broiler industry in that the major consumer markets are in countries different than production. Figures 3 and 4 show the major shrimp culture countries and the market consumption by the United States and Japan. Indonesia and Thailand are major producers, while the United States and Japan, followed by European countries are the major consumers (Csirke et al. 1998).

Table 2. United States production and marketing costs (Ready-to-Cook (RTC) chicken, USDA, November 1999)

	Cost
Feed cost per kg. live weight produced (US$)	0.286
Total live weight production cost delivered to plant (US$)	0.410
Conversion from live weight to RTC (including giblets) %	75
Total live bird input cost per kg (US$)	0.550
Processing and packaging cost per kg (US$)	0.250
Ex plant RTC per kg (US$)	0.800
Marketing expenses and freight to wholesale market per kg (US$)	0.139
Wholesale RTC per kg (US$)	1.320
Marketing expenses, wholesale mark-up and freight to retail market per kg (US$)	1.001
Retail price RTC per kg (US$)	2.321
Total cost of processing, distribution and retail sale per kg (price spread) (US$)	1.390

Table 3. Economic comparison of broiler and shrimp production (recent estimates (US$) from America and Thailand, 2000)[3]

	Broilers		Shrimp	
	America	Thailand	America	Thailand
Market price (live)	0.368	0.686	5.000	5.870
Feed cost	0.150	0.234	0.605	0.980
FCR	1.900	1.950	1.800	1.500
Feed cost per kg	0.286	0.456	1.080	1.470
Other costs per kg	0.090	0.166	0.510	0.860
Gross margin per kg	0.010	0.064	4.150	4.360
Liveability (%)	97	95	60	55

[3]Data from G. Chamberlain (pers.comm) and O. Sukpriyagul (pers.comm)

In the late 1980s and early 1990s, the Asian shrimp aquaculture industry was focussed mainly on Japan. However, a decline in exports to Japan due to the protracted economic slowdown and an increase in export to and demand by the United States has created substantial problems due to sanitary issues and quarantine concern over viruses that might potentially affect natural United States shrimp fisheries. A concerted effort between exporting and importing governments, as well as sellers and buyers, is required to overcome these problems and concerns. Clearly, if the shrimp disease problems can be remedied, the industry will continue to advance. The shrimp industry in Thailand and Indonesia has already begun a creative international marketing campaign to promote shrimp consumption in Japan and the United States and in this respect, is already ahead of broiler producers.

The market for farmed salmon has grown tremendously over the past 10-15 years to where salmon is now regarded as a much more affordable food item and has penetrated newer, nontraditional, markets such as Asia. Further expansion of the market for farmed salmon will depend on its ability to compete with other foods, either fish or meat items. Frozen salmon products, rather than fresh or chilled salmon, are easier and cheaper to distribute and can increase the market penetration.

The growth of the United States market for tilapia has also had a significant impact on the way in which this fish species is marketed. Before 1986, demand for tilapia in the United States was mainly centred around localized demand in Asian communities for live product and was met by domestic producers (Fitzsimmons, pers. comm.).

The import of frozen whole tilapia from Taiwan Province of China in the mid-1980s, coupled with a greater awareness of the fish among United States consumers, led to an expansion of the market, with annual consumption of tilapia now estimated at over 51 000 mt. Although Taiwan Province of China continues to be the main exporter to the United States, mainland China, Thailand and Indonesia have become significant sources of frozen fillets and some Caribbean and Central and South American countries have also become important suppliers of fresh tilapia. In order to position tilapia products better in the United States market, the Tilapia Marketing Institute (TMI) was established in 1998 by a group of large producers and marketers. The TMI intends to pursue a generic marketing campaign to benefit all producers and product forms, both domestic and foreign, and will seek to encourage producers to meet high standards of quality. This follows the beef marketing model more than that for chicken, and it remains to be seen whether it will be more

Like chicken, there is considerable potential for brand identification in marketing salmon. This has already happened to some extent, on a national basis, with strong "branding" efforts being developed for farmed Canadian, Scottish and Norwegian salmon. Value-added processing, particularly of smoked product and salmon steaks, is a significant feature in salmon marketing, and there is considerable potential to widen this to include other salmon-based products.

successful for tilapia than it has been for beef.

Figure 3. Major Shrimp Producing Countries

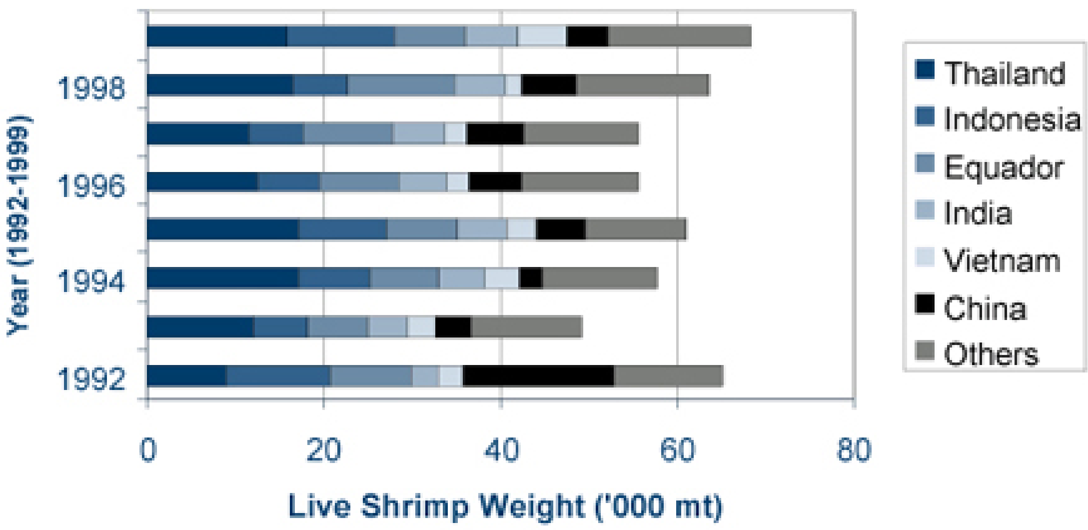

Figure 4. Shrimp Consumption by USA and Japan

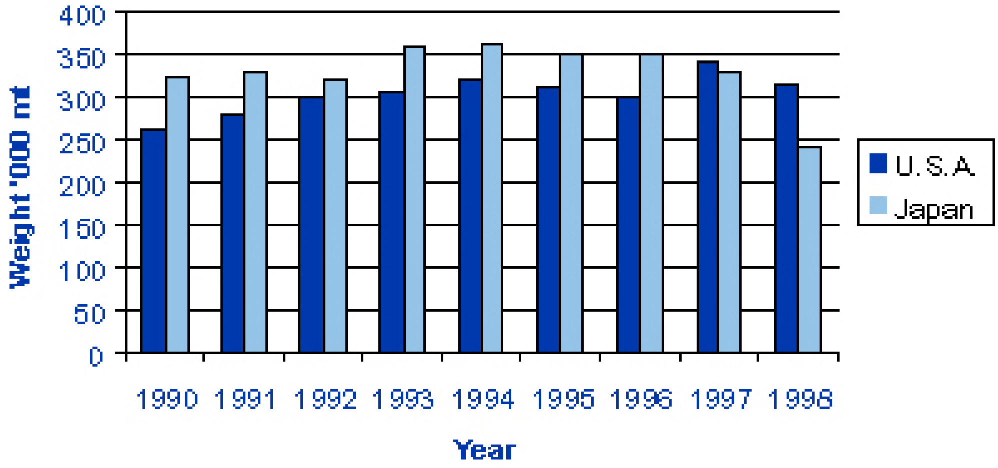

Table 4. Mixed sex commercial broiler performance improvement over 30 years

	1970	1980	1990	2000	%
Market age (days)	59	51	44	49	47
Market weight (kg)	1.70	1.85	1.95	2.02	19
Food conversion	2.18	2.04	1.89	1.85	15
Liveability %	96.1	96.6	96.9	97.0	1

Technological advances

The growth rate of commercial broiler chickens has increased from a 1.70 kg bird grown for 59 days in 1970 to a 2.02 kg bird grown in 40 days today, as shown in Table 4. This could not have been possible without the continued improvement in genetics, disease control, management and nutrition over the years.

Breeding and genetics

In the broiler industry, genetic improvement has been responsible for the major increases in growth and

More recently, selection for feed conversion has been found to further improve economics and carcass quality (Pym and Nichols, 1979).

Shrimp culture, in contrast to broilers, has much catching up to do in the area of domestication, selective breeding, gene mapping, and biology in general. An excellent review of this topic was recently published by Argue and Alcivar-Warren (1999). At present, shrimp culture depends largely on wild capture of postlarvae or broodstock. This does not allow selection pressure for desired traits and is risky, as diseases may be transmitted. Selection pressure has improvement in meat quality. Much of the genetic improvement work started in the early days at academic institutions was taken over by commercial breeder companies. Today the largest four or five major broiler breeding companies are owned or controlled by the major global poultry integrators. Today's modern broiler is a four-way hybrid cross (Boyle, 1999). The pedigree programmes of breeders have evolved into sophisticated breeding schemes which maximise selection intensity and speed while using statistics to make selections. Reproduction, growth, liveability, skeletal integrity, meat yield and feathering have all been considered as important traits. Heritability for growth rate is relatively high at around 0.4, and substantial gains have been realised over the years (Chambers, 1990).

been found to be effective in improving performance in penaeid shrimp, with heritability for growth rate ranging from 0.34 to 0.98 in Penaeus vannamei (Carr et al. 1997), and significant for P. monodon (Jarayabhand et al., 1998). Little work has been done in the area of cross-breeding or development of pedigree shrimp. Work at the Oceanic Institute in Hawaii has shown potential for breeding shrimp resistant to Taura syndrome virus (TSV), although it may be more practical to select shrimp for general immune response or osmoregulatory capacity than for a specific disease. Production of specific-pathogen free nauplii has begun at the Oceanic Institute and, although it appears to be an effective way to limit disease transfer, there is concern that such programmes may decrease genetic variation because only a few female shrimp are required to produce large numbers of nauplii.

DNA techniques using PCR technology have improved ability to follow generations of shrimp, and work in the area of polyploidy, sex reversal and interspecific hybridisation have shown early promising results (Argue & Alcivar-Warren, 1999). Triploid penaeid shrimp appear to have faster growth, better survival rates and may be sterile, which would protect the investment of breeding companies and the environment by not allowing exotic species to spawn. Breeding and genetics of shrimp is an area where much greater study is warranted.

Genetic improvements have played a major role in the development of the finfish industry. The application of breeding and selection programmes in salmon, tilapia and carp has led to considerable improvements in growth and productivity in these species (Gjedrem & Fimland, 1995). Improvements in genetics and breeding of salmon, along with major improvements in feed and health care for farmed salmon have, for example, considerably reduced the production time for salmon in sea water.

Disease and biosecurity

Disease has been a major, yet often under-appreciated factor in changing the course of human history and development. This is no less true for

In addition, the drug and pharmaceutical industry has had numerous breakthroughs during this time, including the development of ionophore antibiotics to control coccidial parasites and improved antibiotics and new antimicrobials such as fluoroquinolones.

Management and facility layout in breeder farms, broiler farms and hatcheries has been found to be a key factor in disease control. The best and most obvious way to control disease is to avoid contact with sources of infection. Monitoring of pathogens is thus essential. Multi-age flocks are avoided on farms controlled by successful broiler companies. Routine and planned complete depopulation has been found to be the most effective way to control many diseases, as most disease-causing viruses cannot survive for more than a week or two outside of the chicken host. Those who disregard basic principles of disease prevention may succeed in times of favourable market conditions, but will go out of business when profit margins are small.

Many devastating diseases have been encountered in shrimp culture. As shrimp are not visible under the water, disease may go unnoticed until disaster occurs. Furthermore, overfeeding of diseased and anorexic shrimp leads to water quality problems that further exacerbate the condition. As in poultry, pathogens the livestock which man has farmed and hunted. In modern times, the impacts of rinderpest and foot and mouth disease have caused major disruption, particularly in developing countries (Thrusfield, 1995). The aquaculture industry is no exception to the general principle that, as farming activities intensify and spread, the likelihood of major disease problems occurring increases.

The broiler industry has been plagued with its share of diseases and problems related to viruses, bacteria and parasites over the years. The use of antibiotics, chemicals, disinfectants and vaccines, coupled with an understanding and application of biosecurity concepts, has been for the most part, successful in controlling many economically crippling diseases.

The past 30 years have seen major developments in poultry vaccines to control viral diseases such as laryngotracheitis, infectious bronchitis, Newcastle disease, infectious bursal disease, Marek's disease and viral arthritis. Vaccines have been improved by back passage of the viruses through chickens to enhance transmissibility, the use of bivalent antigens and recombinant DNA technology (Shane & Lasher, 1999).

are transmitted by transport containers, contaminated vehicles, wild animals and in air and water. Bacterial diseases, particularly those caused by Vibrio species, appear to be widespread. Vibrio spp. are generally regarded as opportunistic pathogens, although one, Vibrio harveyi, the cause of luminous disease, is regarded as a primary pathogen. Viral diseases, however, have been the most devastating.

One particularly devastating viral disease that affects shrimp producers in all parts of the world is white-spot disease, caused by white spot syndrome virus (WSSV). This disease can cause losses of 90 percent or more of shrimp being produced on a farm. The agent is a baculovirus-like virus that is transmitted horizontally through seed stock, contaminated feed, infected shrimp and other carriers, especially crustaceans such as wild crabs. Vertical transmission is unlikely, although recently posthatched stock are soon infected by the virus present in feed or water.

Other diseases that are devastating to shrimp producers are yellowhead disease, caused by yellowhead virus complex (YHV), encountered mostly in Asia, and Taura syndrome, caused by Taura syndrome virus (TSV), which is most prevalent in the Americas. Recent developments in DNA assay procedures using the polymerase chain reaction (PCR) are becoming useful to detect infection of seedstock and contamination of feed ingredients, although testing costs and utility of this procedure in the field are limiting factors.

The transmission of WSSV to the Americas and reports of TSV in Asia have highlighted the dangers of uncontrolled and unregulated transfers of stocks between countries. Quarantine regulations and practices are not so highly developed for aquatic animals as they are for terrestrial ones, although the situation is expected to change with the 2000 revision of the International Aquatic Animal Health Code and the Diagnostic Manual for Aquatic Animal Diseases by the Office International des Epizooties (OIE) in Paris. The OIE, or World Organization for Animal Health, is the recognized agency responsible for informing governments of the

Feed formulation on a digestible nutrient basis is being practised more often to reduce costs and allow transparent changes when ingredients are substituted for one another. Supplementation of diets with methionine as well as threonine, lysine and tryptophan is becoming more common in commercial practice. The practice of removing expensive fishmeal from diets is gaining ground as more nutritionists recognise that the unidentified growth factors have been identified as selenium, vitamin B12, methionine and omega-3 fatty acids.

Shrimp nutrition and feed production have several major differences when compared to broilers. The ratios and requirements of nutrients are different, and cholesterol and ascorbic acid are required. Growth responses have been observed with addition of lecithin, and attractants from fishmeal appear to improve feeding rate. Grinding, conditioning and pelleting are more critical in production of shrimp feed than broiler feed, as pellets must be small and durable in water. Leaching of water-soluble vitamins and amino acids needs to be considered. Contamination of feed with disease-occurrence and course of animal diseases throughout the world, of ways to control these diseases, for coordinating studies devoted to the surveillance and control of animal diseases and for the harmonization of regulations for trade in animals and animal products among OIE-member countries. The Fish Disease Commission of the OIE compiles information on diseases of fish, crustaceans and molluscs and on methods of control of these diseases, and harmonizes rules governing trade in aquaculture products, as well as the control of products for diagnosis or prophylaxis. Regional initiatives, under the guidance of NACA and FAO, are also under development to reinforce regional capacity to meet OIE recommendations.

Nutrition and feed processing

Each of the required amino acids, energy sources, vitamins, minerals, other nutrients and their interactions have been studied in depth in countless feeding studies and laboratory examinations in broilers. While there is still a great deal to learn, the commercial industry is now focussed on reducing cost of production and reducing feed-related bacterial contamination with organisms such as Salmonella and Campylobacter, and also on reducing nitrogen and phosphorus levels in causing agents from marine meals and live sources is a major concern. Post-hatched juvenile shrimp must be fed algae, zooplankton and other marine-derived ingredients such as live artemia. Juvenile shrimp are considered to be particulate feeders, whether feeding on processed feed or natural sources of plankton. The use of flocculants in pond water has been shown to improve feeding and performance in shrimp, as organic particles such as algae and bacteria are aggregated and made available for consumption (Moss, 1995; Tacon et al., 1999).

The use of soybean meal in shrimp feed has been studied extensively (Akiyama et al., 1989; Akiyama 1989). Fibre level of the meal is important, as excess fibre reduces pellet stability and energy density of the diet. Levels of 25-30 percent dehulled soybean meal have been demonstrated to give good performance in shrimp (Lim and Dominy, 1990). Reducing the reliance on fishmeal in shrimp feed will reduce cost and lower the possibility of diet-transmitted pathogens. Formulation on a digestible amino acid basis and the use of ideal amino acid ratios will reduce nitrogen loading of pond water and effluent. Use of phytase enzyme will have a beneficial impact on phosphorus levels in water if methods of application can be found to increase enzyme stability and reduce possibility of leaching. Ingredients such as porcine plasma manure. Supplemental feed enzymes are being examined to reduce waste output and as replacements for antibiotic growth promoters, which are losing favour.

protein, soy protein concentrate and partially hydrolysed vegetable protein may have future utility as attractants and nutrient sources.

Environment

Environmental control and management are critical to the broiler industry. Of particular concern are litter (manure) control, water treatment and the handling of dead animals. Poultry litter contains excreta and bedding material such as rice hulls or wood shavings. The waste material litter is valuable as an organic fertiliser. In the United States, litter is removed from broiler houses only once per year unless there is a disease outbreak. Depopulation of broiler houses for several weeks after flock marketing is effective to eliminate viruses that cannot live outside their hosts. Starting new chicks on used litter helps populate the digestive flora quickly and excludes pathogens. Used litter is disposed as fertiliser in accordance with government soil and water conservation service guidelines to avoid runoff. Water used for processing carcasses is

The use of closed biosecure culture systems with reduced or zero water exchange is an area under intense evaluation at the present time. Such novel production systems have the potential to increase productivity, reduce effluent and control disease. These systems have already been developed, tested and proven to work on a prototype basis. At the present time however, they are not cost effective on a commercial scale because of high electricity costs necessary to run aerators and pump water through raceways and filters (Leung and Moss, 1999). Further refinement of biofilters required to clarify water and metabolise nitrogenous wastes, along with improvements in genetics of shrimp, may make biosecure systems economically viable in the future. This would allow farms to be located some distance away from the ocean and would reduce the incidence of disease. Much like broiler production on litter floors, several crops of treated to remove organic material and other pollutants before being released into the environment. Equipment such as dissolved air flotation systems (DAF) is now being used to remove fat and particulate matter from processing wastewater. Dead bird carcasses are typically frozen and subsequently recycled and sterilised in rendering operations. The material is used as a feed ingredient along with other treated waste products such as feathers and offal collected during processing.

Aquaculture and in particular, shrimp farming, differs from broiler farming in that the growout operations are typically located along ocean-front and estuarine areas and are, therefore, under environmental scrutiny. Semi-intensive culture requires large ponds, location on clay soil to reduce seepage, low soil acidity and low land elevation to reduce pumping costs. Problems with pollution and disease have occurred in shrimp culture areas because of concentrated development without coordination and the use of infected postlarvae. Improved pond management and development according to plans and guidelines will help the situation. In important culture areas such as Thailand, codes of conduct are being developed for shrimp farming to ensure sustainability and provide for environmental, social and economic benefits for present and future generations. Businesses, shrimp could be grown in the same water, with time allotted for depopulation between growouts.

Conclusions

Aquaculture has many attributes that give it the potential to become a major source of protein in the human diet in the future, much like broilers are today. Feed conversion ratios are more favourable than for broilers, and many species such as salmon and shrimp are especially well suited for the production of a wide variety of attractive further-processed food products. Such development will require consolidation of the value chain by vertically integrated companies to a point where single businesses control feed supply, growout, seed stock, processing and marketing of branded finished products. International marketing of food products will require creativity to gain brand recognition. Technological improvements in genetics, disease control, nutrition and the environment are vitally important, just as they have been in other livestock industries. Increasing the use of vegetable protein sources in feeds will have a positive impact on reducing feed cost and prevention of disease. The high value and consumer acceptability of shrimp make the development worthwhile.

organizations and stakeholders involved in the industry are involved in generating, reviewing and commenting on the codes of conduct.

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Part III - Thematic Reviews

Increasing the Contribution of Aquaculture for Food Security and Poverty Alleviation

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ABSTRACT: Hunger and malnutrition remain amongst the most devastating problems facing the world's poor and needy, and continue to dominate the health of the world's poorest nations. With the world population doubling in size from three to six billion people from 1960 to 1999 and currently growing at 1.33 percent per year (or an annual net addition of 78 million people), and expected to reach 7.3 to 10.7 billion by 2050 (with 8.9 billion considered most likely), there are growing doubts as to the long-term sustainability of many traditional agricultural systems required to meet increasing global demand for food. Nowhere is this more critical than within many of the world's developing countries, and in particular, within those Low-income Food-deficit Countries (LIFDCs; currently representing over 62 percent of the world's population) which are net importers of food and lack sufficient earnings to purchase food to cover basic dietary needs.

Of the different global food production systems, aquaculture is generally viewed as an important domestic provider of much needed high-quality animal protein and other essential nutrients (generally at affordable prices to the poorer segments of the community). It also is an important provider of employment opportunities, cash income and valuable foreign exchange, with developing countries producing over 90 percent of total aquaculture production by weight in 1998. However, if aquaculture is to play an even greater role in improving food security and the alleviation of poverty, it is recommended that: 1) the actual and potential contribution of aquaculture to food security and poverty alleviation be fully documented; 2) funding for aquaculture for the poor should be increased, especially for countries where traditional aquaculture practices already exist; 3) aquaculture projects should do no harm to the food supplies of the poor; 4) existing aquaculture activities of the poor should be strengthened through the use of improved farmer/farming participatory systems research and people-centered development/extension approaches; 5) investment be encouraged to support knowledge building for management of sustainable aquaculture practices; 6) participatory production practices be pursued within a framework of sustainable integrated management of natural resources (including their improved use) and different agricultural production systems; 7) the focus should be on low-cost products favoured by the poor; 8) emphasis be placed on improving culture systems for aquatic species feeding low in the food chain; 9) production for local consumers/markets be encouraged; 10) community-based (rather than individual or corporate) production should be encouraged; 11) consumption of aquaculture products from a human nutrition viewpoint should be encouraged and promoted; and 12) food security impacts of aquaculture projects should be monitored.

KEY WORDS: Aquaculture, Malnutrition, Poverty, Food Security

The problem: malnutrition, food security and poverty

Malnutrition: the on-going global travesty

Hunger and malnutrition remain amongst the most devastating problems facing the majority of the world's poor and needy, and continue to dominate the health of the world's poorest nations (WHO, 2000). Nearly 30 percent of humanity, including infants, children, adolescents, adults and elderly within the developing world, are currently suffering from one or more of the multiple forms of malnutrition. This remains a continuing travesty of the recognised fundamental human right to adequate food and nutrition, and freedom from hunger and malnutrition, particularly in a world that has both the resources and knowledge to end this catastrophe.

The tragic consequences of malnutrition include death, disability, and stunted mental and physical growth and as a result, retarded national socio-economic development. Some 49 percent of the 10 million deaths among under-five children each year in the developing world are associated with malnutrition, iodine deficiency currently being the greatest single preventable cause of brain damage and mental retardation world wide, and vitamin A deficiency remaining the single greatest preventable cause of needless childhood blindness. Moreover, there is also the concurrent epidemic of obesity which is emerging within many industrialised countries, so much so that more than half the adult population in some countries is affected, with consequent increasing death rates from heart disease, hypertension, stroke and diabetes (WHO, 2000).

According to WHO (2000), the current global scale of malnutrition and nutrition-related disease can be listed as follows:

- intrauterine growth retardation: 30 million (23.8 percent of all births) per year;
- protein-energy malnutrition: 149.6 million under-five children;
- iodine deficiency disorders: 740 million;
- vitamin A deficiency blindness: 2.8 million under-five children;
- iron deficiency anaemia: 1,480 million women, children and men;
- obesity: 203 million adults, 21.9 million children;
- cancer (diet-related): of 10.3 million cases of cancer per year, 3-4 million (30-40 percent) are preventable by feasible appropriate diet and exercise;
- malnutrition of the elderly: 540 million elderly, with well over half having some diet/nutrition-related degenerative disease such as cardiovascular disease, cerebrovascular disease, diabetes, osteoporosis or cancer; and
- osteoporosis: around 2 million hip/spine fractures per year (80 percent in women), with calcium, vitamin D and exercise being critical for prevention.

Other important and related nutrition issues affecting large population groups

- 34 percent of infants never exclusively breast-fed between 0-4 months of age;
- poor complementary feeding practices very widespread and a major cause of childhood malnutrition;
- scurvy, beriberi and rickets in badly deprived and refugee populations;
- foliate deficiency in women of childbearing age and adolescent girls causes 75 percent of cases of anaemia and neural tube defects;
- zinc deficiency in deprived populations causing growth retardation, diarrhoea, immune deficiency and skin lesions; and
- selenium deficiency widespread in China and Russia.

Food security and poverty: adequate food - a human right

According to Mary Robinson (United Nations High Commissioner for Human Rights), "few economic rights are violated on such a scale as food and nutrition rights" (Robinson, 1999). Approximately 790 million people in developing countries and 34 million in developed countries, mainly women and children, are not eating sufficient food to meet their basic nutritional needs (FAO, 1999). As a footnote, it is important to mention here that it is national governments (not international organizations) which are the primary agents for the realization of human rights, and that these rights are clearly articulated in national law (Kent, 2001).

The Food and Agriculture Organization of the United Nations (FAO) defines food security as "access by all people at all times to the food needed for a healthy and active life" (FAO 2000a) However, achieving food security necessitates that food be available on a regular basis and that all those people in need of it can obtain it.

According to FAO, chronic undernutrition and food insecurity are principally caused by a combination of factors, including 1) low agricultural productivity (caused in part by policy, institutional and technological constraints), 2) high seasonal and year-to-year variability in food supplies (often the result of unreliable rainfall and insufficient water for crop and livestock production), and 3) lack of off-farm employment opportunities (contributing to low and uncertain incomes in urban and rural areas).

At present, the main focus of FAO's programmes is to try to break the vicious circle of poverty and food insecurity by placing food security on the top of its agenda. Programme activities are focused on increasing food production, improving the stability of food supplies, generating rural employment and contributing to more accessible food supplies; ensuring humanity's freedom from hunger being one of FAO's main objectives stated within FAO's Constitution (De Haen, 1999; FAO, 2000b). With this in mind, FAO has launched a Special Program for Food Security (SPFS), focused on Low-Income Food-Deficit Countries (LIFDCs), the countries least able to meet their food needs with imports.

This approach was endorsed by the World Food Summit (FAO 2000c) held in Rome in November 1996, which called for concerted efforts at all levels to raise food production and increase access to food in 86 LIFDCs, with the objective of cutting the present number of malnourished people in the world by half by the year 2015. The Plan of Action (FAO 2000d] adopted by the Summit concludes that in order to reduce hunger, action is required in the following areas: ensuring enabling conditions, improving access to food, producing food, increasing the role of trade, dealing adequately with disaster and investing in food security.

Poverty is generally consi-dered as one of the major causes of food insecurity, and poverty eradication is essential to improve access to food.

The World Bank (WB) defines poverty as a "multidimensional pheno-menon, encompassing inability to satisfy basic needs, lack of control over resources, lack of education and skills, poor health, malnutrition, lack of shelter, poor access to water and sanitation, vulnerability to shocks, violence and crime, lack of political freedom and voice" (World Bank, 2000).

It is estimated that about one-fifth of the world's population is currently living in extreme economic poverty, defined as living on less than US$1 per day (in 1993 dollars, adjusted to account for differences in purchasing power across countries).

Aquaculture: a sustainable food and income source for the poor?

Global aquaculture production

Of the different global food production systems, aquaculture (the farming of aquatic plants and animals) is widely perceived as an important weapon in the global fight against malnutrition and poverty, particularly within developing countries. Aquaculture is regarded as an important domestic provider of much needed high-quality animal protein and other essential nutrients (generally at affordable prices to the poorer segments of the community) and/or a provider of employment opportunities and cash income. In view of these positive characteristics, it is perhaps not surprising that aquaculture has been the world's fastest-growing food production sector for nearly two decades. The sector has exhibited an overall growth rate of over 11.0 percent per year since 1984, compared with 3.1 percent for terrestrial farm animal meat production and 0.8 percent for landings from capture fisheries (Figures 1 and 2).

By economic country-grouping, approximately 90.0 percent and 82.2 percent of total world aquaculture production in 1998 was produced within developing countries (35.49 million mt).

Figure 1. Contribution of Aquaculture to Total Fisheries Landings

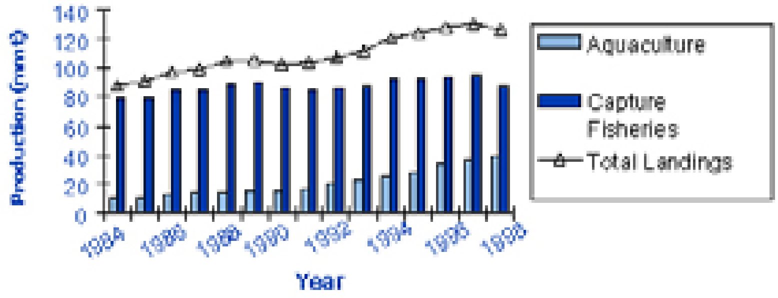


Figure 2. Total World Farmed Meat Production

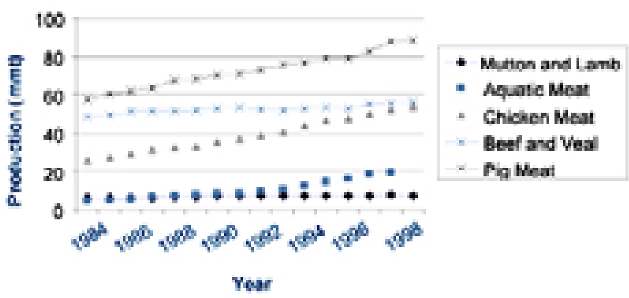
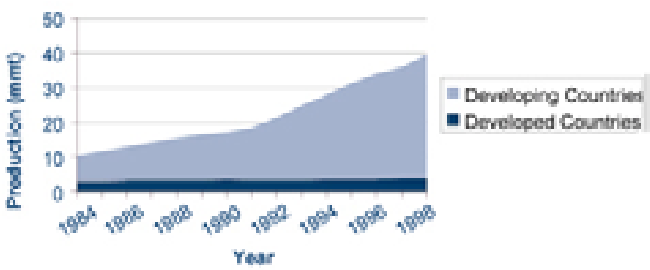


Figure 3. Total World Aquaculture Production in Developing and Developed Countries



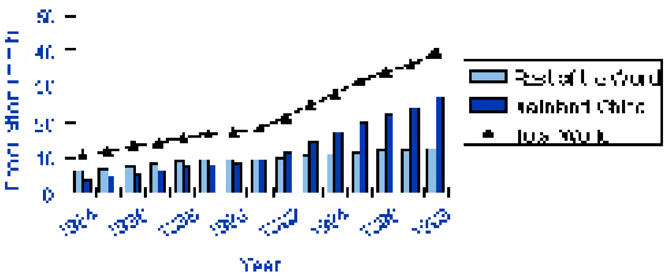
and, in particular, within LIFDCs (32.41 million mt; LIFDCs having an average per capita income <US$1 505/annum in 1996, and including: Africa - Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Congo Democratic Republic, Congo Republic, Cote d'Ivoire, Egypt, Ethiopia, Gambia, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Morocco, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Sudan, Swaziland, Tanzania, Togo, Zambia; North America - Cuba, Guatemala, Honduras, Nicaragua; South America - Bolivia, Ecuador; Asia - Armenia, Azerbaijan, Bangladesh, Bhutan, Cambodia, China, Georgia, India, Indonesia, Korea DPR, Kyrgzstan, Laos, Nepal, Pakistan, Philippines, Sri Lanka, Syria, Tajikistan, Turkmenistan, Uzbekistan; Europe - Albania, Macedonia [World Bank, 2000), respectively. Moreover, whereas the developing country share of aquaculture production has increased from 72.6 percent (7.37 million mt) of total aquaculture production in 1984 to 90 percent (35.49 million mt) in 1998, the share of production from developed countries has decreased from 27.4 percent (2.78 million mt) in 1984 to 10 percent (3.93 million mt) in 1998 (Figure 3). Aquaculture production within LIFDCs has been growing over five times faster (13.7 percent per year since 1984) than within developed countries (2.7 percent per year since 1984), with aquaculture production within developing countries displaying an average growth rate of 12.8 percent per year between 1984 and 1998.

Table 1. Top aquaculture producing countries in the world in 1998

	Country	Production[1] Metric tons	Production[2] % total world	Growth APR[3] 84-98, % yr⁻¹	Growth[4] 97-98, %	Total value US $ 1,000	Unit value US $/kg
1	China	27,071,942	68.6	+ 16.2	+ 12.7	25,499,016	0.94
2	India	2,029,619	73.8	+ 11.2	+ 9.0	2,222,789	1.09
3	Japan	1,290,406	77.1	+ 0.5	- 3.7	4,126,039	3.20
4	Philippines	954,512	79.5	+ 5.5	- 0.3	639,080	0.67
5	Indonesia	814,090	81.6	+ 7.2	+ 4.7	2,149,508	2.64
6	Korea, ROK	796,632	83.6	+ 1.2	- 23.4	766,260	0.96
7	Bangladesh	583,877	85.1	+ 12.7	+ 13.9	1,493,670	2.56
8	Thailand	569,577	86.5	+ 13.0	+ 3.1	1,806,795	3.17
9	Vietnam	537,870	87.9	+ 12.3	+ 5.7	1,356,724	2.52
10	Korea, DPR	481,500	89.1	- 2.9	- 1.6	302,950	0.63
11	USA	445,123	90.2	+ 2.4	+ 1.5	781,069	1.75
12	Norway	408,862	91.3	+ 23.6	+ 11.3	1,133,500	2.77
13	Chile	361,430	92.2	+ 33.3	- 3.6	1,001,544	2.77
14	Spain	313,518	93.0	+ 1.8	+ 31.1	282,208	0.90
15	France	273,920	93.7	+ 2.7	- 4.7	614,156	2.24
16	Taiwan province of China	255,205	94.3	+ 0.3	- 5.5	818,395	3.21
17	Italy	249,625	94.9	+ 7.5	+ 15.2	471,139	1.89
18	Ecuador	146,590	95.3	+ 12.0	+ 0.3	731,299	4.99
19	Egypt	139,389	95.7	+ 13.4	+ 89.8	327,263	2.35
21	UK	137,421	96.0	+ 17.1	+ 5.9	427,895	3.11
	Total world	**39,430,834**	**100.0**	**+ 11.0**	**+ 9.4**	**52,458,185**	**1.33**

[1]Total aquaculture production (includes finfish, crustaceans, molluscs, miscellaneous aquatic animals/products, aquatic plants)
[2]Accumulative total as % total world production
[3]Annual Percent Growth Rate in production by weight between 1984 and 1998
[4]Percent change in production by weigth between 1997 and 1998
(source: FAO, 2000)

Figure 4. Global Aquaculture Production vs Production in P.R. China



By region, Asia produced over 90.8 percent of total global aquaculture production by weight in 1998 (35.81 million mt), with mainland China reporting a total aquaculture production of 27.1 million mt or 68.6 percent of total global aquaculture production in 1998. Apart from mainland China, all of the world’s top ten aquaculture-producing nations were found in Asia in 1998, and included India (2.03 million mt), Japan (1.29 million mt), Philippines (0.95 million mt), Indonesia (0.81 million mt), Korea Republic (0.80 million mt), Bangladesh (0.58 million mt), Thailand (0.57 million mt), Viet Nam (0.54 million mt), and Korea DPR (0.48 million mt). These top ten producing countries represented 89.1

Interestingly, analysis of global aquaculture production excluding mainland China showed a moderate growth rate, with production doubling from 6.32 million mt in 1984 to 12.36 million mt in 1998, and the sector growing at an average rate of 5.3 percent per year since 1984 (Figure 4). In general terms, aquaculture’s contribution to total world fisheries landings has increased three fold since 1984, aquaculture production increasing from 10.15 million mt or 11.4 percent of total fisheries landings in 1984 to 39.43 million mt or 31.1 percent of total fisheries landings in 1998 (Figure 1). By continent, aquaculture supplied 45.3 percent of total fisheries landings in Asia (up from 21.1

percent of total global aquaculture production by weight (see Table 1).

The next major region in terms of production by weight, was Europe (4.97 percent or 1.96 million mt): Norway (0.41 million mt), Spain (0.31 million mt), France (0.27 million mt), Italy (0.25 million mt), the United Kingdom (0.14 million mt), and the Netherlands (0.12 million mt); followed by South America (1.70 percent or 0.67 million mt): Chile (0.36 million mt), Ecuador (0.15 million mt), Brazil (0.095 million mt), and Colombia (0.046 million mt); North America (1.66 percent or 0.65 million mt): the United States (0.44 million mt), Canada (0.090 million mt), Mexico (0.041 million mt), and Cuba (0.038 million mt); Africa (0.48 percent or 0.19 million mt): Egypt (0.14 million mt), Nigeria (0.020 million mt), Madagascar (0.0069 million mt), South Africa (0.0052 million mt), and Zambia (0.0042 million mt); and Oceania (0.36 percent or 0.14 million mt): New Zealand (0.094 million mt) and Australia 0.028 million mt (FAO, 2000e).

percent in 1984), 10.9 percent of total landings in Oceania (up from 3.7 percent in 1984), 10.2 percent in Europe (up from 6.9 percent in 1984), 8.0 percent in North America (up from 4.5 percent in 1984), 5.7 percent in South America (up from 0.5 percent in 1984) and 3.2 percent in Africa (up from 0.9 percent in 1984 (FAO, 2000e).

At a species-group level, finfish contributed over half of total aquaculture production by weight in 1998 (20 million mt or 50.8 percent), followed by molluscs (9.1 million mt or 23.2 percent) and aquatic plants (8.5 million mt or 21.7 percent (see Figure 5). The growth of the different major specific groups over the past decade has been rapid, with most groups exhibiting double-digit growth rates over the period 1984 to 1998, including finfish (12.3 percent per year, with production up by 6.7 percent since 1997), molluscs (11.5 percent per year, with production up by 6.5 percent since 1997), aquatic plants (7.7 percent per year, with production up by 18.9 percent since 1997), and crustaceans (16.0 percent per year, with production up by 13.9 percent since 1997) (Figure 6).

Figure 5. Total World Aquaculture Production (Volume) in 1998

Figure 5. Total World Aquaculture Production (Value) in 1998

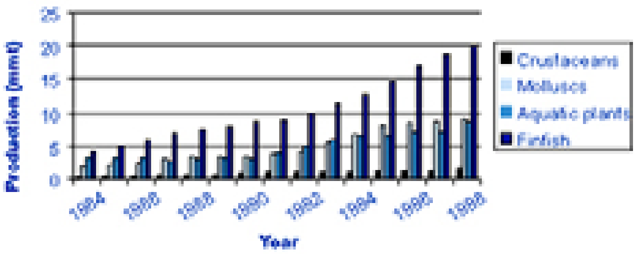
Global food fish supply

In terms of per capita availability of "food fish" from aquaculture (i.e. the production of farmed aquatic finfish and shellfish on a whole live weight basis, and excluding farmed aquatic plants; 30.86 million mt in 1998) has increased by 261 percent from 1.45 kg in 1984 to 5.23 kg in 1998, with supply growing at an average rate of 10.4 percent per year. By contrast, per capita availability of "food fish" from capture fisheries (i.e. 62.45 million mt - excludes captured fish destined for reduction into fishmeal) has remained static, decreasing from 10.88 k

in 1984 to 10.58 kg in 1998. On the basis of the above data, over 33.1 percent of total global "food fish" supplies was supplied by aquaculture in 1998. Aquaculture currently ranks fourth in terms of global farmed meat production (19.5 million mt in 1998; after gutting/shelling), with pig first (88.0 million mt), beef and veal second (55.3 million mt) and chicken third (52.1 million mt) (Figure 7).

Globally, more "food fish" is consumed on a per capita basis than any other type of meat or animal

Figure 6. Total World Aquaculture Production by Major Species Groups



protein (16.0 kg per capita supply in 1998, up from 12.5 kg in 1984), followed by pig meat (14.9 kg in 1998), poultry meat (10.1 kg in 1998), beef and veal (9.8 kg in 1998), eggs (7.8 kg in 1998) and mutton and goat (1.9 kg in 1998) (FAOSTAT, 2000). Although developing countries produced over two-thirds of total food fish supply in 1998, per capita supply was highest in developed countries (23.2 kg in 1998, down from 25.6 kg in 1984), followed by developing countries (14.0 kg, up from 8.0 kg) and LIFDCs (13.6 kg, up from 6.9 kg). By region, per capita supply was highest in Oceania (20.2 kg, down from 21.3 kg), followed by Europe (19.7 kg, up from 17.8 kg), Asia (17.6 kg, up from 10.5 kg), North and Central America (16.8 kg, up from 16.6 kg), South America (9.8 kg, up from 7.9 kg), and Africa (7.0 kg in 1998, down from 8.1 kg in 1984) (FAOSTAT, 2000). In terms of animal protein supply, food fish represented 16.5 percent of total supply in 1997 (total global animal protein supply was reported as 27.1 gm per capita in 1997), followed by pig meat (14.7 percent), beef and veal (13.6 percent), and poultry meat (12.5 percent). It is interesting to note here that farmed aquatic meat production in China currently ranks second to pig meat (Figure 8); the per capita availability of food fish in China increasing from 6.3 kg in 1984 to 25.5 kg in 1998 (FAOSTAT, 2000). In general, people living within Asia and Africa (including LIFDCs) are much more dependent on fish as part of their daily diets than people living within most developed countries and other regions of the world (Figure 9).

For example, figures for 1997 show that while fish represent only 7.3 percent of total animal protein supplies in South America (Brazil - 4.7 percent, Chile - 12.4 percent, Ecuador - 9.0 percent; mean per capita supply 10.0 kg), 7.5 percent in North and Central America (Canada - 9.9 percent, Mexico - 9.5 percent, the United States - 6.8 percent; mean per capita supply 16.7 kg), 9.1 percent in Oceania (Australia - 6.5 percent; mean per capita supply 19.9 kg), and 10.3 percent in Europe (France - 8.6 percent, Greece - 12.1 percent, Italy - 10.8 percent, Norway - 24.8 percent; mean per capita supply 18.5 kg), they provided 17.2 percent of total animal protein supplies in Africa (Benin - 28.5 percent, Burundi - 29.6 percent, Cameroon - 25.0 percent, Cape Verde - 30.6 percent, Congo Democratic Republic - 31.0 percent, Congo Republic

Figure 7. Total World Farmed Meat Production in 1998

- 48.8 percent, Cote d'Ivoire - 36.9 percent, Egypt - 18.4 percent, Equatorial Guinea - 61.9 percent, Ethiopia - 0.8 percent, Gabon - 35.0 percent, Gambia - 61.7 percent, Ghana - 63.2 percent, Guinea - 60.2 percent, Malawi - 37.7 percent, Nigeria - 21.6 percent, Senegal - 47.4 percent, Sierra Leone - 63.0 percent, Tanzania - 33.6 percent, Togo - 50.2 percent, Uganda - 30.0 percent; mean per capita supply 7.1 kg), and over 24.5 percent in Asia (Bangladesh - 48.3 percent, Cambodia - 28.3 percent, China - 23.9 percent, India - 15.3 percent, Indonesia - 53.1 percent, Japan - 45.8 percent, Korea - DPR 55.7 percent, Korea Republic - 43.3 percent, Malaysia - 34.5 percent, Myanmar - 45.4 percent, Philippines - 42.8 percent, Sri Lanka - 54.3 percent, Thailand - 41.5 percent, Viet - Nam 39.4 percent; mean per capita supply 17.9 kg).

In general, the main factor driving the apparent high demand for staple food fish (in particular, low-value farmed freshwater food fish species feeding low on the aquatic food chain), within most developing countries and LIFDCs is their greater affordability to the poorer segments of the community, including the rural poor, compared with other animal protein sources (Philippines - Tacon and Barg, 2001; Fred Yap - pers. comm.; Bangladesh - Lena Westlund Lofvall, M.C. Nandeesha: China - Chen Shuping,

India - M. Sakthivel - pers. comms.). At present, food fish represents the primary source of animal protein (contributing more than 25 percent of the total animal protein supply) for about one billion people within 58 countries world wide, and in particular within developing countries and LIFDCs (value excludes China; FAO, 2000e; Ye, 1999).

Figure 8. Total Farmed Terrestrial and Aquatic Meat Production in P.R. China

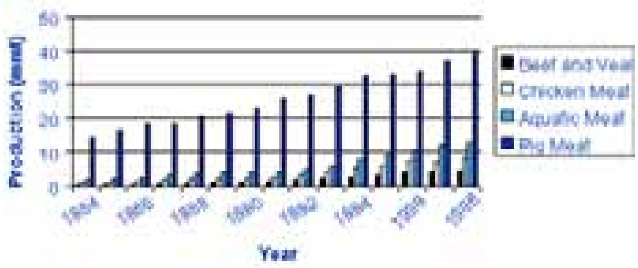
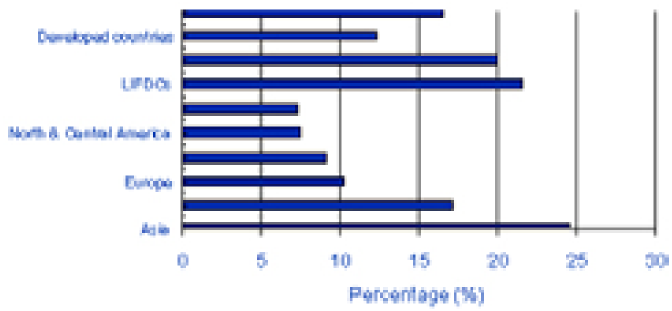


Figure 9. Percentage Contribution of Foodfish to Human Diet in 1997



The future: increasing the contribution of aquaculture for food security and poverty alleviation

Current role of rural aquaculture

In general terms, aquaculture may benefit the livelihoods of the poor, either through an improved food supply and/or through employment and increased income; benefits being either direct to a household farming aquatic products or indirect from

Increasing the contribution of aquaculture

In line with the Rome Declaration on World Food Security and the World Food Summit Plan of Action, and following the recommendations of Kent (1995), if aquaculture is to play a greater role in improving food security and the alleviation of poverty, it is recommended that:

- the actual and unfulfilled potential of aquaculture to contribute to food security and poverty alleviation be fully documented (Peter the increased availability of low-cost fish in local markets, or from employment within the aquaculture sector (Edwards, 1999). However, at present, little or no hard statistical information exists concerning the scale and extent of rural or small-scale aquaculture development within most developing countries and LIFDCs or concerning the direct/indirect impact of these and the more commercial-scale farming activities and assistance projects on food security and poverty alleviation (Edwards, 1999; Tacon et al., 1997). However, it is useful to mention here how contribution of rural aquaculture to poverty alleviation is explained by Edwards (1999): "rural aquaculture contributes to the alleviation of poverty directly through small-scale household farming of aquatic organisms for domestic consumption and/or income; or indirectly through employment of the poor as service providers to aquaculture or as workers on aquatic farms of wealthier farmers; or indirectly by providing low-cost fish for poor rural and urban consumers."

Despite the lack of information concerning the role of rural aquaculture, there is one sure benefit of consuming fish, and that is the nutritional and health benefit to be gained from its valuable nutrient content; food fish having a nutrient profile superior to all terrestrial meats, being an excellent source of high quality animal protein and highly digestible energy, as well as an extremely rich source of omega-3 polyunsaturated fatty acids (PUFAs), fat-soluble vitamins (A, D and E) and water-soluble vitamins (B complex), and minerals (calcium, phosphorus, iron, iodine and selenium). In fact, if there is a single food that could be used to address all of the different malnutritional disorders listed at the start of this paper, it is fish - the staple animal protein source of traditional fisherfolk.

Edwards, Mahfuzuddin Ahmed - pers. comm.);

- funding for aquaculture for the poor should be increased, especially within those fish-eating countries where traditional aquaculture practices already exist (Edwards, 1999; Kent, 1995);
- aquaculture projects should do no harm to the food supplies of the poor (Kent, 1995);
- existing aquaculture activities of the poor should be strengthened through the use of improved farmer/farming participatory systems research and people-centered development/extension approaches (Ahmed and Lorica, 1999; Edwards, 1999; Kent, 1995);
- investment be encouraged in building the institutional capacity and knowledge base concerning sustainable aquaculture practices to manage the sector (Tacon and Barg, 2001; M.C. Nandeesha - pers. comm.);
- participatory production practices within the framework of the sustainable integrated management of natural resources (including their improved use) and different agricultural production systems be pursued (World Food Summit recommendation as cited by FAO, 2000d); Tacon and Barg,2001; M.C. Nandeesha, Yugraj Singh Yadava, Mahfuzuddin Ahmed - pers. comm.);
- the focus should be on low-cost products favoured by the poor (Kent, 1995; note: there is a growing school of thought that if aquaculture is to significantly contribute to increased income of poor farmers, that they should not just be restricted to low-value species (Yap, 2001);
- emphasis be placed on improving culture systems for aquatic species feeding low in the food chain (Tacon and Barg, 1998; M.C. Nandeesha - pers. comm.);
- production should be for local consumers (Kent, 1995);
- community production should be encouraged (Kent, 1995);

- the consumption of aquaculture products from a human nutrition viewpoint should be encouraged and promoted; and
- that food security impacts should be monitored (Ahmed and Lorica, 1999; Kent, 1995).

Major recommendations of the Bangkok Conference

Aquaculture and fish as food

- From a nutritional point of view, the production of aquaculture products for human consumption should be encouraged and promoted.
- Systems for the production of low-value fish affordable for the poor should be promoted.

Aquaculture for rural livelihoods

- The extension and development approaches used for rural aquaculture need to be improved. These should include:
- a holistic, farming systems-based approach integrating aquaculture into rural livelihoods;
- a participatory, needs-based approach that takes full account of the capacity of the poor, the resources available to them, and the risks they face;
- farmer-led extension and research;and
- promotion of sustainable, appropriate technologies commensurate with the resources available.
- Rural aquaculture has to be developed as an entrepreneurial activity that is financially viable, even for small-scale operations. This means that choices regarding the species produced should be based on the best benefits for the producer.
- Improved information on small-scale rural aquaculture, its role in rural livelihoods and its impact on food security and poverty alleviation need to be developed and understood, and monitoring systems established. This will require the development of better indicators.

Aquaculture and poverty alleviation

- The involvement of the poor in aquaculture must be based on a careful and realistic assessment of their needs, capacity and access to resources, and the risks they face.
- Aquaculture development should not adversely affect the livelihoods of poor people. All aquaculture developments should specifically address and minimise any potential adverse impacts on the poor.

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Integrating Aquaculture into Rural Development in Coastal and Inland Areas

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ABSTRACT: Aquaculture has an important role in rural development. Three quarters of aquaculture production comes from low-income countries, the key region being Asia, within which Chinese production predominates. Integrating aquaculture into the rural economy can bring benefits, as well as environmental and social risks, especially in coastal areas. Lessons must be learnt from the case of uncontrolled expansion of intensive marine shrimp production. In developing economies, peoples' livelihoods, which include aquaculture, benefit from participatory approaches, which build management capacity. In inland areas, fry nursing networks represent low-risk entry points for rural development, and fish-in-rice systems have wide application. In coastal areas, reforestation can benefit coastal defences and aquatic resource production, whilst integrated pond-dyke cropping systems in delta areas have demonstrated complementary resource and energy flows. In more developed countries, where the objective is the development of remote rural economies, the stability and environmental impact of aquaculture should be key considerations in any future planning.

Effective rural development comes through sound governance, participation at all stakeholder levels, people-centred integrated sustainable development and a multi-sectoral agenda. Policy coherence must be a primary objective, developed through wide-ranging public involvement and, where necessary, through the promotion of effective representative organizations. Much greater emphasis on advocacy (outside of the subsector) is required to raise awareness of the role for aquaculture in rural development and to raise the stakes for institutional change. Regulation and policy should aim to internalise the external effects of aquaculture (e.g. the "polluter pays" principle). Special attention is required to empower and link stakeholders to policy decisions.

KEY WORDS: Aquaculture, Rural Development, Poverty Alleviation, Aquatic Resource Management, Integration of Aquaculture

Introduction

Aquaculture has an important role in the development of many national economies and plays a key role in rural development. It provides livelihood options in rural areas of the developing world (over 75 percent of aquaculture yields are produced in low-income countries), as well as income and employment in remote regional, as well as more developed economies (salmonid production in western Europe being an important example). Aquaculture production continues to grow at more than 10 percent per annum globally, outpacing terrestrial livestock and capture fisheries. Excluding aquatic plants, 60 percent of production comes from inland and 40 percent from coastal or marine areas (Shearer et al., 1997). Farmers in the Asia-Pacific Region

Such sustainable development conserves land, water, and plant and animal genetic material, is environmentally nondegrading, technically appropriate, economically viable and socially acceptable.

Aquaculture is the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated. In rural areas of poorer countries, agronomy, water management, aquaculture and wild aquatic resource harvesting are often physically and functionally integrated. Thus aquaculture is an integral and indivisible part of the management of aquatic resources.

Rural development is the

contribute over 80 percent of the world's aquaculture production, with China producing 50 percent of global production (Edwards and Demaine, 1997).

The objectives of a more integrated approach to minimize harmful externalities include:

- optimal allocation of resources to competing activities;
- the resolution or minimization of conflict;
- the minimization of environmental impact; and
- the conservation of natural resources.

However, integrating aquaculture into a functioning rural economy brings with it some risks. For example, rapid expansion of coastal shrimp aquaculture skewed market forces and led to both environmental and social problems. Mangrove deforestation, land degradation, habitat loss and disease all resulted from poorly planned development in this sector. Degradation of, and exclusion from, resources has marginalised many poor people who have not benefited from this growth.

In inland and coastal areas, improved aquatic resources management, including aquaculture integrated into existing farming systems, therefore, has the potential to enhance livelihoods, but management of human development and the orientation of technological and institutional change in such a manner as to improve inclusion, longevity, knowledge and living standards in rural areas, in the context of equity and sustainability.

Livelihood comprises the capabilities, assets and activities required for sustaining, maintaining or enhancing capabilities and assets, both now and in the future.

Aquaculture and rural development - a diverse issue

The objective of rural development is to facilitate a sustainable rural economy. The opportunities for the integration of aquaculture into rural development are characterized by diverse aquatic resources (see Box 1), and a wide range of stakeholders and their livelihoods. Objectives may further range from food production, income generation, wild stock enhancement or recreation (ornamental fish or sport). The scale may be intensive commercial operations through to subsistence aquatic resource management within developed and less-developed economies.

At the local/national level, the integration of aquaculture into rural considerable effort is required to include local people and support their management of sustainable development.

Definitions and interpretation

Sustainable development (in the context of this paper) means the management and conservation of the natural resource base and the orientation of technological and institutional change to ensure continued supply of human needs for present and future generations.

development may take place in growing (e.g. developing economies) or declining (e.g. remote rural regions in developed economies) populations. At all levels, this is occurring within the context of globalization, increased mobility of goods, services, capital and ideas, as well as increased transfers of aquatic species and disease transmission. Where there are stable and predictable political and institutional environments, transparent laws, fair competition and reliable legal systems, this will attract inward investment.

Box 1. Resource diversity - temperate and tropical climates

Inland	**Coastal**
Riverine	Estuaries
Rivers	Bays
Floodplains	Lagoons
Irrigation channels	Coral reefs
Lacustrine	Mangroves
Lakes	Mudflats
Reservoirs	Ponds
Palustrine	
Swamps	
Rice fields	

The integration of less intensive aquaculture systems into rural development

Rural aquaculture in rural development

The term "rural aquaculture" has recently been used to distinguish the farming of aquatic organisms by small-scale households using mainly

Where rural development fails to create the policy environment and skills to exploit global opportunities, aquaculture like other subsectors, may decline.

Examples of significant regional differences in aquaculture resources, users and their livelihood objectives include western Europe and North America, where social status, religious edicts and the emergence of leisured classes during the industrial revolution have all shaped present day aquaculture (Williamson and Beveridge, 1994). Inland and coastal aquaculture development has tended to focus on piscivorous species related to sport fishing and high-value products from inland and coastal areas. Unlike temperate fresh waters, those in the tropics abound with fish low in the food chain such as carps, tilapias and catfish, and fish farming in rural tropical fresh waters has been driven primarily by the need to produce food (Ling, 1977). In contrast, coastal fish culture systems in the tropics, with the exception of the species used in traditional coastal fish farming (mullets and milkfish) have tended to focus on high market value species such as shrimp, grouper and seabass.

Issues and examples of aquaculture development in less developed rural economies

In the context of rural development, sustainable livelihoods in rural areas are benefited through the promotion of more secure access to, and better management of natural resources. Aquaculture encapsulates a range of systems for the management of aquatic and associated terrestrial resources; extensive and semi-intensive husbandry for household consumption and or income (Edwards & Demaine, 1997) from more commercially intensive aquaculture systems. This could include groups and communities with a broader range of aquaculture contributions to rural livelihoods, and this is currently a matter of debate (Yap, 1999; Edwards, 1999).Until recently, much rural aquaculture production was inaccessible to researchers and rural developers, because of:

- dispersed and small-scale production data which does not appear in official statistics, and
- local consumption and/or trade of produce.

However, the vital role of small-scale yet widespread systems in family nutrition, food security and income generation, is now beginning to gain recognition (UNICEF, 1994; Gregory and Guttman, 1997; Ahmed et al., 1998; Haylor et al., 1999). Taking rural development in the selected examples are illustrated below, divided into intensive and less intensive systems.

lower Mekong basin as an example, 80 percent of the 60 million people living in rural areas are rice farmers with 1-2 ha plots and a per capita income of US$186-400; rice and aquatic resources from paddies and nearby wetlands are the basis of their food security. Agronomy, water management, aquaculture and wild aquatic resources are often physically and functionally integrated in these circumstances. Thus aquaculture is an inextricable part of the aquatic resource base and must play a key role in the development of rural livelihoods.

Water is essential for developing rural livelihoods (bathing, livestock, vegetable cultivation, irrigation) and certain forms of aquaculture production can represent simple, low-risk activities providing a quick return to fund other activities and build confidence. A number of successful low-input systems for rural aquaculture may be widely applicable, including local fry nursing, fish rearing in different rice agro-ecosystems and small-scale pond management.

Box 2. Developing a fry nursing network, i. e. the development of a network of farmers nursing fish fry to fingerlings. (Regional Development Committee, Southern Laos, N. Innes Taylor, pers. comm.).

Key issues

- Poverty focussed (low investment availability to landless, builds capital).
- Robust technology (low investment, low risk, quick return, simple technologies, easily copied, easy to extend, easy to train trainers in 2-3 h).
- Addresses key fish seed constraints common to rural aquaculture across the developing world.
- Good for new entrants (helps to change capture perspectives towards basic husbandry and management).
- Builds institutional capacity (develops local seed supply capacity, supports operational budget at local institutional level in line with work done, builds local management capacity).

Farmers

- Negotiate & agree access to a water body with some natural productivity.
- Acquire & set up 4x5 m hapa.
- Feed sieved rice bran.
- Nurse for six weeks up to 5-6 cm.
- Sleep nearby.
- Sell or stock in ponds/paddies.

Local support staff

- Facilitate setting up a network of farmers interested in fry nursing.
- Facilitate negotiation & agreement of access to water body.
- Acquire & administer leasing of 4x5 m hapa.
- Acquire & supply first time farmers with 2-3 cm fry.
- Train farmers in sieving and feeding rice bran & basic nursing for six weeks up to 5-6 cm.

Of these, fry nursing and the operation of a nursing network (see Box 2) provide opportunities to address key constraints, not only to aquaculture (e.g. available fish seed) but also to more diverse livelihoods (e.g. management and institutional support capacities). This is a powerful example of where aquaculture represents a useful entry point for rural development .

Rural development and aquaculture in Asian floodplains

In addition to the Mekong Delta, in Southeast Asia, rural development on many other Asian floodplains, including major river systems in the Punjab and Bangladesh, has concentrated in recent times on achieving self-sufficiency in food grains through agricultural intensification and floodwater management. However, this has been at the expense of aquatic animal production, which has declined due to drying out of fish habitat and blocking of migration routes (Haylor and Bhutta, 1997; Barr and Haylor, 2001). Agricultural growth at the expense of fish production in rural development in societies where culture and food security are based on fish and rice (e.g. Bangladesh, Cambodia, Laos, Thailand) has obvious shortcomings which disproportionately impact the poor and landless (e.g. 50 percent are classed as functionally landless in Bangladesh, 13 percent in Cambodia, 21 percent in the Vietnamese Mekong Delta).

It is essential that rural developers appreciate the importance of aquatic resources in the livelihoods of floodplain dwellers, especially poor people. Some forms of aquaculture may even help ameliorate lost aquatic resources. Widespread application of integrated rice-fish farming on floodplains is receiving sustained interest for replenishing diminished wild fish stocks. In Bangladesh, for example, the world's largest farmer field-school programme is supporting resource-poor men and women to learn about integrated pest management in rice cultivation and associated fish production.

Rural development and coastal aquaculture

An interesting example of successful integration of coastal aquaculture and rural development is Thai Binh Province on the Red River Delta in northern Vietnam.

Vietnam is elongate and has an exceptionally long coastline, extending for about 5,230 km. The two major deltas forming the latitudinal extremes of the coastal zone (the Red River and Mekong River deltas) support high population densities in a habitat transformed immensely for agricultural use, salt production and aquaculture. As a result, the natural resources, which include mangrove forests, fish and shellfish populations, have been severely depleted, with significant implications for the livelihood, nutrition and vulnerability of the coastal communities (among the poorest in Vietnam).

The Red River Delta is located within the typhoon zone. About eight to ten typhoon storms strike the coast every year, generating wind speeds of 72-108 km per hour (wind force 9-10), or more (wind force 12). Tidal heights are increased by up to 2.5 m, with even higher wave surges. Consequently, the northern provinces of Vietnam have built an extensive system of sea-dykes to protect the coastline and estuarine areas from seawater flooding; these are in constant need of expensive repair and upgrading.

It is widely accepted in Vietnam that the best form of protection from typhoons involves:

- upgrading the sea-dykes by raising their height and strengthening them with rock revetment (bank stabilisers) on the seaward facing slope; and

Moreover, all the evidence to date suggests that the variety and supply of economically valuable aquatic species, especially the mud crab Scylla, have increased as a result of mangrove reforestation. These improved conditions have also stimulated an acceleration in the development of coastal aquaculture, since the mangroves help protect aquaculture ponds and contribute to the supply of aquaculture seed (crabs, shrimp and certain species of fish) and feed (molluscs, trash fish, small mangrove crabs etc.).

The main beneficiaries from the boom in aquaculture are: fishermen/aquatic seed collectors, aquaculture producers/workers (pond operators and clam farmers) and seafood dealers. Some of the poorest people are those that go out daily to collect crab seed, clams and other species, which they sell to the pond operators or to dealers.

- planting a mangrove buffer zone in front of the sea-dyke system to reduce the water velocity and wave strength striking the defences, and to absorb some of the wind energy (if the mangrove trees are tall enough). Various nongovernmental organization (NGO) supported projects are helping to plant mangrove buffer zones (ranging from 100 m to 2 km wide) along much of the coastline.

According to engineering studies for the United Nations Food for Work Programme (FWP), a sea-dyke in northern Vietnam with good mangrove forest protection could last up to 50 years, compared to only 5-10 years for a dyke without mangroves.

Following a particularly bad typhoon in Thai Binh in 1986, the Danish Red Cross, supported by the Danish International Development Agency (DANIDA) began planting and protection of 2000 ha of Kandelia mangroves along almost 26 km of coastline (average depth of the buffer zone - 800 m) in front of sea-dykes protecting five communes in Thai Thuy District. In a second phase of the project (1997-2000), up to a further 6000 ha of mangrove are being planted in three neighbouring coastal districts in Thai Binh and in neighbouring Nam Dinh Province (Tien Hai, Giao

The situation in one commune, Thuy Hai, has been monitored since 1996. Thuy Hai has no agricultural land and has traditionally depended on fishing and salt production for its economy. Official statistics indicate that these activities support 51 percent and 36 percent, respectively, of households in the commune. About ten percent of the commune's 1173 families are below the poverty line, while only five percent are classified as relatively wealthy. Over the last several years, aquaculture has been contributing to a significant increase in the overall wealth of the commune.

Aquaculture in Thuy Hai is based on mud crabs. Hand collecting for crab seed from the mangroves is a popular activity for many poor people. Collectors tend to be women and children earning some additional income for their household. It has been said that the mangroves look like a small town lit up at night with lanterns carried by the large number of collectors who catch crabs in the peak season. People can earn about VND.30 000 (US$2.20) from one collecting trip, but this can increase to VND.100 000 to 200 000 in the peak season (July to September). There is a perception among the local people that there is up to ten times the number of crab seed now than was available in 1996, with the majority

Thuy and Nghia Hung districts).

Based on the growth performance of the Kandelia mangroves planted in Thai Thuy District in 1994-1995, it is clear that within four to five years, Kandelia will form an impressive forest protection belt against typhoon flooding of homesteads and agricultural land. The families in the project area feel better protected because of the mangroves.

being found in the mangrove plantation.

The majority of aquaculture ponds in Thuy Hai are situated in front of the main sea-dyke but behind the mangrove plantation. Those pond owners who have ponds adjacent to the mangrove forest requested permission to remove a strip of mangrove to rebuild their pond dykes. The commune accepted this proposal and planted a new strip of mangrove in front of the old mangrove to make up what was lost in pond reconstruction.

In general, the ponds used for coastal aquaculture in Thai Binh Province vary in size from as small as 1200 m2 in Thuy Hai, to about 50 ha for more traditional extensive pond culture. The smaller ponds, which are generally situated closer to the sea-dyke, are stocked mainly with shrimp and crab, but some are used for seaweed and fish. All are introduced as “seed” into the pond. The larger ponds are totally dependent on natural (wild) seed entering the pond with tidal in-flow when sluice gates are opened (i.e.

Dykes and ponds are sized (commonly 1:1) and designed to facilitate particular production systems. These may vary in relation to latitude, landform conditions, land-based production of fodder and crops, livestock rearing and water-based fish production, to ensure material, energy and output complies with market and community needs. Dyke-pond systems transform low-lying and waterlogged lands with low productivity. Different systems vary in their ecological, social and “trapping and holding”). One exception is the seeding and harvesting of Gracilaria, which gives daily employment to local labour, often women.

Since 1996, there has been a trend for larger ponds to be subdivided and operated on a “semi-intensive” basis, using selected species of seed purchased from hatcheries (tiger shrimp), or from dealers (crabs). Potentially, profits are much higher from semi-intensive aquaculture (hence its fast development), but this requires careful management, including attention to seed selection, feeding, water exchange, disease and other risks. Similar trends are being observed elsewhere. As such progression is probably inevitable, it means that the benefits to be gained from coastal aquaculture by the poorest of the population will likely evolve through employment (pond labour), seed collection, and ancillary work such as transporting seed, feed and other aquaculture products. However, it is interesting that many of the small-scale dealers who trade in crab seed (buying daily from the collectors) are women, many of whom also trade in clams and other species. The middle-income families who have invested in aquaculture ponds were, in many cases, former salt producers. Thus the direct and indirect beneficiaries from coastal aquaculture represent a wide cross-financial benefits. However, the decision-making processes in relation to planning and operation of these systems are currently less well documented. More recently, technologies integrating agricultural development and aquaculture in rural low-lying coastal areas (many just below sea level) have been developed. Ponds are dug to raise the height of fields to protect from flooding, giving rise to field-pond agro-ecosystems (commonly at ratios of 9:1). These systems are used to integrate fish production with water-logging-resistant rice or salt-resistant sugar cane. Pigs and poultry are raised along the field ridges. The pond size is partly dependent on the original field altitude and the crop; sugar cane fields need to be higher and are associated with deeper ponds.

In saline alkaline lands with high water tables and strong evaporation, inter-arranged field-pond systems, associated with an access route and drainage ditches, are being developed in the Yellow River-Huaihe River plain. The field to pond to ditch ratio is 2:2:1. Crops such as corn, cotton and fruit are raised together with ducks and fish.

The integration of intensive aquaculture into rural development

Rural development and

section of the total local community, including the poor (Macintosh, 1999).

Rural development and aquaculture in delta areas in China

Less intensive examples of aquaculture integration into rural development are the delta dyke-pond and field-pond systems of the Pearl River and Yangtze River and the field-pond systems in the saline-alkaline habitat of the Yellow River-Huaihe River plain (Zhong et al. 1997).

intensive cage fish culture

The development of intensive inland and coastal cage aquaculture of high-value salmonids has been encouraged and supported by the Highlands and Islands Development Board in Scotland and the Norwegian Government, as an opportunity for developing remote rural areas. These systems are now contributing to economic development in areas of Chile, the Faroes, Canada, the United States (e.g. Washington State and Maine), Ireland, Iceland and Australia. Salmon production has grown 600 percent in a decade, bringing local employment to remote rural areas with positive impacts on local rural economies. However, the salmon industry has been prone to boom and bust cycles during its development.

The capacity for smolt production required for on-growing at coastal sites has often poorly matched requirements, resulting in price fluctuations. Whilst over-capacity has occurred in the production sector, economic recession and its impact on high-value products has seen ex-farm price reductions. Disease problems and associated issues of chemical treatments have also had a destabilising affect on the industry, with important local impacts on rural economies. A further consideration in high-input intensive systems, especially in areas of limited water exchange (often selected for their shelter), is environmental impact, its assessment, monitoring and control.

Intensive aquaculture industries are also emerging for high-value warmwater piscivorous fish, such as groupers and barramundi (in Hong Kong, Malaysia, Thailand, Indonesia, the Philippines, Taiwan Province of China, Singapore and Australia). Similar opportunities for rural development exist in some areas, e.g. grouper culture by poor farmers in rural areas in the Philippines (Yap, 1999), however, concerns about market stability, disease, environmental impacts, and their control are still relevant. In addition, since most grouper and barramundi culture currently depends on trash fish as feed, as well as wild-caught seed, issues of

Many of the costs associated with these dramatic environmental changes remain unknown. Loss of local resources and concentration of shrimp farming profits amongst a minority, largely composed of outsiders (e.g. 70 percent of shrimp ponds in Khulna in Bangladesh are owned by outsiders), have created social unrest. In the absence of an enforceable regulatory framework, environmental impacts are rarely addressed by producers. Important lessons must be learnt from the rapid expansion of coastal aquaculture aimed at high-value products, which has skewed market forces and led to both environmental and social problems.

So what are the objectives, scope and priorities for aquaculture within rural development?

The integration of aquaculture into rural development to date has been associated with both beneficial and detrimental trends. Benefits have included economic growth, more stable, diversified livelihoods and increases in income and food security. However, there have also been significant environmental, social and economic losses. Environmental impacts of aquaculture on rural development include aquatic pollution, disease, mangrove deforestation, salt intrusion, impacts on seed supplies, species introductions and reliance sustainability and environmental impact are also pressing.

Rural development and intensive shrimp farming

Marine shrimp farming has attracted particular interest throughout the tropics because of its high value and opportunities for export and earning foreign exchange. Investments in intensive shrimp farming have delivered very high short-term profits, often in remote rural areas of developing countries where monitoring or control of development is limited.

Poor site selection and management have led to reduced soil and water quality, pollution, disease and disease transmission between farms. The conversion of huge areas of mangrove forests to shrimp ponds has also led to saltwater intrusion, reduced shoreline protection and activation of acid sulphate soils and has affected inshore and offshore fisheries. Information on mangrove cover and numbers of abandoned ponds is difficult to access. However, it is estimated, that 99 percent of the Indus Delta mangrove has been deforested, a reduction of 34 percent has occurred in Indian mangrove areas and 60 percent of the Chakoria Sundarban mangroves have been lost to conversion to shrimp ponds (Brown, 1997).

on exotics, concerns over biodiversity and genetics, negative environmental perceptions and pressure from lobby groups, and rapid and unplanned growth. Social impacts include exclusion of the poor from participating in (by being physically removed), or enjoying the benefits of, aquaculture production; resource appropriation by elites and/or politically powerful sectors; conflict and violence.

Many negative consequences associated with aquaculture in rural development relate to a weak institutional context. Poor linkages, coordination and coherence between sectors, unclear mandates, unclear public/private sector responsibilities, tenure, property and user right uncertainties, weak regulatory regimes and enforcement capacity, rent seeking, ineffective communication strategies and little involvement of primary stakeholders. Without some form of intervention, short-term financial perspectives tend to dominate environmental and social issues. Thus there is a strong case for such interventions to be strategically planned, rather than reactive and uncoordinated. Planning performance is frequently disappointing, since the process is complex and significant institutional and legal changes are needed, which require time, resources and continuity participation.

Experience does not yield a universal model for improved planning and management of aquaculture development. However, a number of important principles can be defined. For example:

- Planning should be holistic, not sectoral;
- People should be in the centre, with rural development and the role for aquaculture determined by an understanding of people's livelihoods. Put people first - but poor people first of all;
- Link people to policies - facilitate poor people to have a voice within policy-making processes.

Effective rural development comes through sound governance; with participation at all levels, sustainable development will be people-oriented, integrated and have a multisectoral agenda. Policy coherence must be a primary objective, developed through wide-ranging public involvement and, where necessary, through the promotion of effective representative organizations. Much This approach provides an overall management framework to enable efficient use of limited resources and adds diversity and value to sectoral interventions.

Although there is no consistent model for integration of aquaculture development into rural development planning and management, we recommend an advocacy function to raise awareness and educate policy makers and those who implement rural development plans, of aquaculture's potentially important role. This will include raising awareness of appropriate entry points.

Balance of impact

- There is a strong case for intervention to be planned and strategic.
- Regulatory and mitigative mechanisms (e.g. taxation, financial incentives, voluntary compliance etc.) should be in place and related to best management guidelines.
- Innovative solutions are required to the issues of

greater emphasis on advocacy (outside of the subsector) is required to raise awareness of the role for aquaculture in rural development and to raise the stakes for institutional change. Regulation and policy should aim to internalise the external effects of aquaculture (e.g. the "polluter pays" principle). Special attention is required to empower and link stakeholders to policy decisions.

Major recommendations of the Bangkok Conference

Policy coherence

To encourage essential policy coherence, we suggest a multi-sectoral coordinating process which brings the stakeholders together to harmonize rural development activities and maximize coherence. Two focal points for coordination, one at the sectoral policy formulation level and one at the point of service extension, would help validation, if policy coherence is being achieved; this would also provide a mechanism to link stakeholders to policy decisions.

Aquaculture planning and rural development objectives

Aquaculture planning should be integrated into water resource management planning for inland tenure and user rights for open access and common property resources.

- Aquaculture development responsibilities should be clearly defined within and among the public sector, private sector, civil society and producers.
- Improved communication strategies are needed, particularly through extension delivery systems and information technology.
- Put people first in planning and development, and give special consideration to poor people.
- Aquaculture should be integrated into rural development, as it has the potential for poverty alleviation through direct involvement of rural people in aquaculture production, as well as through employment or involvement in support activities (e.g. fry nursing, feed collection, transport etc.).
- Poor people are sometimes inadequately considered and served by aquaculture initiatives in rural development; this should be addressed by a strong national policy.
- The mechanism for policy development, implementation and feedback should be participatory and involve an understanding of the livelihoods of poor people. It

areas and into coastal management planning in coastal areas, as well as into other economic and food security interventions for rural areas.

should improve basic knowledge and skills, use indigenous knowledge and empower people to make informed actions.

Integration for wider benefit sharing

- hese successes need to be documented and more widely shared and promoted, in order to provide better options for diversified and more stable livelihoods and to optimize use of limited resources (e.g. multiple use of irrigation water, optimal energy flows, human resources).
- Strong efforts are needed to document, disseminate and use successful farmer-proven examples (e.g. case studies with well-identified benefits).

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Involving Stakeholders in Aquaculture Policy-making, Planning and Management

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Sevaly, S. 2001. Involving stakeholders in aquaculture policy-making, planning and management. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp.83-93. NACA, Bangkok and FAO, Rome.

ABSTRACT: The emergence of stakeholder involvement in policy-making, planning and management has arisen out of a new general development model which seeks a different role for the state, which is based on pluralistic structures, political legitimacy and consensus. In aquaculture, as in other areas, stakeholder involvement in policy-making, planning and management is expected to lead to more realistic and effective policies and plans, as well as improve their implementation. The reasons for this are that greater information and broader experiences make it easier to develop and implement realistic policies and plans, new initiatives can be embedded into existing legitimate local institutions, there is less opposition and greater political support, local capacities will be developed and political interference minimized.

Stakeholder involvement can be classified into three types: i) instructive, ii) consultative and iii) cooperative. Instructive involvement is where government makes the decisions but mechanisms exist for information exchange. Consultative involvement is where government is the decision-maker but stakeholders have a degree of influence over the process and outcomes. Cooperative involvement is where primary stakeholders act as partners with government in the decision-making processes. None of these types of involvement is more desirable than another, or mutually exclusive. Much depends on the tasks to be undertaken and the political and social norms, as well as the capabilities and aspirations of the stakeholders themselves.

Critical aspects of stakeholder involvement in aquaculture policy-making, planning and management include: the institutional capacity of stakeholder

organizations; legitimacy of the organizations and process, costs of stakeholder involvement, degree of stakeholder competition, and level(s) at which stakeholders are involved.

KEY WORDS: Aquaculture, Stakeholder Involvement, Policy-making, Regulations, Development

Introduction

In recent years, the involvement of stakeholders in aquaculture policy-making, planning and management has often been advocated, but less frequently applied. The purpose of this paper is to briefly review the stakeholder approach, the terms used and the rationale for promoting stakeholder involvement, and to examine the key issues that affect the successful application of this approach.

Context

During the late 1970s and early 1980s, there was significant upheaval in several social and political systems, most notably the collapse of the Soviet Union, the emergence of democratic regimes in hitherto authoritarian states, the rapid proliferation and accessibility of new technologies, improved

The stakeholder approach

Good governance, the promotion of democratization and the transparency of decision-making processes are, therefore, the context for involving stakeholders in policy-making. Such involvement was regarded as critical to the development of new partnerships that governments had to forge in order to create and deliver the benefits of economic and social development.

This was reaffirmed in 1992 by Agenda 21 of the United Nations Conference on Environment and Development, which called for greater involvement of individuals and communities at all levels of decision-making. Such involvement included the establishment of mechanisms to encourage and support participation of all stakeholders in the identification of telecommunications systems and the accelerated integration of the world economy. At the same time, many developing countries experienced poor economic performance. This was attributed to slower global growth, the debt crises in Latin America and Africa, worsening terms of trade, natural disasters and political instability. Against this backdrop, there was a reorientation towards market economics focusing on the increased role of the private sector and placing greater emphasis on the fiscal responsibility and responsiveness of the state.

During this time, a new development model emerged which sought a different role for the state, based on pluralistic structures, political legitimacy and consensus. There were calls for widespread administrative and economic reforms to reorient the role of many governments to be more open, responsive and democratic. In development cooperation, these trends were reflected in a shift towards programmes that supported a reduction in the role of the state, the removal of subsidies, privatization of state businesses, and liberalization of prices and trade. The state was no longer regarded as the provider of economic and social development, but rather as a partner, catalyst and facilitator.

objectives for the subsector, identification of the problems inhibiting achievement of those objectives, the possible strategies to overcome those problems, and the resources and institutional arrangements required.

The stakeholder approach argued that good governance requires political, social and economic priorities to be based on broad social consensus, and that the poorest and most vulnerable populations should be able to directly influence political decision-making. This can be achieved by actively involving stakeholders in decisions that affect their interests. The approach thus assumes that participation will enable stakeholders to identify their diverse objectives, flag problems and conflicts, and contribute to their resolution.

The stakeholder approach for policy-making, planning and management is expected to yield two positive outcomes: realistic and more effective policies and plans and improved implementation. These outcomes are achieved because the stakeholder approach improves decision-making processes in seven main ways:

- by making it easier to develop more realistic and effective policies, laws, regulations and projects by bringing greater

Policy-makers and planners began to recognize that development must be people-centred, equitably distributed, and environmentally and socially sustainable. Such a process would be heavily influenced by a set of favourable legal and institutional environments that formed an integral part of the governance framework of a state.

information and broader experiences into the decision-making process;

- by embedding new initiatives into existing legitimate local institutions and cultural values;
- by building political support for, and reducing opposition to, policy proposals, through incorporation of stakeholder concerns;

- by helping to build local and national capacity to effectively plan and implement activities;
- by minimising political interference in situations where policy-making and planning processes are well established and transparent;
- by minimising conflicts between stakeholders with different interests by showing promising ways of resolution; and
- by increasing the cost-effectiveness of policy and plan implementation through anticipating difficulties and problems that might otherwise arise unexpectedly.

What is a stakeholder?

These definitions, how-ever, have their own difficulties. There is still a need to define "directly or indirectly affected." For example, do the activities of shrimp farmers adjacent to fishing grounds directly or indirectly affect fishers? This question could be answered in the affirmative or in the negative, depending on the perceptions of those involved. It could be argued that fishers have certain attributes that are directly affected, such as the proximity of shrimp farms to their fishing grounds or the extent that shrimp culture impacts their livelihoods. However, it could also be argued that they are indirectly affected because fishers cannot be differentiated from any other

There are multiple definitions of stakeholders, and these can differ between and even within organizations. Whilst acknowledging this difficulty, the definition used in this paper is that adopted by the World Bank (WB). The World Bank (1996) defines two types of stakeholders:

primary stakeholders who are directly affected (positively or negatively) by proposed interventions/policies; and secondary stakeholders who are indirectly affected by proposed interventions/policies. Secondary stakeholders include those who have technical expertise and/or links to primary stakeholders, e.g. non-governmental organizations (NGOs), various intermediary or representative organizations and technical and professional bodies. They often represent public interests.

persons in the coastal area, and cannot show a direct link between shrimp culture and reduced catches/income. Unfortunately, there are no widely accepted procedures for determining who is, and who is not, directly affected. Much will continue to depend on the power and influence of different stakeholders and their ability to negotiate with government. To illustrate the diversity of primary and secondary stakeholders in aquaculture, Table 1 provides an example of a categorization.

The need to differentiate between primary and secondary stakeholders is relevant where the stakeholder approach envisages different roles for primary and secondary stakeholders. It is often anticipated that primary stakeholders have a more active role in policy-making, planning and management, whilst secondary stakeholders have a less active role.

Table 1. General list of primary and secondary stakeholders in aquaculture policy-making (not ranked in order of importance).

Primary Stakeholders = Directly Affected
1. Aquaculturists (local, non-local, private entrepreneur, corporate etc.)
2. Processors, wholesalers and retailers
3. Fry/fingerling/seed/broodstock producers and suppliers
4. Feed manufacturers and suppliers
5. Drug, chemical and equipment manufacturers and suppliers
6. Fishers/farmers/other local residents close or adjacent to aquaculture farms or sites
7. Other water resource users
8. Government planners in aquaculture, agriculture, fisheries, coastal zone management
9. Government aquaculturists
10. Extension agents (government and private)
11. Aquaculture researchers (government, university)
12. Aquaculture development project workers
13. Contributors to financial or technical resources (government, donors, banks, other sponsors)
Secondary Stakeholders = Indirectly Affected
(a) Consumer groups
(b) Public interest represented by environmental groups
(c) Exporters
(d) Quarantine and customs officers
(e) Adjacent landowners
(f) Forestry organizations (government, private, NGO)
(g) Tourism organizations
(h) Fishers (where juveniles for aquaculture are sourced from the wild or where there is market competition between wild-caught and farmed species)

In a sector such as aquaculture, where there are likely to be multiple stakeholders, the ability to differentiate between primary and secondary stakeholders becomes important. Omission of primary stakeholders, failure to clearly define and identify primary and secondary stakeholders, or defining participation boundaries too broadly, increases the likelihood of conflict, makes decisions difficult to achieve, and/or compromises decision quality (Ostrom et al., 1994).

Furthermore, enabling individuals without a direct stake in aquaculture to participate in decision-making may introduce values and issues that are tangential to aquaculture development interests (NRC, 1999). Since methods used to define and identify stakeholders have a significant impact on the overall effectiveness of the stakeholder approach, it is imperative to have clearly defined criteria for who should and should not be involved in the process. Although most definitions will vary with country or situation, the criteria used for defining stakeholders need to be both transparent and objective. Furthermore, the identification process must be iterative and enable potential stakeholders to make informed decisions on whether or not they wish to participate. In some contexts, the

Instructive stakeholder involvement. Where government is the decision-maker, but mechanisms exist for limited exchange of information with other stakeholders. This tends to be government informing stakeholders about decisions they plan to make. Examples include countries with an undeveloped aquaculture industry, or policy-making and planning for small-scale aquaculture where farmers are not yet organized and/or are geographically dispersed, e.g. Tanzania, Malawi and India (until recently).

Consultative stakeholder involvement. Where government remains the decision-maker, but there are formal and informal mechanisms for consultation with stakeholders. Stakeholders have some degree of influence over outcomes. For example, in Sri Lanka, development of a “Code of Best Practice”, as well as guidelines for the shrimp industry, were developed in consultation with over 12 stakeholder groups. In Australia, a draft National Action Plan for Aquaculture is currently being developed in consultation with industry, national and state government fisheries agencies and researchers. Consultative involvement may also be used for the formulation of regional and international aquaculture policies and plans. For example, up until recently in the European Union concerns of vulnerable groups may need be specifically addressed.

What is policy-making, planning and management?

Within the context of this paper, policy-making is defined as the formulation of objectives for aquaculture development. Polices can be made at the local, state/provincial, national, regional or international level. Planning is defined as the strategies required for achieving these policies. Management is defined as the implementation of policies and plans, including institutional development, regulatory aspects, capacity building and establishing practical links to other policies and plans of use for aquaculture development.

What is stakeholder involvement?

This paper defines stakeholder involvement as the participation of stakeholders in policy-making, planning and management processes. This can take place in three broadly defined ways (Sen and Nielsen, 1996):

(EU), the Advisory Committee for Fisheries was the forum used for consultation with aquaculture operators and other stakeholders on legislative proposals and Community actions.

Cooperative stakeholder involvement. Where all primary stakeholders and government work together as partners in the decision-making process. Secondary stakeholders play a consultative role. An example, is the new European Community (EC) Consultative Committee on Fisheries and Aquaculture, which includes industry representatives (producers, processors and organizations), and consumer, worker and environmental organizations.

None of these three types of involvement is more desirable than the others, nor are they mutually exclusive. Different approaches may be used for different tasks and for different groups of stakeholders. Certain tasks, such as development of policy objectives, may lend themselves better to a consultative approach with primary stakeholders and an informative approach with secondary stakeholders.

A code of practice may be developed in a cooperative approach with primary stakeholders and a consultative approach with secondary stakeholders. The choice of approach will depend on the legal and institutional environment, decision-making processes and the capacity of stakeholder organizations. Finally, it should be emphasized that none of these processes are static and are likely to adapt to changes in experience and situation(s) over time.

Stakeholder involvement in aquaculture

Information on stakeholder involvement is scarce, however, it is apparent that its current status in aquaculture policy-making, planning and management varies considerably between countries and within sectors. For example, in Sub-Saharan Africa, aquaculture has such a low profile that institutional structures are very weak and there may be no aquaculture policy at all, or it is incorporated into other policies, such as the fisheries policy. Of the 12 countries reviewed in a study of the Strategy for International Fisheries Research on Aquaculture Development and Research (Coche et al., 1994), only

A critical mass, such as number of fish farmers or the amount of fish produced from aquaculture, is required. The experience of aquaculture in the EC is a good example. In 1969, the European Federation of Trout Growers was created, comprising six associations producing less than 30 000 mt of fish. In 2000, the association, which had become the Federation of European Aquaculture Producers, comprised 28 national producer organizations whose members produce more than 1 million mt and have a significant influence in aquaculture planning and management within the EU.

Increasingly, where stakeholder involvement occurs in policy-making, planning or management, there is recognition that other stakeholders, apart from producers, should also be involved. For example, in Sri Lanka, guidelines for the shrimp industry were developed in consultation with shrimp farming societies, shrimp breeder associations, shrimp processors, banks, research agencies, the Aquaculture Development Authority, the Export Development Division of the Ministry of Fisheries and Aquatic Resources, and the Department of two countries (Malawi and Nigeria), had specific aquaculture development plans and only one country, Zambia, had a section on aquaculture in it's Fisheries Development Plan. In 1990, it was reported (Pillay, 1990) that the growth of aquaculture in Asia had not, generally, been guided by relevant national development plans. However, a number of Asian countries have now developed aquaculture plans: Bangladesh, India, Malaysia, Thailand, Philippines, Nepal (included in fishery plans), Myanmar (included in fishery development plan), Sri Lanka and Vietnam. In the EU, aquaculture forms part of the Common Fisheries Policy developed in 1983, but the bulk of aquaculture regulation and planning is ongoing under the overall framework of European legislation (although certain aspects fall within the Common Fisheries Policy). In Australia, a new aquaculture plan is under discussion, as the 1994 plan is now considered inappropriate, given the expansion of the industry over the last five years.

The presence or absence of specific aquaculture policies and plans is usually a reflection of the importance of the sector to the national economy. Governments are reluctant to allocate scarce resources for an activity that may be carried out by few and contributes little to the national Customs and Excise. Other examples of extensive stakeholder involvement can be found in Integrated Coastal Area Management (ICAM) programmes, where coastal aquaculture is only one component of coastal zone planning (e.g. Thailand, Malaysia). As part of the ICAM process, primary stakeholders may include associations representing the public interest (e.g. environmental NGOs), associations and government departments representing other sectors of the economy (such as tourism, agriculture, forestry and fisheries), as well as community development organizations.

Prior to the late 1980s, stakeholder involvement in aquaculture policy-making, planning and management was rarely espoused. For example, the 1987 Food and Agriculture Organization of the United Nations (FAO) Thematic Evaluation of Aquaculture emphasized the role of the state when recommending guidelines for United Nations Development Programme (UNDP)/FAO assistance to national policy-making and planning (UNDP/NORAD/FAO, 1987). Stake-holder involvement was not mentioned at all. Since this time, the donor community has, to a limited extent, included some form of stakeholder involvement in assisting national aquaculture policy-making and planning. With the exception of community-based economy. In such situations, it is unrealistic to expect extensive stakeholder involvement in policy-making.

management policies and plans, such involvement has tended to be instructive rather than consultative or cooperative. Also, stakeholder consultation is viewed as important under Integrated Coastal Area Management (Barg, 1992).

The 1997 FAO Technical Consultation on Policies for Sustainable Shrimp Culture (FAO, 1998) concluded that sustainable shrimp culture is dependent on effective government policy, regulatory actions and the cooperation of industry. The Technical Consultation also stressed the importance of participatory (consultative or cooperative) planning and implementation approaches of all stakeholders, although the processes to achieve this were not explored in detail.

Critical issues concerning stakeholder involvement

As the previous section illustrates, there is limited documented experience on the stakeholder approach in aquaculture policy-making, planning and management.

Political, social and legal environment

The opportunities for effective stakeholder involvement are very limited in situations where laws and regulations prohibit participation, bureaucracies frustrate active involvement and social norms undermine the legitimacy of some stakeholders (e.g. poor or landless farmers, women farmers, indigenous peoples and religious groups). Effective stakeholder involvement requires (UNDP, 1999):

- political structures encouraging participation;
- regulatory and legislation frameworks guaranteeing the right of association;
- mechanisms allowing such organizations to participate in policy-making, planning and management processes; and

This is partly to do with the characteristics of the sector itself which, in many countries, is still in the early stages of development. Not only are policies, plans and management still under development, but many primary stakeholder organizations are either in their infancy or nonexistent. This section explores the critical issues affecting implementation of the stakeholder approach, based on limited experience in the aquaculture sector and on more extensive experiences in other sectors, particularly fisheries.

policies to validate decision-making processes.

Institutional capacity and aspirations of stakeholder organizations

Assuming that the political, social and legal environment exists for stakeholder involvement, one of the most critical aspects influencing effective stakeholder involvement is that the stakeholder organizations have the capacity and aspirations to match the task they wish to do.

Table 2. Main factors that affect the strength of stakeholder organizations

Factor	Description
Constitution	Democratic with clear goals and structures.
Members	Representative and legitimate; high levels of membership.
Financial resources	Sufficient (e.g. adequate membership fees) and sustainable to fund involvement, particularly lobbying and negotiations. Some external funding possible, especially for activities where government required the involvement of an organization which could speak on behalf of the industry.
Staff and office holders	Appropriate skills to carry out designated functions. This includes strong advocacy skills as such networking, consensus-building and dialogue between stakeholders.
Policies	Clear and achievable.
Visibility	Recognition for tasks achieved.
Aspirations	Desire to actively participate in the decision-making processes.
Responsibility	Behaving and performing as members and other stakeholders would expect from the organization.

In many countries, aquaculture stakeholder groups are often poorly organized, or not able to exercise management responsibilities unless their administrative capacity, knowledge base and legal foundation is considerably strengthened. Table 2 gives the main factors that affect the strength of a stakeholder organization. This is based on the experience in European aquaculture, aquaculture policy-making in Australia (ACIL Consulting, 1999), and user participation in fisheries management (Jentoft and McCay, 1995; Hanna, 1996; Sen and Nielsen, 1996; IFM, 1998).

Legitimacy

Legitimacy, in this context, is defined as the extent to which principles, rules or standards are consistent with existing values and norms. If such standards or rules are legitimate, then it is more likely that people will comply with them. In a study on user participation in fisheries (Jentoft and McCay, 1995), it was concluded that legitimacy among all affected interests was a key to the success of fisheries management regimes and was contingent upon content as well as process (the way decisions are

For example, government might engage in a process of stakeholder consultation as a way to relieve the frustration of stakeholder groups who feel they are not being listened to, although government may not take into account these views when formulating policy or plans.

Another important issue is that if the rules for decision-making or the objectives of the process are not clarified at the start of the decision-making process, stakeholders may misunderstand the process and/or their roles in the process. Furthermore, the more complex or unrealistic the objectives, the less likely stakeholder involvement will be effective. In addition, the earlier stakeholders are brought into the decision-making process, the more likely objectives will be clearly understood and appropriate.

The decision to exclude some primary stakeholders also affects process legitimacy. For example, in Ecuador, the lack of involvement by the shrimp farming sector in the policy-making, planning and management process has produced laws and regulations which are considered unrealistic and lacking legitimacy. Consequently, this has led to noncompliance. In Canada, reached). Aquaculture is no different. Aquaculture policy-making, planning and management will be more stable and enduring if it is being legitimate and because it is considered legitimate by all directly or indirectly affected by developments, compliance will be greater (Walker et al., 1986).

With respect to stakeholder involvement, there are two aspects of legitimacy. The first aspect relates to the process itself - do stakeholders consider the process of involvement (be it instructive, consultative or cooperative) as legitimate? The second aspect relates to the organizations themselves: are they considered legitimate by their own members and by other stakeholders participating in the process?

Process legitimacy

In order to have effective stakeholder involvement in policy-making, planning or management processes, emphasis has often been placed on establishing the institutional set-up, i.e. identifying the stakeholders, organizing meetings, encouraging the formation of stakeholder associations and sensitising government officials to the concept - rather than determining whether or not the process is considered legitimate by all affected.

the Fish Health Protection Regulations had to be revised recently due to industry concerns over lack of input into original regulations and disease listings.

Thus process legitimacy deals with the critical issue concerning the quality of the stakeholder involvement. If stakeholders view the process as both transparent and fair because their norms, values and expectations are listened to and they have a good understanding of the process and what is expected from them, then it is far more likely that they will be committed to achieving these outcomes. In addition, all stakeholders must have realistic expectations of their roles and not be misled in believing that they are involved in a cooperative or consultative process when, in reality, their role is merely symbolic.

Organizational legitimacy

Even if stakeholder organizations have the capacity and resources to participate in the policy-making, planning or management processes, a critical question is whether or not these associations or organizations invited to represent the stakeholder groups are considered legitimate by the stakeholders they claim to represent or by other stakeholders within the sector. For example, at a recent workshop on the future of aquaculture in Australia, industry

The creation of procedures to involve stakeholders does not always ensure that they will participate or that they will participate in meaningful ways. One critical issue is whether or not stakeholders believe their participation is of value.

concluded that the existing industry organization was considered to be insufficiently representative (ACIL Consulting, 1999) and changes were suggested to ensure better representation at a national level.

Also, stakeholders may not be adequately represented by the organization that claims, or is considered, to represent them, even though they may share the same status as aquaculturalists. For example, a national association of aquaculturists whose members are mainly engaged in shrimp culture is unlikely to be considered representative of all aquaculturists. However, they may be the only association invited to participate in a policy-making process because, for example, they are the only association in existence.

The effectiveness and forcefulness of stakeholders as participants in policy-making, planning or management processes depends on the ability of their organization to speak with one voice. Achieving this

Conversely, stakeholder involvement in the policy-making process is likely to be a more costly process, at least in the short term. The higher the degree of stakeholder involvement, the more costly it will become as more time and resources are required (e.g. staff, travel, meeting expenses). For example, within the EC, it has been estimated that for one EC meeting, US$20 000 is required to cover travel, accommodation, translation and meeting facilities for 20 people. This excludes the time of the people involved.

In the longer term, however, implementation, monitoring and enforcement of the programme might be less costly because the policies and plans are considered legitimate by the stakeholders who position makes it more difficult for other stakeholders, including government, to ignore their contribution. However, there can be a conflict between the size of an organization and the democratic processes within the organization (Jentoft and McCay, 1995). As organizations get larger, they rely on processes through which members deliver their demands to a higher body within the organization, whose responsibility is to find a consensus position. Members can become more focused on getting their personal view across, rather than trying to reach agreement on the position their organization should take on a particular issue. Attendance becomes geared to making statements, rather than finding constructive solutions. This can result in general disillusionment amongst members who felt that their views are not represented. This outcome differs from the consensus approach often achieved within smaller organizations, where all members participate in the dialogue required to reach/define the organization-level position.

Representation of the public interest, such as environmental or consumer concerns, is another issue. For example, in situations where there are many organizations which represent environmental interests, the question of which are the most legitimate representatives of environmental concerns arises. have participated in their formulation. If there is a lack of information to plan and manage the sector, stakeholder involvement might lead to lower transaction costs at the planning and management phases because stakeholders can provide information and advice to achieve realistic objectives.

Costs are inevitably a constraint to stakeholder involvement. Where costs have to be borne by the stakeholders themselves, participation, particularly of poorer stakeholders, will be restricted. This will weaken the consultative or cooperative process and reduce the associated benefits.

Stakeholder competition

Involvement of stakeholders in aquaculture policy-making and planning means that there will inevitably be stakeholders with different objectives and mandates for the policy-making process. This gives rise to stakeholder competition and can significantly influence the consultative process.

Influence can be defined as the amount of resources each stakeholder can apply to bring about their preferred outcome. Certain stakeholders may be able to apply resources to help their preferred outcomes occur. For example, in India, powerful and rich

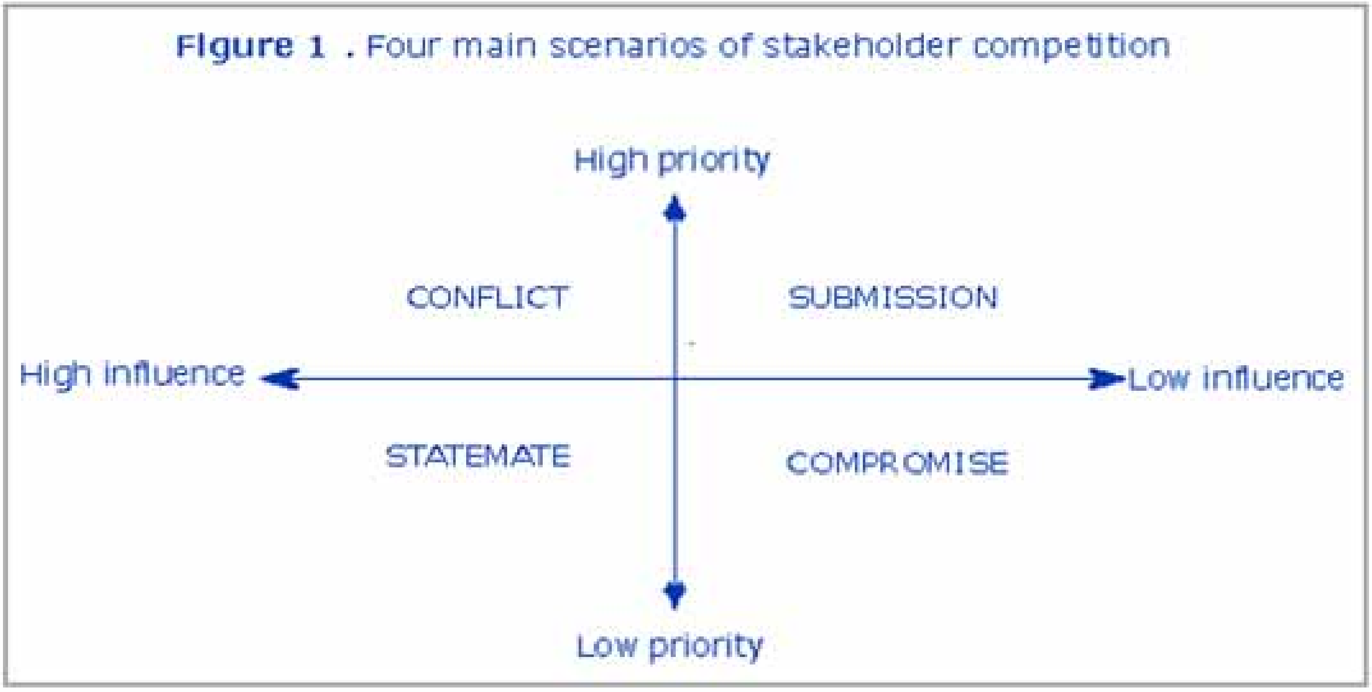
The decision on which organization to include may further complicate legitimacy if based less on representation strength and more on political or other influences.

Costs of stakeholder involvement

Information on the costs of stakeholder involvement is particularly scanty, despite the importance of both the choice of stakeholder approach and the outcome. A centralized approach at the policy and planning stages will tend to have lower design costs than instructive, consultative or cooperative approaches, as it is likely to take less time to reach decisions (Hanna, 1996).

entrepreneurs from outside the locality are able to exert considerably more influence than poorer farmers within the locality.

Relative priorities refer to how much each stakeholder cares about this issue relative to other concerns. For example, fish farmers may have more at stake than exporters concerning policies that affect their production, whilst exporters will be more concerned about tariffs.



Also, at certain times, priorities may change. For example, processors and exporters may be more active in the decision-making process when export prices are falling or trade restrictions have been imposed on a particular product.

The way each stakeholder behaves will depend on their willingness to compromise their desired outcome (e.g. a favourable policy for them) with political satisfaction (being part of a "winning" coalition). Ideally, it may be possible to have a win-win situation where all stakeholders are happy with the final policy or plan, but a number of other scenarios are the more usual outcome (Figure 1).

Depending on the priority of the issue and the level of influence, the four main outcomes are:

It is impossible to say what the outcome of multiple stakeholder involvement will be in any given situation, but it is important to be aware of the potential outcomes, and to realize that not all outcomes will be positive for aquaculture policy-making and planning processes. Influence (either access to resources or political influence) can have a major impact on the process and result in policies that reflect solely the interests of stakeholders with the highest influence. Equally, relative priorities of stakeholders will affect their contribution to the process and the dynamics of the process itself.

Level of stakeholder involvement

- Conflict: where stakeholders expect to win as they consider the issue a high priority and they have a high level of influence. There is no incentive for these groups to make concessions.
- Submission: some stakeholders are compelled to concede, as they do not have enough influence to achieve their preferred outcome, even though they consider the issue a high priority.
- Compromise: where some stakeholders make concessions, as they have less influence and do not consider the issue of the highest priority.
- Stalemate: stakeholders have considerable influence but do not agree that the issue is a very high priority. They do not expect to win and there is bluff and posture but no intention to do anything. Conflict is unlikely and the status quo maintained.

The question of level addresses the "natural" level of stakeholder involvement in policy-making, planning and management, whether this be local, regional, national, regional or supra-national (regional or international). "Natural" means the most effective level at which stakeholders can become involved and participate in decision-making (Jentoft and McCay, 1995). In this context, the EU concept of subsidiarity is very relevant. Subsidiarity means that decisions which affect people's (or stakeholders') lives should be taken by the lowest capable social organization. Some tasks of policy-making, planning or management may be best undertaken at the local or district level; others may be best undertaken at the national, regional or international level (see Figure 2).

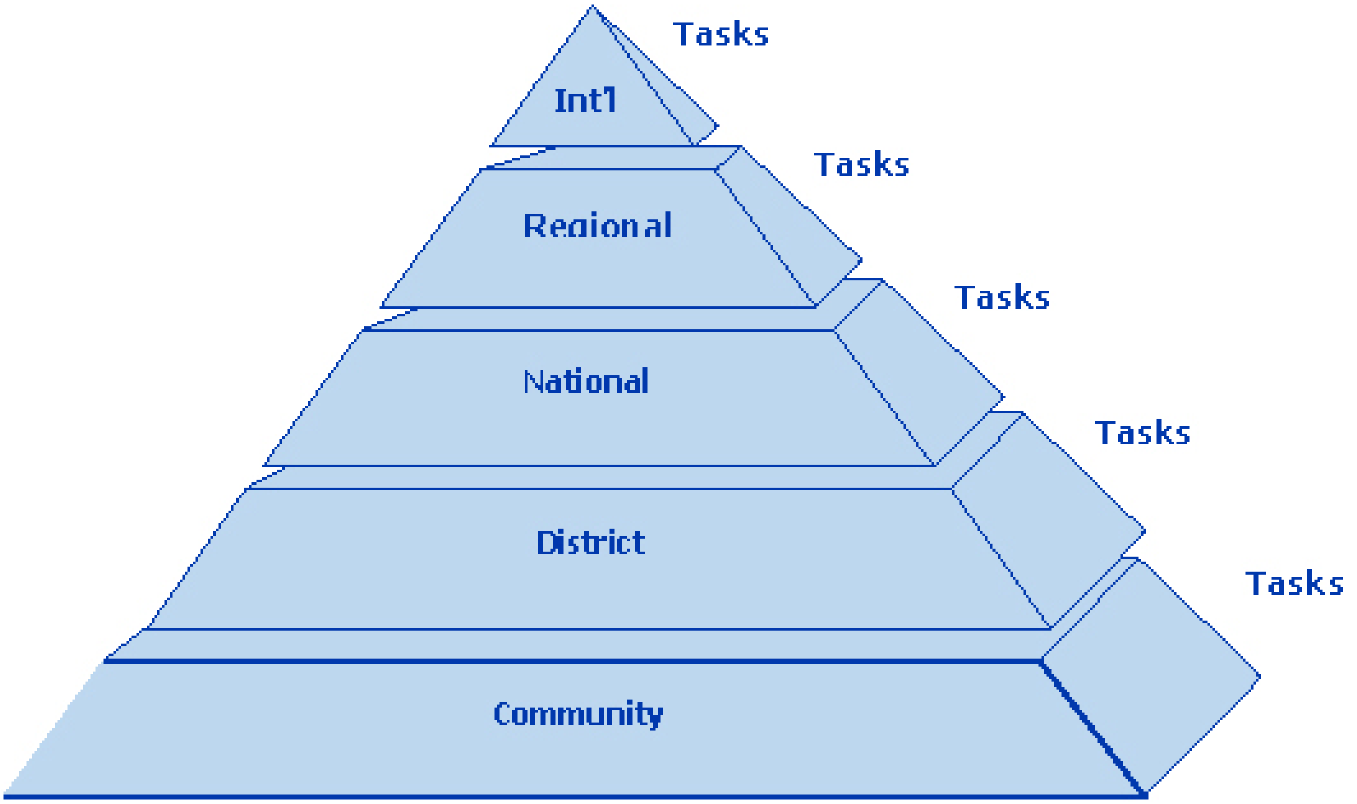


Figure 2. Levels of policy-making, planning and management

For example, in countries where ecosystems are very diverse, some policy-making, planning or management tasks concerning aquaculture production systems or environmental issues may be more naturally undertaken at a provincial level, whilst policies on exports of farmed fish or legislative aspects may be best formulated at the national level.

Enabling environment

- Laws and regulations which enable participation.
- Commitment from government to have active stakeholder involvement.
- Development of mechanisms to include vulnerable groups and overcome social norms undermining certain

Additionally, the level may not be administrative or geo-political, but be based on the species or the farming system.

Generally speaking, stakeholder involvement should occur at the level where stakeholders are affected and associated tasks carried out at that level. In some cases, however, the most effective level for stakeholder involvement may not correspond to the capacity of the stakeholders, especially where stakeholders are not well organized, or are diverse or poorly resourced. Alternative arrangements may have to be made, with the risk of stakeholder involvement being weakened, less representative and/or increasing costs of consultation. For example, in countries where fish farmers are geographically dispersed, poor and lacking in organization, alternative means for their involvement may have to be used in national or even provincial policy-making. This might be achieved through the participation of a “proxy” organization such as community development organizations or an NGO that is able to represent fairly the views of these diverse farmers. Alternatively, policy formulators may have to rely on participatory research such as participatory rural appraisal and participatory action research to enhance stakeholder involvement.

stakeholders.
- Ensuring issues are kept simple and appropriate. Development of policies which validate the process.

Decision-making processes

- Development of transparent processes for stakeholder identification and selection so that inclusion of stakeholders and exclusion of other stakeholders is an objective process.
- Information disseminated to stakeholders to enable them to make informed decisions.
- Development of stakeholder involvement/decision-making processes (i.e. instructive, consultative, cooperative) which match the capabilities and aspirations of stakeholders.
- Establishment of decision-making rules and clear objectives which are communicated to stakeholders.
- Improvement of the legitimacy of policy-making, planning and management processes by ensuring transparency and consistency with existing values and norms.
- Anticipation of potential areas of competition between stakeholders and development of methods to manage expectations, minimize

Conclusions and recommendations

There are often high expectations that, by involving stakeholders, more realistic and effective aquaculture policies and plans will be formulated and their implementation improved. Although the potential benefits of stakeholder involvement may be significant, this paper has attempted to illustrate the complexity of the process. In order for stakeholder involvement to be effective, a number of critical issues must be addressed. There is some overlap between issues, so that by addressing one (e.g. institutional capacity of stakeholder organizations), another may also be addressed (e.g., organizational legitimacy). What emerges from the review of stakeholder involvement in aquaculture is that optimal effective stakeholder involvement requires action in three main areas:

competition and maximize winning coalitions.

- Calculation of realistic time-frames and costs of stakeholder involvement and provision of sufficient funds.
- Identification of the tasks and level (international, supra-national, national, district, local) at which stakeholders are directly affected and able to participate in decision-making processes.

Roles and responsibilities of stakeholders

- Provision of training for stakeholders on their role in the stakeholder process.
- Strengthened legal frameworks, administrative capacities, resources and knowledge bases of stakeholder organizations

- Improvement of the legitimacy of stakeholder organizations where they are considered to be unrepresentative by members, nonmembers and other stakeholders.

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Promoting Sustainable Aquaculture through Economic and other Incentives[1]

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ABSTRACT: Economic incentives have been widely applied to encourage growth in aquaculture production, especially in the "infant" phase of development where risks are often high and scale economies cannot yet be realized. In recent years, increasing attention has been given to incentives that encourage the use of environmental and natural resources in a sustainable manner. This growing interest is not least due to the frequently disappointing performance of command and control measures. Different kinds of incentives can be developed in isolation or in combination, including tradable use/access rights, taxes/subsidies, codes of conduct, eco-labelling and others. While practical experiences are still very limited in aquaculture, these measures have proven effective in other sectors to induce producers to adopt better and more environmentally friendly production practices.

KEY WORDS: Incentives, Taxes, Subsidies, Tradable Rights, Codes of Conduct, Eco-labelling

Introduction

Many agencies (local, national, regional or international) have provided incentives for aquaculture development. These include subsidies for production inputs or outputs, e.g.:

- subsidies to fixed capital or to operating capital by direct grants, soft loans or debt-equity swaps;

Concerns about the environmental sustainability of certain aquaculture activities relate, inter alia, to the degradation or removal of ecologically valuable habitats, the waste production levels that exceed the assimilation capacity of nearshore waters and freshwater aquifers, the capture of wild postlarvae for stocking and high by-catch mortalities, and the transmission of pathogens and genes between cultured and wild stocks. Economic, social and cultural sustainability

- income and profit tax rebates (tax holidays);
- public investment in collective infrastructure (e.g. water channels and bunds, electricity supply);
- market promotion of aquaculture products;
- investment in human capital (skill development through training and extension) and public investment into innovation (research and development); and
- technology transfer4.

The traditional concern of these agencies was to accelerate the growth of the aquaculture sector in order to realize economic and social objectives, such as generation of income and employment, foreign exchange earnings and rural development for food supply and poverty alleviation. These policy objectives and tools are not specific to aquaculture but, in the past, emerging aquaculture industries, both in industrial and developing countries, have benefited from such public support. The main arguments for this support have been:

- the risky character of aquaculture production for which knowledge is still rather limited;
- the relatively high-tech content of some aquaculture practices; and
- the significant potential of aquaculture to provide socio-economic development opportunities, especially in deprived regions and poor countries.

An additional argument is that "infant" industries face cost disadvantages because scale economies do not yet apply and the gains from learning-by-doing are not yet available. As a consequence, a late starter may not become internationally competitive, or may become so only after a great length of time, without government assistance.

In recent years, increasing attention has been given to the kind of public policy and support needed to ensure that aquaculture concerns include dramatic production losses caused by epidemic outbreaks of diseases; obstruction of traditional access by local communities to common resources; and nutritional, socio-economic and cultural impacts of conversion from agricultural multi-crops to pond culture5.

Growing interest in economic incentives to achieve sustainability objectives is not least due to the frequently disappointing performance of command and control measures (the setting of regulatory norms and standards that forbid or allow certain actions or outcomes), especially under conditions where growth incentives exist concurrently. Command and control measures generally focus on blocking the incentive created by various types of market failure for private operators to over-utilize or pollute natural resources. Conversely, economic incentives attempt to align the incentive structure with sustainability objectives.

The underlying economic rationales for the provision of sustainability incentives are various types of market failures. Markets are frequently absent or ill defined for important aquaculture production inputs such as land, water and specific valuable environmental resources and functions. As a consequence, these inputs are under-priced vis-à-vis their social value or not priced at all. In turn, this has the effect that the price of the cultivated products carries a "subsidy" element whose ultimate beneficiaries are the consumers of these products.

Ideally, incentives should create "win-win" conditions, achieving both social and economic development objectives, as well as environment protection. In reality, however, growth-oriented incentives are known to have caused or contributed towards unsustainable production systems. Similarly, sustainability incentives can, at least in the short and medium term, retard achievement of growth objectives.

development proceeds in a sustainable manner and is not negatively impacted by other economic activities.

Moreover, proper social costing of production inputs can place domestic producers at a competitive disadvantage with foreign producers who are not required to internalize environmental costs.

Command and control versus economic incentive schemes

Command and control (C&C) standards are usually tailor-made to regulate how a specific activity or class of activities need to be carried out. Compliance monitoring and eventual sanctioning of trespasses are usually indispensable features of effective C&C. The primary disadvantages of the C&C approach are that it is overly constraining, leaves little room for flexibility, is not adaptable on a case-by-case basis and tends to retard technological change. Moreover, regulations underlying the C&C approach offer no incentive for producers to attain standards higher than those imposed by the law. While C&C is often criticized for these reasons, it is widely used by government agencies and even sometimes requested by the industry. Producing regulations is done within the logic of public administration, often regardless of their enforceability. In terms of political relations, "something has been done", and since the same norm or standard applies to everybody, it provides a sense of fairness. The frequent weakness of results monitoring and accountability, in the political arena, however, often leaves implementation in the shadow.

Incentives are a different approach. The idea of incentives is not to strictly forbid/allow, but rather to provide signals on public objectives while leaving some eco-labelling requires that certification standards are established and complied with. So rather than two different approaches, incentives plus command and control should be seen as a continuum of policy means, having relative advantages or disadvantages depending on what they are supposed to achieve. Presently, the diversity of available incentive instruments is probably under-used, with a continuing bias towards command and control.

Crafting institutions to improve the structure of rights and stakeholders participation

The first arena to provide incentives is to define and enforce rights. The enforcement of human rights is as important for social sustainability as the definition and enforcement of rights of nature for environmental sustainability. Within the last several decades, the times of abundant natural resources have globally given way to conditions of scarcity, as many resources become degraded, depleted or even irrevocably lost. Free and unregulated access, or simply the lack of enforcing access rights, have been important reasons for unsustainable use patterns of many natural resources. The conservation of landscapes and valuable ecosystems, preservation of water quality and quantity, accessibility to the shore and avoidance of room for individual and collective decision-making to respond to them. Incentives play indirectly through the determinants of individual/collective choices, such as the profit motive or normative values. Market or social forces can be very efficient vectors to force the global outcome of individual actions towards collectively set objectives. Different kinds of incentives can be developed in isolation or in combination:

- improving the institutional framework (definition of rights and participatory processes);
- developing collective values (education, information, training);
- creating nonmarket economic incentives (taxes and subsidies); and
- establishing market incentives (tradable property/access rights; eco-labelling).

Any of these instruments rely, to some degree, on command and control. Creating the conditions for an efficient market over property rights requires that these rights are legally set and practically enforced. Similarly, creating a market-based incentive for environmentally friendly production methods through product

land erosion are all major sources of dispute raised by opponents of certain aquaculture practices. Defining basic rules to impartially arbitrate among potentially conflicting interests may prevent many of these conflicts arising in the first place. Legislation on integrated coastal area management, defining access rights and limitations to various types of activities, recognizing basic individual rights (such as the accessibility to the shore or to water with specific properties) would help private and public promoters of aquaculture development to plan their activity in more secure and informed circumstances. Well-defined individual or collective rights act as an incentive where those who have these rights, either on the side of the aquaculture promoter or on the part of another interested party, can use them for persuasion or can claim them in front of a jurisdiction capable of enforcement. When defining and allocating use rights to natural resources, an important and often controversial issue is how to deal with the old and the modern, how to balance recognition of the historical rights of the first comer or user, the rights of the best economic offer and the rights of future generations.

For many kinds of environmental resources, there are limitations to establishing private property regimes. These limitations are caused by, on one hand, the interconnectedness of functionalities of many natural resources and, on the other hand, by high enforcement costs. Thus nature is often hard to appropriate under a private property regime. Innovation in terms of common property rights definition is needed for water management

Optimal pollution is not usually a point of zero pollution, but a level where the cost of reducing pollution any further outweighs the environmental, social and economic benefit received. Implementing such a tax has its difficulties:

- it is often next to impossible to determine the optimal pollution level because of measurement and valuation problems of the damage caused and (integrating fresh, brackish and marine waters), for landscape and land protection, or the conservation of biodiversity and valuable ecosystems. Beyond the legal definition of rights, crafting of institutions and decision-making processes, structuring of interest representation and development of enforcement and monitoring schemes all have to be taken into consideration. The main difficulty in designing and establishing rights regimes is the capacity to enforce them. But this difficulty should not prevent active efforts to design, publicly discuss and legislate these rights and obligations. Creating private property rights that can be allocated by the market is, theoretically, appealing, but they require certain conditions to be fulfilled to function effectively.

Fees, charges, taxes and subsidies[6]

Economic instruments including fees, charges, taxes and subsidies seek to “get prices right” for production inputs and/or outputs. Absent or inadequate markets, i.e. market failures, as well as government price controls/price support schemes, may all distort real social and environmental costs (or benefits) of goods and services. Economic instruments explicitly affect private costs and benefits. They seek to induce individuals and firms to change their behaviour to more socially and environmentally desirable alternatives.

The difficulty in applying economic instruments is to design the levy or tax in such a way that it gives a clear economic signal to producers and consumers about the objective it seeks to attain. The basic rationale of a pollution charge or tax is for the one who causes the damage to compensate the victim of it. This reasoning underlies the “polluters pay principle” which has been adopted by Organisation for Economic Cooperation and Development (OECD) countries in 1972 and is reflected in

cost of mitigation and clean-up; and

- it is also difficult to calculate and apply the tax in proportion to the value of the damage caused.

In practice, environmental levies and taxes may not be directly applied to the polluting substance released or natural resource used, but a closely correlated input or output7.

Economic instruments, as with all instruments, need some monitoring and enforcement capacity. To be efficient, the authority should be able not only to collect the tax or fee but also to monitor the phenomena on which tax calculation is based. Such control is difficult at the very decentralized level of the individual farm, so taxes may be imposed directly at the pollution source (antibiotics, pesticides, feed) or at the level of production outputs, where taxes can be more conveniently collected. The consequence, however, is that the tax becomes a much less fine-tuned policy instrument, as all kinds of economic activities using such inputs will be taxed in a similar fashion irrespective of actual damage caused. At the worst, a tax may have unintended effects that could potentially worsen rather than lessen environmental damage. Consider the imposition of a tax on pellet feed to incite farmers to adopt more efficient feeding strategies that result in low feed conversion ratios and low organic effluent loading per unit of production. While some farmers may indeed be incited to economize on pellet feed, other farmers may shift to alternative non-taxed low-quality feeding materials with high feed conversion ratios.

In addition to the above implementation problems, arguments raised against environmental taxes in aquaculture, as in any other business, are their effect on competitiveness and the fact that by raising the production cost they are a disincentive to innovation. These arguments are not necessarily tenable for the following the 1992 Rio Declaration on Environment and Development. It traces its origin to arguments first advanced by Pigou, who proposed its implementation through a tax. Appropriately named, the "Pigouvian tax" should be set equal to the pecuniary value of the marginal damage caused by pollution at the point of "optimal" pollution.

reasons. A well-designed and implemented environmental tax that, for example, reduces water pollution, can result in a more stable and higher production level for all farms.

Moreover, farmers will seek to reduce the use of the taxed production input through technological innovations. On theoretical grounds, there is little that speaks against the use of economic instruments. The difficulties lie in designing cost-effective schemes that can practically be implemented and achieve their intended objectives8.

Subsidies and grants have been widely used to compensate for the high level of risks in the start up of aquaculture farms9. When evaluated on the basis of whether or not they have accelerated production growth, they have been fairly successful in many countries. If evaluated on the basis of whether or not they have led to sustainable development, however, their track record is less laudable for some types of aquaculture. There appears to be a need to reorient subsidy schemes, if maintained at all, towards reaching more efficient and rational use of environmental and other resources. One obvious area is targeted research to develop more environmentally friendly production techniques. Another obvious area is to explicitly target alleviating poverty not just for social and humanitarian reasons, but also because poverty is a major cause of environmental degradation in developing countries.

Education and, more broadly speaking, persuasion, are important factors. Public information about potential risks, training of aquaculturists on the environmental and social dimensions of their business and, likewise, sensitization of politicians and other policy-makers, should be promoted.

In recent years, associations of producers and industry play increasingly important roles in information dissemination, awareness creation, education and training, as well as in the development of codes of best practices, production and product standards, and codes of conduct10. These efforts, while in some cases building upon traditional institutions and organizations, are generally a modern-day response to the well-known environmental, socio-economic and marketing issues facing certain types of aquaculture systems. Voluntary industry codes can significantly reduce the need for costly government regulatory interventions. Moreover, the reassurance of consumers and intermediaries, such as wholesalers and retailers, about the absence of adverse environmental impacts and respect of human rights and labour standards when producing a product is known to have the potential of increasing demand for such products in international and national markets.

Information dissemination, development of normative values and other tools of persuasion

Cultural values and norms regulating behaviour, and shared among a group, are a good source of incentives that guide individual and collective decision-making. The problem is that traditional value systems, based on common knowledge and alive through moral obligations and social sanctions, can break down when social groups face rapid changes and are subject to strong outside influences. In these frequent instances, short-term economic and political interests tend to erode traditional norms and values that are seen as barriers to modernization. A careful balance appears to be needed between maintaining, or even rejuvenating, traditional sources of behavioural norms that can positively contribute to fostering sustainability, while not curtailing the dynamic changes needed for economic and social progress. Building collective concerns about sustainability and fostering human resources development certainly need the formation and promotion of common values.

A central function of a code is to coordinate the behaviour of decision-making units such as individual farmers or cooperatives. By agreeing to behave in a specified manner, common problems can be resolved, such as maintaining water quality within common water bodies used by several farmers. Codes offer the advantage of being more flexible and readily "amendable" than command and control. However, rules originally conceived as voluntary guidelines or recommendations can have an impressive "juridical career" in that they may develop within a short time into binding rules. This may happen because the recommendations or guidelines are shared by the overwhelming majority of those concerned by them.

Eco-labelling

Eco-labelling schemes have been introduced in various sectors and for different objectives by nongovernmental organizations (NGOs), private industry and governments. Their common feature is that the consumers' purchasing behaviour is directed to take into account attributes of the products other than their price and mandatory quality and health standards.

These attributes can relate to economic and social objectives (fair trade, support to small farmers, discouragement of child labour), health-related product quality objectives (organic production), in addition to environmental and ecological ones.

The potential usefulness of eco-labelling schemes to create market-based incentives for environmentally friendly products and production processes was internationally recognized at the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, where governments agreed to "encourage expansion of environmental labelling and other environmentally related product information programmes designed to assist consumers to make informed choices". Consumers are provided with the opportunity to express their environmental-ecological concerns through their choice of products. The consumers' preferences are expected to result in price and/or market share differentials between eco-labelled products and those that either do not qualify to be eco-labelled or those whose producers do not seek to obtain such labelling. The label is obtained through a certification process based on a set of criteria (i.e. the desired standard). Potential price and/or market share differentials provide the economic incentive for firms to seek certification of their product(s).

According to their design and administration, eco-labelling schemes are often classified into:

- first party labelling schemes, emanating from individual companies based on their own product standards;
- second party labelling schemes, established by industry associations for their members' products. Certification criteria are elaborated by the members, sometimes by drawing upon external expertise from academia and environmental organizations, and verification of compliance is achieved

Environmental organizations generally advocate eco-labelling schemes based on third party certification because of the heightened confidence that private commercial interests will not compromise the criteria applied to the schemes and strict compliance with them will be based on verifiable and impartial certification procedures.

Currently, the most attractive opportunity is offered by rapidly expanding markets for organic food products which offer price premiums in the range of 30 to >100 percent. These relatively high premiums may not be exclusively, or perhaps even primarily, associated with the consumers' desire to buy products produced with environmentally friendly technologies, but their desire to eat healthy and uncontaminated food. Presently, no international guidelines are available specifically for organic aquaculture production, but a number of specifications laid down for agricultural production are readily applicable to aquaculture. The adaptation of current international standards for organic food to fish and shellfish from aquaculture is likely to require significant changes in production methods and processes, especially for semi-intensive and intensive aquaculture systems.

Concern has been expressed that eco-labelling is a marketing and product-differentiation strategy that ultimately will benefit big businesses at the production, distribution and marketing levels. Small-scale producers, especially those in developing countries, would have more limited access to costly "best available technologies" and not be able to realize economies of scale in both production and product certification, labelling and verification. Experiences made in organic agriculture indicate that small producers can be competitive in national and international markets but may require proper institutional and organizational arrangements (e.g. group certification, cooperative input through internal certification procedures within the industry or employment of external certifying companies; and

- third party labelling schemes, usually independent from the producers, distributors and sellers of the labelled products; while the criteria may be established through a negotiation process among the various interested parties, they are often motivated by the environmental objectives of the private initiators of such schemes.

purchases and product marketing etc.) that allow them to capture scale economies.

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4 Many examples from around the world can be found in Ridler and Hishamunda (2001)

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benefits of providing start-up funding were positive (Ridler, 1998). In shrimp culture, most countries provided subsidies, at least in the initial phase of development (see for example the papers in FAO 1999).

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11For a review of eco-labelling issues in fisheries, see Deere (1999) and Cochrane and Willmann (Forthcoming).

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[1] The views expressed in this paper are those of the authors. They do not necessarily represent the views of CEDEM or of the Food and Agriculture Organization of the United Nations (FAO).

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Establishing Legal, Institutional and Regulatory Framework for Aquaculture Development and Management

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ABSTRACT: Aquaculture raises legal and institutional issues because it is an activity that impinges on natural resources and matters at the heart of most legal regimes. Aquaculture interacts with the environment, being dependent on land, water and aquatic species, and causing environmental changes. It also must produce a product safe for human consumption in domestic or foreign markets. Therefore, the development and management of aquaculture is likely to fall within the scope of various pieces of legislation and the expertise of various institutions. In recent years, these features have been central to the evolution of the law of aquaculture.

This paper identifies, actual institutional and legal practices, as well as the legal and institutional changes in regimes governing aquaculture, that have taken place over the last decade. It provides a comparative account of some new features and on-going shifts in different countries. For government bodies, the use of law to promote sustainable aquaculture is not an easy task, and law is only one amongst a number of mechanisms that may be required to secure this objective. Faced with an environmental challenge, it involves multi-disciplinary and inter-disciplinary approaches. Any belief that a legal prohibition of unacceptable behaviour will solve an environmental concern is erroneous.

Faced with the increasing difficulty in regulating aquaculture because of the numerous interests involved, the diversity of natural resources used and the

variety of institutions concerned, increasing importance and recognition are awarded to issues such as local and private/semi-private aquaculture management; sustainable aquaculture management; use and planning; improved design and awarding of aquaculture leases; more frequent adoption of codes of practices, guidelines or other soft law instruments; and involvement of a wider range of stakeholders from both public and private sectors.

Aquaculture activities need to be carefully monitored and controlled. Some countries are witnessing the early development of a qualified inspectorate with sufficient powers of inspection and resources. Even more important, however, is the need to recognize that compliance is in the collective self-interest of all members of the aquaculture sector. Space is also being made for various mechanisms of individual or collective "self regulation". Conclusions and recommendations are made in summary of the subject matter reviewed.

KEY WORDS: Aquaculture, Legislation, Regulatory Frameworks, Institutional Arrangements, Law

"9.1.1 States should establish, maintain and develop an appropriate legal and administrative framework which facilitates the development of responsible aquaculture." Code of Conduct for Responsible Fisheries (CCRF), Article 9

Foreword

In the latter cases, the existing legislation has a broad application, i.e. laws and similar regulations have been adopted to cover fisheries or water in general, rather than aquaculture specifically. These laws tend to set up some principles on aquaculture and then invest the legitimate authority with the power to regulate aquaculture. On the other hand, the last decade has witnessed a steady increase of countries enacting either:

In the preparation of this review, primary focus has been placed on those laws and regulations directly governing aquaculture activity. At this stage, and in the light of the other thematic reviews undertaken under the auspices of this Conference, this review has not taken into consideration those laws dealing with the aquaculture product (disease control, health management, quality and safety), genetically modified organisms (GMOs) and the marketing and trade thereof. Likewise primary reliance has been put on materials based in the Legal Office of the Food and Agriculture Organization of the United Nations (FAO) and those made available by the panel members.

Part I - a legal regime for aquaculture

Trends

Setting the scene

Aquaculture has been practised for many centuries, but surprisingly the legal regime governing aquaculture has only recently (over the last 15 years) received detailed attention. This is quite remarkable given that much of the aquaculture activity impinges on matters at the heart of most legal systems. It will

- a particular act and/or regulation dealing with aquaculture or a certain type of aquaculture, or
- a specific point relating to this activity[8].

In doing so, these countries often responded to a precise need. Crucial questions frequently regulated relate to:

- access to aquaculture,
- fish health,
- collection of information,
- registration of aquaculture,
- the import of seed, and
- special environmental aspects.

Few countries were found with solely an enabling clause on aquaculture, i.e. countries which, while not having a special law, section or provision on aquaculture, have vested the power to regulate this activity in a Minister or Director. In a few developing countries in Africa, this is a common situation[9] . Some countries are in the process of drafting a specific set of rules for aquaculture, for example, Bulgaria, Croatia, Cyprus, Malaysia, Malta, Morocco, Thailand and Vietnam.

The status and progress of laws on aquaculture do not always reflect the importance of the activity (including the importance of fish in be, for example, directly affected by the land laws, including the use of public domains, such as foreshore or mangrove areas, the water laws, environmental laws, animal health and animal disease laws, fish and game laws, and trade laws, as well as others applying more generally (e.g. public health and sanitary laws, import and export laws, tax laws etc.[3]).

In recent years growing attention has been given to the role of law and legal institutions in aquaculture development. Numerous countries have enacted specific rules relating to aquaculture under an aquaculture-specific legislative text[4], under a basic fisheries law[5], under a water law [6] or under another piece of legislation[7].

national diet, employment or economic values). This is the case of Bangladesh and Vietnam, where fisheries resources, though of great importance, have been governed virtually entirely by ad hoc policies. However, this does not mean that aquaculture is not regulated in one way or another. Land laws, water laws, environmental regulations etc. can have an effect on aquaculture and the conditions of its development, which, in some situations, can be decisive.

In some countries, the rules set up for aquaculture follow the public/private water or the sea/freshwater classification. This situation is common in France, the Republic of Moldavia, Myanmar, Syria and New Zealand.

Scope of the legislation: a few words

The review conducted (and still being conducted) shows that countries where a degree of aquaculture development has taken place have built up a legal framework which, in one way or another, allows for control of the access to and operation of aquaculture activities. It also sets the institutional framework and orientations for the management of aquaculture activity. In relation to the operation of aquaculture facilities, such a legal framework provides a means of preventing or curing the problem of pollution caused and suffered by aquaculture.

The diversity and complexity of the legal frameworks among the countries taken into consideration may depend on the:

- legal status of waters used (public or privately owned)[10];
- nature of the waters used (marine/brackish vs. fresh water)[11];
- legal status and the nature of the land used (coastal area vs. inland, private vs. public)[12];
- need for a government to regulate aquaculture in general or a specific aquaculture activity[13]; and

Aquaculture *is the* ***farming*** *of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the* ***stock*** *being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to* ***aquaculture*** *while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of* ***fisheries****.*

In this definition, the emphasis on ownership, if only for statistical purposes, has the consequence of excluding from the definition several aquaculture activities which would almost certainly be included in the dictionary definition, or even in legal definitions, for it is the nature of the activity rather than the often elusive equation of ownership which is central concern. Furthermore, this definition seems to overlook the fact that aquaculture is the propagation and husbandry of aquatic plants and animals for commercial, recreational and scientific purposes. This includes production for

- different questions it is called upon to deal with (use of natural/chemical feed, wild/hatched seed, fish health management[14] effluents, restoration etc.).

No considerable disparity was found between legislation governing marine and freshwater aquaculture. The diversity lays mostly in the authorizing and enforcement authority (Cyprus, Israel).

A major threshold question regarding the establishment of a legal regime of aquaculture: a definition of aquaculture

A major threshold question regarding the establishment of a legal regime for aquaculture is how aquaculture should be defined. It is defined in the Oxford Dictionary as the "cultivation of plants and breeding of animals in water" and the Encyclopaedia Britannica as *"the cultivation of the natural produce of water (as fish or shellfish)".* These definitions seem straightforward enough, though for legal purposes, they may be insufficient.

The Aquaculture Steering Committee of the Fisheries Department defined aquaculture in the following terms:

supplying other aquaculture operations, for food and industrial products, for stocking sport fisheries, for producing aquatic bait animals, for fee fishing, for ornamental purposes and for use by the pharmaceutical and chemical industries. These activities can occur both in natural waters and in artificial aquatic impoundments.

Throughout the legislative texts consulted, aquaculture is invariably also called "fish farming", "fish culture", or "mariculture", and sometimes becomes an approximation to agriculture. The latter status appears to be influenced by the location of the aquaculture activity (inland vs. coastal, fresh water vs. marine), the legislative point being dealt with (animal disease, sanitary rules) or the jurisdiction of the government institution responsible for aquaculture. A clear status, therefore, is not always accorded to aquaculture. For instance, a fisheries-based law falls under an ambiguous definition covering both fisheries and aquaculture [15].

There is little uniformity in the definitions provided, and this is well-illustrated by some of the different legal definitions currently in use:

"Aquaculture means rearing (cultivation) of aquatic species aiming at their economical

exploitation"[16]

Fishing is defined as "any operation involving the rearing, capture or extraction of animals or plants, whose livelihood is most normally or most frequently marine (marine fisheries) or freshwater or brackish water (freshwater fisheries)". A concession is required for the establishment of "établissements de pêche" which are defined as "any establishment supplied with sea water, freshwater, or brackish water with the view to capture, rear and culture of marine or freshwater animals and plants on the public domain."[17]

"A fishing activity is any lawful operation in support of extracting, catching and rearing of aquatic organisms. Aquaculture is defined as the rearing or breeding of aquatic organisms (fish, mollusc, crustaceans, seaweed, etc.) under human control including the harvesting, processing, transport, sale and consumption thereof." [18]

"Fish culture means any operation involving the maintenance,

In light of the above, one may ask whether or not a universal definition for aquaculture is necessary. It may be easier to handle aquaculture, from a legal (and institutional) point of view, as a fisheries-related activity or as an agricultural activity. Aquaculturists often wonder why they are not offered the same protections afforded agricultural practices. Likewise, experiences have shown that the amount of governmental agencies with jurisdiction over aquaculture may be reduced or increased, in accordance with a definition of aquaculture. The role a legal definition of aquaculture is likely to play also needs to be closely examined. And finally, when a legal definition of aquaculture is being prepared, collateral issues (e.g. relating to the aquaculture facility or the aquaculture product) also need to be taken into account and covered by the appropriate legislation.

Sustainable aquaculture

propagation or promotion of growth of fish, in captivity within the waters of China, HongKong SAR."[19]

"Fish farming''--- (a) Means the activity of breeding, hatching, cultivating, rearing, or ongrowing of fish, aquatic life, or seaweed for harvest; but (b) Does not include--- (i) Any such activity where fish, aquatic life, or seaweed are not within the exclusive and continuous possession or control of the fish farmer; or (ii) Any such activity where the fish, aquatic life, or seaweed being farmed cannot be distinguished, or kept separate, from naturally occurring fish, aquatic life, or seaweed; -- and "to farm'' has a corresponding meaning and includes any operation in support of, or in preparation for, any fish farming".[20]

"Aquaculture means the propagation of fish seed or the raising of fish through husbandry during the whole or part of its life cycle." [21]

"Aquaculture a form of agriculture which is the controlled cultivation of aquatic plants, animals and micro-organisms." [22]

"Aquaculture means the rearing or culture of aquatic organisms using techniques designed to increase the production of the organisms in question beyond the natural

Another element for discussion is the imperative for sustainable aquaculture. The Bruntland Commission (the World Commission on Environment and Development) in its report Our Common Future states that sustainable development is:

"development which meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs"

While the concept of "sustainable development" as well as "sustainable aquaculture" per se is widely endorsed, it is convenient to note that the latter concept is not formally defined at any point in the laws consulted. Indeed the concept of sustainable development is a central objective of:

- many laws[24];
- approaches towards decision-making processes in aquaculture (e.g. provisions on planning for aquaculture[25], integrated management

capacity of the environment; the organisms remain the property of a natural or legal person throughout the rearing or culture stage, up to and including harvesting." [23]

processes including coastal zone management[26], participatory approaches[27]);

- purposes for establishing subsidiary legislation[28] ; and
- respective legal duties/commitments of aquaculturists and the government[29].

All have to contribute to reach a balance between the need for environmental protection and economic development, between interests of present stakeholders, and between present and future generations.

With respect to the respective duties of government and aquaculturists to ensure that aquaculture is sustainable, it was noted that roles tend to be formulated in an indicative manner rather than in an imperative manner. The latter is more common in developed countries[30]. At the time of writing legislation governing aquaculture in 1989[31], the main obligations demanded of aquaculturists were to:

The granting of concessions/leases as a method of aquaculture management, accompanied with recognition of private and community rights over ownership and use of land and water resources on which aquaculture is depending[33] reflects this approach.

However, this trend is not common to all parts of the world. A recent review among the countries bordering the Mediterranean Sea pointed out that the concept of sustainability, with the exception of Albania, Croatia and Greece, did not really underpin the legal framework governing aquaculture[34].

Even if a harmonized approach

- provide information on production;
- grant access by authorized government officials to an aquaculture site;
- start the exploitation, or not to stop it for a stated duration;
- mark or delimit the concession/lease area; and, last but not least,
- pay the licence/registration/permit fee(s).

Now the idea of sustainable aquaculture is gaining importance and underpinning the duties of aquaculturists. For example, practitioners generating pollution, disease or other environ-mental adversity are firmly restricted or prohibited from undertaking aquaculture. In addition, there is an increasing tendency to subject aquaculturists to environmental impact assessment (EIA) processes before and during the operational phase[32]. Numerous conditions attached to an aquaculture authorization now relate to the collection and use of wild seed; the quantity and quality of feed; chemicals; placing and changing of equipment; the restoration of a site; emergency/alert systems; and the discharge and deposit of sludge, stone or other deleterious matter.

towards the concept of "sustainable aquaculture" would exist world-wide, a threshold question is whether, in the light of the diversity of options available to a government, differences in opinion about what is "sustainable" will draw countries away from the strictest intent of the approach?

Outstanding new features and shifts in legislation governing aquaculture

The problems of studying the legal regime of aquaculture were brought out very strongly in the first attempt to look at the subject undertaken by the Development Law Service in 1989, which was entitled "A Preliminary Review of Selected Legislation Governing Aquaculture, written by A. Van Houtte, N. Bonucci and W. Edeson.

This section looks into the major changes that have occurred in national legislation concerning aquaculture and the potential consequences these may have. In summary, the legislation reviewed reflects new attention to:

- environmental and social responsibility for management of those natural resources on which aquaculture development depends; and
- the production processes

required to meet public and consumer expectations.

As far as government authorities are concerned, the concept of sustainable development underlies:

- aquaculture planning activities,
- aquaculture site allocation processes,
- participation in the decision-making processes, and
- the delegation of authority for the management of aquaculture developments.

This view takes into account the wide diversity of interests relating to fisheries, land and water resource use, as well as conservation, in the move towards a looser notion of public ownership of natural resources.

Outstanding features and shifts in legislation include (but are not limited to) the elements below.

Reforms in planning for aquaculture

One of the features of the present period is that increasingly, more countries have introduced elements of planning for aquaculture, taking into account the need to manage an economic activity as well as environmental interests, and have streamlined the use of environmental impact assessment as a tool for aquaculture planning and management[35].

During the 1989 review referred to above, it was observed that very few countries (especially developing countries) have established plans for aquaculture development. Laws were aimed, instead, at orienting the development of the industry, for instance location wise, species wise or aquaculture techniques wise.

Further, in the planning process for aquaculture, governments have established consultation procedures with various parties interested in aquaculture development, for example, non-governmental organizations (NGOs), industry, scientists and producers' organizations.

An attempt towards a coordinated authorization system for aquaculture

All countries under review require government authorization to engage in aquaculture[36]. Such authorization may fall under different terminology: authorization, licence, permit, lease and concession. Bearing in mind the different resources aquaculture depends on, and the fact that these resources are at the heart of other legal regimes, some governments may attempt to streamline the authorization procedures, for example via:

Where public lands are put aside specifically for aquaculture procedures, one authority is often responsible for the development and operation of aquaculture[39]. Conversely, aquaculture authorization may be merged into a general water permit, as this is the case in the Republic of Moldavia, Finland, Hungary, Tajikistan and Uzbekistan. A procedure of close consultation with other competent agencies may also be found[40]. None of these procedures are perfect, and undoubtedly the institutions and their people play a key role in making these approaches work.

There is also a tendency to develop transparent authorization systems (not necessarily less burdensome). This transparency is realized through the publication by the government of (explanatory) guidelines for engaging in an aquaculture activity[41]. They are specifically addressed to potential future aquaculturists. Transparency also benefits non-aquaculturists, as the decision-making process may include public hearings and/or official publication procedures which allow outside people to voice their comments. To illustrate this, the Fisheries Ministerial Policy Guidelines for the Assessment of Applications for Authorisations for Aquaculture and Pearling in coastal waters of Western Australia[42]

- designation of a lead agency;
- clearly defined procedures and information requirements;
- specified criteria to assess proposals; and
- simplified lines of action.

Although authorization is still most often provided under the fisheries legislation[37] and/or some form of aquaculture-specific regulation[38], it appears that the general plea from the aquaculture industry for a single government agency dedicated to aquaculture (development and operation) is beginning to be heard. In some countries, like Albania, permits for access to land and water are merged into a general aquaculture authorization, under a fisheries law. This was made possible because the authorization is issued by a board constituted under the Committee of Environmental Protection and grouping representatives of various ministries concerned. A similar, so-called "scoping" procedure, was instituted in Sri Lanka, Mexico and Madagascar to ease the receipt of approvals from several government agencies covering different mandates.

provide guidance to the Executive Director of Fisheries Western Australia on the processes to be used in assessing aquaculture licence and lease applications under Sections 92 and 97 of the Fish Resources Management Act 1994, and Section 23 of the Pearling Act 1990 for leases, licences and permits. Before granting an aquaculture (operating) licence, the Executive Director must advertise a notice of the proposal to allow affected persons the opportunity to object[43]. Any objections raised are referred to the Minister and dealt with by a tribunal appointed by the Minister. Equally, the Minister must publish notice of the granting of a lease in the Government Gazette, however, there is no right of objection in the case of lease issuance.

The provision of an authorization procedure for setting up and operating an aquaculture farm may constitute a good basis for ensuring that the farm will be managed in an environmentally friendly manner. Hence, given the emphasis often placed on the adverse impacts of culture activities, aquaculturists would be unable to engage in aquaculture without an effluent discharge permit and without going through the process of environmental impact assessment[44]. This situation is most common in developed countries.

The increased zoning of land and water areas for aquaculture purposes

The increasing concern regarding environmental impacts caused and suffered by aquaculture has induced governments to set aside public lands for multiple uses (e.g. coastal zone management techniques), as well as land and waters for aquaculture uses[45]. Indeed legislation goes now beyond just the setting of standards or fixing requirements for the ambient environment. Zoning of land and water areas for certain types of aquaculture is a method used as a tool for integrating aquaculture into coastal areas. This is with a view to control the environment at farm level, as well as competing interests, and to resolve conflicts in relation to protection, use and exploitation of coastal resources. For example, Hong Kong SAR has 26 designated "Marine Fish Culture Zones"[46] and requires all marine fish culture activity to operate under a licence in designated fish

Emphasising social values in aquaculture

The recognition of the need to grant security to the aquaculturist, irrespective of size, in cases where public lands are involved, characterizes a number of aquaculture-related laws. To this end, in some countries[55], agricultural status is granted for aquaculture use of public land, or the duration of leases are extended or renewable, or marine tenure systems for private-sector involvement are introduced[56]. In Vietnam, rules relating to the allocation of land to households and individuals have been provided for with the view to grant "stable and long term use" for the purposes of aquaculture[57]. The duration of the land lease is of maximum 20 years, and is renewable.

Long-term leases/concessions (up to 10, 20 and 50 years) are also being designed in some developing countries in Asia and Latin America, in order to:

culture zones. In Ecuador, local zoning plans have been agreed upon between shrimp farms and local residents, allowing shrimp farming to continue along with mangrove planting and with traditional uses[47]. Likewise in Zambia, conservation-planning areas have been set up wherein layout of land for fish farms can be specified.

The development of integrated coastal zone management tends to redress the historical ineffectiveness of various sectoral approaches in the coastal areas. The United States was the first country to enact legislation specifically to implement integrated coastal zone management[48]. The relative success of this coastal zone management initiative has encouraged many other countries, like Costa Rica[49], France[50], India[51], Indonesia, New Zealand[52], Spain[53], Sri Lanka[54] and the United Kingdom to adopt this approach during the last decades. Most legislation provide for a variety of techniques (e.g. coastal setback rules, buffer zones, exclusion zones, protected areas, restrictions on private ownership rights, environmental impact assessment, environ-mental compensation, recognition of traditional and/or indigenous rights etc.) to further integrated coastal area management objectives. These

- create a more permanent linkage over time between producers and supervisors;
- generalize the concept of sustainability; and
- guarantee future and permanent supplies to the aquaculture industries holding these concessions.

The government's right to revoke such leases/concessions is limited and may only be used in cases of serious violations of management plans and/or relevant laws. Wide powers to terminate leases for poorly defined reasons tend to disappear. However, this increasing trend remains still ambivalent. Despite more security being provided, one should look in practice whether or not:

- such leases/concessions tend to put aside the monopolistic approach to aquaculture ownership;
- competition is distorted; and
- access to aquaculture by others is being limited.

Likewise, there is a tendency to recognize community management agreements (semi-private and private) for lagoons, coastal areas or adjacent (mangrove) areas, with a view to obtain an ecologically balanced and sustainable use of fishery resources[58]. An example of techniques are also likely to protect aquaculture developments from environmental impacts and vice versa to protect other coastal developments from aquaculture impacts.

this is the Fisheries Law of Albania, which clearly provides agreements for the management of lagoons and adjacent waters for the purposes of protecting the environment and ensuring sustainable use of fishery resources.

Such an agreement must include a management plan for the area, define the objectives of the agreement, the rights and duties of the contracting parties (including the government, in relation to the aquatic flora and fauna), the measures taken to protect the environment and existing customary rights, as appropriate.

This private agreements/partnership can help the government and the private sector in facing the complexity of regulatory aspects. It provides an ideal opportunity for the government, industry and the community to promote sustainable and rational aquaculture management, along with compatible conservation and economic goals. Last but not least, it is likely to provide governments

ADF provides financial assistance for up to one year.

Another shift is increasing concern over collection of seed from the wild, along with introduction and transfer of exotic and nonexotic species. These activities are now extensively regulated through authorization processes, general prohibitions and the incentives for setting up of hatcheries (e.g. Albania, Chile, Mexico, Peru).

For purposes of disease management, alert systems have been introduced (e.g. Hong Kong SAR, Republic of Korea), emergency plans have been designed (e.g. New Zealand) and rules for prevention, control and diagnosis of disease have been defined (e.g. Mexico). Some countries (e.g. in the European with a tool for enforcement action, for example, to prevent/stop destructive and/or polluting practices. Another interesting example thereof is the User's Agreement of Jambeli in Ecuador, promoted under the Program for Coastal Resource Management, since 1990.

There are more examples in Bangladesh, Indonesia, Japan and Thailand that are likely to demonstrate the importance of this kind of arrangement for private-sector involvement in marine conservation. In the same sense, legislation in the Pacific Region tends to recognize the importance of marine tenure for private-sector involvement, by providing recognition of statutory, community and/or customary marine tenure arrangements.

Other noticeable emerging shifts in legislation

Commercial aquaculture production is increasingly recognized as a major revenue producer for many countries, hence, some national laws use aquaculture-generated funds for resource conservation, as well as maintenance and management of aquaculture. Legislation mandating such funds is likely to be associated with other national public expenditure processes (e.g. Bolivia, Nicaragua, Union (EU)) also provide financial compensation for ordered stock eradication.

With integration of the concept of sustainable development, the inclusion of noncommercial values, such as biodiversity and environmental conservation, is especially noticeable in countries commercially active in aquaculture[59].

Another issue that has begun to emerge in developed countries is the "welfare and well-being of fish". For instance, the Marine Farming Amendment Act 1993 provides regulatory powers "for the management and control of the well-being of fish in the area farmed under a lease or a licence, or a marine farming permit issued under the section 67J of the Fisheries Act". Likewise, along with the EU legislation, farmers are responsible for (i.e. have to take care of) their "livestock", including (farmed) fish.

Towards Self-Regulation?

Faced with increasing difficulty with regulating aquaculture activity, because of:

- the numerous interests involved;the diversity of the natural resources;the variety of institutions involved;

Peru) and may be directed towards different purposes, e.g., environmental restoration (India, Tamil Nadu State), research and development (Bolivia) etc. In Western Australia, establishment of an Aquaculture Development Fund (ADF) was an important part of the state government's aquaculture initiative. The ADF is used to assist development of the aquaculture industry in Western Australia, specifically projects that demonstrate wide industry benefits, a direct impact on industry development, transfer of technology and knowledge within and across industry sectors a positive production and profitability impact on the industry, and for which at least 50 percent of the total value of the project is contributed by the applicant.

- the tangled web of laws and regulations and related difficulties in enforcement; as well as
- the forces driving global and regional markets towards environmentally and socially sustainable practices,

increasing importance and recognition are awarded to best management practices, codes of conduct and codes of practice.

This is especially common in developed countries (e.g. Australia, Ireland, France, Japan and the United States), as well as a few developing countries with commercially important aquaculture sectors (e.g. Thailand, Malaysia, Sri Lanka)[60]. This tendency is not only noticeable at a national level, but also at the international level61 .

Laws such as those described above are most often enforced by "command and control measures" (C&C) and require strict legal definitions to distinguish between conduct that is legally permissible and that which is not. For instance, it may be very hard for a legislator to promote qualitative improvements in the monitoring and control of environment-related activities surrounding aquaculture operations. These usually depend on identifying better methods, rather than distinguishing between right and wrong. Therefore, although legal rules are useful to outlaw the worst practices, they are often of limited value in promoting continuous improvements in an industry and its products over the long term. An example where a more practical approach has been adopted, in addition to legal tools, is found in the Thai regulation for intensive shrimp farms. This includes both effluent monitoring requirements and a "best

Hence, the management of aquaculture has led to a self-imposed and self-controlled system and also to proprietary access to resources[65].

The driving forces behind this shift in the regulatory framework appear to include: the need to reach a competitive advantage, a market image, a quality of the product and to provide the outside world with a pro-active response/demonstration that the aquaculture sector can be responsible.

The concept of best management practices and of codes of conducts and practices is not new. Generally speaking, the precautionary approach/principle paved the way towards the adoption of the former concept in numerous environmental laws. Likewise, codes have often been used to regulate issues relating to human health (like the use of pharmaceuticals), to regulate professional activities (codes of conduct for doctors in medicine, lawyers etc.) or simply to regulate traffic (e.g. the United Kingdom Highway Code). This is developing slowly but surely for aquaculture too.

To illustrate this, a few initiatives have been taken by the Food and Agriculture Organization of the United Nations (FAO), like the FAO "Technical Guidelines for management practices" (BMP) guideline for shrimp farming[62].

In Japan, access to aquaculture in public waters is regulated under the Fisheries Law enacted in 1949. Coastal aquaculture rights are granted to Fisheries Cooperative Associations (FCAs) by the prefectural government for a specific area. Members of a FCA engage in aquaculture in accordance with the FCA's management plan, approved by the prefectural authorities and implemented by the FCA's "Exercise Regulation for Fishery Right". In addition to this self-imposed control by the FCA, some prefectures have issued guidelines for the development of aquaculture in the area under their jurisdiction. In addition, Japan recently passed the "Law to ensure Sustainable Aquaculture Production"[63]. This law empowers the Minister of Agriculture, Forestry and Fisheries to establish the "Basic Guidelines to Ensure Sustainable Aquaculture Production"[64] and the FCAs to develop and implement an "Aquaculture Ground Improvement Programme" (hereinafter called "the Programme"). The Programme can be developed individually by a single FCA or jointly by more than one FCA. It must be approved by the Prefectural Authority and forms an integral part of the FCA's "Exercise Regulation for Fishery Responsible Fisheries"[66] and the FAO and World Health Organization (WHO) Code of Practice for Good Animal Feeding. In Europe, the Monitoring and Regulation of Marine Aquaculture (MARAQUA) project is another case in point. One of its objectives is to develop Scientific Guidelines for Best Environmental Practice, in relation to the regulation and monitoring of marine aquaculture in Europe. To cite an example at a national level, the Australian National Aquaculture Council has developed an industry code of practice which provides a framework for development of industry-specific codes. To date, such codes have been developed for prawn, tuna and silver perch farming.

A code is voluntary in nature, thus a key question is how to ensure compliance. Incentives that have been used so far include:

- membership in an association is contingent upon signing the code (e.g. the Federation of European Aquaculture Producers (FEAP)[67], France);
- authorization to engage in a professional activity is contingent upon adherence to a code (e.g. Thailand);
- legislative texts linked to best management practices or a code under specific provisions or licence condition; and

Right”.

- certification of facilities being contingent upon demonstration of a particular operational status (e.g. first, second and third class).

Other examples include quality schemes such as the “Label Rouge” in France and the “Tartan Quality Salmon” and “Scottish Quality Trout” in Scotland. These labels provide a written guarantee that the producers have observed certain criteria. These criteria are set by lawyers and representatives of the participating industries, are legally recognized by the government and, hence, binding on the producers wishing to use the labels. Such quality schemes are likely to provide important benefits, i.e. a significant increase in both quality (for the consumer) and financial return for the producer in a competitive market place. Noncompliance with a scheme leads to heavy fines and, where necessary, exclusion from the scheme.

There is no apparent change or trend in the severity of these sanctions. However, in 1989 aquaculture was rarely considered in the enforcement sections. Aquaculture was mainly regulated under a general fisheries law, thus, the powers and priorities of the inspectors were clearly focussed on capture fisheries.

Nowadays, where aquaculture is regulated under more recently adopted fisheries laws, progress has been made. Inspection powers have aquaculture in mind as well as capture fisheries. In addition, regulatory infractions are receiving attention. For example, practising aquaculture without appropriate authorization, discharge of waters likely to pollute the surrounding environment, obstruction of navigable waters, diversion of water courses, unauthorized collection of wild seed, and illegal import of live fish or exotic species commonly invoke defined penalties. At the heart of this increasing enforcement recognition, however, There can be little doubt that international trends towards introducing quality assurance systems and standards and more rigorous identification of the origins of fish and fishery products will continue. However, a key element in compliance is the decision on best management practices and codes of conduct. Who decides and at what level? What are tangible quality measurements? There can be no overall best management practice for aquaculture due to the wide diversity of climatic, geographic, species and system differences.

Constraints, limitations and measures to overcome

Enforcement - a weak link in legal regimes governing aquaculture

The regulatory framework alone cannot not be held responsible for unsustainable aquaculture practices. It matters how (or if) the regulations are enforced. Weak institutions with complicated, overlapping and fragmented management responsibilities, due to conflicting statutory mandates between legislation (e.g. between aquaculture and environmental laws) have impeded enforcement of relevant laws governing aquaculture in many countries. Also critical to the enforcement issue is the question of what is an appropriate deterrent. Sufficient sanctions are required so that they cannot be perceived by potential violators as just another cost of doing business. Sanctions may be administrative, penal or even deprivation of freedom[68]. They may also involve suspension of financial incentives awarded through an aquaculture fund, expulsion from a produce quality scheme etc. Areas which are more severely regulated than others can be found in laws and regulations concerning the use of pesticides and insecticides, the use of pharmaceutical products (therapeutants), their availability for treatments and the setting the maximum residue levels.

Compliance issues in relation to a code of conduct or code of practice have been discussed above, but the question remains: what is sufficient to promote self-regulation, as well as optimum levels of responsibility and quality?

Finally, the current pressure induced by consumer concerns and the related potential shift in consumer demand (driven by environmental and social concerns over production methods) is, in itself, a significant trade-related incentive towards compliance with environmentally and socially sustainable practices.

Generally speaking, the legislation reviewed tends toward traditional enforcement efforts, i.e. command and control measures, including administrative sanctions (revocation or suspension of an authorization), as well as monetary penalties (fines).

Constraints, limitations and measures to overcome

Nearly all countries experience difficulties and overlaps with legislation of other sectors, including (but not limited to) land and water access, finance, environmental protection, quality control and grading standards, consumer protection, animal health protection, and import and export laws. Inter-sectoral cooperation and protocol development is a challenge in many countries.

Governments are still discovering the legal issues likely to arise, as well as the tangled web of institutions likely to be involved in governing aquaculture. Increasing publicity of environmental and social issues, together with disease outbreaks, has raised questions of sustainability of aquaculture practices and urged legislators to find ad hoc solutions.

Over the last 15 years, many countries, especially in the developing world, have witnessed the setting up of authorities

By overlooking this point, the legislator runs the risk of not passing a law, or passing a law that is completely unrealistic. Undoubtedly, the trend towards greater community involvement is a highly relevant issue as far as enforcement is concerned. Such involvement contributes to greater compliance with the law and induces outsider compliance. Transparency and accountability in aquaculture- related decision-making processes are key elements. Unjustifiably burdensome and/or lengthy approval processes responsible for the protection and management of the environment. This has often been accompanied by extensive promulgation of new laws and regulatory enactments relating to environmental conservation. Problems faced by legislators under these conditions may simply relate to the amount of information that is being generated, in addition to the challenge of familiarization with the various aquaculture practices that may be implicated. In nearly all instances, these new laws and regulations are being drafted, implemented and enforced by officers not familiar with aquaculture.

Have legislative measures really failed to keep pace with the rapid expansion of aquaculture? Have they contributed to the development of aquaculture or hindered economic and social development? Is self-regulation a solution? Against these questions, private and semi-private arrangements involving technical and scientific approaches appear to be, not just theoretically desirable, but essential, in that they often enhance effective enforcement.

Measures to overcome constraints and limitations relate not only to the substance of the written law itself, but also to the process of drafting the law. Law reforms are may serve as a magnet for rent seeking by public officials. Attention to the level of government involvement required for authorization is essential to avoid unnecessary hurdles and costs. Minor permissions granted solely by central or distant authorities can become an incentive to act illegally. Evaluating penalties and their effectiveness is not an easy task, however, too severe sanctions may induce prosecution officers, local courts etc. not to apply the fine at all. In addition, inflexible laws cannot adapt to rapid changes in penalties, e.g. in response to inflation or the severity of the infringement. Some countries provide for automatic indexation (to avoid lengthy legal amendments) or link the importance of the damage into the penalty. Last, but not least, enforcement requires appropriately trained, competent staff as well as a knowledgeable industry, community and public.

Potential future role and the contribution of law to the overall development of aquaculture?

It will take some time before a "State of Art" aquaculture law will be drafted.

For government bodies, the use of law to promote sustainable frequently over ambitious, with goals and objectives that cannot be met within the implementation capacity of the country. For instance, some laws may establish complicated and expensive procedures that require financial or human resources that are not available, or they may require sudden institutional changes with no allowance for a transitional period. Further, the drafting of laws requires a genuine involvement of all concerned (government and nongovernmental institutions, central and local institutions, communities and resource-dependant people, private-sector organizations).

aquaculture is not an easy task, however, law is only one of a number of mechanisms that may be used to secure this objective. Faced with an environmental challenge a multi-disciplinary and inter-disciplinary approach is required. Any belief that legal prohibition of an unacceptable behaviour will solve environmental concerns is erroneous. Recent years have also witnessed reforms to aquaculture institutions that increasingly recognize the multiple interests involved in or affected by aquaculture development and management. These reflect a growing appreciation of the environmental and social role played by aquaculture development at the national, regional and international levels.

Continued legislative attention will still be needed for issues related to resolving disputes:

- within user groups,
- between user groups and outsiders,
- between user groups and government, and
- to balance aquaculture needs with ecological and social requirements.

Finally, legislative reforms have obvious limits in any fight against lawlessness in the aquaculture sector. Societal problems, with deep-set and complex causes, go well beyond the capacity of any law - especially sector-specific legislation. In the light of these and other implementation difficulties, a more practical approach like best management practices and codes of conduct may be the ultimate solution.

Part II - establishing an institutional framework

Status: emerging trends

The overall effectiveness of a legal system for the management of aquaculture depends in large measure on effective government administration of the aquaculture sector. Today the dividing lines between public and private sectors Australian aquaculture developments in marine and coastal waters have frequently encountered difficulties gaining regulatory approvals, due primarily to community concern over potential environmental impacts. Further, in Australia, the government also has a policy of promoting industry self-regulation to increase the competitiveness of rural industries.

In attempting to identify the current trends in the institutional settings of different countries, it is important to bear in mind that, as stated in the State of the World Fisheries and Aquaculture (FAO/SOFIA-1998), not many countries have well-defined aquaculture policy. Debates still rage over form, functions and sizing of units of central and local governments, (e.g. New Zealand69, the Philippines, Sri Lanka and Vietnam). A recent study conducted in the Mediterranean Region in July 1999 demonstrated that, in the majority of countries, administration is centralized and aquaculture policies are developed by ministries such as the Ministry of Agriculture, the Ministry of Fisheries and the Ministry of Environment or a combination thereof. However, there are some countries where the responsibility for aquaculture is given to local governments (e.g.

are becoming blurred, with shared public and private interests. Responsibilities are also becoming diffused over various societal sectors and inter-relationships are changing. Reshuffling of government tasks and greater awareness of the need to cooperate with other sectors of society does not render traditional government obsolete; it merely recognizes the limitations of traditional public command and control mechanisms. Responses to societal problems require a broad set of instruments. At a workshop held in Canberra, Australia, in August 1999, key government, aquaculture industry and research representatives resolved to develop an Action Plan for Australian Aquaculture. It was agreed that the plan, called Aquaculture Beyond 2000, would involve input from government, industry, community and environmental groups, in order to overcome potential impediments to future aquaculture growth in Australia to reach a production target of AU$2.5 billion value by 2010.

It is not by coincidence that the need to involve community and environmental groups in the development of the Australian Action Plan is raised here.

municipalities) (New Zealand[70], the Philippines[71], Japan, China).

The most common problem concerning administration of aquaculture is administrative overlap and interference. This problem normally arises from unclear regulation of the sector and a confused administrative set-up. This problem is recognized in Africa (Africa Regional Aquaculture Review, 1999) and in Latin America (The Economic, Environmental and Social Impacts of Shrimp Farming in Latin America, Coastal Resources Centre, University of Rhode Island [1998). African aquaculture was assigned to a variety of institutional "homes", sometimes the Ministry of Agriculture, others with forestry or livestock agencies and even with the Ministry of Natural Resources and Tourism, as in the case of Tanzania. At one time, aquaculture in the Congo (Brazzaville) was simultaneously assigned to two different ministries. This was not limited to aquaculture, since agriculture research and extension services have also found themselves in different ministries, confounding efforts to coordinate the two activities. Another important problem identified in Africa is a general lack of stability of the institutional frameworks - relative stability exists only in Malawi and Madagascar. Likewise, in Latin American countries (e.g.

Belize, Honduras, Ecuador), overlapping jurisdictions, lack of trained staff, weak policy directions, centralized decision-making and minimal/absent consultation with stakeholders have led to a poor management of the aquaculture sector.

Efforts are duplicated and conflicts are frequent between government departments, as well as between different levels of government. However, while some countries are still adopting a piecemeal approach to address these problems (e.g. Ecuador), others have attempted to adopt a more comprehensive legal regime for aquaculture (e.g. Peru - Ley General de Pesca 1992 and Decrees 1 and 2 of 94, respectively implementing the Law and adopting the Testo Unico de Procedimentos Administrativos; Mexico - Reglamento de la Ley de Pesca, 2000; and Bolivia - Decreto Supremo Nº 22.581 Reglamento de pesca y acuicultura,1990). In the latter countries, institutional changes have been introduced in an attempt to streamline institutional responsibilities related

Finally, producer organizations can play important roles at both national and international levels. They provide a strong link between industry and government, especially through consultation processes[72]. Industry-funded organizations such as Seafood Services Australia provide support and assistance in promoting best practice in food safety, quality and disease management.

Constraints and opportunities

The issue consists, in a majority of cases, of how to reconcile the inherent unity of the natural resources upon which aquaculture depends and the manifold management functions relevant to them. Government bureaucracies tend to be patterned along:

to aquaculture. A striking feature behind this effort, however, is that many government departments share several responsibilities at the same time: they are regulators, industry promoters and industry operators. As a consequence, none of these roles may be completely fulfilled. In Nicaragua, for instance, the Ministry of Economy and Development (MEDE) establishes and implements the economic policy for aquaculture (Decreto No 19-93). A similar situation is found in Mexico. An important challenge in these countries would be to revise, analyse and "re-organize" the institutional framework in order to reach more efficiency, transparency and accountability.

In light of the complexity of issues related to the governance of the aquaculture sector, as seen above, mixes of government-driven approaches and voluntary arrangements have emerged. Likewise, the option of divesting the government of responsibility for operational aspects and maintenance of systems in favour of the aquaculturists is attracting much attention. A policy move in this direction raises a number of institutional (and legal) issues. Divestiture may entail transfer of physical assets (i.e. an area or infrastructure), or limit it, with the government retaining ownership of the assets, while their use (i.e.

- use-specific lines - i.e. separate administrations responsible for water supply, land allocation, seed supply, import/export etc.;
- functional lines - separate administrations for water resources allocation, pollution control, disease control etc.;
- types of water resources - freshwater, brackish water and sea water; or
- land resources - public lands, foreshore, lagoons, private land management etc.

There is a need to look at the areas requiring involvement of the government. At what level should a government be involved? In what subject matters should it be involved? When should it enter onto the scene? On the other hand, at what stage and on what subject(s) should aquaculturists or other stakeholders have a say and assume responsibility? Should they play an active role in the management of the resources, e.g. participating in the design of decision-making processes regarding other user's rights? Should they have the authority to determine how and where aquaculture occurs, and how the structure of the resources used may or may not be changed? Should they have the right to regulate access to, and operation and maintenance) is transferred to the users/aquaculturists. The sections above have shown that co-management agreements, user group leases, and decentralization of various aspects of aquaculture administration to local government bodies are becoming common in a number of countries.

mechanisms for transfer of relevant resources? What could be considered constructive and appropriate involvement of industry and/or other users? Or is self-regulation a solution?

Whether a regulatory approach is effective or not, producers remain responsible for the daily management of aquaculture operations and play a key and direct role in formulating and implementing the best available practices.

Part III - conclusions and recommendations

Aquaculturists and industry are critically interested in long-term resource conservation and will work towards this.
Aquaculture law has to be directed towards being ecologically sustainable and commercially sustainable, and to the public benefit. Foremost, it is important to set policy orientations. To this end, effective aquaculture legislation, or any reform of existing legislation,

Close scrutiny should be given to statutory responsibilities, conflicting functions, decision-making processes and conflict resolution processes.

An institutional framework for aquaculture should:

- Be geared towards the objectives of an aquaculture policy and legislation, in order to ensure their successful implementation;
- Clearly identify the responsibilities of the agency

should:

- recognize, define and assess the activity (the practice, the facility and the product) and the various actors/players involved;
- integrate environmental and social values into the planning and decision-making process for allocation of land, water and other natural resources for aquaculture purposes;
- recognize the legitimacy of regulatory instruments like codes of practice and codes of conduct that reinforce responsible aquaculture practices such as the FAO Code of Conduct for Responsible Fisheries;
- include effective monitoring, implementation and enforcement mechanisms, (economic, administrative and penal) to ensure compliance with the regulatory instruments, including codes of conduct and best management practices; and
- develop and regularly implement performance criteria and indicators that will assess whether the objectives of responsible aquaculture have been achieved by the government and by stakeholders.

Conducting reviews of institutional or agencies in relation to the development, operation and management of aquaculture. Where several agencies are involved, it should foster and promote the creation of appropriate networks to facilitate the implementation of responsible aqua-culture practices;

- In relation to the use of natural resources, open the process of aquaculture management to nongovernment interests, including the private sector, the community, traditional users and aquaculturists by, for example:
  - partnership/cooperation agreements: e.g. between other users and aquaculturists for a designated land/water area; between the other users, aquaculturists and the government;
  - delegation of powers.
- Foster a coordinated approach between government and nongovernment interests for efficient enforcement of all laws and regulations applicable to aquaculture;
- Create incentives (financial, educational and others) for responsible aquaculture, geared towards:
  - improving existing farming systems,
  - developing and

systems would apparently be opportune in many countries. These reviews should focus on the objectives and outcomes expected in relation to aquaculture development and management, as well as consider the most appropriate structure, systems, resources and linkages required to implement and deliver those expectations.

implementing best management practices,
- supporting implementation of effective environmental controls to maintain and improve requirements for aquaculture, and
- supporting maintenance and restoration of the environment.

- Regularly assess the efficiency of aquaculture management on the basis of criteria that reflect efficient resource use, economic viability and public benefit.

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[1] The views expressed in this manuscript are personal to the author and do not necessarily reflect the views of FAO.

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[3] The problems of studying the legal regime of aquaculture were brought out very strongly in the first attempt to look at the subject undertaken by the Development Law Service in 1989, which was entitled "A Preliminary Review of Selected Legislation Governing Aquaculture, which was written by A. Van Houtte, N. Bonucci and W. Edeson.

[4] AUSTRALIA (New South Wales): Fisheries Management (Aquaculture) Regulation 1995. Date of original text: 13 January 1995; CHILE: Decreto Nº

464 que establece procedimiento para la entrega de información de actividades pesqueras y acuicultura.: 31 July 1995; Decreto Nº 604 que modifica el Reglamento de Concesiones y Autorizaciones de Acuicultura. Date of text: 3 November 1994; Decreto Nº 499 que aprueba el Reglamento del Registro Nacional de Acuicultura. Date of text: 27 September 1994; Decreto Nº 290 que aprueba el Reglamento de concesiones y autorizaciones de acuicultura. Date of text: 28 May 1993; COSTA RICA: Reglamento para el otorgamiento de concesiones y licencias acuicolas. Date of text: 6 February 1996; ECUADOR: Decreto Nº 1.062 que establece el Reglamento para cría y cultivo de especies bioacuáticas. Date of text: 26 August 1985; EL SALVADOR: Decreto Nº 14 que aprueba el Reglamento para el establecimiento de salineras y explotaciones con fines de acuicultura marina en los bosques salados. Date of text: 1 April 1986; GUATEMALA: Acuerdo Nº 176-83 relativo a la acuicultura. Date of text: 29 March 1983; HONG KONG SAR: Marine Fish Culture Ordinance (Chapter 353). Date of text: 30/06/1997; Fish Culture Zone (Designation) Order (Chapter 353, section 5(a)). Date of original text: 4 March 1983; Marine Fish Culture Regulations. Date of text: 30/06/1997; IRAQ: Resolution No. 995 of 1985 relative to the establishment of pisciculture farms. Date of text: 24 August 1985; ITALY: Ministerial Decree adopting the third national plan for fisheries and aquaculture in marine and brackish waters. Date of text: 15 January 1991; Presidential Decree No. 555 regulating the implementation of EEC Directive 91/67/EEC establishing norms of sanitary police for aquaculture products, 1992. Date of original text: 30 December 1992; LUXEMBOURG: Règlement grand-ducal relatif aux conditions de police sanitaire régissant la mise sur le marché d'animaux d'aquaculture; NEW ZEALAND: Freshwater Fish Farming Regulations, 1983. Date of text: 19 December 1983; MYANMAR: Aquaculture Legislation by the State Law and Order Restoration Council 1989 (No. 24/89). Date of text: 7 September 1989; NORWAY: Decree relative to desinfection of water flowing into and water flowing out from aquaculture-related operations (No. 192 of 1997). Date of text: 20 February 1997; Decree relative to desinfection and cleaning aquaculture facilities (No. 194 of 1997). Date of text: 20 February 1997; Decree relative to the approval of methods and equipment for the treatment of dead fish, fish waste, discharge of wastewater from aquaculture installations which may carry the risk of infection. Date of original text: 17 April 1992.; Act No. 68 relating to the Breeding of Fish, Shellfish etc. Date of text: 14 June 1985; PERU: Resolución Nº 449-94-PE que dicta normas para la inversión en actividades acuícolas. Date of text: 24 November 1994; Resolución Nº 232-94-PE que aprueba los lineamientos para la elaboración

de los estudios de impacto ambiental para la acuicultura. Date of text: 15 June 1994. PORTUGAL: Order No. 113/96 amending Order No. 522/95 of 31 May (approving the Regulation on sanitary control for the placing into the market of fish and aquaculture products). Date of text: 12 April 1996; Order No. 578/94 establishing temporary assistance regime to the development of aquaculture sector. Date of text: 12 July 1994; SRI LANKA: Aquaculture Management Regulations of 1996. Date of text: 31 October 1996; SYRIA: Order No. 12/T on the Licencing of Fish Farms. Date of text: 3 January 1991; TUNISIA: Décret nº 95-1537 portant création d'une unité de gestion par objectifs du système d'information pour la promotion de l'aquaculture en Méditerranée et fixant son organisation et les modalités de son fonctionnement. Date of text: 4 August 1997; UNITED STATES OF AMERICA: National Aquaculture Act of 1980 (16 USC 2801).

[5] ALBANIA: Law on Fishery and Aquaculture 1995 (No. 7908 of 1995). Date of text: 5 April 1995; BELGIUM (Flandres): Arrêté du Gouvernement flamand portant l'aide à la pêche maritime et à l'aquiculture. Date of original text: 24 November 1993; BOLIVIA: Decreto Supremo Nº 22.581 Reglamento de pesca y acuicultura. Date of text: 14 August 1990; BULGARIA: Fish Husbandry Act 1982. Date of text: 1982; CAMBODIA: Proclamation No. 0002.PROR.KOR.KOR.SOR.KOR. on competent authorities in issuing permission to do fishery in open water, aquaculture, fish processing and special permissions. Date of text: 10 January 1989,; the Fisheries Management and Administration, Fiat-Law No. 33 KRO. CHOR. Date of text: 9 March 1987; CAMEROON: Décret nº 95/413/PM fixant certaines modalités d'application du régime de la pêche. Date of text: 20 June 1995; Loi nº 81-13 portant régime des forêts, de la faune et de la pêche. Date of text: 27 November 1981; CHINA-PEOPLE'S REPUBLIC: Fisheries Law of the People's Republic of China, 1986. Date of text: 20 January 1986; COLOMBIA: Ley Nº 13 por la cual se dicta el Estatuto General de Pesca. Date of text: 15 January 1990; EGYPT: Act No. 124 promulgating the Act on Fishing, Aquatic Life and the Regulation on Fish Farms, 1983. Date of text: 1983; GAMBIA: Fisheries Regulations, 1995 (L. N. No. 18 of 1995). Date of text: 1995; GUINEA: Décret nº 198/PRG/SGG/90 portant statuts de l'Office de promotion de la pêche artisanale et de l'aquaculture (O.P.P.A.). Date of text: 5 October 1990; HONDURAS: Decreto Nº 74-91 que crea la Dirección General de Pesca y Acuicultura. Date of text: 10 June 1991; HUNGARY: Law No. XLI of 1997 on fishing. Date of original text: 13 May 1997; MADAGASCAR: Ordonnance nº 93-022 portant réglementation de la pêche et de l'aquaculture. Date of text:

4 May 1993; MALAYSIA: Fisheries Act 1985 (No. 317 of 1985.; UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND: Fisheries and Aquaculture Structures (Grants) Regulations 1995 (S.I. No. 1576 of 1995). Date of text: 20 June 1995; MEXICO: Reglamento de la Ley de Pesca. Date of text: 17 July 1992, Reglamento de la Ley Federal de Pesca. Date of text: 29 December 1987; PARAGUAY: Ley Nº 799 de Pesca. Date of text: 17 January 1996; PERU: Decreto Supremo Nº 009-94-PE que modifica el Reglamento de la Ley General de Pesca. Date of text: 29 December 1994; SYRIA: Resolution No. 1983 on Freshwater Fisheries. Date of text: 8 November 1965.

[6] GABON: Loi nº 1-82 d'orientation en matière des eaux et des forêts. Date of text: 22 July 1982;
REPUBLIC OF MOLDOVA: Water Code. Date of text: 22 June 1993; PORTUGAL: Decree-Law No. 74/90 regulating water quality standards. Date of text: 7 March 1990; REPUBLIC OF MOLDOVA: Water Code. Date of text: 22 June 1993; ROMANIA: Water Law (No. 107 of 1996). Date of text: 25 September 1996; TAJIKISTAN: Water Code of the Republic Tajikistan. Date of text: 27 December 1993; UZBEKISTAN: Law of the Republic of Uzbekistan on Water and Water Use of 6 March 1993. Date of text: 6 March 1993.

[7] BULGARIA: Concessions Act. Date of original text: 5 October 1995; BURKINA FASO: Loi nº 006/97/ADP portant Code forestier au Burkina Faso. Date of text: 31 January 1997; BELGIUM (Flandres): Arrêté du Gouvernement flamand désignant les eaux de surface destinées à la production d'eau alimentaire, catégories A1, A2 et A3, aux eaux de baignade, aux eaux piscicoles et aux eaux conchylicoles. Date of text: 8 December 1998; BRAZIL: Act No.8.171 on Agricultural Policy. Date of text: 17 January 1991, Order No. N-1 making provisions on the construction of dams and dykes diverting the water course. Date of text: 4 January 1977; BURKINA FASO: Kiti nº AN VIII-0328 TER/FP/PLAN-COOP portant application de la réorganisation agraire et foncière au Burkina Faso. Date of text: 4 June 1991; EUROPEAN UNION: Council Directive 78/659/EEC of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life. Date of text: 14 August 1978; ECUADOR: Ley Forestal y de Conservación de Areas Naturales y Vida Silvestre.

[8] AUSTRALIA (New South Wales): Fisheries Management (Aquaculture) Regulation 1995. Date of original text: 13 January 1995; BRAZIL: Decree No. 1.694 creating the National System for Fishing and Aquaculture Information - Sinpesc. Date of text: 13 November 1995, Decree No. 1.695 regulating aquaculture activity in public waters. Date of text: 13 November 1995, Order No. 95-N regulating the registration for aquaculture activity. Date of text: 30 August 1993; CHILE: Decreto Nº 464 que establece procedimiento para la entrega de información de actividades pesqueras y acuicultura. Date of text: 31 July 1995, Decreto Nº 604 que modifica el Reglamento de Concesiones y Autorizaciones de Acuicultura. Date of text: 3 November 1994, Decreto Nº 499 que aprueba el Reglamento del Registro Nacional de Acuicultura. Date of text: 27 September 1994, Decreto Nº 290 que aprueba el Reglamento de concesiones y autorizaciones de acuicultura. Date of text: 28 May 1993; COSTA RICA: Reglamento para el otorgamiento de concesiones y licencias acuicolas. Date of text: 6 February 1996.
EUROPEAN UNION: Council Directive 98/45/EC of 24 June 1998 amending Directive 91/67/EEC concerning the animal health conditions governing the placing on the market of aquaculture animals and products. Date of text: 24 June 1998. FINLAND: Decree of the Ministry of Agriculture and Forestry relative to the Register for Aquaculture (No. 212 of 1996). Date of text: 25 February 1996.
FRANCE: Décret nº 95-100 relatif aux conditions de police sanitaire de l'aquaculture des mollusques et des crustacés marins vivants. Date of text: 26 January 1995.
ITALY: Ministerial Decree authorizing fishing in aquaculture plants. Date of text: 29 September 1995.
HUNGARY: Decree No. 41 of 1994 of the Ministry of Agriculture regarding the authorisation and regulation of fish hatchery plants. Date of text: 28 June 1994.
MEXICO: NOM-010-PESC-1993 que establece los requisitos sanitarios para la importacion de organismos acuáticos vivos en cualesquiera de sus fases de desarrollo, destinados a la acuacultura u ornato, en el territorio nacional. Date of text: 20 July 1994, NOM-011-PESC-1993 para regular la aplicación de cuarentenas, a efecto de prevenir la introducción y dispersión de

enfermedades certificables y notificables, en la importación de organismos acuáticos vivos en cualesquiera de sus fases de desarrollo, destinados a la acuacultura y ornato en los Estados Unidos Mexicanos. Date of text: 20 July 1994.
NORWAY: Decree relative to desinfection of water flowing into and water flowing out from aquaculture-related operations (No. 192 of 1997). Date of text: 20 February 1997, Decree relative to desinfection and cleaning aquaculture facilities (No. 194 of 1997). Date of text: 20 February 1997.
PERU: Resolución Nº 449-94-PE que dicta normas para la inversión en actividades acuícolas. Date of text: 24 November 1994, Resolución Nº 232-94-PE que aprueba los lineamientos para la elaboración de los estudios de impacto ambiental para la acuicultura. Date of text: 15 June 1994.
SRI LANKA: Aquaculture Management Regulations of 1996. Date of text: 31 October 1996.
TUNISIA: Décret nº 95-1537 portant création d'une unité de gestion par objectifs du système d'information pour la promotion de l'aquaculture en Méditerranée et fixant son organisation et les modalités de son fonctionnement. Date of text: 4 August 1997.

[9] E.g. Kenya, Malawi, Zambia.

[10] E.g. France, Mexico, Philippines.

[11] E.g. France, Mexico, Philippines.

[12] E.g. Bolivia, France, India, Madagascar, Mexico, Mozambique, Peru, Sri Lanka, United Kingdom.

[13] E.g. Ecuador, France, Hong Kong SAR, Malaysia, Peru, Singapore.

[14] E.g. Japan, the Law to ensure sustainable fish management, entered into force on November 19, 1990.

[15] See for instance, the Fisheries Legislation of Bolivia, Cuba and Mexico.

[16] Albania, Law on Fishery and Aquaculture 1995 (No. 7908 of 1995), article 3.

[17] Algeria, Décret législatif nº 94-13 fixant les règles générales relatives à la

pêche., articles 3, 17 and 18.

[18] Bolivia, Decreto Supremo Nº 22.581 of 1990 Reglamento de pesca y acuicultura.

[19] China, Hong Kong SAR, Marine Fish Culture Ordinance (Chapter 353).

[20] New Zealand, Fisheries Act 1996, section 2.

[21] Malaysia, Fisheries Act 1985 (No. 317 of 1985).

[22] United States (State of Pennsylvania), Act 1998-94, the Aquaculture Development Act, 4203.

[23] EU. December 1999 Regulation on Structural Funds.

[24] E.g. Australia, Tasmania, The Marine Farming Planning Act, 1995, states in Section 4:
(1) The purpose of this Act is to achieve well-planned sustainable development of marine farming activities having regard to the need to -(a) integrate marine farming activities with other marine uses; and (b) minimise any adverse impact of marine farming activities; and (c) set aside areas for activities other than for marine farming activities; and (d) take account of land uses; and (e) take account of the community's right to have an interest in those activities.
(2) A person must perform any function or exercise any power under this Act in a manner which furthers the objectives of resource management.

[25] E.g. Australia, Tasmania, The Marine Farming Planning Act, 1995, states in Schedule 1 of the Act the overall objectives of the resource management planning system in Tasmania.

[26] E.g. Australia (Tasmania), France, New Zealand, Philippines, Spain, Sri Lanka, the United States.

[27] E.g. Nicaragua, Decreto 9/1996; Peru, Resolución Ministerial No 096-91-PE, of 11 March 1991.

[28] E.g. Nicaragua, Decreto No 19-93; Peru, Decreto Ley No 25.977/1992.

[29] E.g. Albania, Australia, Bolivia, Bulgaria, the United States.

[30] E.g. Australia, the EU, the United States.

[31] "A Preliminary Review of Selected Legislation Governing Aquaculture, which was written by A Van Houtte, N Bonucci and W Edeson.

[32] E.g. Denmark.

[33] E.g. Albania, Bangladesh; Ecuador, Indonesia, Thailand.

[34] Consultation on the Application of Article 9 of the FAO Code of Conduct for Responsible Fisheries in the Mediterranean Region; Rome, 19-23 July 1999.

[35] E.g. Albania, Australia (Tasmania), Bolivia.

[36] A list of countries reviewed is in endnote sopra.

[37] E.g. Albania, Bolivia, Cyprus, Israel, Madagascar, Malaysia, Mexico, Norway, Peru, Sweden, Switzerland, Syria, United Kingdom.

[38] E.g. Ecuador, Hong Kong SAR, Ireland, Malaysia, New Zealand, Singapore.

[39] E.g. Costa Rica and Hong Kong SAR.

[40] E.g. Denmark, Hong Kong SAR, Scotland.

[41] E.g. Australia, Sri Lanka.

[42] Issued pursuant to Section 246 of the Fish Resources Management Act 1994 and Section 24 of the Pearling Act 1990.

[43] Currently, the term "affected persons" means those who hold an aquaculture licence and are likely to be significantly affected by the proposal.

[44] E.g. Australia, Cyprus, EU Member States, New Zealand, the United States.

[45] E.g. Albania, Australia, Bulgaria, the EU, Hong Kong SAR, Peru, Vietnam.

[46] The Marine Culture Ordinance, Chap.353, as amended in 1997 and the Fish Culture Zone (Designation) Order, Chap.353, B.

[47] Bodero A.Q. and D. Robadue, Jr. 1995. Strategies for managing mangrove ecosystems. In Eight Years in Ecuador: the road to integrated coastal zone management (Ed. Robadue), p.43-69.

[48] The 1972 Coastal Zone Management Act.

[49] Law of 2 March 1977.

[50] Loi No 86-2 du 3 janvier 1986 relative à l'aménagement, la protection et la mise en valeur du littoral.

[51] The Indian Coastal Regulation Zone Notification of 1991, Gazette Notification S.O. No 114 (E) of 20 February 1991.

[52] The Resource Management Act of 1991.

[53] The Shores Act, 1988 and Royal Decree 1471/1989.

[54] The Coast Conservation Act, 1981.

[55] E.g. Albania, Madagascar, Vietnam.

[56] The United States (State of Washington), Indonesia, Solomon Islands. It should be noted that these elements have also been introduced for the purposes of enhancing environmental conservation, and in particular, marine conservation.

[57] Land Law, 1996.

[58] Albania, Australia (Tasmania), Bulgaria, Indonesia, Solomon Islands, Thailand.

[59] see above section on the concept of sustainable development.

[60] In the latter countries being currently drafted.

[61] The FAO Code of Conduct for Responsible Fisheries and the FAO Technical Guidelines for Responsible Fisheries, No 5 concerning Aquaculture Development; Principles of the Hazard Analysis Critical Control Point ("HACCP") System and Guidelines for their Application currently being developed under the auspices of the World Health Organization; the draft Code of Conduct for Responsible Shrimp Culture promoted by the Global Aquaculture Alliance.

[62] For further information, see Phillips M. and Barg U., Experiences and opportunities in shrimp farming in Sustainable Aquaculture, food for the Future, Balkema Publishers, 1999.

[63] In force as of 19 November 1999.

[64] They have been developed on August, 30 1999.

[65] Uoya,T., Fishery Agency of Japan, Establishment of the Law to ensure Sustainable Aquaculture Production.

[66] This document is based on the Code of Conduct for Responsible Fisheries (CCRF), adopted at the FAO 32nd Conference in 1995, which includes one thematic article on "Aquaculture development". The Code and Guidelines have been formulated so as to be interpreted and applied in conformity with relevant rules of international law.

[67] FEAP is an international organization that is composed of the National Aquaculture Associations of European countries. Membership of the Federation is restricted to National Aquaculture Associations. In certain cases, countries have National Associations for defined species (e.g. the United Kingdom has National Associations for Trout, Salmon) while others have National Associations for all species (e.g. Italy and France have National Aquaculture Associations that incorporate all species). At present, the FEAP is composed primarily of associations concerned with finfish production. The basic aims of the federation are to develop and establish a common policy on questions relating to the production and the commercialization of aquaculture species reared professionally; and to make known to the appropriate authorities the common policies envisaged above. For the purposes of consultation, FEAP maintains a policy of constructive dialogue and transparency. In order that this policy is respected, it has established formal links to the following institutions and organizations: the Commission of the EU (DG XIV - Fisheries); FAO (European Inland Fisheries Advisory Commission (EIFAC) - Observer, General Fisheries Council for the Mediterranean (GFCM) - Observer); Confederation of European Agriculture (CEA) - Member; Working Group for Aquaculture of the COPA/COGECA - Observer; Maritime Industries Forum - Member of Panel 2 - Marine Resources; European Aquaculture Interface (ad-hoc Group), with European Aquaculture Society, AquaTT, and CIHEAM (for further information: http://www.feap.org/General_Information).

[68] E.g. Bolivia, Ecuador.

[69] A key component of 1989 local government reforms and Resource Management Act 1991 was for regional councils to have a dominant role in environmental management (including fisheries and aquaculture), through their regional policy statements.

[71] The Local Government Act, 1992.

[72] The National Aquaculture Council (NAC) is the peak industry association for aquaculture in Australia. This is a relatively new organization, and to date has not established a firm role for itself. However, Queensland, Southern Australia, Tasmania, Victoria and Western Australia have state aquaculture councils which provide the link between industry and government. In addition, most industry groups have sectoral-based associations, such as the Australian Prawn Farmers Association, the NSW Oyster Growers Association, the Tasmanian Salmon Growers Association, the WA Marron Growers Association, the Tuna Boat Owners Association and so on. There are close linkages between policy-makers and regulators and the various peak industry associations at the state and national level, and consultations on key issues occur through these groups. Industry-funded organizations such as Seafood Services Australia provide support and assistance in promoting best practice in food safety, quality and disease management. (Extract from Agriculture, Fisheries and Forestry - Australia (AFFA).

Building the Information-base[1] for Aquaculture Policy-making, Planning and Management

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Cho, Yong-Ja. 2001. Building the information-base for aquaculture policy-making, planning and management. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp.121-128. NACA, Bangkok and FAO, Rome.

ABSTRACT: The thematic session agreed on two general purposes for building the information bases necessary to support and manage sustainable development of the aquaculture sector. (The participants also noted that the other sessions were describing specific information issues that relate to their respective topics). It was emphasized that the role of information gathering and the task of building the capacity of countries for information management assume a greater urgency by the fact that policy-makers, planners and managers usually: i) have little time to assimilate bulky data and information, ii) make decisions with or without information and iii) fall under political pressure to make rapid decisions. Having established the above boundaries for discussion, the session tackled the linked issues of how to facilitate policy-making, planning and management and how to define the information required and the channels through which it can best be disseminated.

The discussions highlighted the concerns that: i) the high-level political will that is essential to implement actions for improving access to and use of information is often lacking; ii) many recommendations from previous meetings have not been implemented, and the reasons for this situation need to be examined; iii) costs of information collection and analysis often do not, or are not seen to match the benefits from informed decisions and subsequent good policy and management action; and iv) efforts should be increased to improve the use of data and information. The discussions led to the synthesis of six issues and the formulation of recommendations to resolve these issues.

KEY WORDS: Aquaculture, Information, Policy-making, Planning, Capacity-building

Introduction

Aquaculture has been practised since the beginning of civilisation. However, the concept of aquaculture management is relatively new. The challenge for aquaculture policy-makers, planners and managers is to fully realize the potential contribution of aquaculture in satisfying current and future human needs, while conserving and protecting natural

The complexity of the interactions of aquaculture with other sectors further complicates this formidable task at all levels of decision-making.

Information and aquaculture policy-making, planning and management

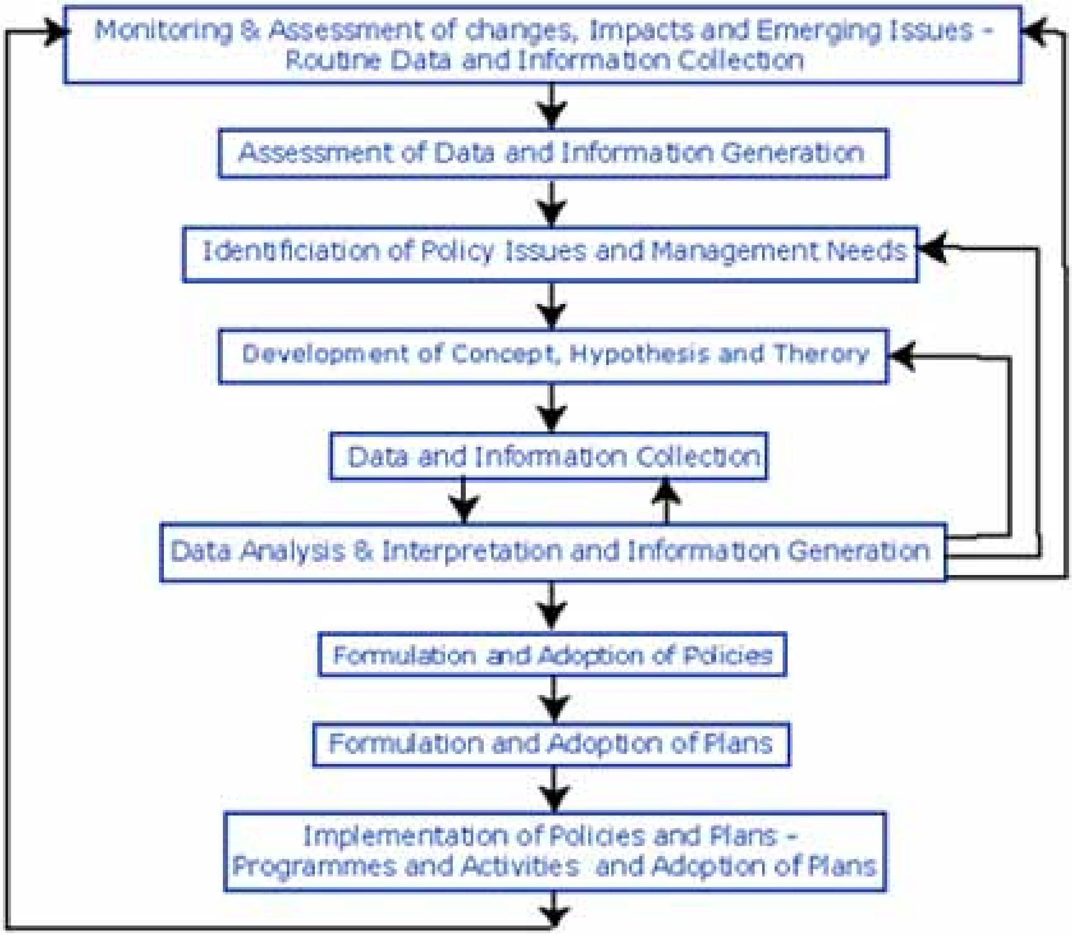
The processes of aquaculture policy-making, planning and management are dynamic and involve a continuous flow of information vertically (national economic to sectoral levels, national to regional levels and regional to local decision-making levels) and horizontally (between farms, associations or unions, and between government departments) to ensure that the policies and plans developed at each level of the planning hierarchy harmonize with each other (see Fig. 1). To formulate effective policies and mitigate potential adverse effects, it is necessary to:

- assess and quantify impacts and implications of aquaculture policy changes and management interventions on production, supply, demands, revenues, expenditures and related resources;
- monitor and understand the response mechanisms of farmers and markets to changing socio-economic conditions; and

resources.

The successful application of aquaculture technologies has been constrained by a lack of optimal political and economic conditions under which environmentally sound and socially equitable aquaculture can develop. Enabling mechanisms, particularly appropriate policies and institutional arrangements, have been lacking or weak. These difficulties stem from different interest spheres and complex interrelationships between aquaculturalists, environmentalists and socio-economists. Decision-makers at various levels of government, aquaculture operations and

Figure 1. Role of information in policy-making, planning and management



supporting communities (research and industry), as well as international and donor organizations, are key contributors to the policy and technology elements required to produce effective policies and strategies. All of these require open communication and support for collection and utilization of all pertinent information.

There is broad consensus throughout the aquaculture sector that informed policy and management decision-making call for improved data and information. This includes information from the aquafarm gates to the office of the minister responsible for planning and management of the sector (FAO/NACA, 1998). Current decision-making on the role of aquaculture in sustainable fisheries is hampered by a lack of information and awareness of the nature and extent of the impacts of aquaculture on the economy, environment, food security, nutrition and rural development. Another significant knowledge gap is clear documentation of the effects of any changes in aquaculture policies or management actions.

- determine the most appropriate and realistic objectives for each sector, and establish the optimum framework required to achieve planning or policy objectives (priorities and nature of interventions).

All these activities require substantial amounts of physical, natural, biological and socio-economic data from a wide range of sources, e.g. population demographics; physical geography and hydrology; national and regional development programmes; land and water-use policies; environmental and fishery legislation; national food policy and nutrition requirements; status and trends of aquaculture and fisheries sectors; impacts of aquaculture on national, regional and local economies; national infrastructure and manpower; global, national, regional and local economic influences etc.

Various agencies, including government and non governmental organizations (NGOs), are involved in the compilation, analysis and dissemination of these data. For instance, national statistical offices/departments collect a variety

Information issues

A variety of aquaculture data and information bases are available, although their relevance and usefulness for policy-making, planning and management differ. Rapidly advancing information and communication technologies provide powerful tools for aquaculture data and information management. High-speed and high-capacity processing and analytical systems can now process massive volumes of data, which would have been inconceivable 10 years ago. The same systems have ever strengthening transmission networks that enhance data exchange and dissemination wherever required. Remote sensing technology can be employed to gather data on resources that were previously difficult to access or monitor, and geographic information systems (GIS) are now routinely used to process spatial data and information. Various Internet-based systems are being developed to further enhance accessibility, availability and dissemination of fishery and aquaculture data and information, e.g. the FGIS (Fisheries Global Information System) of FAO, which of data that are required to formulate national development policies and plans. State/provincial and local administrations, farmer's cooperatives and professional organizations also collect and process data, but often at a regional level, for the purpose of local administration or to promote the welfare of their members. Thus the data often provided to central government agencies is an aggregate from different sources.

At the same time, specific data and information are compiled and managed by the aquaculture sector, often in collaboration with the related agencies, such as national statistics departments and/or agricultural and fisheries statistics offices. Aquaculture productivity monitoring and assessment involves routine collection and analysis of basic data through established mechanisms. Depending on policy and management purposes, supplementary data may also be compiled and analysed, e.g. for sector or sub sector reviews.

Data and information compiled at the national level are then shared regionally and globally, through various collaborative agencies such as the fishery and aquaculture statistical programmes of FAO, regional fishery bodies, GLOBEFISH, INFOFISH, ASFA (Aquatic Sciences and Fisheries Abstracts) and AAPQIS (Aquatic Animal Pathogen will incorporate SIPAL (Système Informatique du Promotion de l'Aquaculture de l'Amerique-Latin - Information System for the Promotion of Aquaculture in Latin America) and SIPAM (Système Informatique du Promotion de l'Aquaculture dans la Mediterranée - Information System for the Promotion of Aquaculture in the Mediterranean). These approaches have brought about tremendous advances in sharing of ideas and information over the Internet.

On the other hand, the higher volume and speed of data processing and exchange, easier monitoring and access to information have made data quality control a critical issue. Greater attention to the vast number of data quality control points is needed now, compared with information processing and transmission using traditional media. It also suggests a greater importance and increasing role of institutions that can serve as "honest" information brokers and certifiers - a paradox in this information age, where new information and communication technology enables greater and faster information exchange between or among individuals, thus tending to bypass bureaucracy and institutions. Theoretical approaches, analytical methods and software applications, including decision support systems, are now becoming more and more available to a wider and Quarantine Information System).

audience, although at a slower pace in the "less-connected" regions of the world.

Despite this growth in aquaculture data collection and transmission capacity, there is a clear indication that this does not adequately meet the needs of policy-making, planning and management sectors in many countries. The fundamental problems relate to:

- the purposes for data collection;
- what data and information need to be compiled;
- how to undertake the compilation and analysis of the data and information in an accurate, reliable and timely manner; and
- how to ensure effective dissemination and utilization of the results from this data and information analyses.

As an example, the government planners and decision-makers participating in the International Workshop on Integrated Coastal Management in Tropical Developing

- the purpose of data collection and the analysis expected be clearly defined and identified;
- norms, standards, definitions, classifications and harmonized methodology for data collection be developed;
- countries should be assisted in evaluating the monitoring of aquaculture activities;
- well-presented statistical and non statistical information with analytical explanations should be considered in order to provide relevant time-series and reliable information for efficient aquaculture management and planning; and
- the scope of the data collected should be considered in view of the changing data needs for outputs, as well as planning processes.

In addition, many information systems were found to have been developed on the basis of the capacity of the software, rather

Countries, held in Xiamen, China, 24-28 May 1996, pointed out that scientific input is often undermined by the way the information is presented, i.e. it is not in a form readily usable and/or understandable by policy-planners or managers (Chua, 1996). They noted that:

- there are times when policy-makers cannot afford to consider long-term environmental management issues.
- management has to be a combined with indigenous knowledge, i.e. scientific data and non scientific information are required for management issues.Neither should be used in isolation.
- there is a need (for scientists) to present information in a format that can be readily used by planners and decision-makers;and
- planners and managers need to have clear and measurable indicators of success or failure, and understand how the field data is analysed to obtain information for decision-making.

Furthermore, the Southeast Asian Fisheries Development Center (SEAFDEC)-FAO Ad Hoc Expert Consultation on Variables and Terminology for Aquaculture than on what the users needed, and the primary focus was to record data rather than analyse, disseminate or use the data and information compiled (IOA, 1996).

What emerges from the above, as well as from other recent regional and international meetings (EAC/EC/FAO, 1994; FAO/NACA,1998)is that there are some fundamental deficiencies in existing aquaculture data and information, particularly those required to support policy-making, planning and management. These deficiencies include:

- Poor understanding of the purpose. Data collection efforts concentrate mainly on data collection, rather than its analysis or use. The purpose of the data being collected and linkage to decision-making processes are often neglected. Too little attention is often given to whether or not the data collected are those required to answer the policy and management questions.
- There is a lack of common definitions, classification and “normal” reference levels that are agreed upon and adopted by all parties involved in the data collection and compilation.
  Data and information collection systems can be of poor or inconsistent quality (e.g. lack

Monitoring in Asia, held in Bangkok, Thailand, 13-16 September 1999, recommended, among other points, that:

- aquaculture statistical work should not be isolated, but rather, coordinated and integrated with aquaculture management and planning at both central and field levels;
- aquaculture data collection capacity of countries be evaluated;
- a closer collaboration between aquaculture development and monitoring be promoted;

of relevance, reliability and timeliness) due to weakly designed collection strategies at local/field levels, particularly in the developing parts of the world.

- Under-utilization of data and information compiled due to (a) insufficient and inadequate analysis and (b) ineffective communication and presentation.
- Limited capacities (generation and storage) of national aquaculture data and information programmes, particularly in the developing regions of the world.

Opportunities for regional action

Aquaculture policy-making, planning and management, as well as collection and analysis of data and information at national, state/provincial and local levels, are primarily national responsibilities. Although their capabilities vary, most countries have their own data and statistical systems for the purpose of aquaculture policy-management decisions. Significant amounts of data and information are being collected, but are not effectively utilized due to:

- insufficient analysis;
- ineffective packaging and communication; and
- poor reliability/quality, relevance and timeliness.

Most importantly, existing data and information systems tend to focus making, planning and management.

Nevertheless, the above noted issues render several opportunities for regional cooperation (see Table 1). Such cooperative actions enhance efficiency of the national aquaculture data and information gathering programmes and promote regional collaboration in management and utilization of aquatic resources. Therefore, regional cooperation should be guided by the following principles:

- Regional cooperation must take into account national needs and interests.
- Existing systems and programmes should be used wherever possible and appropriate.
- Activities should build on existing systems and programmes.

Establishment of data and information programmes for aquaculture policy-planning and management is a long-term commitment. Therefore, formulation of regional cooperative actions on information, particularly establishment of regional aquaculture information networks, must carefully consider the sustainability of such cooperative actions. Information activities must be built into the regular programmes of the appropriately mandated agencies/institutions, both within on the processes of data collection, rather than the overall purpose and goals of the exercise, i.e. service and utilization. Collection of data and information is an undertaking that requires tremendous resources from the agencies involved. Therefore, questions must be asked of the significance of data and information compiled to ensure that they provide "meaning" and serve the intended purpose(s).

Information needs for policy-making, planning and management are expanding as concerns over sustainable aquaculture, support of disadvantaged rural communities in a market-oriented economies and protection of natural resources grow. No single recommendation or action can respond to all these concerns, or the needs of the sector. To overcome the existing deficiencies, a concerted and persistent effort to collect useful information and data is necessary.

The primary role of international and regional organizations/institutions is to support and facilitate national efforts. Thus, formulation of regional actions should be based on national commitment and interests. While collection and analysis of aquaculture data and information for national policies and management are primarily national responsibilities, countries will derive substantial benefits from regional central government agencies and local administrations, so that the activities become part of their core programmes. Similarly, regional aquaculture information programmes and systems should be built into the core programmes of the appropriate regional or international bodies.

Conclusions

Aquaculture data and information collection, along with their compilation, is not an end in itself. Information should be used to support and/or influence aquaculture policy and cooperative efforts. Additionally, regional collaboration helps muster political will, and this will reinforce the synergy required for national actions.

Recommendations

To address poor understanding of the purpose of data and information collection in some sectors:

- Improve awareness of non-research target users - aquaculture policy-makers, planners and managers.
- Improve dialogue with users, definition of precise needs, perceived knowledge gaps and impediments to improved aquaculture policy, planning and management.

To address under-utilization of data and information collected:

- Improve accessibility of required data and information, while taking into account individual farmer confidentiality (possibly via codes or cooperative-based data storage), if applicable.
- Improve awareness of benefits (including cost-benefits) derived from access to, and use of, accurate and reliable data - especially for aquaculture planning and management.
- Promote and coordinate programmes at national and regional levels as an integral part of sector aquaculture management and planning. Where the scale of aquaculture warrants, this may include computer-based communication and data networking.
- Initiate compilation and exchange of aquaculture policy reviews and proposals, including lessons learned and successful policy and management interventions, based on data and information availability/unavailability.
- Produce national and/or regional directories of existing data and information resources.

To address ineffective

- Improve access to standardized compilation methods, such as:
  - record-keeping formats and
  - access to safe data storage and/or computerized networks, where possible.
- Training for data and information collectors and compilers, to ensure that data/information is treated in a consistent manner, including regular verification processes.

To address a lack of internationally comparable methodologies for aquaculture data and information handling:

- Give national and regional priority to establishing internationally agreed-upon standards, definitions and classifications for aquaculture data and information collections, data analyses, interpretations and applications.
- Encourage national efforts to harmonize methodologies used for aquaculture data and information processing. These may need to be developed separately for different aquaculture sectors (e.g. marine, estuarine, inland, shellfish, finfish).
- Establish regular cross-checking of international standards against regional needs/capacity, to ensure

communication and presentation:

- Define the communication mechanisms required to disseminate results to all users (annual reports, statistical summaries/reports, workshops, management meetings, stakeholder meetings etc.) through hard-copy or electronic media.
- Define the data/information needs of the policy-makers, planners and managers to ensure the information gathered is readily understandable - raw data or analytical jargon can be "inaccessible" to non statisticians, economists etc.
- Provide training in effective communication of data and information analyses to promote understanding of their applications for aquaculture, policy-making, planning and management.

To address poor relevance, reliability, and consistency of data and information:

- Improve stable support (manpower, materials and data storage mechanisms) for required data and information collection, to ensure conscientious dedicated expertise is maintained and consistent within long-term data/information collection continued compatibility with aquaculture policy, planning and management goals.

To address limited capacity of national programmes:

- Promote awareness and examples of effective and efficient use of data/information for enhanced development and management of sustainable aquaculture.
- Use such examples to reinforce political will and commitment to promote strong and consistent national data and information collection, as well as analyses.
- Strengthen links between human resources dedicated to aquaculture policy-making, planning and management and those dedicated to data and information collection.

programmes.

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Table 1. Opportunities for regional cooperative actions

Issues	Requirements	Opportunities for Regional Cooperation
Poor understanding of the purpose	Better understanding of information requirements. Better awareness of the intended use(s) of the data being compiled.	Capacity and awareness building in determination of data needs. Cooperative organization of intended uses, to fit knowledge gaps that can improve aquaculture development on a regional scale, e.g. knowledge of regional seed-sources and production levels could promote monitoring and, in turn, promote a wider marketability.
Poor quality of data and information (e.g. lack of relevance, reliability and timeliness).	Better knowledge of type, nature and scope of data and information being compiled . Improved support for required data collection and compilation methods (standardized record-keeping formats, access to safe data storage and/or computerized networks, where possible). Training for data collectors and compilers to ensure that data are treated in a consistent and conscientious manner, including regular verification processes, further ensuring its reliability.	Development of region-wide guidelines and methodologies for collection and review of aquaculture data and information systems - particularly their adequacy for support of sector policy-makers, planners and management. Regional training opportunities to improve consistency/comparability of data collection methodologies – including record keeping, data analyses and applications of results. Provision of assistance to participating countries to strengthen aquaculture data and statistics systems, including linkages with relevant agencies/institutions and training for data collectors and compilers, particularly at local and field levels.
Lack of internationally comparable methodologies.	Internationally agreed upon standards, definitions and classifications for aquaculture data and statistics. These could be established via workshops aimed at filling data gaps. Common and compatible methodologies for data and information handling. These may need to be developed separately for different aquaculture sectors (e.g. marine, estuarine, inland, shellfish, finfish). Regular cross-checking of international standards against regional needs/capacity, however, must be built in to ensure continued compatibility with user goals.	Internationally accepted methodologies will facilitate national and regional efforts to harmonize methodologies for data and information handling. This will also promote cross-checking, quality consistency and stronger justification for methodologies chosen.

Table 1 (continued). Opportunities for regional cooperative actions

Issues	Requirements	Opportunities for Regional Cooperation
Inadequate data analysis.	Clear understanding of the context and issues in hand. Improved support for data and information analysis, including computer storage and analytical packages, where applicable. Support is also required for cross-checking and back up of raw data. Development/training on analytical tools and methods required to meet aquaculture policy-making, planning and management needs.	Development of analytical tools that will facilitate region-wide data and information exchange and thus, enhance capability to develop harmonized aquaculture policies and management.
Ineffective communication and presentation.	Improved understanding of required application of results generated from data and information collected. Better understanding of communication mechanisms required to disseminate results to all users (who may vary significantly in knowledge of data and information compilation and analytical mechanisms). Training in communication of data and information analyses in order to promote clear understanding of their application and use for aquaculture, policy-making, planning and management.	Enhanced communication of data and information analyses will promote more effective exchange with policy-makers, planners and managers. Region-wide aquaculture policies, planning and management will be based on more consistent and clear data and information foundations.

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[1] Information, in its technical sense, refers to systematically generated and interpreted data and is purposely designed to meet or satisfy needs of its users.

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Aquaculture Systems and Species[1]

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Background

Sustainable improvements in technological aspects of aquaculture will not be achieved unless they are accompanied by appropriate policies that address the social and economic environment within which the aquaculture system is placed. The development of such systems must lie within the context of environmentally sound regulatory frameworks (e.g. systems providing for monitoring and enforcement, and good governance) This requires consideration of sustainability criteria, particularly socio-economics and the wider interaction between aquaculture and other processes and activities. These interactions have to be considered– both as aquaculture's impact on other water and natural resource users, and the impact of these on aquaculture.

Types of aquaculture systems

Systems and species

In the 21st Century, water resources will be at a premium, with water shortages expected after 2015. With such a pressure on this vital resource for aquaculture, business-as-usual scenarios will no longer be possible. Competition for this resource will increase with drinking water shortage expected to affect large populations by 2025. This important constraint will have a major bearing on how aquaculture can and will develop in the new millennium, and appropriate technologies and farming systems will be required to address this issue.

Within the context of this paper, the essential elements of aquaculture incorporate: the care of aquatic stocks; requires confinement or site allocation; isolation to varying degrees of the farmed stock from the external environment; allows for various levels of internal control of the system; and requires some form of ownership or contractual arrangement to that effect.

Aquaculture systems must be considered in relation to natural resource systems and human development circumstances within which reside.

Aquaculture systems range from very extensive, through semi-intensive and highly intensive to hyper-intensive. When using this terminology the specific characterization of each system must be defined, as there are no clear distinctions and levels of intensification represent a continuum.

Farming systems are also diverse for example including:

- Water-based systems (cages and pens, inshore/offshore).
- Land-based systems (rainfed ponds, irrigated or flow-through systems, tanks and raceways).
- Recycling systems (high control enclosed systems, more open pond based recirculation).
- Integrated farming systems (e.g. livestock-fish, agriculture and fish dual use aquaculture and irrigation ponds).

Various aquatic organisms are grown in different ways including:

- Fish (ponds, polishing ponds, integrated pond systems).
- Seaweeds and macrophytes (floating/suspended culture, onshore pond/tank culture).
- Molluscs (bottom, pole, rack, raft, long-line systems also culture based fisheries)
- Crustaceans (pond, tank, raceway, culture based fisheries).
- Other minor invertebrates, such as echinoderms, coelenterates, seahorses, etc (tanks, ponds, culture based fisheries)

The phases of aquaculture include broodstock holding, hatchery production of seed, nursing systems, grow-out systems, and quarantining.

Together, this mix of intensity, culture systems, species, farming systems and different phase of culture create an extreme diverse collection of aquaculture systems and technologies.

Although such techniques exist, their widespread dissemination requires effective communication networks, reliable data on the merits and drawbacks of the various approaches, and help in the decision-making process through which people design their production systems.

Future developments in systems and technology

Conventional pond systems

Shortage of water will become a limiting factor in many areas. Low input and extensive land based pond aquaculture is an inefficient use of fresh water – in warm, dry countries, a 1-hectare pond might lose 30,000 tonnes of water per annum through seepage and evaporation, yet produce only 1-2 tonnes of fish. Ponds must become more "intensive" with respect to water use. Aquaculture ponds can be integrated into water conservation and management systems and rainfed aquaculture can be an effective storage mechanism in areas that experience water shortages.

Management interventions, infrastructure and support technologies

The management interventions, infrastructure and supporting technologies utilized in aquaculture include a wide range of activities, such as seed supply and stocking, handling, feeding, controlling, monitoring, sorting, treating, harvesting, processing and use of prophylactic measures.

Driving forces in the development of aquaculture

There are a number of factors, which drive aquaculture, again covering a spectrum from the needs of people (the provision of local employment, food security and the alleviation of poverty) to the needs of industries (with particular emphasis on profits, productivity and consistent-quality products).

Consequently, the requirements for sustainable aquaculture development will include both technological and people based approaches From this range of choices, the design and selection of appropriate culture systems can be made, which most effectively meets

This means that millions of farmers will require education, technical assistance and effective extension of improved methods of aquaculture that utilize scare water resources effectively.

In some climates, flow-through systems can become more efficient through the re-use of heat energy, balancing the cost of water.

Crucial positive trends are the integration of pond systems (with other agriculture and water-using processes), reuse of water, and recirculation. For example, a recirculation system can achieve 150L water per kg of fish, or 40L per kg with a de-nitrification unit, although such systems may have limited transferability to the majority of aqua farmers.

Integration of aquaculture into other systems

Many “outputs”, often called “wastes” or “byproducts” of farming subsystems, can become basic inputs for other subsystems rather than just additive components of the overall farm economy.

There are examples of such integrated systems. Dual pond systems in Israel, for example, link irrigation water storage with aquaculture ponds, with seasonal their needs and best, fits the opportunities and constraints of the local environment.

transfers according to respective needs of irrigation and culture. Cages placed within reservoirs and ponds can also provide integrative processes on a small scale, making more effective economic use of the water resources as a whole.

The use of rainwater storage ponds for aquaculture is another effective use of the resource. The aquaculture production is a bonus. In other small-scale systems the aquaculture component is the primary role, with water storage as an accessory feature (for garden irrigation and watering of livestock).

Integration of livestock and aquaculture is common in many countries although in the future, the use of livestock or industrial effluents (e.g. sewage, heated water, process water) for aquaculture may raise ethical issues (moral and public health), that will have to be addressed. Specific issues are those of disease transmission and accumulation of toxic compounds.

These include minimum water demand, limited space demand, reduced water discharges, controlled conditions to optimise productivity, tight control of feeding to maximise feed conversion efficiency, fairly site-independent, exclusion of predators and climatic events, and necessarily little use of chemicals. But such systems often involve high capital costs, are more complex, and failures can result in serious crop loss. Such systems place greater demands on management control, feed design, health management, and demand professionalism in their use.

A well-designed recirculation system must be readily managed and competitive in terms of cost-efficiency, as such current applications are principally targeted at high value intensive aquaculture.

There are alternative sources of water readily available for aquaculture arising from, for example, floodwater control in Bangladesh, or use of saline ground or surface water not suitable for irrigation or municipal consumption. Saline waters and land cover large areas in several Asian countries, and provide significant opportunities for aquaculture.

Recirculation systems

The uses of recirculation vary widely, from broodstock management, hatchery and nursery rearing, grow-out and quarantine holding. It is likely that use of recirculation systems in intensified commercial aquaculture will increase in future. There are many possible solutions, adaptable to specific local situations.

The PAS system for American catfish is one example. It combines an extensive set of channels within the pond, for water treatment, with a highly intensive growth enclosure. The very slow circulation with low energy requirement provides good control of pond environmental processes whilst conserving water.

The recirculation of water is not necessarily highly intensive. Shrimp farmers in Thailand are successfully

Hyper-intensive recirculation is currently particularly suited to Europe due to environmental pressures and the market for high value aquacultured species. As economic and resource conditions change in the future, alternative applications of recirculation are likely.

Technology issues in recirculation approaches:

There are a number of technology issues in recirculation technologies that include:

- Limited knowledge about component interactions (biofilters, mechanical filters, energy flows).
- Interaction of pathogens and benign microbes in biofilters is very poorly understood.
- Biofilms, biomats etc need more study.
- Scale up problems are common: thorough testing is still necessary.
- Modified processes may be required when using new feeds.
- Accumulation of bi-products in the systems are poorly understood.
- There is a need for predictive modeling to assess multifactor interactions in recirculation system design and testing.

using closed pond systems for removing the requirement for water exchange making efficient use of brackishwater and helping to reduce risks of introduction of shrimp pathogens to the farming system.

Active suspension ponds, which reduce the requirement for water exchange, have been demonstrated for tilapia in Israel and the USA and in shrimp culture in Belize Hyper-intensive recirculation systems have many advantages.

The design of feeds for recycling systems will: need to weigh conversion efficiency versus water treatment efficiency. Currently, feeds can be designed to facilitate the separation of faeces from the water and for reduction of nutrient leaching.

Recirculation systems would be preferred for culture of exotics species and GMOs, since escape to the wild can be more effectively controlled.

Intensification can cause stress by disrupting fish social structures – but this varies with species – some do better at high stock densities, and we need to know more about such behavioural characteristics. Fish may require pre-adaptation to the recirculation environment. Recirculation techniques can also be highly species-specific. Species

The immediate need in these regions is to address the socio-economic barriers to aquaculture development.

Fish cage systems

The production of fish from cages is increasing globally. The technologies are now well developed in Europe, parts of South America (Chile in particular) and China. In SE Asia, cage farming of fish is advancing rapidly, in a wide range of species; the main limitations being the availability that are currently difficult to culture can be selected to perform better in recirculation systems. As expected, strains that have been cultured and adapted to recirculation systems seem to perform best.

Welfare concerns as well as the desire for improved productivity will compel us to design systems to suit the needs of the cultured animal.

Water is not always the limiting factor that makes recirculation an attractive option– in some cases it may be energy conservation such as heated hatchery and/or grow-out systems.

New approaches

An important future environment for aquaculture expansion is the sea, particularly offshore waters. Currently coastal waters, bays and inlets etc. are utilized but the cost of open water development is currently prohibitive in most instances.

As we enter the new millennium, it is noticeable that the rate of increase in global aquaculture production is slowing. If this is due to production limitations, it suggests we are not using current technologies well, or alternatively those future increments will be more expensive to achieve. We therefore need fundamental and high cost of feeds and shortage of seed. There is already considerable transboundary movement of fish seed and fingerlings in Asia, mainly for live fish markets in Hong Kong and China. Little is known of environmental impacts, although this trade is known to result in some destructive fishing techniques for fish fingerlings.

Each country has its own species, markets and issues that need to be addressed in the development of cage culture, but future expansion of this farming system is expected.

Inshore-nearshore cage farms:

Environmental impact minimization, or even positive impacts, can be achieved with inshore and nearshore cage farms. For example, combinations of fish cages with seaweed and shellfish culture can reduce nutrient and organic loading, combining cages and artificial reefs can contribute to stock enhancement and could have a long term potential for culture based fisheries.

There are a number of other technical issues that include:

- Making better nets, (stronger, less prone to attack by predators, and coping with fouling (while reducing use of innovations in aquaculture technology and it would also be useful to determine the potential performance of the available species, to help us optimise culture conditions.

The slowing of growth of aquaculture production is largely due to the effect of major current producers, as a result of saturation, problems with disease and environmental limitations. We should also take account of huge longer-term potential in South America and Africa, for which suitable technologies might already be available but have yet to be effectively transferred in a manner suitable to the prevailing local conditions.

antifouling paints);

- New designs, in particular deeper, larger and submersible cages;
- Increasing scale requires new levels of risk management;
- Equipment for sorting, handling, counting, biomass estimates.

Environmental management issues will be particularly important for the future development of cage culture. The issues to be addressed include:

- Better knowledge about mortality and real number of fish in cages, better feeding regimes, with less waste of feed;
- Thorough study of material and energy flows through cage systems;

- Modeling of the environmental impacts (not only benthic deposition, but also nutrient release and dispersal);
- Better knowledge about recovery processes, so as to estimate fallowing time;
- Site rotation: better equipment for simpler mooring;
- Models are lacking that relate to remote zones and interactions between nearby farms.
- Improved management of coastal zones, access rights and ownership are required in many countries that have the potential for expansion of coastal aquaculture.

Offshore cage farming - its technology needs and future

Open sea farming provides better exchange and dispersion of wastes, can be designed to be technically safe, but needs better surveillance techniques, and remote control of feeding. Production costs are still too high and most current examples are still prototypes. Furthermore, performance of fish may be different offshore than inshore – not enough is known on this issue.

2. Improved zoning and regulation and environmental management

- Incorporating GIS in System management
- Better methodologies for Impact assessment - e.g. carrying and holding capacity models.
- Mass application of vaccines and parasite treatments within production areas.

Standards for materials

Other food sectors have strict regulations on the materials used: these are largely lacking for aquaculture. For example, plastics contain low molecular weight components, which may be a source of contamination. These include plasticizers, stabilizers, lubricants, coloring material, UV absorbers, antistatics, and flame retardants. Here there may be a need for standards for materials in recycling systems because those going into solution may contaminate the system and the product.

The quality and standards for feeds in aquaculture whilst relatively rigorous in some countries will need to become more rigorous in many countries in order to respond to export and market requirements.

Infrastructure needs are likely to be different from near-shore cage systems. Systems may be offshore for a long time without being brought inshore for service - net repair and maintenance will be special issues. Different support systems (platforms) may be needed offshore - space for sorting, harvesting, handling, checking, treating.

Options for this technology in the short term will revolve around the high value species.

Infrastructure and support technology

Infrastructure and support technology issues relate mainly to environmental assessment and planning and include:
1. Computerization of aquaculture

- Financial control
- Decision support systems for planning
- Better farm management software
- Better online monitoring equipment and reliable calibration and self-diagnosis (for biomass, environmental parameters).

Future potential species for aquaculture

When aquaculture is compared with the livestock sector it may appear that we may be trying to culture too many species. On the one hand it is the sheer diversity of species that allows us to exploit many varied environments and niches to enhance aquaculture production (also considering that livestock are all mammals). On the other, this diversity also makes it problematic to standardize and generalize in the same way that we now control the limited options within the livestock sector.

Species choices need to be made with great care, taking into account market demand, availability of seed and of culture technologies, and the potential environmental constraints. Some of these issues include:

- Development of indigenous species rather than exotics;
- Filling market niches in particular areas (for example cod, haddock and halibut in cold waters);
- Diversification is still a priority for Mediterranean aquaculture, where several faster-growing species can occupy the same infrastructure, and their life cycles have been closed.

- Pelagic species may become more significant if economic culture systems can be developed.
- Air-breathing fish could fill specific situations of low technology and poor water quality.
- Improved seed supply (both in terms of quantity, quantity and distribution). More microalgal species are required for hatchery feeds and for production of fine chemicals.
- Similar comments apply in tropical and subtropical areas, with alternative shrimp and other crustacean species, indigenous fishes rather than the Chinese and Indian cyprinids, freshwater mussels, shrimps and snails being mentioned.

There is a priority to close life cycles of species currently being grown out in aquaculture.

New Products

The requirements for sustainable aquaculture development will include both technological and people based approaches From this range of choices, the design and selection of appropriate culture systems can be made, which most effectively meets their needs and best fits the opportunities and constraints of the local environment.

Although such techniques exist, their widespread dissemination requires effective communication networks, reliable data on the merits and drawbacks of the various approaches, and help in the decision-making process through which people design their production systems.

We predict that access to supplies of suitable water (coastal, estuarine and particularly freshwater) will become increasingly problematic and will be the source of widespread competition. Aquaculture will have to adapt to this. Therefore, we must adopt or develop approaches which:

The economic efficiency of aquaculture can be greatly improved by the discovery of new products, not only for consumption but also for other uses, resulting in fuller use of currently cultured species. An example of using fish as bio-reactor or as tool in developing pharmaceuticals, is the possible use of salmon in finding a cure for osteoporosis.

Education and training

Education and training has to be given more attention in the new millennium. The quality of training should be assured through industry-based competency standards, the accreditation of courses and frequent re-training of the training providers themselves.

New techniques for the effective dissemination of information to others who influence the progress of aquaculture, such as policy makers, public servants, investors, engineers, journalists and the general public is urgently required.

Recommendations

The factors, which drive aquaculture development, cover a spectrum from the needs of people

- Use water more efficiently;
- Promote further integration of aquatic production with agriculture (e.g. crops and livestock), particularly in areas where such approaches are not common;
- Link with, share with or complement other water resource users; and
- Use water for which there is less competition due to its reduced suitability for drinking, irrigation, agriculture etc..

High-technology systems are often proposed to achieve the more efficient use of water (e.g. recirculation), or to avoid competition for water (e.g. offshore/oceanic farming). Since there is a relatively high risk of failure of such systems, we recommend:

- Pilot-scale and full-scale testing, in real settings, for newer culture systems before their adoption by users;
- Standard criteria for materials, procedures and safety margins applied in newer culture systems;
- Codes of practice for specific culture systems as used in specific applications.

Current recirculation systems are

(the provision of local employment, food security and the alleviation of poverty) to the needs of industries (with particular emphasis on profits, productivity and consistent-quality products).

expensive and limited in their applications for most species. The functional interactions of their components are not well understood, and this makes it difficult to optimise systems for specific applications (e.g. quarantine, hatchery, grow-out).

There is an increasing need for environmental and system control as a result of intensification. We therefore recommend:

- The further development of cost-effective recirculation systems for other species;
- The further development of recirculation techniques for green-water or turbid water as well as clear-water systems;
- Research and development on reliable monitoring and management tools that go beyond current limited water quality criteria (e.g. biomass, mortality, growth, behaviour, critical events);

The composition of discharged water is an important factor in

One critical option is the cultured species. We therefore recommend that research on new species continues in a judicious and selective fashion, particularly in the following areas:

- Development of suitable indigenous species rather than exotics;
- Additional species in geographical regions where major market niches are not yet satisfied, (for example cold water regions and the Mediterranean);
- Closure of life cycle of species already being grown out on a substantial scale;
- Air-breathing fish species suitable for culture in systems with unsophisticated technology and poor water

environmental sustainability. We recommend that research continues strongly in the areas of:

- Biological treatment of waste waters, leading to improved design, reliability and cost-effectiveness of such systems, and methods for the disposal of sludge;
- The design of feeds which minimise the wastage and excretion of nutrients, and facilitate more efficient waste treatment (e.g. faeces separation);
- Use of effluents, including sediments, in other agricultural processes.

Both the need for efficient use of resources (especially water), and pressures exerted by the community, will require that farming systems are designed to meet the needs of the farmed animal. We therefore recommend more research on:

- The behavioural responses of cultured animals to the culture environment, leading to system optimisation, and in particular to achieve species compatibility in polyculture systems;
- The minimisation of stress and other adverse physiological responses to the culture environment and the quality;
- A wider range of species, including molluscs and crustaceans, for freshwater culture.

Aquaculture can be made more economically efficient through the development of additional products from the species grown. We recommend more research and development of fine chemical and pharmaceutical products from cultured organisms, including fish and invertebrates as well as algae and microorganisms.

Whilst further exploratory research must be done to achieve a quantum leap in aquaculture productivity, the effective dissemination of this knowledge is a key to future growth. Aquaculture of all types requires high levels of skill and professionalism, whether it is highly integrated with other users, or highly intensive and industrial, and generally because of its complex interactions with the local environment. We therefore recommend:

- That all relevant agencies strongly encourage programs for the training of aquaculture producers and service providers;
- That the quality of training be assured through industry-based competency standards,

harvesting process;

- Domestication and selection of animals for improved performance in culture.

The ability of aquaculturists to meet their diverse needs, in the various environments used, depends on the diversity and adaptability of their system options.

the accreditation of courses and frequent re-training of the training providers themselves;

- Effective dissemination of information to others who influence the progress of aquaculture, such as policy makers, public servants, investors, engineers, journalists and the general public.

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[1] The views expressed in this manuscript are personal to the authors and do not necessarily reflect the views of NACA and FAO. This paper is a synthesis based on the presentation and discussions during the Conference session on aquaculture systems and technologies. The session panelists identified the principal issues that will confront aquaculture in the new millennium. These issues must be addressed if the application of aquaculture technologies and development of farming systems is to continue its current expansion.

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Aquaculture Systems and Species[1]

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Review of the Status of Aquaculture Genetics

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ABSTRACT: Genetic intervention has been used to enhance animal and plant agriculture production for many years. These techniques are now being applied to aquatic animals in an effort to overcome many different production challenges. As with agriculture, however, such advances are coming under increased scrutiny, thus the challenge facing geneticists and aquaculturists alike, is deciding which strategies are necessary, beneficial and acceptable in terms of social and environmental safety. Aquaculture genetics shows immense potential for enhancing production in a way that meets aquaculture development goals for the new millennium. This review covers the progress made to date, discusses the questions which need focussed research to answer and summarizes the areas where genetic knowledge can make a positive difference to aquaculture sustainability.

KEY WORDS: Genetics, Aquaculture, Breeding, Selection, Sustainability

Introduction

With global population expansion, the demand for high-quality protein, especially from aquatic sources, is rising dramatically. Increased aquaculture production is clearly needed to meet this demand in the third millennium, because capture fisheries are at capacity or showing precipitous declines due to overfishing, habitat destruction and pollution. Further increases in capture fisheries are not anticipated under the current global conditions.

Increased demands for aquaculture production mean increasing pressure for development of more efficient production systems. Major improvements have already been achieved through enhanced management, nutrition, disease diagnostics and therapeutics, water quality maintenance and genetic improvement of production traits. A common theme through all these is genetics, which, actively and passively, has been used to meet many production challenges, such as disease resistance, tolerance of handling, enhanced feed conversion and spawning manipulation, i.e. all those areas to which wild animals must adapt for productive “domestication”.

Aquaculture genetics began with the advent of aquaculture in China

Genetic enhancement programmes began in the 1960s. Molecular-based knowledge emerged in the 1980s and has continued to gain momentum. Efforts are now well established in traditional selective breeding, biotechnology and molecular genetics of finfish, and are rapidly developing for aquatic invertebrate domestication.

Current status of aquaculture genetics

Domestication and strain evaluation

When wild fish are moved to aquaculture settings, a new set of selective pressures comes into play that often changes gene frequencies. Thus an organism better suited for the aquaculture environment begins to evolve. This process, termed domestication, occurs even without directed selection by the fish culturist. Domestication effects can be observed in some fish within as few as one to two generations after removal from the natural environment (Dunham, 1996a). In channel catfish (*Ictalurus punctatus*) an increased growth rate of three to six percent per generation was observed. The oldest domesticated strain of channel catfish (89 years), the more than 2,000 years ago, at about the same time as the Romans began to hold fish in ponds and learned how to breed them. Without realizing it, the first fish culturists who completed the life cycles of species such as the common carp, Cyprinus carpio, began changing gene frequencies and altering the performance of the fish they were domesticating. When the farmers noticed mutations in colour, body conformation and finnage, those with attractive traits were chosen as broodstock, and selective breeding was "born"! Fish culturists and scientists who compared and evaluated closely related species for their suitability for aquaculture over the past two millennia also unknowingly conducted genetic-based research. Closely related species, under wild circumstances, are reproductively isolated and have species status because of their genetic differences. Thus comparison for culture suitability is a genetic comparison.

Directed breeding programmes did not develop an intense or strongly focussed approach until the Japanese started to develop fancy varieties of koi carp in the 1800s. Fish genetics programmes became more prevalent in the 1900s with greater knowledge of breeding and inheritance (Mendelian principles).

Kansas strain, has the fastest growth rate of all strains of channel catfish. Although most domesticated strains usually perform better in the aquaculture environment than wild strains, there are exceptions, e.g. wild *Nile tilapia, Oreochromis niloticus* (T. Gjedrem, pers. comm.), and rohu, *Labeo rohita*, grow better in the aquaculture environment (Dunham, 1996a). The explanation for this appears related to a lack of maintenance of genetic quality and genetic degradation in domesticated strains. Poor performance of some domestic tilapia is related to poor founding (parental) lines, random genetic drift, inbreeding and introgression with slower growing species, such as *O. mossambicus* and slower growing strains such as Nile tilapia from Ghana. Channel catfish strains differ in growth, disease resistance, body conformation, dressing percentage, vulnerability to angling and seining, age of maturity, time of spawning, fecundity and egg size (Dunham and Smitherman, 1984; Smitherman and Dunham, 1985). Strains of rainbow trout, *Oncorhynchus mykiss*, show similar variability (Kincaid, 1981).

Domestication of farmed shrimp (*penaeids*) has been relatively slow compared to that of finfish.

This can be attributed to use of wild broodstock and postlarvae, a lack of understanding of shrimp reproductive biology for domestication of the species and perceptions of low potential for genetic improvement. Current reliance on wild broodstock is risky and negates the opportunity to enhance disease resistance (as well as other production traits) through selective breeding. Efforts to domesticate broodstock are now hampered by endemic disease challenges; however, recent collaborative research between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia and the shrimp culture industry has resulted in successful captive breeding of Penaeus japonicus. Economic analysis has demonstrated that domesticated broodstock are more cost-effective than wild broodstock (Preston et al., 1999) and that reproductive performance of domesticated P. monodon can match that of wild broodstock of a similar size (Crocos and Preston, 1999).

Use of established, high-

Common carp crossbreeds generally express low levels of heterosis (Moav et al., 1964; Moav and Wohlfarth, 1974; Nagy et al., 1984; Wohlfarth, 1993; Hulata, 1995), however, those that exhibited positive heterosis are now the basis for carp aquaculture in Israel, Vietnam, China and Hungary.

The crossing of common carp lines in Szarvas, Hungary (Bakos and Gorda, 1995) is a good example of the relative success of crossbreeding. During the last 35 years, more than 140 crosses have been tested. Three were chosen, based on ~20 percent improvement in growth rate (and other qualitative features), compared to parent and control carp lines, for culture purposes. Now approximately 80 percent of common carp production comes from these “Szarvas” crossbreeds. Production of gynogenetic female lines and gynogenetic sex-reversed inbred male lines from common carp with the best combining ability was an important part of the Hungarian crossbreeding programme. A higher heterosis was expected from crossing inbred lines, performance domestic strains is the first step in applying genetic principles to improved aquaculture mana-gement. Strain variation is also important, since there is a strain effect on other genetic enhancement approaches, such as intraspecific crossbreeding, interspecific hybridization, sex control and genetic engineering.

Inbreeding and maintenance of genetic quality

It is as important to prevent production losses due to inbreeding as it is to increase production from genetic enhancement. This applies especially to species with high fecundity, e.g. Indian and Chinese carps, where few broodstock are necessary to meet demands for fry and broodstock replacement. The detrimental effects of inbreeding are well documented and can result in decreases of 30 percent or greater in growth production, survival and reproduction (Kincaid, 1976a, b, 1983a; Dunham, 1996b).

Intraspecific crossbreeding

Intraspecific crossbreeding (crossing of different strains) may increase growth rate but heterosis (differences between offspring and parents) may not be obtained in every case. Increases of 55 percent and 22 percent in growth rate of channel catfish and rainbow trout but the growth rate of F1 crossbreeds was only 10 percent higher than controls (Bakos and Gorda, 1995).

Kirpichnikov (1981) successfully produced a new strain of cold resistant carp - the “Ropsha” carp - for cold zones in northern Russia using local carps and Siberian wild carps from the River Amur. The Czech Republic also had a national common carp breeding programme and improved growth rates with crossing, “South Bohemian” x “Northern mirror” carp and the “Hungarian 15” x “Northern mirror” (Linhart et al., 1998). Likewise in Israel, over 20 years of crossing common carp strains revealed that the cross using the strain “DOR-70” (Wohlfarth et al., 1980) and the Croatian line “Nawice” produced fast growth, and this is now one of the most popular crosses for Israeli carp production (Wohlfarth, 1993).

In Indonesia, strain development using artificial gynogenesis and sex-reversal resulted in 10 common carp inbred lines, which were later used for crossbreeding (Sumantadinata, 1995). In Vietnam, eight local varieties of common carp, along with “Hungary”, “Ukraine”, “Indonesia” and “Czech” strains are maintained, with significant heterosis observed in F1 generations of crossbreeds. Double crosses among Vietnamese, Hungarian and Indonesian strains crossbreeds, respectively, were achieved using this technique (Dunham and Smitherman, 1983; Dunham, 1996b). Chum salmon crossbreeds, however, have shown no increase in growth rates compared with parent strains (Dunham, 1996a).

have subsequently been used for carp selection and crossbreeding programmes throughout Vietnam (Thien and Trong, 1995).

The Vietnamese x Hungarian common carp crossbreed is particularly popular, due to fast growth and high survival rates under different production conditions (J. Bakos, unpublished data). Under various rice-field conditions, growth rates of different strains of Nile tilapia and their crosses showed that the crosses were superior to pure Senegal strains (Circa et al., 1994). Breeding programmes are also under development in several countries for the Java or silver barb, Barbodes (formerly Puntius) gonionotus, another economically important fish species in Southeast Asia (Bentsen et al., 1996; Hussain and Islam, 1999). The Bangladesh programme used three strains: “Bangladesh”, “Thailand” and “Indonesian”. The growth rate of

Channel catfish females x blue catfish, *I. furcatus*, males (“channel-blue”) is the only cross (between 28 catfish hybrids examined) that exhibits superiority for growth rate, growth uniformity, disease resistance, tolerance of low oxygen levels, dressing percentage and harvestability (Smitherman and Dunham, 1985). However, mating problems between the two species have prevented commercial utilization.

The “sunshine” bass is a cross between white bass, Morone chrysops, and striped bass, *M. saxatilis*, and grows faster, with better overall culture characteristics than either parent species (Smith, 1988). In addition, crosses of the silver carp (*Hypophthalmichthys molitrix*) and bighead carp females from six crosses was 23 percent higher than the average growth rate of the parent strains. Even higher growth rates (35 percent improvement) were found in the three crosses using the Thailand strain as either the sire or dam. In the Vietnamese breeding programme, six different strains were used to produce a population ideally suited for culture (Bentsen et al., 1996).

Cross-breeds of different strains of European catfish, *Silurus glanis*, are characterized by outstanding adaptability under warmwater holding conditions and mixed diet feeding regimes (Krasznai and Marian, 1985). In addition, crosses with the walking catfish, *Clarias macrocephalus*, have shown improved resistance to Aeromonas hydrophila infections (Prarom, 1990). Studies on "domestic a" x "domestic b" channel catfish also showed greater heterotic growth rates than "domestic" x "wild" crosses (Dunham and Smitherman, 1983. The same was found in rainbow trout crosses (Gall, 1969; Gall and Gross, 1978; Kincaid, 1981; Ayles and Baker, 1983). Strain mating incompatibilities, however, can occur and can impede fry output.

Interspecific hybridization

Interspecific hybridization has been (*Aristichthys nobilis*), black crappie (*Pomoxis nigromaculatus*) and P. annularis (Hooe et al., 1994) and African catfish hybrids (*Clarias gariepinus, Heterobranchus longifilis and H. bisorsalis*)(Salami et al., 1993; Nwadukwe, 1995) all show faster growth than parent species. Numerous crosses of common carp with rohu, mrigal (*Cirrhinus cirrhosus*) and catla (*Catla catla*) (Khan et al., 1990); tambaqui (*Colossoma macropomum*) and Piaractus brachypoma and P. mesopotamicus (Senhorini et. al., 1988; green sunfish (Lepomis cyanellus) crossed with bluegill (*L. macrochirus*) (Tidwell et al., 1992; Will et al., 1994), and gilthead seabream (*Sparus aurata*) with red seabream (*Pagrus major*) (Knibb et al., 1998a), have also resulted in improved overall performance for aquaculture systems. In the family Sparidae, hybrids of P. major and common dentex, *Dentex dentex,* also grow faster than parent stocks (Colombo et al., 1998).

Hybridization in commercial Thai oysters (*Crassostrea belcheri, C. lugubris and Saccostrea cucullata*) was carried out to explore the possibility of producing hybrid oysters with superior traits. Hybridization of *C. belcheri* x *C. lugubris* was only successful to the spat stage, and growth rates of the hybrids and reciprocal crosses were significantly lower than their parents. Intergeneric hybridization used to increase growth rate, manipulate sex ratios, produce sterile animals, improve flesh quality, increase disease resistance, improve tolerance of environmental extremes, and improve a variety of other traits that make aquatic animal production more profitable (Bartley et al., in press). Although interspecific hybridization rarely results in an F1 suitable for aquaculture application, there are a few significant exceptions.

was only successful with female C. lugubris and male S. cucullata. Growth rates of this hybrid were significantly higher than those of S. cucullata, but did not differ significantly from those of C. lugubris. Shell morphology of the hybrid was intermediate between the two parental types. Effects of intergeneric hybridization on the genetic diversity of natural oyster populations, however, require further investigation.

Hybridization between some species, such as *Nile tilapia* and *blue tilapia, Oreochromis aureus*, result in predominantly male offspring (Rosenstein and Hulata, 1994). Other tilapia crosses, which produce mainly male offspring, include *Nile tilapia x O. urolepis honorum* or *O. macrochir*, and *O. mossambicus* x *O. urolepis honorum* (Wohlfarth, 1994). Conversely, the cross between striped bass and yellow bass (M. mississipiensis) produced 100 percent females (Wolters and DeMay, 1996). This can be desirable for culture purposes where i) there are: growth

Hybrid triploids of Atlantic salmon (*Salmo salar*) x brown trout (*S. trutta*) showed survival and growth rates comparable to those of Atlantic salmon monospecific diploids. Triploid Pacific salmon hybrids have also shown earlier seawater acclimation (Seeb et al., 1993).

Increased environmental tolerance may also be imparted to hybrids where one parent species has a wide or specific physiological tolerance or due to increased heterozygosity (Nelson and Hedgecock, 1980; Noy et al., 1987). Hybrid red tilapia, O.

differences between the sexes; ii) sex-specific products such as caviar are wanted; or iii) reproduction needs to be controlled (e.g. overpopulation and stunting in tilapia production ponds).

Hybridization between species can also result in offspring that are sterile or have diminished reproductive capacity. As with monosex production, the production of sterile hybrids can reduce unwanted reproduction or improve growth rate by energy diversion from gametogenesis. Karyotype analysis can be used as a general predictor of potential hybrid fertility. For example, hybrid Indian major carps are generally fertile because they share similar chromosome numbers (2N = 50). When crossed with common carp (2N = 102), the hybrids are triploid and sterile (Khan et al., 1990; Reddy, 2000). A natural triploid results from the cross between grass carp, Ctenopharyngodon idellus, and bighead carp. Grass carp are commonly produced for aquatic weed control, but there is concern about spread to natural water bodies and the potential impact on desirable vegetation. The triploid hybrids have reduced fertility, but some progeny maintain diploidy and could be fertile (Allen and Wattendorf, 1987). Other exceptions to the chromosome number-fertility rule are crosses of some sturgeon species with mossambicus, (high salinity tolerance) and Nile tilapia, O. niloticus, (low salinity tolerance) show enhanced salinity tolerance (Lim et al., 1993). Florida red-strain hybrids (*O. mossambicus x O. urolepis hornorum*) can reproduce in salinities of 19 ppt (Ernst et al., 1991) and O. niloticus x O. aureus hybrids also show enhanced salinity tolerance (Lahav and Lahav, 1990; Wohlfarth, 1994). Reciprocal hybrids of O. niloticus (N) x O. mossambicus (M) have different salinity tolerances (Thanakijkorn, 1997). The hybrid with an O. niloticus mother (NxM) had a higher survival rate after salinity challenges at 20 ppt than pure O. niloticus, but lower survival rates than those of the reciprocal hybrid (MxN). At 30 ppt salinity, a direct transfer killed all tilapia with O. niloticus maternal genes. Growth rates of NxM hybrids were comparable to those of Nile tilapia, while those of the NxM hybrids and O. mossambicus were comparable, but lower, than the first two groups. There were no statistical differences in carcass percentages of the four groups. Back-crosses were also evaluated. MNxN showed the highest salinity tolerance (comparable to that of *O. mossambicus*), but no significant differences in salinity tolerances were found in the remaining backcross (NxNM, NMxN, NxMN) or pure O. niloticus. Carcass percentage of the back-cross different chromosome numbers that produce fertile F1 offspring (Steffens et al., 1990).

Dorson et al. (1991) investigated hybridization of coho salmon, (*Oncorhynchus kisutch*), which is considered resistant to several salmonid viruses. Disease resistance in the hybrids was improved, but overall viability was poor. Viability increased when hybridization was followed with triploidization. The same authors also reported that triploid hybrids from rainbow trout and char (*Salvelinus spp.*) were resistant to several salmonid viruses, but grew more slowly than their diploid counterparts. Similar results were found with rainbow trout and coho crosses.

hybrids, however, tended to be higher than those of the parent species.

Hybrids between marine species, and between marine and freshwater spawning species, have produced surprising results. Hybrids between Sparus aurata and Pagrus major (both belonging to the Sparidae) developed vestigial gonads at two to three years and were sterile (Knibb et al., 1998a). Similar vestigial gonads were observed in offspring of the reciprocal crosses. No consistent growth or survival superiority, compared with the parent species, was detected until sexual maturity in the reciprocal crosses. Hybridization between European sea bass, (*Dicentrarchus labrax*) females and striped bass (*Morone saxatilis*) resulted in viable larvae; however 28 percent were triploids, and only the triploids appeared to survive to six months of age. At eight months, the survivors showed poor growth compared to diploid *D. labrax.*

Such hybrids may be of commercial value where reproduction needs to be restricted for ecological reasons.

Sometimes an interspecific hybrid does not exhibit heterosis for specific traits, but may still be important for aquaculture if it expresses other useful traits from the parent species. The main catfish cultured in Thailand is the hybrid between African (*Clarias gariepinus*) and Thai (*C. macrocephalus*) catfish. This combines the fast growth of the African catfish and the desirable flesh characteristics of the Thai catfish (Nwadukwe, 1995). Although it does not grow as fast as pure African catfish, overall production rates are improved and the flesh is still acceptable to Thai consumers. Likewise the rohu (*Labeo rohita*) x catla (*Catla catla*) hybrid grows almost as fast as pure catla, but has the small head of the rohu considered desirable in Indian aquaculture (Reddy, 2000). Catla catla x Labeo fimbriatus (fringe-lipped peninsula carp) hybrids have the small heads of L. fimbriatus, plus the deep body and growth rate of catla (Basavaraju et al., 1995). The "sunshine" bass has a suite of advantageous traits from the parent species (white and striped bass) including good osmoregulation, high thermal tolerance, resistance to stress and certain diseases, high survival under intense culture, and ability to use soy bean protein in feed (Colombo et al., 1998).

There are few national breeding programmes in fish and shellfish which aim at improved aquaculture production. In 1975, a National Breeding Program for Atlantic salmon and rainbow trout was started in Norway, and today this supplies about 75 percent of the Norwegian industry with improved eyed eggs. In Canada, a similar breeding programme is operated by the Atlantic Salmon Federation (Friars, 1993). In 1993, The Philippines National Tilapia Breeding Program (PNTBP) was started with broodstock from the GIFT programme (Genetically Improved Farmed Tilapia) and is now operated by the GIFT Foundation (A.E. Eknath, pers. comm.). In Israel (Wohlfarth, 1983) and Hungary (Bakos, 1979), crossbreeding programmes with common carp (Cyprinus carpio) exist. In addition, some private companies in several countries, including the United States and Chile, now have their own breeding programmes.

Selection for body weight and disease resistance in salmonids has been particularly successful (Embody and Hayford, 1925; Gjedrem, 1979; Kincaid, 1983a). By 1925, three generations of selection of brook trout (Salvelinus fontinalis) survivors of endemic furunculosis (caused by Aeromonas salmonicida) improved survival from 2 percent to 69 percent. Ehlinger (1977) further

Interspecific backcrossing has also been used to successfully introgress (merge) genes from one closely related species into another. Cold tolerance and colour genes have been transferred among tilapia in this manner.

Genetic selection

Very little was done in this area prior to 1970, however, the field has grown significantly in the past three decades and is now extremely active (Dunham, 1996a). In general, the response to selection for growth rate in aquatic species is very good compared to that with terrestrial farm animals. Fish and shellfish often have higher genetic variance compared to farmed land animals, e.g. Gjedrem (1997) notes the genetic variation for growth rate is seven to ten percent in farmed land animals and 20-35 percent in fish and shellfish. Fecundity is also higher in aquatic organisms than land organisms. This allows for higher selection intensity for aquaculture production improvement, and over 200 heritability estimates have been obtained for several traits of cultured fish and shellfish.

increased resistance to furunculosis in brown trout and brook trout with selective breeding programmes. Okamoto et al. (1993) reported that an infectious pancreatic necrosis virus (IPNV)-resistant strain of rainbow trout showed 4.3 percent mortality compared with 96.1 percent in a highly sensitive strain.

With respect to body weight, a 30 percent increase in rainbow trout was achieved within six generations of selection (Kincaid, 1983b). In Atlantic salmon, an increase of seven percent was achieved within a single generation (Gjedrem, 1979) and an increased growth rate of 50 percent was achieved within ten generations in coho salmon (Hershberger et al., 1990). Body weight has also been improved in channel catfish, by 12-20 percent over one to two generations of genetic selection (Dunham and Smitherman, 1983; Bondari, 1983; Smitherman and Dunham, 1985). The best line grew twice as fast as nonselected lines (Burch, 1986). After three generations, the growth rate of channel catfish in ponds was improved by 20-30 percent (Rezk, 1993). Four generations of selection in a Kansas strain of channel catfish resulted in 55 percent improvement in growth rate (Padi, 1995). Four generations of selection also increased body weight by 50.5 gm and total length by 0.88 cm in walking catfish, C. macrocephalus (Jarimopas et al., 1989).

Genetic selection in gilthead seabream (*Sparus aurata*) has also been successful (Knibb et al., 1997a) despite early difficulties with producing single-pair offspring groups (full- and half-sibs). This led to the conclusion that family mating designs were inappropriate for group spawning of S. aurata (Gorshkov et al., 1997). Mass selection proved more effective and resulted in significant heritability estimates for growth (Knibb et al., 1997b; 1998a, b).

Different strains of common carp appear to possess varying amounts of additive genetic variation. Smisek (1979) estimated heritabilities for body weight of 0.15-0.49 in a Czechoslovakian strain of common carp. Vietnamese common carp also show significant heritability (0.3) for growth rate (Tran and Nguyen, 1993). Kirpichnikov et al. (1993) reported a successful selection programme, which started in 1965, against dropsy (spring viremia of carp) in common carp.

Production trials and socio-economic surveys in five Asian countries show that cost of production per unit fish is 20-30 percent lower for GIFT strain tilapia than other Nile tilapia strains in current use.

Body weight of common carp appears unresponsive to selection; however, body conformation can be dramatically changed (Ankorion et. al., 1992). Selection for carcass quality and quantity has also been initiated for salmonids and catfish (Dunham, 1996a). In Thailand, selection results are not yet available for many species and traits, but numerous heritability estimates have been obtained, e.g. for growth and disease resistance in pangasiid freshwater catfish (Pangasius sutchi, syn. of P. hypophthalmus), rohu (Labeo rohita), Thai walking catfish (Clarias macrocephalus), Java barb (Barbodes gonionotus), bighead carp (Aristichthys nobilis) and Asian rock oyster (Saccostrea cucullata) (Table 1).

Responses can differ depending on the direction of selection. Body weight of common carp in Israel was not improved over five generations, but could be decreased in the same strain selected for small body size (Moav and Wohlfarth, 1976). Virtually identical results for Nile tilapia has also been reported.

Several authors reported that, in tilapia, mass selection improved body weight in Oreochromis mossambicus, red tilapia and O. aureus. However, selection for increased body weight in other red tilapia has been less successful. This is similar to the situation in Nile tilapia (Hulata et al., 1986; Huang and Liao, 1990). This may reflect a narrow genetic base in the founder stock or sole use of mass selection. Selection for increased growth in GIFT Nile tilapia gave much different results, with 77 percent to 123 percent growth improvement. The genetic gain was superior to results from crossbreeding experiments. The 11 percent genetic gain per generation in GIFT tilapia is better than that obtained in most other species of fish; the channel catfish (Padi, 1995) increased body weight by 14 percent per generation over four generations. However, a more typical genetic gain is five to seven percent per generation, as demonstrated by salmonids following approximately ten generations of selection (Gjedrem,

Selective breeding has also improved growth of the shrimp Penaeus japonicus in laboratory (Hetzel et al., 2000) and pilot-scale farm trials using offspring from CSIRO broodstock (Preston et al., 1999). In 1998/1999, comparative trials demonstrated significant improvements in the growth, survival and total yields in two selected lines (10-15 percent increase in mean yields) (Preston and Crocos, 1999). In a related species, P. vannamei, Fjalestad et al. (1997) estimated a response within one generation of selection of 4.4 percent for growth rate and 12.4 percent for survival of the viral disease Taura syndrome.

A genetic improvement programme was recently started for Pacific oysters, Crassostrea gigas, in Australia (Ward et al., 2000). This followed demonstrations that little genetic diversity had been lost since the Pacific oyster industry was founded in Australia with imports from Japan some 50 years ago (English et al., 2001). The improvement programme aims to combine family and mass selection with molecular genetics. Two generations of mass selection and two generations of family selection have been completed, with a growth rate improvement of about eight percent in the first generation from a mass selection. Based on work with a congeneric oyster species, C. virginica, Haley et al.

1979; Kincaid, 1983a; Hershberger et al., 1990). The only other exceptions that come close to the results with GIFT tilapia and the channel catfish study of Padi (1995) are the 13-14 percent increase per generation observed by Gjerde (1986), and five percent per generation for common carp after six generations of selection (Tran and Nguyen, 1993).

(1975) reported that mass selection of adult oysters gave an apparent strong response to selection for growth rate.

Table 1. Heritabilities for aquacultured species in Thailand.

Species	Traits[1]	h^2	References
Pangasius hypophthamlus	TL at 99 days old	h^2_D = 0.052±0.171	Leeprasert (1987)
	TL at 126 days old	h^2_D = 0.195±0.227	
	TL at 182 days old	h^2_D = 0.173±0.204	
	TL at 240 days old	h^2_D = 0.062±0.440	
	BW at 99 days old	h^2_D = 0.056±0.273	
	BW at 126 days old	h^2_D = 0.139±0.199	
	BW at 182 days old	h^2_D = 0.122±0.213	
	BW at 240 days old	h^2_D = 0.126±0.424	
Labeo rohita	TL at 118 days old	h^2_D = 0.075±0.155	Supsumram (1987)
	TL at 202 days old	h^2_D = 0.046±0.074	
	TL at 285 days old	h^2_D = 0.893±0.094	
	BW at 118 days old	h^2_D = 0.102±0.107	
	BW at 202 days old	h^2_D = 0.024±0.044	
	BW at 285 days old	h^2_D = 0.093±0.088	
Clarias macrocephalus	TL at 9 months old	h^2_R = 0.39	Jarimopas *et al* (1989)
	BW at 9 months old	h^2_R = 0.84	
C. macrocephalus	TL at 210 days old	h^2_R = 0.23	Chamnankuruwet (1996)
	BW at 210 days old	h^2_R = 0.31	
C. macrocephalus	Resistance to *Aeromonas hydrophila*	h^2_S = 2.34±0.07	Rasatapana (1996)
		h^2_D = 0.15±0.22	
	BW at 53 days	h^2_S = 2.01±0.95	
		h^2_D = 0.31±0.51	
Barbodes gonionotus	TL at 111 days old	h^2_D = 0.012±0.055	Jitpiromsri (1990)
	TL at 170 days old	h^2_D = 0.044±0.246	
	TL at 231 days old	h^2_D = 0.168±0.541	
	TL at 276 days old	h^2_D = 0.202±0.332	
	BW at 111 days old	h^2_D = -0.217±0.090	
	BW at 170 days old	h^2_D = -0.067±0.322	
	BW at 231 days old	h^2_D = 0.055±0.626	
	BW at 276 days old	h^2_D = 0.291±0.517	
Aristichthys nobilis	TL at 124 days old	h^2_D = 0.019±0.159	Nukwan (1987)
	TL at 208 days old	h^2_D = 0.078±0.122	
	TL at 292 days old	h^2_D = 0.038±0.109	
	TL at 362 days old	h^2_D = -0.014±0.039	
	BW at 124 days old	h^2_D = 0.077±0.186	
	BW at 208 days old	h^2_D = 0.069±0.128	
	BW at 292 days old	h^2_D = 0.048±0.156	
	BW at 362 days old	h^2_D = 0.004±0.043	
Saccostrea cucullata	LW at 15 months old	h^2_R = 0.184 (50 oysters/net)	Thavornyutikarn (1994)
	LW at 15 months old	h^2_R = 0.148 (150 oysters/net)	

[1]TL = total length, BW = body weight, LW = live weight, h^2_D = heritability estimated from Dam's variance, h^2_R = realized heritability.

Table 2. Response to selection in growth rate

Species	Mean Body Weight	Gain per Generation (%)	No. of Generations	Reference
Coho salmon	250 gm	10.1	4	Hershberger et. al., 1990
Rainbow trout	3.3 gm	10.0	3	Kincaid et al., 1977
Rainbow trout	4.0 kg	13.0	2	Gjerde, 1986
Atlantic salmon	4.5 kg	14.4	1	Gjerde, 1986
Atlantic salmon	6.3 kg	14	6	Gjerde and Korsvoll, 1999
Channel catfish	450gm	14	4	Dunham, 1987
Channel catfish	67 gm	20	1	Bondari, 1983
Tilapia	100gm	15	5	Rye and Eknath, 1999
Rohu	400gm	17	2	Mahapatra et al., 2000
Shrimp	20 gm	4.4	1	Fjalestad et al., 1997
Shrimp	15 gm	10.7	1	Hetzel et al., 2000
Oysters	42 gm	9-12	1	Toro et al., 1996
	36 gm	9	2	Nell et al., 1999
	33 gm	9	1	

These authors concluded that, because of large environmental variability, a combination of family and mass selection would be required to achieve maximum response. Newkirk (1980) obtained considerable selection response in growth rate of oysters after one generation of selection. He concluded that 10-20 percent gain per generation in growth rate is a reasonable expectation. Nell et al. (1999) reported a genetic gain of nine percent increased growth rate in Sydney rock oysters (Saccostrea commercialis) and similar results were obtained by Toro et al. (1996) in the Chilean oyster (Ostrea chilensis). In the hard-shell clam or quahaug (Mercenaria mercenaria), a genetic gain of nine percent per generation of selection for growth rate has been Progeny from selected broodstock grew faster during fingerling trials in the first season than control populations in all strains examined (Dunham and Smitherman, 1983). Two of the three select groups grew more rapidly during winter, and all select lines grew slightly faster than controls during the second season of growth.

Thodesen (1999) reported a correlated response in feed conversion when selecting for growth rate in Atlantic salmon. Wild salmon had a 17 percent higher intake of energy and protein/kg growth compared with fish from the 4th generation selected for growth rate. At the same time, they demonstrated eight percent lower retention of both energy and protein.

estimated (Table 2).

Correlated responses

Although selection for body weight has generally been associated with positively correlated responses (e.g. increased survival and disease resistance), there are examples of long-term selection resulting in decreased bacterial resistance, possibly due to genetic correlation changes or inbreeding. Increased fecundity, fry survival and disease resistance were correlated to selection for increased body weight in channel catfish after one generation of selection for body weight (Dunham and Smitherman, 1983; Smitherman and Dunham, 1985). Three and four more generations of selection resulted in increased dressout percentage, decreased tolerance of low oxygen and no change in body composition or seinability (Rezk, 1993; Padi, 1995). Progeny from select broodfish had greater feed consumption, more efficient feed conversion and greater disease resistance than controls (Dunham, 1981; Al-Ahmad, 1983). This indicated that selected fish make better use of feed resources than wild counterparts.

Polyploidy

Polyploidy has been well-studied in fish and shellfish. Triploid fish are generally sterile. Females produce less sex hormones and, although triploid males may develop secondary sexual characteristics and exhibit spawning behaviour, they are generally unable to reproduce. Triploidy can also be used to improve viability to nonviable interspecific hybrids.

Channel catfish triploids become larger than diploids at about nine months of age (90 gm) when grown in tanks (Wolters et al., 1982). This occurs slightly after the first appearance of sexual dimorphism in body weight. In tank experiments, the triploids converted feed more efficiently than diploids (Wolters et al., 1982), had six percent greater carcass yield at three years of age (Chrisman et al., 1983) and were darker than diploids.

However, triploid catfish hybrids did not grow as rapidly as diploids in commercial settings, such as earthen ponds (Dunham and Smitherman, 1987) and had decreased tolerance of low dissolved oxygen. This appears to be related to genotype-environment interactions.

The flesh of triploid rainbow trout females is superior to that of diploid females because postmaturation changes are prevented (Bye and Lincoln, 1986). In Scotland, a system of sex-reversal and breeding (see Sex Manipulation etc.) is used to produce monosex female populations of rainbow trout. There is also a smaller demand (<10 percent) for monosex triploid females, where larger fish are required for aquaculture or restocking into angling waters. This will produce fish with both superior growth rate and flesh quality (Bye and Lincoln, 1986). Other European countries also produce monosex females and triploids according to requirements. Triploid salmonid hybrids show similar (Quillet et al., 1987) or slower growth than diploid hybrids, but may grow faster than controls once they reach maturity (Quillet et al., 1987). The rainbow trout x coho salmon triploid showed decreased growth, but increased resistance to infectious haematopoietic necrosis (IHN) (see also section on hybridization above).

Overall carcass percentages and resistance to haemorrhagic septicaemia (caused by Aeromonas hydrophila) showed no difference between the triploid or diploid catfish (Lakhaanantakun, 1992).

Triploidy has been induced in oysters, e.g. Crassostrea gigas, (Guo et al., 1996) primarily to increase their size and flesh quality (Dunham, 1996a). Triploid oysters do not produce large gonads and are therefore more marketable. This technique may or may not result in complete genetic sterilization for oysters, as some triploids are able to revert a portion of their cells back to the diploid state, thus creating “mosaics” (S. Allen, pers. comm.).
CSIRO has induced polyploidy in embryos of Kuruma prawn (Penaeus japonicus) via heat shock (N. Preston, pers. comm.) to assess the effects of polyploidy under controlled laboratory conditions. To date, no effects on growth, maturation or fertility have been detected.

Polyploidy is not commercially feasible for all species. Brämick et al. (1995) suggest that the use of triploid tilapia would reduce unwanted reproduction and stunting and would significantly increase yields from pond culture. However, mouth brooding of many tilapia, low numbers of eggs per batch and asynchronous spawning mean that

The culture potential of triploid common carp was evaluated by Cherfas et al. (1994). Most one-year-old triploids had undeveloped gonads and were sterile; however, in contrast to the expected positive effect of sterility on growth rate, the triploids grew slower than their diploid siblings under all conditions investigated. Thus the potential for culture of triploid common carp appears questionable. Results from India, however, found that triploid common carp had a higher dressout percentage than diploid controls (Y. Basavaraju, pers. comm.). Results were also equivocal for gilthead seabream x red seabream triploid hybrids (Gorshkova et al., 1995), compared to either parent.

Polyploidy in the Asian catfish Clarias macrocephalus was induced by cold shock and resulted in 80 percent triploidy (Na-Nakorn and Legrand, 1992). The effects on survival rate were not significantly different from diploid controls during the first two months, but in the third to fifth month, triploid fish showed lower survival rates and body weight compared to the diploid group. Diploids showed better food conversion ratios than triploids in the first month, but this evened out between the second and fourth month.

it is not currently feasible to commercially produce triploid tilapia.

Sex manipulation and breeding

Various strategies utilizing sex reversal and breeding, progeny testing, gynogenesis and androgenesis can lead to the development of predominantly, or completely, male or female populations, or a "super-male" genotype (YY). The primary aim is to take advantage of sexually dimorphic characteristics (including flesh quality), control reproduction or prevent establishment of exotic species. All female populations have been successfully developed for salmonids, carps and tilapias. Populations of super males (i.e. fish with two rather than one Y chromosome) have been established for Nile tilapia, salmonids and marginally, for channel catfish (Dunham, 1996a).

Monosex populations may be produced by direct hormonal treatment; however, where the fish are destined for human consumption, some countries (e.g. the European Union (EU), the United States, India) may prohibit such treatment.

Alternative methods require additional understanding of the variety of mechanism(s) determining sex differentiation for each species in question. While many commercially cultured families exhibit the usual XX/XY sex determination mechanism (carps, salmonids), where XX are females and XY are males, others may be sequential hermaphrodites (change sex as they mature), such as gilthead seabream and groupers, or have temperature-controlled sex determination in addition to an XX/XY mechanism (e.g. in *Nile tilapia* (Mair et al., 1991) and hirame [Yamamoto, 1999]]. For others, such as the European seabass, sex differentiation mechanisms have yet to be identified, although temperature appears to be important (Dunham, 1996a; Blázquez et al., 1998). Different mechanisms may also be found in closely related species. The Nile tilapia has the XX/XY system with the female being XX, while the blue tilapia has a WZ/ZZ system with the male being ZZ 2.

Sex reversal and breeding has allowed production of YY channel catfish males that can be mated to This has enabled the production of YY males and all male progeny, XY (known as "genetically male tilapia" [GMT] to distinguish them from sex reversed male tilapia), on a commercial scale. The YY male technology provides a robust and reliable solution to culture problems with early sexual maturation, unwanted reproduction and overpopulation (Mair et al., 1995; Tuan et al., 1998, 1999; Abucay et al., 1999).

Sex ratios vary widely between spawnings of *Nile tilapia*, but at the population level, they maintain a normal distribution of around 1:1 males to females. Overall sex ratios vary, however, among strains of Nile tilapia (Shelton et al., 1983; Mair et al., 1991). Lester et al. (1989) observed greater heterogeneity in the sex ratios of families collected from a mix of strains, some of which were introgressed with O. mossambicus (Macaranas et al., 1986). YY males crossed with XX females produce 95-100 percent males, and Scott et al. (1989) observed no females from the mating of 285 progeny of a single YY male crossed to ten separate females.

normal XX females to produce all-male XY progeny. Males that are XY can be turned into phenotypic females by use of sex hormones and can then be used as breeders (Goudie et al., 1985). The sex ratio of progeny from the mating of XY female and XY male channel catfish was 2.8 males: 1 female, indicating that most, if not all, the YY individuals are viable. All-male progeny are beneficial for catfish culture, since they grow 10-30 percent faster than females (Benchakan, 1979; Dunham and Smitherman, 1984, 1987; Smitherman and Dunham, 1985). YY males are also viable in salmonids, Nile tilapia, goldfish and channel catfish (Donaldson and Hunter, 1982). The channel catfish YY system has stalled, however, because YY females have severe reproductive problems, and large-scale progeny testing is not economically feasible to identify YY males (K. Davis, pers. comm.). A combination of sex-reversal and breeding to produce all-female XX rainbow trout is now the basis for stocking most of the culture industry in the United Kingdom (Bye and Lincoln, 1986), as is the case for the chinook salmon industry in Canada. All-female populations are desirable, in this case, because males undergo maturation at a small size, and have poorer flesh quality. Monosex chinook (*O. tshchawystcha*), and coho crossed with chinook have also YY-GMT technology has strong potential for commercial application, since YY *Nile tilapia*, unlike channel catfish, can be sex reversed to produce functional females. The progeny of the YY-GMT males increase yields by up to 58 percent compared to mixed sex tilapia of the same strain (Mair et al., 1995). This is also greater than yields from sex-reversed male tilapia. In addition, YY-GMTs have more uniform harvest size, greater survival and better food conversion ratios. GMT production is relatively environmentally friendly. No hormones are applied and hormone application to the broodstock is low. Species/strain purity is maintained and the fish produced for culture are normal genetic males. Although the development process is time-consuming and labour-intensive, once developed the production of monosex males can be maintained through occasional feminization of YY genotypes and existing hatchery systems without any special facilities or labour requirements. Additional costs for application of this technology at the hatchery level would be minimal. Research on YY male technology has been widely disseminated in the Philippines since 1995, Thailand since 1997 and, to a lesser extent, in a number of other countries including Vietnam, China, Fiji and the United States. In the Philippines and Thailand, broodstock are been produced (Hunter et al., 1983).

YY male *Nile tilapia* were as viable and fertile as XY males, and capable of siring 95.6 percent male offspring (G. Mair un published data). YY genotypes can be feminized to mass produce YY males, eliminating the need for time-consuming progeny testing to discriminate XY and YY male genotypes.

distributed from breeding centres to accredited hatcheries. This maintains quality control and, although limiting scale of dissemination, keeps it within financial viability - essential for long-term sustainability.

Based on impending availability of further improved GMT, along with increasing resistance to use of hormones in aquaculture, this technique is likely to impact tilapia culture on a global scale.

A meiogynogenetic line of blue tilapia (O. aureus) was established and gynogenetically propagated for five generations at the Faculty of Life Sciences, Bar-Ilan University, Israel. Mitogynogenetic O. aureus were subsequently produced (Shirak et al., 1998) using third generation meiogynogenetic females from this stock. Three generations of gynogenetic O.

Gynogenesis, androgenesis and cloning

Gynogenesis, and androgenesis are techniques to produce rapid inbreeding and cloned populations. Gynogenetic individuals ("gynogens") produced during meiosis ("meitoic gynogens") are by definition "inbred", since all genetic information is maternal. "Meiotic gynogens" are not homozygous, since cross-overs and recombination during oogenesis produce different gene combinations in the ovum and second polar body. The rate of inbreeding through gynogenesis is niloticus were also produced, and males from this line were used for hybridization with gynogenetic O. niloticus females, resulting in consistent production of 100 percent male hybrids (R.R. Avtalion, pers. comm.).

In Israel, all-female common carp populations (Cherfas et al., 1996) have been established using sex-reversed XX gynogenetic females crossed to males (Gomelsky et al., 1994), and using these XX males for breeding. All-female offspring were released to commercial farms and resulted in 10-15 percent yield improvement over existing commercial stocks. Gynogenesis and sex-reversal have also successfully induced in Morone spp. to produce monosex populations to avoid limitations on introductions to areas where this species is exotic (Gomelsky et al., 1998, 1999).

Monosex female Java barb are another example of sex manipulation being adapted to a commercial scale over a relatively short period (eight years), and largely in Asia (Thailand and Bangladesh). Pongthana et al. (1995, 1999) found that gynogenetic Java barb were all female and showed it was possible to hormonally masculinize these fish. Most of the breeding of the resultant neomales produced all, or nearly all, female progeny. These gave greater yields in pond culture roughly equivalent to one generation of full-sib mating. Mitotic gynogens are totally homozygous, but are more likely to die during embryonic development due to the higher frequency of deleterious genotypes found in 100 percent homozygous individuals.

Androgenesis, or all-male inheritance, is more difficult to accomplish than gynogenesis (Scheerer et al., 1986), since diploidy can only be induced in androgens at first cell division, a difficult time to manipulate the embryo. Also androgens are totally homozygous, so a large percentage with deleterious genotypes probably die (Scheerer et al., 1986).

Gynogenesis and androgenesis can be used to elucidate sex-determining factors in fish. If the male is the homogametic sex when androgens are produced, the androgens will be 100 percent ZZ (all-male). If the male is the heterogametic sex, XX and YY androgens will be produced, resulting in both sexes.

Fully inbred clonal lines have been produced in zebrafish, ayu, common carp, Nile tilapia and rainbow trout (Komen et al., 1991; Sarder et al., 1999) using both gynogenetic and androgenetic techniques. These should have identical genotypes throughout their than mixed-sex batches and, perhaps surprisingly, had higher survival rates than the mixed-sex fish. Hatchery trials in Thailand showed that neomale broodstock performed satisfactorily. Monosex female fingerlings from neomale broodstock are now supplied on a commercial scale in Thailand. Similar research is ongoing elsewhere in the region.

entire genome. However, the performance of individuals within such clones is highly variable. Individuals with extreme homozygosity appear to lose the ability to respond to environmental variables in a consistent, stable manner, and even micro-environmental differences affect performance among individuals (Komen et al., 1991). Therefore, as genetic variation decreases, environmentally induced variation increases, and at a more rapid rate than in heterozygous populations.

Interspecific nuclear transfer

Interspecific nuclear transfer has been accomplished, primarily for cyprinids in China, resulting in embryos with the cytoplasm and mitochondrial DNA of the host species and the nuclear DNA of the donor species. As a result, these fish may exhibit traits from both parental species. This technology may later prove key for the application of gene knock-out technology3.

Gene transfer and genomics

More recently, GH gene constructs have been developed that are comprised entirely of fish gene sequences: ocean pout (Macrozoarces americanus) antifreeze promoter driving a chinook salmon GHcDNA, or sockeye salmon (*Oncorhynchus nerka*) metallothionein promoter driving the full-length sockeye GH1 gene. When introduced into salmonids, these constructs elevate circulating GH levels by 40 fold in some cases (Devlin et al., 1994; Devlin, 1996) and induce 5-11 fold increases in weight after one year

Compared to the thousand years of aquaculture and its genetic improvement programmes (deliberate and "unintentional", see Domestication section), aquaculture genomics and gene mapping are truly in their infancy. Molecular genetics is less than thirty years old, although DNA was only discovered 47 years ago. However, the late 1990s have seen an explosion in genomics and gene mapping of aquatic organisms. Many fish genes and regulatory sequences have been identified and isolated, and the fish genome is now better understood (Kocher et al., 1998). Likewise, gene maps are also being generated for oysters (Gaffney et al., 1997) and some penaeid shrimp (Li et al., 2000).

The first successful form of gene transfer, "genetic engineering", was accomplished in China in 1985 and has subsequently been achieved in other countries. Most of this work focussed on hormone enhancement of growth (size and rate), with results ranging from 0 percent up to an incredible 300 percent under some conditions. Due to the lack of fish gene sequences, initial transgenic research in the mid-1980s employed mammalian growth hormone (GH) gene constructs, which enhanced growth in some, but not all fish species examined (Zhu et al., 1986; Enikolopov et al. 1989; Zhu 1992; of growth (Du et al., 1992; Devlin et al., 1994, 1995a). Precocious smoltification (physiological adaptation from fresh water to sea water) was also noted (Rahman and Maclean, 1999).

When a gene is inserted with the objective of improving a specific trait, it may affect another trait. Such "pleiotropic" effects can be positive or negative, thus it is important to evaluate all important traits in transgenic fish - not just the trait under active alteration. Transfer of growth hormone genes has been documented to affect body composition, body shape, feed conversion efficiency, disease resistance, reproduction, tolerance of low oxygen concentrations, carcass yield, swimming ability and even predator avoidance.

Rainbow trout growth hormone (rtGH) transgene reduces survival of common carp and the number of F2 progeny inheriting the transgene is less than expected. Differential mortality or loss of the recombinant gene during meiosis are likely explanations, since transgenesis was evaluated after the fish reach fingerling size. Remaining transgenic individuals, however, showed higher survival than controls when subjected to a series of stressors, such as low dissolved oxygen (0.4 ppm)(Chatakondi et. al., 1995b).

Gross et al. 1992; Wu et al. 1994). Salmonids showed no effect (Guyomard et al., 1989a, b; Penman et al., 1991), despite the fact that they are very responsive to growth stimulation by exogenously administered GH protein (McLean and Donaldson, 1993). Subsequent gene constructs using fish GH sequences have stimulated some growth enhancement (less than a doubling of weight compared with controls) in carp, catfish, zebrafish and tilapia (Zhang et al., 1990; Dunham et al., 1992; Chen et al., 1993; Zhao et al., 1993; Martinez et al., 1996), providing the first convincing evidence that growth enhancement in fish can be achieved by transgenesis.

Increased growth rate in transgenic individuals may reflect increased food consumption, feed conversion efficiency, or both. Fast growing common carp containing the rtGH gene were found to have a higher feed conversion efficiency than controls (Chatakondi et al., 1995a). Various other transgenic common carp families demonstrated increased, decreased or unchanged food consumption, but had improved feed conversion efficiencies. Body composition of rtGH transgenic common carp differed from controls by having more protein, less fat and less moisture than nontransgenic full-siblings (about a ten percent change). Growth hormone promotes synthesis of protein over fat, thus the protein/lipid ratio is higher in transgenic fish with elevated growth hormone.

Increased protein levels in the muscle of transgenic common carp also increased levels of amino acids. However, amino acid ratios and fatty acid ratios are virtually identical in control and transgenic common carp (Chatakondi et al., 1995a). Fecundity or precocious sexual development appear to be unaffected by insertion of rtGH in common carp; however, transgenic male tilapia show decreased sperm production (Rahman and Maclean, 1999). Body shape of common carp is also changed by insertion of rtGH genes. Transgenic individuals have relatively larger heads and deeper and wider bodies and caudal areas compared to controls. As growth differences increase, body shape differences also increase, but then plateau. These morphological changes do not affect condition factor, but do improve the dressing percentage (Chatakondi et al., 1994).

Salmonids injected with somatotropins display improved feed conversion (Devlin et al., 1994b), an effect also anticipated in GH transgenic salmonids. In some GH transgenic salmon, however, endocrine stimulation could be elevated to pathological levels and excessive, deleterious, deposition of cartilage was observed (Devlin et al., 1995b), analogous to mammalian acromegaly. The effect can be severe enough to impair feeding and respiration, reducing

Much work is ongoing on production of framework linkage maps with greater numbers of markers, particularly type I markers of known genes; quantitative trait loci (QTLs) involved in determination of performance traits important to aquaculture and marker-assisted selection, development of mapping tools, i.e. radiation hybrid panels in tilapia , BAC libraries in catfish (G.C. Waldbiser unpubl. data); and construction of normalized cDNA libraries for EST analysis and functional analysis. Similar work is being undertaken for significant pathogens of commercially important aquaculture species – especially viral, bacterial and protistan agents that are difficult to detect, isolate and/or differentiate from benign relatives. This work is focussed on improving the rapidity and accuracy of current disease diagnosis (Subasinghe et al., this volume).

In the last few years, large numbers of molecular markers have been developed and evaluated for application in the culture of catfish, as well as other commercially important species. Of the several types of markers evaluated, microsatellites and AFLP (amplified fragment length polymorphisms) markers were most reliable, efficient and reproducible for genetic linkage mapping in catfish (Liu et al., 1998a, b, 1999a, b, c, d, in press). Although continuing growth and viability. Thus the fish with the greatest growth enhancement are those that were only moderately stimulated (Devlin et al., 1995a).

Linkage mapping

Although initiated later than for other agricultural animals, aquaculture genomics has seen dramatic progress over the last ten years (Kocher et al., 1998; Liu and Dunham, 1998; Waldbieser et al., 1998). This includes progress in construction of framework genetic linkage maps for catfish (Li et al., 2000), tilapia (Lee and Kocher, 1996; Kocher et al., 1998; Agresti et al., 2000; McConnell et al., 2000) , salmonids (Young et al., 1998; Hoyheim et al., 1998), penaeid shrimp (Li et al., 2000), and Crassostrea and Ostrea spp. oysters (Hubert et al., 2000)). Genomic mapping of these five phyletic groups was recently approved by the United States Department of Agriculture (USDA) as a regional project (NE-186). The P. monodon genome is being mapped in an International Shrimp Map collaborative effort, initiated in 1998 (Li et al., 2000).

efforts by several laboratories are producing more type II markers in catfish for linkage mapping, fine linkage mapping depends on availability of large numbers of ESTs and anchoring of well-ordered contigs of BAC clones to linkage maps.

Early work on catfish linkage mapping used isozyme markers (Hallerman et al., 1986; Carmichael et al., 1992; Liu et al., 1992; Morizot et al., 1994). Over the last few years, however, over 350 microsatellite markers and over 600 AFLP markers have been mapped (Li et al., 2000) and an additional 100 microsatellite markers are anticipated by the end of 2000. Similar progress has been made with tilapias (T. Kocher, pers. comm.).

Marker-assisted selection

In aquaculture species, much effort is devoted to QTL mapping. QTL markers for growth, feed conversion efficiency, tolerance of bacterial disease, spawning time, embryonic developmental rates and cold tolerance have been identified in channel catfish, rainbow trout and tilapias (LaPatra et al., 1993, 1996). Putative linked markers to the traits of feed conversion efficiency and growth rate have been identified for channel catfish.

In trout and salmon, a candidate DNA marker linked to infectious haematopoietic necrosis (IHN) disease resistance has also been identified (Palti et al., in press). In shrimp, Dr Acacia Alcivar-Warren and several researchers at the Oceanic Institute of Hawaii are evaluating for marker-assisted selection for penaeid shrimp. Drs Gaffney, Guo, Allen, Hedgecock and others are working toward QTLs for control of disease problems in oysters.

Combining genetic enhancement programmes

The best genotypes for aquaculture applications in the future will be developed by using a combination of traditional selective breeding and the new biotechnologies described above. Initial experiments indicate good potential for this combined approach, with examples using mass selection and crossbreeding, genetic engineering and selection, genetic engineering and crossbreeding, and sex reversal and polyploidy; all work more effectively in combination than alone.

development, a number of constraints and limitations need to be recognized and addressed, including:

- environmental issues - biodiversity, genetic conservation, and environmental risk of genetically altered aquatic organisms;
- research issues - funding and training of scientists;
- economic and consumer issues - proprietary rights, dissemination, food safety and consumer perceptions;
- political issues - government regulation and global cooperation; and
- ethical issues - manipulating and owning life at the chemical and biological level.

Environmental issues

The impact of aquacultured organisms, including domesticated strains, interspecific hybrids, polyploids and genetically engineered stocks on genetic variation, population numbers and

Genotype-environment interactions

Since the best genotype for one environment is not necessarily the best genotype for another environment, genetically improved animals that work well in a research environment may not necessarily be the best performers under commercial conditions. In general, genotype-environment interactions increase for aquacultured animals with increasing genetic distance and increasing environmental differences, especially associated with species such as carps or tilapias that can be cultured simply and low on the food chain or with complete artificial feeds.

Future development

Genetic improvement is an ongoing process with tremendous opportunity for sustainable aquaculture development. As current demands increase and wild stocks are overexploited, more management tools will be required to increase aquaculture production. Genetic enhancement is an increasingly important component of the management toolbox and, if used properly, has strong potential to enhance aquaculture production, efficiency and sustainability.

Constraints and limitations

fitness of conspecifics, as well as on the ecosystem in general, is currently under debate. Unfortunately, few scientific data exist on interactions between domestic and wild aquatic populations to enlighten the debate or assist policy and management decisions.

It is recognized that farmed species can interact with other species under open-culture systems. The degree of interaction constitutes the basis for determining the ecological hazard(s), if any. Likewise, interaction with conspecifics constitutes the genetic hazard. Physical containment has, historically, only been partially successful in containing aquaculture stocks. A mechanism that prevents breeding in exotic, highly selected or transgenic stocks is considered to be a better option. CSIRO has begun research on a transgenic technology that creates functional sterility, so stocks can only complete their life cycle under culture conditions and any escapees are unable to breed or produce viable offspring.

Where viable culture stock can escape, ecological hazards include alteration of predation, resource competition, or other behavioural dynamics, as well as establishment of the cultured stock in ecosystems outside the natural range of their species. The degree of

Before any of the opportunities discussed above can be fully realized and genetics can achieve its maximum on aquaculture

interbreeding impact will depend on the fitness of the novel genotypes in the wild. Concerns about environmental hazards posed by genetically improved species are generally inferred on ecological principles (Kapuscinski and Hallerman, 1990a, 1991; Hallerman and Kapuscinski, 1992, 1993).

Experimental evidence (Dunham, 1996a, b; Farrell et al., 1997; Devlin et al., 1999; Guillen et al., 1999; Muir and Howard, 1999) supports the view that some genetically improved fish could pose ecological risks, e.g. infertile triploid male salmon undergo sexual maturation, seek matings and can negatively impact brood production. This would pose a significant demographic risk to small natural populations they might enter. Triploid Pacific oysters, Crassostrea gigas, can exhibit reversion to diploidy ("mosaics"), although it is not known if they can re-assume reproductive capability. Since oysters are cultured, by necessity of access to natural feed in open water, the use of triploidy to limit potential for

Evidence suggests that increased efficiency in capture fisheries has selected against certain traits, such as size, over the last 200 years (Ricker, 1975, 1981). Restocking fish appropriately genetically managed could help restore genetic diversity.

- Replacement of genetically wild populations - long term survival of an escaped population of farmed fish to the point that it would replace a wild population is unlikely unless there are continued releases or escapes of the farmed strains. Data to date indicate that this is unlikely, especially in the case of highly domesticated strains, e.g.

interaction/establishment needs further evaluation.

Depending in the extent of phenotypic and/or genotypic change due to transgenisis improvement, a genetically improved species can be considered to be analogous to an exotic species. For example, attempts were made to introduce antifreeze protein genes from winter flounder into Atlantic salmon to increase their cold tolerance (Shears et al., 1991), allowing the fish to be farmed in areas outside their natural distribution. In such cases, sterilization would reduce the risk of establishing wild populations, but methods such as triploidy decrease performance (Dunham 1996b) and fertile broodstock are still necessary, so risk is minimized but not eliminated. In many countries, it has also been common practice to introduce exotic species to address shortcomings in aquaculture performance of native species (Welcomme, 1988). Use of genetically improved organisms from indigenous aquaculture species is probably an environmentally safer means of addressing the aquaculture productivity shortcomings and is less likely to impact biodiversity or genetic diversity compared to introduction of exotic species.

With respect to escaped farmed species, there are three scenarios

genetically modified organisms (GMOs) (Devlin et al., 1995a; Dunham, 1995; Dunham et al., 1995; Chitminat, 1996). However, escaped Atlantic salmon in Norway do outnumber wild salmon in many rivers.

- Co-existence of the escaped fish with no interbreeding - This appears to be the case in Atlantic salmon culture in the Pacific Northwest, as escaped Atlantic salmon are breeding in small numbers, but not with Pacific salmon (B. Harvey, pers. comm.).

Article 9.3 of the FAO Code of Conduct for Responsible Fisheries (CCRF) addresses "Use of aquatic genetic resources for the purposes of aquaculture including culture-based fisheries". This article calls for:

- conservation of genetic diversity and ecosystem integrity;
  minimization of the risks from nonnative species and genetically altered stocks;
- creation and implementation of relevant codes of practice and procedures; and
- adoption of "appropriate" practices for genetic improvement and selection of broodstock and their progeny.

specific to genetic issues:

- Addition to genetic diversity - artificial genetic diversity could increase fitness in some endangered populations or species and make such genetic units more viable. Although aquatic examples are few, an analogous terrestrial example would be the cheetah, where genetic homogeneity now threatens their survival. Interbreeding in this case, could be an option to restore reproductive performance and sustain the species.

Article 9.2.3 advises, *"States should consult with their neighbouring States, as appropriate, before introducing non-indigenous species into transboundary aquatic ecosystems"* and the Technical Guidelines on Aquaculture Development state, *"Consultation on the introduction of genetically modified organisms should also be pursued. The definition of 'non-indigenous', in the broadest sense of the term, should include organisms that are the product of domestication, selective breeding, chromosome manipulation, hybridization, sex-reversal, and gene transfer".*

Research Issues

The current lack of trained fishery and aquaculture geneticists is a constraint that needs to be addressed in order to effectively

Bearing in mind collaborative vs. competitive issues mentioned under research issues, another prime economic issue is related proprietary rights. Ownership, in cases of international genetic material transfer, is an ongoing issue, with clear examples emanating from human genetic studies. Genetic research and breeding programmes require significant financial support. Appropriate, equitable dissemination and ownership of genetic material developed with tax money or donor funding, and aimed at improving economic development in impoverished countries, is a complex and often controversial topic. The issue is further complicated by the initiation of private biotechnology companies that supply alternatives to government-mediated technology transfer. The pursue research and accurate impact assessment protocols. Both are needed to ensure that genetic research and genetic material development are appropriate for the commercial sector, applied properly and disseminated efficiently to achieve maximum benefit. With respect to environmental risks, more research is needed on reproductive performance, foraging ability and predator avoidance as key factors determining fitness of transgenic fish. This should be standard data gathered for risk

most cost-efficient dissemination strategies with the highest impact have not yet been completely defined or evaluated.

Patenting and intellectual property protection are so complicated that international instruments dealing with the issue are in conflict. The World Trade Organization (WTO) and the United States allow patenting of living organisms, whereas the European Community (EC) does not (http://www.uspto.gov/web/offices/pac/doc/general/what.ht). Aquaculturists need to be aware of the controversies associated with patenting GMOs, and how these affect marketing, proprietary rights and trade in certain areas.

Political issues

Worldwide, policies for research and marketing of transgenic food organisms range from non-existent to stringent, as in the European Union (EU). Government regulation of transgenic aquacultured species, based on sound scientific data, is lacking and much needed. Not surprisingly, global cooperation on issues of biotechnology is not unified. Countries party to the Convention on Biological Diversity (CBD) and involved in the WTO are divided on key issues such as:

- transport of transgenic organisms between countries,
- precautionary principles driving biosafety decisions,
- liability in the case of negative effects on human health or biodiversity,
- possible social and economic impacts on rural cultures,
- regulation of transgenic products across borders,
- food safety, and
- protection of transgenic trade goods.

assessments prior to any commercial release or application.

Aquatic animal research in aquaculture is underway throughout Asia, Europe and the Americas. Organized development of these programmes is required to help ensure that environmental risk and fitness traits, as well as food safety issues, are well-addressed at the research stage. Collaborative networks to develop protocols for, and conduct sound and safe review of genetically improved aquatic animal research are needed to help ensure that results are beneficial. Cooperative learning from previous research oversights, rather than competitive secrecy, should also enhance future research economically and technologically.

Economic and consumer issues

Consumer education on the positive aspects of genetic biotechnology, as well as risk management, is particularly urgent. Concerns over consumption of transgenes, related proteins, toxic by-products, activation of viral sequences and allergenicity of transgenic products are all questions requiring science-based answers. Most have been analysed, and allergenicity appears to be the most critical concern with a data basis, making it one of the strongest arguments for enactment of some type of labelling (Weiss, 1999). A recent example of a transgenic soybean expressing a gene from Brazil nuts to increase its protein content was found to be allergenic to humans (Nordlee et al., 1996). Food safety issues posed by transgenic fish are discussed by Berkowitz and Kryspin-Sorensen (1994). Those from other aquatic animals are still under investigation.

Recently, however, international legislation, guidelines and codes of conduct have been, or are being, established to help address these areas of concern.

International instruments, some legally binding and others voluntary, cover a broad range of issues associated with GMOs in aquaculture, including introduction (transboundary movements) and release into the environment, international trade, human health, labelling, intellectual property rights and ethics.

Kapuscinski et al. (1999) proposed a framework of adaptive biosafety assessment and management involving definition of goals,

Since commercialization of aquatic GMOs will go forward within a global market for fisheries products, it is appropriate to consider international trade policies that will affect commercialization of GMOs. Multilateral discussion of means for promoting international trade occurs within the WTO. The mandate of the WTO, organized through the General Agreement on Tariffs and Trade (GATT), is to promote international commerce. While this mandate may not seem relevant to conservation of biodiversity or to environmental and food safety issues posed by GMOs, certain decisions made by the WTO have important bearing (Baker, 1998). The recent meeting of the WTO in Seattle was aimed at problem analysis and policy design, policy implementation, and monitoring for the effects of management actions. This recognizes the fact that our knowledge of the environmental and social systems into which GMOs will enter is always incomplete, and that unexpected effects of GMOs are inevitable. Biosafety regimes cannot simply be divided into sequential phases of research, policy design and implementation. Nor can they be reduced to a single passage through these different phases. They also need to be transparent to the general public, and to engage society at critical points in decision-making, in order to maximize the public's trust in policy implementation. Kapuscinski et al. (1999) propose that fisheries and aquaculture professionals press for adoption of an adaptive management framework by relevant national or international bodies. In terms of implementation, a truly comprehensive set of biosafety policies would include measures for risk management, capacity-building programmes, national permitting of trade and uses of GMOs, genetic marking for international trade of GMOs, and an international system of liability and compensation. Aspects of this framework are relevant at any level of political jurisdiction, from local to national to international.

The management framework should setting the agenda for a new round of international trade negotiations. There were concerns over commercialization of GMOs, and one of the key issues that deadlocked talks between trade ministers at the meeting was biotechnology. The United States sought formation of a WTO working group on genetically modified goods, hoping to establish rules that would protect trade in these goods. Europe resisted, arguing that the safety of such products had not been proven (Kaiser and Burgess, 1999). General agreement ultimately was reached on establishing a WTO group to study international trade in genetically modified foods (Pearlstein, 1999).

Although debate focussed on genetically modified crops and related products, similar issues loom for aquaculture products. For example, starting in 1996, Otter Ferry Salmon in Scotland initiated a growth trial with transgenic Atlantic salmon in a closed system. The fish were grown for 18 months and destroyed. The Scottish Salmon Association distanced itself from the experiments, fearing a market backlash. There was an uproar in the United Kingdom in late July when it was revealed in the British House of Commons that the government had approved the privately funded experiment with transgenic salmon. Seafood Datasearch (1999) noted that be based upon science. Biosafety assessment of transgenics has begun for aquaculture species such as channel catfish ,salmon and Nile tilapia. In general, the data from these initial studies indicates that these transgenic fish demonstrate fitness traits such as decreased predator avoidance , lack of enhanced growth under foraging conditions, decreased swimming ability and lower sperm counts(Dunham 1995,1999;Dunham et al. 1995,1999;Farrell et al. 1997) that would likely make their genotypes less competitive than wild genotypes in the environment.

although the technology worked – the salmon grew at four times the rate of controls – the extent to which the technology will be adopted will depend on market acceptance of genetically modified foods. They reported that nine salmon-growing countries agreed to ban use of genetically modified fish.

The challenge to aquaculturists, fisheries scientists, and policy-makers is to strike an appropriate balance between realizing the potential for economic development posed by aquaculture biotechnology while minimizing any risks to the environment and human health. Beneficial use of biotechnology in aquaculture development programmes will require sustained efforts aimed at deploying well chosen, sustainable applications.

This will require active participation by a wide range of aquaculturists, fisheries scientists, public policy specialists and other professionals. As described above, decision support aids now exist for assessing and managing any risks posed by the use of aquatic GMOs.

Recommendations

General recommendations

Genetic improvement of cultured fish and shellfish that increases productivity and turnover rate, results in better use of resources and reduces production costs, should be given higher priority by government, NGOs and commercial organizations. Such improvement methods include:

- multiple trait selection programmes;
- efficient breeding plans, in which selection is combined with other genetic technologies;
- better genetic controls for monitoring the progress of breeding programmes;
- more education and training programmes for aquaculture geneticists, especially in developing countries;
- the establishment of national and international genetic controls, including homozygous and heterozygous

- Networking (e.g. International Network for Genetics in Aquaculture (INGA)) to circumvent the current lack of resources (human and infrastructure) in developing countries and to strengthen sharing of information, experience, education and research and to assist in obtaining funding.
- Design and promotion of equitable dissemination strategies that ensure genetic enhancements have positive impacts on aquaculture, food security and enhance livelihoods.
- Research should be carried out to assess the impact of research, development and dissemination of genetically improved stocks, including intellectual property rights issues.
- Species and traits need to be prioritized for genetic enhancement programmes that better address global food security.

Biodiversity issues

- Aquatic biodiversity needs to be characterized and protected.
- Population genetics of many key species require closer examination.
- Interactions of wild and

clonal populations for key species to help in comparing genetic results and genetic material from different research institutions, increase global cooperation and enhance research efficiency; and
- domestication of cultured organisms such as shrimp and molluscs that still rely on wild seed.

Specific development issues

- There is an urgent need for intervention and collaboration in developing hatchery management and breeding programmes for low-value/low-input species in developing countries.
- Good broodstock management needs to be promoted to avoid inbreeding problems.
- Species and traits relevant to low-input systems need to be prioritized for genetic enhancement programmes that better address food security issues.

domesticated species need more detailed study, including modelling.
- There should be an intensification of live, frozen and molecular gene banking efforts strongly linked to in situ conservation.
- More research is needed in the area of effective sterilization techniques for domesticated and genetically improved aquatic organisms.
- There is a need for greater controls of transboundary movements of aquatic genetic material, and development of more efficient containment systems.
- Research on genetically improved aquatic organisms should continue because of their potential benefits (especially in developing countries); however, much greater understanding of potential environmental impacts is necessary.
- Linkages should be formed among the general public, organizations, scientists, industry and governments to address genetic issues and to support the development of practical regulation and sound policy.
- Dissemination of genetically improved aquatic organisms for aquaculture should only be carried out within the

framework of adequate regulations and policy.

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[2] Sex chromosomes are named differently in Nile tilapia (X and Y, with females being the homogametic sex) and blue tilapia (W and Z, with males being the homogametic sex) to indicate the different sex-determining mechanisms in the two species.

[3] Cell lines would be transfected with knock-out constructs to disrupt specific genes. The cells would then be screened to identify transformed cells, and these cells grown. Nuclei from the transformed cell line would be transferred to activated enucleated embryos to make knock-out transgenic embryos with

the targeted gene knocked-out or inhibited (Z. Liu, pers. comm.).

Aquaculture Development, Health and Wealth[1]

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ABSTRACT: This paper describes how disease has become a primary constraint to sustainable aquaculture production and product trade. It provides specific examples of the impacts of transboundary aquatic animal diseases on international trade, as well as socio-economic and biodiversity implications. Different measures to deal with diseases of fish and shellfish are also enumerated in terms of international codes, regionally oriented guidelines, national programmes and legislation (with specific examples from both developing and developed countries), technology for diagnostics, therapy and information communication. Approaches to aquatic animal health management covering generic (e.g. good husbandry, prevention and control), systems health management and epidemiological approaches and disease surveillance and reporting systems are also discussed.

Aquatic animal health management programmes carried out in different parts of the globe are evaluated with respect to efficacy of disease prophylaxis/control and pathogen detection/disease diagnostics, inherent problems with national legislation and international/regional codes, and the effectiveness of programmes on education, training and extension services. Health management problems that pose risks to rural small-scale aquaculture are discussed, and the need for special consideration of this aquaculture context is emphasized. The need for effective communication at all levels of the production system is also discussed. The roles of the private sector (e.g. aquaculturists, industry associations, cooperatives etc.); professional societies; diagnosticians and researchers; and education, training and other related extension services in effective health management are also discussed. The roles of government at the regional and international levels, along with actions needed to address gaps in effective health management are also discussed.

The importance of aquaculture in meeting increasing demands for aquatic animal production and it's role in providing livelihood opportunities and economic security are underlined. These and the difficult options available for health management present a truly big challenge to all concerned. If maintained at present levels, major epidemics will continue to threaten many sectors, break out and impact the ultimate goal of aquaculture sustainability.

KEY WORDS: Aquaculture, Health Management, Quarantine, Disease Control, Transboundary Movement

Introduction

Aquaculture, as clearly indicated elsewhere in these proceedings, is the fastest growing food-production sector in the world, providing a significant supplement to, and substitute for, wild aquatic organisms. However, disease is a primary constraint to the growth of many aquaculture species and is now responsible for severely impeding both economic and socio-economic development in many countries of the world. Addressing

Reports and records of these diseases are provided by an OIE Collaborating Centre (www.cefas.co.uk/oie.html), in order to keep up-to-date on their geographic distributions.

In addition to OIE-listed diseases, many more diseases of regional or national interest have significant impacts on aquaculture productivity. Some of these are well-studied and understood, while others are of unknown aetiology or newly emergent. Such diseases can pose health questions with both pro-active and reactive programmes has thus become a primary requirement for sustaining aquaculture production and product trade.

The Office International des Épizooties (OIE - World Organisation for Animal Health) lists 29 diseases of finfish, molluscs and crustaceans which fit the criteria of the OIE as being of significant economic importance and thus reportable to the (OIE, 2000a). The criteria used for this list are as follows:

"Diseases notifiable to the OIE means the list of transmissible diseases that are considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of aquatic animals and aquatic animal products. Reports are normally submitted once a year, although more frequent reporting may be necessary in some cases to comply with Articles 1.2.0.2. and 1.2.0.3. The diseases notifiable to the OIE are set out in Part 2, Section 2.1. and 2.2. of this Code. ('Diseases notifiable to the OIE', as used in this Code, were previously known as 'List B diseases'.)" (OIE, 2000a).

A brief summary of information on the causative agents of listed diseases, as well as "other significant diseases" (see definition below), are provided by the OIE equal, if not greater, challenges for aquaculture development in some regions, especially where they fall outside the OIE list and subsequent protection from exposure to "unreportable" disease agents. For example, Asia has been faced with mass mortalities of cultured marine seabass (Dicentrarchus labrax and Lates spp.) and groupers (Epinephelus spp.) due to several viral diseases. "red spot disease" has seriously affected grass carp (Ctenopharyngodon idellus) in Vietnam (Phan 2001), and epizootic ulcerative syndrome (EUS) has resulted in mass mortalities of a wide range of wild and cultured species throughout Asia and Australia (Lilley and Roberts, 1997; Lilley et al., 1998). Epizootics in shellfish have also impacted aquaculture in the Asia-Pacific Region, e.g. zhikong scallops (Chlamys farreri) in China (Wei Qi, 2000), Akoya pearl oysters (Pinctada fucata) in Japan (Miyazaki et al., 1999), and related pearl oyster species in Indonesia and the Philippines (Bondad-Reantaso et al., 1999). Microbial diseases also plague crustacean culture, e.g. spawner-isolated mortality virus (SMV) in the shrimp Penaeus monodon and red-claw crayfish, Cherax quadricarinatus (Owens et al., 1998; Owens and McElnea, 2000).

In addition to the direct threat of aquatic pathogens to sympatric wild

(OIE, 2000b), as well as on their website (OIE, 2000c).

"Other significant diseases means diseases that are of current or potential international significance in aquaculture but that have not been included in the list of diseases notifiable to the OIE because they are less important than the notifiable diseases; or because their geographical distribution is limited, or it is too wide for notification to be meaningful, or it is not yet sufficiently defined; or because the aetiology of the diseases is not well enough understood; or approved diagnostic methods are not available." (OIE, 2000a).

populations, the confluent nature of the aquatic environment means that use of chemical treatments (disinfectants, therapeutants etc.) in some culture systems may also have untargeted effects. Although chemicals are often used in aquaculture, their use is coming under increased scrutiny and revised disease management practices.

Noninfectious diseases are also common in aquaculture and, although they generally receive less attention than exotic diseases, can have equally devastating effects on production over a very short period. Such diseases are usually caused by various biotic and abiotic conditions.

For example, inadequate management, poor water quality, inappropriate nutrition, aquatic environment degradation (both fresh water and salt water), and exposure to chronic (e.g. urban development pressures as in Manila Bay, Philippines) or acute contamination (e.g. the Erika tanker spill off Brittany, France, in January 2000) have all been linked to mass mortalities of a wide range of cultured and wild species.

Why is health a constraint to aquaculture?

International trade and health issues

A multitude of factors has contributed to the health problems currently faced by aquaculture. As noted above, over the past three decades aquaculture has expanded, intensified and diversified, based

Other aquaculture disease implications, frequently overlooked, are those related to zoonoses and other human health and food safety issues. These too are receiving increased attention, not only in relation to human infections, but also with respect to therapeutant residues and, for shellfish, decreasing water quality, toxic algal blooms and faecal coliform bacteria. Although not considered to be a direct threat to the health of the aquatic organism or productivity, there is no doubt about the significant negative impact on marketability, trade and consumer confidence.

Although our capability to manage most of these health issues has grown immensely over the last 20-30 years, the rapid and ongoing development of all aquaculture sectors continues to “raise the bar” with new health challenges. This is particularly apparent with increased interest in species diversification, as well as new growout techniques. The rapid expansion of these sectors continually surpasses the rate of education, research and adaptation of expertise in health management. Prime examples are mass mortalities of wild abalones off California (Haliotis cracherodii and H. rufescens) and in China (H. discus hannai), sea urchins (Strongylocentrotus droebachiensis) off Nova Scotia and seaweed disease problems in the Philippines, where heavily on movements of live aquatic animals and animal products (broodstock, seed and feed). This trend has been triggered by changing circumstances and perspectives, especially world trade liberalization. New outlooks and directions have accelerated the accidental spread and incursion of diseases into new populations and geographic regions, for example, through movements of hatchery-produced stocks and new species for culture, enhancement and development of the ornamental fish trade.

Although translocation of pathogens and diseases with movements of their hosts is by no means a new phenomenon (Hoffman, 1970; Alderman, 1996), it has only recently gained focussed attention in many regions (see Box 1). Advances in live aquatic animal trade, facilitated by improved transportation efficiency, are now recognized as having played a pivotal role in the introduction and spread of pathogens and diseases into many aquaculture systems (see reviews by Hoffman, 1970; ADB/NACA, 1991; Arthur 1995; Hedrick, 1996; Hine, 1996; Renault, 1996; Lightner 1996a; Humphrey et al., 1997; Berthe, 2000; Humphrey, 2001; Subasinghe and Arthur, 2001).

Socio-economic and biodiversity impacts of disease in

specialized health expertise is limited to research and assess the potential impact of these on the same species under culture conditions. Furthermore, when a pathogen or microbe causing cytopathic effect (CPE) in a cell-line is detected, its significance, as well as normal distribution in wild or hatchery stocks, is often completely unknown. These gaps in knowledge can cause severe delays in culture development. The actual risks have to be assessed - frequently through controlled and repeated experimental challenges - in addition to extensive field surveys and epidemiological data collection (e.g. husbandry and environmental factors associated with the disease outbreak).

aquaculture

There is now convincing evidence of the serious socio-economic, environmental and inter-national trade consequences arising from transboundary aquatic animal diseases. These impacts occur on top of the routine needs of managing the opportunistic disease challenges mentioned in the introduction. Bearing this in mind, and taking Asia-Pacific as an example of a region highly dependent upon aquaculture production and capture fisheries, we need to look at exactly what these impacts are.

Precise per annum figures of consequences of disease losses in this area are difficult to pin-down, but some estimates are available, e.g. losses due to EUS in several Asian countries before 1990 exceeded US$10 000 000 (Lilley et al., 1999).

Box 1. Some examples of transboundary aquatic animal diseases in the Asia-Pacific: their distribution, socio-economic impacts and other consequences

Epizootic Ulcerative Syndrome (EUS). This serious epizootic, first reported in Japan as mycotic granulomatosis (MG) of freshwater ayu in 1971 and observed in eastern Australia in 1972, now occurs in most Southeast and South Asian countries, affecting over 100 species of wild and cultured fresh- and to a lesser extent brackish-water fish. The primary causative agent of this disease has been confirmed as a fungus of the genus *Aphanomyces*. Combined losses from EUS in several Asian countries before 1990 were more than US$10 000 000; losses in Thailand alone from 1983-1993 were US$100 million (Chinabut *et al.,* 1994). EUS continues to expand its range, the latest being into the rivers of the Indus in the Punjab of Pakistan (Lilley *et. al.,* 1998). Outbreaks of ulcerative disease in *Brevoortia tyrannus* in the United States are very similar to EUS in Asia.

White Spot Syndrome Virus (WSSV). First reported in Taiwan Province of China and the P.R. China between 1991-1992, then in Japan in 1993 from shrimp imported from China, this major viral disease of shrimp is now affecting almost all shrimp-producing countries in Asia and Americas. WSSV has been officially reported from ten countries in the Asia-Pacific Region - Bangladesh, China P.R., Korea RO, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam (NACA/FAO 1999, 2000; OIE 1999, 2000d). As of 1999, WSSV has also officially confirmed in at least nine countries in the Americas: Columbia, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru and the United States. Losses were in the range of more than US$400 000 000 in China in 1993 (Wei Qi, 2001), US$17 600 000 in India in 1994 (Subasinghe *et al*., 1995), US$600 000 000 in 1997 in Thailand (Chanratchakool *et al.,* 2000).

Viral Nervous Necrosis (VNN). Among many other viral diseases, VNN causes serious problems to grouper culture in the Asia-Pacific. VNN was first reported in Japan in 1991 and 1994 and has since been reported in Indonesia, Korea RO, Singapore and Thailand. The expanding trend in grouper aquaculture and related trade, without appropriate health management, increases the risk of introducing the pathogen into new localities and environments (Bondad-Reantaso *et. al.,* 2001).

Neobenedenia girellae. One of the most commonly reported parasites of grouper and other marine fishes, this monogenean was introduced to Japan along with importation of amberjack fry from Hainan, China and China, Hong Kong SAR (Ogawa *et al*., 1995). This parasite caused heavy infection and mortalities among flounder cultured in floating net cages and one year old amberjack in Japan; where a total of 15 cultured marine fishes (e.g. groupers and flounders) and brackishwater cultured tilapia have become susceptible (Ogawa *et al*., 1995). *Neobenedenia girellae* now causes serious problems to grouper culture in most countries of Southeast Asia.

In Thailand, losses between 1983-1993 were estimated at US$100 million (Chinabut, 1994). Reports of shrimp disease losses range from US$400 milliion in China in 1993 (Wei Qi, 2001), US$17 600 000 in India in 1994 (Subasinghe et al., 1995), US$30 million as early as 1992 in Thailand (Nash et al., 1995) to US$600 million in the same country in 1997 (Chanratchakool et al., 2001). Shrimp losses in Ecuador were estimated at US$280 milllion in 1999 (Alday de Graindorge and Griffith 2001). Marine finfish disease losses in Japan in 1992 were reported at US$114.4 million (Arthur and Ogawa 1996). In Thailand, in 1989, losses due to diseases of cage-cultured seabass and grouper were estimated at US$1.9 million (ADB/NACA, 1991).

In western Europe, annual losses due to viral hemorrhagic septicaemia virus (VHSV) were estimated at US$60 million (Giorgetti, 1998). A global estimate of disease losses to aquaculture by the World Bank in 1997 was in the range of US$3 billion per annum.

In addition to the obvious effects of large scale aquaculture losses on rural communities, diseases also cause considerable financial impact on investor confidence. These losses are even more alarming where the success or failure of a harvest will determine the raising of families above or below the United Nations (UN) poverty threshold.

In southern Vietnam, approximately 1200 families dependent on rice-shrimp culture have experienced annual losses of >US$300 000 due to shrimp diseases (J.F. Turnbull pers. comm.). Between 1995-1997, ”red spot disease” of grass carp affected 4000 of 5000 cages in operation, with losses estimated at US$ 500 000 (RIA 1, 1998). Such losses directly threaten the livelihoods of the communities they

- changes in community structure through changes in predator-prey dynamics;
- changes in host energetic demands, behaviour, mortality, fecundity or susceptibility to predation;
- changes in genotypic/phenotypic variation; and
- possible species extinctions.

occur in through reduced food availability and loss of income and employment, as well as other associated social consequences.

The actual biodiversity impacts of diseases which affect aquaculture are still poorly understood, and may include disease and/or mortalities in the "typical" host species (expected) both within and outside the culture system, or affect "atypical" host species (unexpected). Since most diseases thrive best under conditions of easy access to hosts, examples of diseases spreading from culture stocks to surrounding wild populations are rare. However, examples of pathogen detection in wild stocks following a disease outbreak in cultured stocks are beginning to appear. This may simply reflect access to more sensitive pathogen detection tools, i.e. enhanced ability to detect a pathogen in a subclinical carrier. Such detection does not clarify the "chicken and the egg" question of which came first - the cultured stock infection or the wild stock infection. Obviously, there are ways to pursue this question, however, since most involve circumstantial observations and focus on frequently heated aquaculture-environmental debate, they rarely reach a solid conclusion. The consequences of "trickle" infections from wild to cultured have predictable consequences, due to the afore-mentioned accessibility of suitable hosts under culture

Some examples of introduced diseases severely impacting biodiversity include crayfish plague (Aphanomyces astaci), which decimated European crayfish populations; the collapse of the shrimp industry in Taiwan Province of China after introduction of monodon baculovirus (MBV), as well as WSSV and YHV introduction to Latin America from Asia (Bartley, 2001).

What is being done to minimize disease risks?

Background

Measures to combat diseases of fish and shellfish have only recently assumed a high priority in many aquaculture-producing regions of the world. Development of such measures was stimulated by the serious socio-economic losses and environmental impacts caused by aquatic animal diseases, as well as threats to food availability/security and the livelihoods of vulnerable sectors of society. Many countries have improved their laboratory facilities, diagnostic expertise, control protocols and therapeutic strategies in order to better handle disease outbreaks. In addition, many farmers, especially in developed countries, have improved their capacity to respond quickly and effectively to emergent disease situations. They have also greatly conditions. The consequence of culture-borne transmission to wild stocks is harder to predict. Certainly, there are more examples of infection of cultured stocks via wild stock reservoirs than vice versa (Flegel and Alday-Sanz, 1997; Ruangsri and Supamattaya, 1999; Rajendran et al., 1999; Dixon, 1999).

If an exotic pathogen meets a naïve, but suitable host, regardless of it being wild or cultured, the effect is usually overt disease, for example, the spread of Bonamia ostreae throughout naïve populations of European oysters in The Netherlands (Banning, 1982). Conversely, if the hosts are not naïve, or have a degree of innate resistance, they may tolerate the infection and become reservoirs or carriers of the pathogen in the aquatic system, e.g. Pacific oyster carriage of Haplosporidium nelsoni, a severe pathogen of Eastern oysters (Crassostrea virginica) (Burreson, 1996) or WSSV in several wild crustacean reservoirs (Otta et al., 1999).
Arthur and Subasinghe (2001) list some effects on aquatic biodiversity, which can be measured in terms of:

enhanced their disease prevention awareness. Similar efforts towards strengthening aquatic animal health capacities in many developing countries are also being actively pursued, though many are still marginal.

International codes

A number of international codes of practice, agreements, and technical guidelines exist and are aimed, at least in part, at providing a degree of standardization for the protocols used to minimize the risks of disease associated with movements of aquatic animals.

These include the OIE International Aquatic Animal Health Code and Diagnostic Manual for Aquatic Animal Diseases (Hastein, 1996; OIE 2000a, b), the International Council for Exploration of the Sea (ICES) Code of Practice on the Introductions and Transfers of Marine Organisms (ICES, 1995); and the European Inland Fisheries Advisory Commission (EIFAC) Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms (Turner 1988). Bartley and Subasinghe (1996) discussed in detail the health provisions in the OIE and ICES codes. In addition, relevant articles are included in the Food and Agriculture Organization of the United Nations' (FAO) Code of Conduct for Responsible Fisheries (CCRF) (FAO, 1995), the Convention on Biological Diversity (CBD, 2000) (http://www.biodiv.org), and the World Trade Organization's (WTO) Sanitary and Phyto-sanitary (SPS) Agreement (Chillaud, 1996).

Regionally oriented guidelines

Regionally oriented guidelines also exist, e.g. the Great Lakes Fish Disease Control Committee of the Great Lakes Fishery Commission (Meyer et al., 1983) and the North American Commission of the North Atlantic Salmon Conservation

The development of the Technical Guidelines took into account the different socio-economic and environmental circumstances of the participating countries in the Asia-Pacific Region, the diversity of infrastructures (in terms of expertise and institutional capability), the wide range of aquatic species being moved, the different reasons for such movements and the diversity of pathogens currently known.

National programmes and legislation

National programmes and legislation are also being implemented in many countries, particularly in developed regions, and these include some good examples of successful fish health control policies and programmes with effective diagnostic accreditation programmes, as well as quality assessment and quality control (QAQC) procedures. These aquatic animal health programmes emphasise good management, adherence to strict hygiene practices and sanitation standards, and general layout of farm premises and site selection, as well as strict quarantine protocols with biosecure facilities. Other successful examples exist under well-defined legislation, including mandatory reporting of disease outbreaks or detection of specific pathogens, as well as

Organization (Porter, 1992). The most recent initiative was the Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and the Beijing Consensus and Implementation Strategy (FAO/NACA, 2000). The Technical Guidelines were based on a set of guiding principles developed through a consultative process that involved representatives from 21 participating governments and technical assistance from regional and international experts on aquatic animal health. The Technical Guidelines describe a number of health management considerations aimed at minimizing the risk of disease spread via aquatic animal movements and were developed to:

- assist countries in the Asia-Pacific to move live aquatic animals in a way that minimizes the disease risks associated with pathogen transfer and disease spread, both within and across boundaries;
- enhance protection of the aquatic environment and biodiversity, as well as the interests of aquaculture and capture fisheries;
- provide a mechanism to facilitate trade in live aquatic species and avoid unjustifiable trade barriers based on aquatic animal health issues; and
- implement relevant provisions recommended mitigative measures and intensive educational and training support.

Australia's status of freedom from several major aquatic diseases has given it a comparative advantage, both in terms of production and trade. It has recently launched the "AQUAPLAN", which contains Australia's five-year national strategic plan for aquatic animal health. AQUAPLAN was prepared through close consultation between government and industry, and describes initiatives ranging from border controls and import certification, through to enhanced veterinary education and capacity to manage incursions of exotic aquatic diseases (AFFA, 1999).

Canada offers another good example of controls such as quarantine, disinfection of eggs, and disease history documentation, which has reduced disease risks associated with the introduction and transfer of Atlantic salmon (Salmo salar). Since 1977, Canada has had federal legislation to protect the country's fisheries resources, embodied in the Fish Health Protection Regulations (FHPR) and Manual of Compliance (Carey, 1996). Similar regulations are being drafted by Canada for shellfish species (Bower et al., 1994; Bower and McGladdery, 1996).

of FAO's CCRF and other international treaties and agreements (e.g. WTO's SPS agreement) applicable to the Asian Region.

Thailand has a good model for establishing strong relationships between government and industry sectors from a developing country standpoint. In an effort to maintain its status as the number one shrimp producer in the Asia-Pacific Region, the government instituted a number of mechanisms to provide support to the industry. These include re-investing profit from shrimp exports into improved aquatic animal health capabilities, establishing a code of conduct for responsible shrimp farming and intensifying support to shrimp farmers. Thailand's Code of Conduct for Marine Shrimp Farming (CCMSF) was initiated by the government, but developed in collaboration with the Thai Marine Shrimp Farmer's Association, the Thai Frozen Foods Association, the Thai Food Processors' Association and the Aquaculture Business Club. The CCMSF contains a set of principles and processes that provide a framework to meet the

Pathogen screening is another health management technique, which focuses on detection of pathogens in subclinical, or apparently healthy, hosts.

Compared to disease diagnosis, screening/surveillance requires detection tools sufficiently sensitive to detect infections in subclinical carriers and/or relatively large sample sizes (OIE, 2000a). Large sample sizes are necessary to provide statistical assurance at set levels of confidence that negative results are acceptable. Positive results are (nearly) always positive. For the most part, screening healthy aquatic organisms for diseases, such as those listed by the OIE, is predominantly a developed-country health management approach, and is directed at international trade protection. However, there is increasing pressure for other countries to adopt this strategy to protect and enhance the industry's goals for environmental, social and economic responsibility (see S. Sen, in this volume). Likewise in Denmark, the success for controlling VHSV came from strong cooperation between the country's veterinary administration and farmers.

Singapore administers an Accredited Ornamental Fish Exporters Scheme where members must observe and comply with the terms and conditions of the programme, as well as a Code of Practice for Accredited Ornamental Fish Exporters. Almost all major exporters are members of this scheme, which emphasises good management, hygiene practices, and general layout of the premise, especially with reference to quarantine facilities (Cheong, 1996). Singapore remains to be the world's top exporter of live aquatic animals.

Japan has a voluntary system of pathogen inspection carried out by a semi-governmental organization, the Japan Fisheries Resources Conservation Association (JFRCA). This organization provides training to Prefecture government staff and conducts certification of fish health specialists ("Gyorui-boheki-shi"). The Fisheries Agency has a National Research Institute of Aquaculture with a fish pathology research division, 20 of 47 prefectures have fish disease control centres, as well as a number of universities, all international marketability of their aquaculture products. This is becoming more feasible where highly sensitive molecular tools are being developed to detect significant pathogens (e.g. penaeid shrimp viruses).

These tools include both immunoassay and DNA-based diagnostic methods, e.g. fluorescent antibody tests (FAT), enzyme-linked immu-nosorbent assays (ELISA), radio-immunoassay (RIA), in situ hybridization (ISH), dot blot hybridization (DBH) and polymerase chain reaction (PCR) amplification techniques. They are currently used to screen and/or confirm diagnosis of many significant pathogens of cultured finfish (e.g. channel catfish virus (CCV), infectious hematopoeitic necrosis virus (IHNV), infectious pancreatic necrosis virus (IPNV), viral haemorrhagic septicaemia virus (VHSV), viral nervous necrosis virus (VNN) and bacterial kidney disease (BKD)), as well as shrimp diseases (e.g. WSSV, YHV, infectious hypodermic and haematopoeitic necrosis virus (IHHNV) and Taura syndrome virus (TSV)) (Walker and Subasinghe, 2000). Similar tools are under development for molluscan pathogens (Haplosporidium spp., Bonamia ostreae, Marteilia refringens and Herpes virus) (Berthe, 2000). These molecular-based techniques (immunoassays and nucleic-acid assays) provide working together for disease control and research (Wakabayashi, 1996).

Diagnostics, therapy and information technology

Diagnostics is determination of the cause of a disease (clinical pathology). The techniques used range from gross observation to highly technical biomolecular-based tools.

quick results, with high sensitivity and specificity at relatively low cost, and are particularly valuable for infections which are difficult to detect (e.g. subclinical infections) using standard histology and tissue-culture procedures. Molecular tools are also useful for research into the pathology and immunology of specific infections. They can be used with non lethal sampling and are valuable to monitor challenge experiments under controlled laboratory conditions.

Further development of this technology is likely to enhance more rapid detection (field monitoring and laboratory examination) and diagnosis of disease, which is crucial for early and effective control of emergent disease situations.

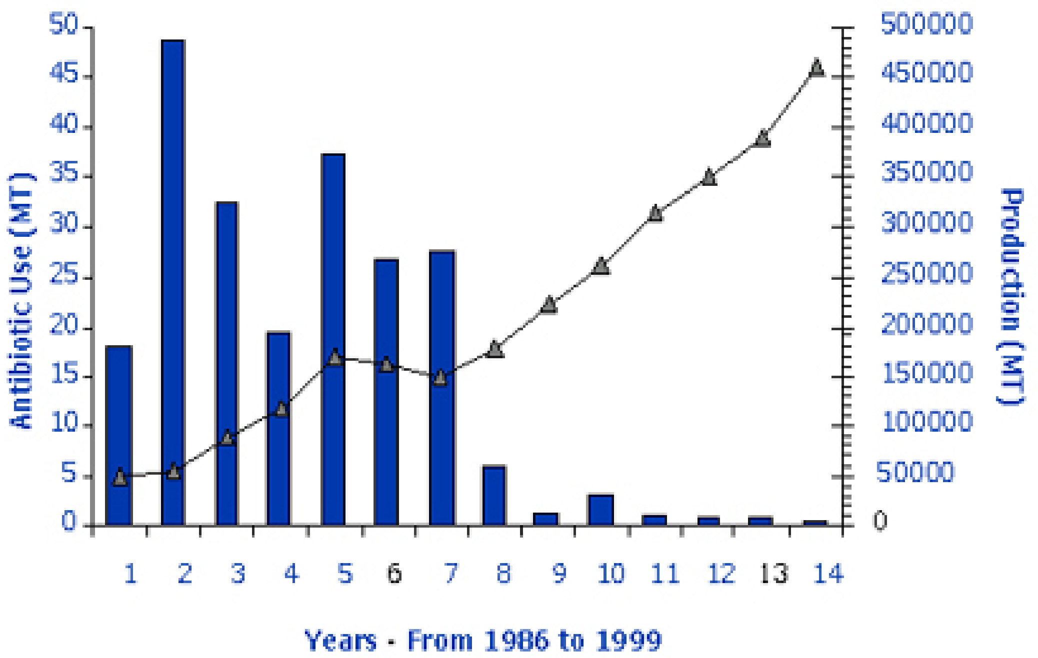
With respect to treatment of disease or pathogen eradication, most countries still rely on

Advances are also being made in both fish and shellfish immunological research towards stimulation of specific and nonspecific defence mechanism. See, for example, recent references for specific and general diseases in Woo and Bruno (1999).

In addition to laboratory and field technology, there has been rapid expansion of computer-based information and training resources (e.g. Internet websites, software, publications and other communication formats) in the last five years. This has lead to a wealth of information, which can be more easily accessed by aquaculture interests in both developed and many developing countries for research, teaching, disease diagnosis and health management (Arthur, 1999). Examples of computerized sources of pertinent information include the FAO’s Aquatic Animal Pathogen and Information System (AAPQIS), the OIE Aquatic Animal Disease Information System based at chemotherapeutants, especially for the control of infectious microbial diseases of finfish (OIE, 1992). In some production facilities, the prophylactic use of drugs, chemicals and biologicals is necessary to meet the sanitation standards used to maintain high health status/certification. Prophylactic drugs are also used to minimize diseases caused by opportunistic infectious agents and prevent spread via personnel and equipment. Examples include disinfection of hatchery equipment and water supply, antiseptic and antibiotic treatment of surface lesions, and trans-shipment sanitation. Such procedures are particularly useful during handling and transportation (e.g. seining, handling, shipping) when aquatic organisms are most vulnerable

the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), United Kingdom (CEFAS, 2000) and the Department of Fisheries and Oceans (DFO Canada) Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish (Bower and McGladdery, 1996). Addresses for these and other useful websites are provided in Box 2.

Figure 1. Use of antibiotics relative to salmon and trout production in Norway from 1986 to 1999 (reproduced from Vinitnantharat, 2001)



to injury, trauma or physiological stress. Chemotherapy has value in preventing and controlling aquatic animal diseases, but must be used in a judicious manner.

Vaccines, developed during the last two to three decades, have also become an established, proven and cost-effective method for controlling certain infectious diseases in cultured animals worldwide. There are now many commercially available for finfish diseases, e.g. enteric red mouth (Yersinia ruckeri), furunculosis (Aeromonas salmonicida), cold water vibriosis or Hitra disease (Vibrio salmoninarum), Vibrio anguillarum serotypes 01 and 02, V. ordalli, Photobacterium (Pasteurella) damsela subsp. piscicida, Streptococcus sp. and IPN and many more are under development (e.g. Flavobacte-rium psychrophilum, Reni-bacterium salmoninarum, IHN, VHS, infectious salmon anaemia (ISA), VNN and Ichthyophthirius multifiliis (“Ich”). In addition to reducing the severity of disease losses, vaccines also reduce the need for antibiotics, leave no residues in the product or environment and do not induce pathogen resistance. A good example of the results of enhanced vaccine use is the reduction of antibiotic use in Norwegian salmon production (see Fig. 1) (Vinitnantharat, 2001).

Box 2. Some relevant websites and other useful sources of information on aquatic animal diseases available to authors at the time of publication

Agriculture, Fisheries and Forestry of Australia (AFFA)
http://www.dpie.gov.au
Aquatic Animal Health Research Institute (AAHRI)
http://www.agri-aqua.ait.ac.th/aahri/seaadcp/AAHRI/aahri.htm/
Aquatic Animal Health Unit (Office of the Chief Veterinary Officer, Australia)
http://www.affa.gov.au/ocvo/fhu/htm/
Aquatic Animal Pathogen and Quarantine Information System (AAPQIS)
http://www.enaca.org
Aquaculture Health Page
http://www.geocities.com/CapeCanaveral/Lab/7490/index.html/
Asian Fisheries Society
http://www.cgiar.org/iclarm/afs/
Australian Quarantine and Inspection Service (AQIS)
http://www.aqis.gov.au/index.htm/
Centers for Epidemiology and Animal Health (CEAH)
http://www.aphis.usda.gov/vs/ceah/
Centre for Environment, Fisheries and Aquaculture Science (CEFAS) http://www.cefas.co.uk/homepage.htm – contact: Prof Barry J. Hill; e-mail: b.j.hill@cefas.co.uk
CSIRO Animal Health Page
http://www.csiro.au/
Department of Fisheries and Oceans of Canada (DFO Canada)
http://www.pac.dfo-mpo.gc.ca/sci/sealane/aquac/pages/title.htm
Diseases of Aquatic Organisms
www.int-res.com
Disease Group, Institute of Aquaculture, University of Stirling
http://www.stir.ac.uk/aqua/Disease/DisHome.html/
Global Aquaculture Alliance (GAA)
http://www.GAAlliance.org
Gyrodactylus salaris Page
http://www.toyen.iuio.no/gyrodactylus/
Hawaii Aquaculture Module Expert System
http://www.library.kcc.hawaii.edu/praise/hames/
International Association for Aquatic Animal Medicine
http://www.iaaam.org/
International Council for the Exploration of the Sea (ICES)
http://www.ices.inst.dk/pubs/ildpfs.htm
Laboratoire de Genetique et Pathologie Home Page
http://www.ifremer.fr/gap/anglais.htm/
National Center of Aquaculture Research (CENAIM, Guayaquil, Ecuador)
contact: Dr. Victoria Alday de Graindorge, Director of Diagnostic Unit, Center for Aquaculture Services; e-mail: csa@espol.edu.ec
Network of Aquaculture Centres in Asia-Pacific (NACA)
http://www.enaca.org
Northeastern Regional Aquaculture Center, University of Massachusetts
http://www.umassd.edu/specialprograms/NRAC/
Office International des Epizooties (OIE)
http://www.oie.int/
Parafish
http://www.anicca.net/parafish/
PROMED
http://www.promedmail.org

Box 2 (Continued). Information on Aquatic Animal Diseases

Shrimp News List
http://www.onelist.com
Southeast Asian Fisheries Development Center, Aquaculture Department (SEAFDEC-AQD)
http://seafdec/org/
The Whirling Disease Foundation
http://whirlingdisease.org/
The Sealice Website
http://www.ecoserve.ie/projects/sealice/
The University of Queensland
http://www.biosci.uq.edu.au/para/
University of Arizona Aquaculture Pathology Home Page
http://www.microvet.arizona.edu/research/aquapath/index.htm/
University of Maryland Aquatic Pathobiology Center
http://www.som1.ab.umd.edu/aquaticpath/
United States Department of Agriculture, Center for Animal Health Monitoring, National Animal Health Monitoring System – Aquaculture
http://www.aphis.usda.gov/vs/ceah/cahm/

Aquatic Animal Field Guides
Australian Aquatic Animal Diseases by A Herfort and G Rawlin; contact:
free call – 1800 020 157 or e-mail: shopfront@affa.gov.au
Diagnostic Procedures for Finfish Diseases, contact: Dr Supranee Chinabut;
e-mail: supranee@fisheries.go.th
Manual for Fish Disease Diagnosis: Marine Fish and Crustacean Diseases in Indonesia; contact: Gondol Research Station for Coastal Fisheries, Bali, Indonesia

CD-ROM/Software
An Exploration of Marine Parasitic Crustacea – An Interactive CD-Rom by Timothy M. Goater, e-mail: custserv@raincoast.com; website: http://www.mala.bc.ca/parasite/
Aquarium Hobby-Vet™Version 1.0. 1998. Danile Zeldis and Shawn Prescot;
e-mail: fishvet@jagunet.com; danzel@inter.net.il;
website: http://www.jagunet.com/fishvet
AquaPath. Histology Atlas of Salmonids; contact e-mail: anil.amin@nl.telia.no
Fish-Vet™2.0; e-mail: danzel@inter.net.il; fishvet@jagunet.com;
website: http://www.jagunet.com/fishvet
CD-ROM on Diagnosis of Shrimp Diseases with Emphasis on the Black Tiger Shrimp (*Penaeus monodon*) by V. Alday de Graindorge and TW Flegel; information:
e-mail: http://www.enaca.org
FishGutsTM Version 1.0. A Multimedia Guide to the Art and Science of Fish Anatomy, Health and Necropsy. 1994, 1996. Andrew S. Kane.
e-mail: akane@umaryland.edu;
website: http://som1.ab.umd.edu/Aquatic Path/fg_html

Professional Societies:
European Association of Fish Pathologists (EAFP) http://www.ifremer.fr/eafp/index.html
Fish Health Section of the Asian Fisheries Society – contact: supranee@fisheries.go.th
Fish Health Section of the American Fisheries Society http://www.fisheries.org/fhs/b
Japan Society for Fish Pathology, contact: Dr. K. Ogawa,
e-mail: aogawak@mail.ecc.u-tokyo.ac.jp
International Society of Aquatic Animal Epidemiology -
Information from Jay F. Levine - Jay_Levine@ncsu.edu

What approaches are available for aquatic animal health management?

Generic approach: good husbandry, prevention and control

Active treatment of disease can be problematic, especially for easily stressed aquatic animals or those grown at extremes in their geographic and physiological tolerance range. Other approaches to disease prevention include:

- control of movement of animals onto the farm/site;
- destruction of clinically sick animals;
- emergency harvest of clinically healthy animals;
- sanitary measures, such as disinfection; and
- fallowing prior to re-stocking.

Although disinfection and control of movements can decrease disease spread via personnel, equipment and farmed animals, the infectious agent may still remain in the water system. By the time a diagnosis is confirmed, the agent may have become firmly established, and the

IRA guidelines are now being designed at both the regional/international and national levels to cover the range of transfer issues which are normally dealt with under these umbrellas. All, however, have the ultimate goal of laying down a set of procedures that will enhance consistency of risk analysis, interpretation of the results and the mitigative (risk-reducing) measures suggested to redress any risk's assessed. Most developed countries routinely conduct risk assessments for aquatic animal health imports. In addition, OIE (2000b) provides guidelines on the conduct of IRA for live aquatic animals.

The Australian Quarantine and Inspection Service (AQIS) has also published two documents on IRA:

- The AQIS Import Risk Analysis Process (AQIS, 1998); and
- Import Risk Analysis on Live Ornamental Finfish (AQIS, 1999).

These provide useful information for making IRA and describe the procedures being followed by the Australian government for importing plants, animals and their products.

Systems approach to health

fate of most infectious agents in the aquatic environment remains largely unknown. Once an infectious agent is ensconced in a water system, eradication or control of spread becomes more complicated. Preventing the introduction and establishment of a disease agent is, therefore, the preferred health management option. Specific disease situations may demand different approaches and risk management. Cost-benefit analyses may also be required to decide/design the best option (e.g. cull, treat, quarantine, disinfect or fallow). As opportunistic infectious agents abound in most aquatic systems, the best control strategy for these is optimizing husbandry practices, which enhances the aquatic organism's innate ability to suppress progression of an "infection" into a "disease".

For exotic infectious agents, the risk of introduction must be identified, assessed, managed and communicated. Import Risk Analysis (IRA) is a methodical, iterative, science-based process of assessing disease risks associated with the importation of aquatic animals and their products (e.g. genetic material, feed stuff, biological products, pathological material). IRA per se is by no means a new concept, however, the traditional ad hoc and qualitative ("gut feeling") approach to the multitude of factors involved with each proposed transfer has

management

The aquatic environment is a complex ecosystem which makes the distinction between health, suboptimal performance and disease obscure. During disease outbreaks, the underlying cause is often difficult to ascertain and is usually the end result of a series of linked events involving environmental factors, health condition of the stocks, presence of an infectious agent and/or poor husbandry and management practices. The whole aquatic production environment, including ecological processes, must be taken into consideration. Therefore, an aquatic system health management approach needs to be developed to replace the more traditional pathogen-focused approach applied to disease diagnosis (Subasinghe et al., 1998).

Epidemiological approach

Epidemiology uses the population as the unit of study, where a bidirectional approach (i.e. downward - from population to individual to organ to tissue to cell and to molecule; and upward - from population to farm to district/province to country) provides a more comprehensive and structured insight into understanding a disease process (Thrusfield, 1995) and facilitates development of effective control strategies.

come under increasing criticism. Inconsistent decisions and conditions made for different methods of transfer, species and geographic ranges have pushed the demand for a more structured approach to risk analyses for aquatic animal transfers.

Although there may be limitations in the use of epidemiological studies on aquatic animal pathogens, especially those with low or unknown host-specificity, this approach shows potential for significantly improving health management and disease control, especially for intensive culture operations.

Disease surveillance and reporting systems

Establishment of national disease surveillance and reporting systems that fulfil regional and international disease reporting obligations are effective strategies for disease control and prevention. They build up an aquatic animal health information base that is useful for verification of disease information generated at the country level, as well as providing a realistic regional

How effective are health management programmes?

Efficacy of disease prophylaxis and control

While chemotherapy will perhaps remain one of the main strategies for controlling transmissible diseases in the foreseeable future, especially in finfish, there is increasing recognition of its limitations in terms of aquaculture situations, host species and effectiveness against certain pathogen groups. In some cases, rather than providing a solution, chemotherapy may complicate health management by triggering toxicity, resistance, residues and occasionally, public health and environmental consequences (Plumb, 1992; OIE, 1992). In Singapore, for instance, Chong and Chao (1986) reported picture of the emergence and potential for spread of aquatic diseases. This also serves as a basis for instituting control and eradication programmes plus early warning and emergency preparedness programmes. Surveillance and reporting systems have proven to be effective in terrestrial livestock disease control programmes. In aquatic animal diseases, however, there are various factors that complicate the disease reporting process (Reantaso et al., 2000). Countries with a sound aquatic animal health infrastructure and a demonstrated record of surveillance, containment and control of disease outbreaks have a significant trade advantage over those without such programmes. Surveillance and monitoring systems serve as a "value added" label to aquaculture and fisheries products because they reflect the country's commitment and ability to collect and provide documented information on the health, origin and quality of each commodity.

The Network of Aquaculture Centres in Asia-Pacific (NACA), in cooperation with OIE and FAO, commenced a quarterly aquatic animal disease reporting system in the Asia-Pacific in 1998 (NACA/FAO, 2000; OIE, 2000d) (Box 3). This list includes diseases considered to be important with respect to transboundary movements of aquatic animals in the Asia-Pacific

drug overdoses which led to fish kills and other detrimental side effects. For example, formalin overdose resulted in severe gill damage and ulcerative dermatitis due to repeated treatments. Potassium permanganate use in marine conditions resulted in rapid reduction of (MNO4)- to [MNO2)-, which is toxic to fish. In the 1970s and 1980s, organic tin was used to coat net mesh in Japan to prevent the growth of fouling organisms. This suppressed the propagation of monogenean infections. When the use of the chemical was banned in 1996 because of fear of accumulation in the host fish, as well as adverse environmental concerns, the monogenean infection recurred (Ogawa, 1996).

In addition to side-effects, the efficacy of chemotherapeutants under certain aquatic environments (e.g. open water systems and shellfish beds) is questionable, both with respect to treatment goals and the potential cost of untargeted effects. Occasional misleading claims and advertising regarding the use of antibiotics and other therapeutic drugs have further complicated the use of chemicals for treating health problems. Other problems with effective chemotherapeutant use include (OIE 1992):

- the lack of pharmokinetic data on many drugs used;
- the lack of standardized

Region. As a result, an accurate, up-to-date health profile for these diseases within the region is beginning to emerge.

protocols for use;

- safety issues, such as handling, storage and application;
- low numbers of licensed products;
- cost and time involved in registration/licensing requirements; and
- existing legislation, which can range from very restrictive to no regulations at all.

Box 3. List of diseases in the *Asia-Pacific Quarterly Aquatic Animal Disease Reports*.

Diseases prevalent in some parts of the region

Finfish Diseases:	Epizootic haematopoietic necrosis*
	Infectious haematopoietic necrosis*
	Oncorhynchus masou virus disease*
	Infectious pancreatic necrosis*
	Viral encephalopathy and retinopathy*
	Epizootic ulcerative syndrome (EUS)
	Bacterial kidney disease
Mollusc Diseases:	Bonamiosis (*Bonamia* sp., *B. ostreae*)*
	Marteiliosis (*Marteilia refringens*, *M. sydneyi*)*
	Mikrocytosis (*Mikrocytos mackini*, *M. roughleyi*)*
	Perkinsosis (*Perkinsus marinus*, *P. olseni*)*
Crustacean Disease:	Yellowhead disease
	Infectious hypodermal and haematopoietic necrosis (IHHN)
	White spot disease (WSSV)
	Baculoviral midgut gland necrosis
	Gill associated virus (GAV)
	Spawner mortality syndrome ('Midcrop mortality syndrome')

Diseases presumed exotic to the region, but reportable to OIE

Finfish Diseases:	Spring viremia of carp*
	Viral haemorrhagic septicaemia*
Mollusc Diseases:	Haplosporidiosis (*Haplosporidium costale*, *H.nelsoni*)*

Any other diseases of importance: In particular, these include the following diseases so far presumed, but not proven, to be exotic to this region:

Finfish Diseases:	Channel catfish virus disease
	Infectious salmon anaemia
	Piscirickettsiosis
	Gyrodactylosis (*Gyrodactylus salaris*)
	Enteric septicaemia of catfish
Mollusc Diseases:	Iridovirus (Oyster velar disease)
Crustacean Diseases:	Nuclear polyhedrosis baculovirosis (*Baculovirus penaei*)
	Crayfish plague (*Aphanomyces astaci*)
	Taura syndrome
	Necrotising hepatopancreatitis

* OIE notifiable diseases

Vaccination is an alternative prophylactic method to control disease impacts. While some commercial vaccines have proven effective in providing protection against certain diseases (mainly of finfish), vaccination is still not possible against shrimp and molluscan pathogens. Their development requires considerable research on the target disease and involves careful planning, field trials and cost evaluation.

Efficacy of pathogen detection and disease diagnostics

Disease surveillance and monitoring is an effective and fundamental foundation for any method of disease prevention and control. However, many factors complicate accurate disease reporting.

These include the wide ranges of socio-economic and technical development in many countries, diversity of species cultured (i.e. from invertebrates to reptiles), the range and complexity of environments used (e.g. freshwater, brackishwater and marine; temperate and tropical waters), the nature of containment (e.g. ponds, raceways, cages and net-pens), the intensity of practice (e.g. extensive, semi-intensive, intensive), culture systems (e.g. monoculture, polyculture and integrated) and management (family to corporate ownership). The variety of disease issues affecting aquaculture systems is also highly complicated. Some show little or unknown host

National legislation and regional/international codes

Even with the best intent, there are some inherent problems with national programmes/legislation and international codes/guidelines. Due to their breadth of scale, they tend to focus on known, significant, diseases and disease agents ("listed diseases"). In addition, they aim at coverage of the most commonly traded species (i.e. salmonids, catfish, oysters and shrimp). This means that they do not address many diseases of intranational concern, or new and emerging diseases, especially those of local, wild or newly domesticated aquatic organisms that may consequently specificity and many elicit non specific clinical signs, e.g. a range of haemorrhagic bacterial and viral septicaemias. Under these circumstances, there is a need to identify appropriate techniques for sampling, surveillance and diagnostics, as well as prioritization of the diseases that should be covered by the surveillance and reporting systems (Reantaso et al., 2000).

Similarly, current molecular-based diagnostic and pathogen screening techniques have limitations, notably in terms of appropriate applications, standardized sampling, testing procedures and interpretation of results (Walker and Subasinghe, 2000). Because they are leading edge technology, there has been a tendency to use them to replace standard diagnostic techniques without proper evaluation of their effectiveness for specific applications (e.g. screening, diagnosis and epidemiology). Until recently, many have required stringent laboratory conditions for effective use, however, some have now been adapted for "field kit" use by non specialists. This raises some concerns over interpretation of field diagnosis and proper interpretation of results. This was further discussed with respect to molluscs (Berthe et al., 1999) and is likely to provoke more stringent guidelines for field and laboratory use in the near future (McGladdery, 2000).

impact international movements and transfers of live aquatic animals. More comprehensive codes of practice, taking into account health, genetic and ecological impact assessments exist, but are not yet refined or widely applied in many developing countries.

In addition, there are currently few if any codes that give consideration to other possible means of spread of pathogens, such as ballast water from ships. Current ballast water codes and studies tend to concentrate on spread of exotic species and ecological impacts (Johnson and Padilla, 1994; Hayes and Hewitt, 1998; Minchin, 1999). Although the potential for disease transfer is recognized, there is no clear evidence linking ballast to disease introduction to aquaculture sites. Conversely, some aquaculture activities using barge transportation or tank transportation could, unwittingly, be transferring pathogens of the fish or another host with them. Likewise, transfers of mollusc seed in collector bags or lines inevitably include other organisms and such "aquaculture substrate" has been shown to transfer pest fouling organisms (MacNair and Smith, 1999) so also merit closer scrutiny with respect to disease transfer potential. Techniques to alleviate release of live aquatic organisms, such as ballast water heating (Rigby et al., 1999) do not take pathogens into

Such techniques are also of little value for "new" or emerging diseases where the causative agent is unknown. In these cases, non specific, general techniques - such as histology - are still necessary to accurately interpret pathology and focus in on the potential causative agent(s). This, by necessity, means that sub clinical carriers may escape detection. Thoensen (1994) and Lightner (1996b) list several diseases caused by primary pathogens that lack procedures for detecting sub clinical infections (e.g. coldwater vibriosis or Hitra disease, CCV; Haplosporidium nelsoni (MSX); and H. costale (SSO) of American oysters; and hepatopancreas parvovirus (HPV) of penaeid shrimp.

account. A further problem with control of disease (as well as pest organisms) in ballast water and other "hitch-hiking" routes is the logistically challenging infrastructure required to implement and enforce codes for dumping, washing etc. In Japan, for instance, even where a strategy is in place and the country has the resources for its implementation, they still face many problems, such as:

- the large number of farms, which precludes regular individual inspection;
- the wide variety of species cultured;
- importation by ship with sea water from ocean or bay sources, which is dumped at the receiving site; and

- limited information on the health status and disease susceptibility of imported marine fish (Wakabayashi, 1996).

Developed countries with well-established strategies and infrastructure, along with stringently enforced complementary regulations, still face diseases that have managed to get through the system. Examples include that of bay scallop (Argopecten irradians) introduction to Atlantic Canadian waters, where two protistan parasites were introduced despite rigorous quarantine and inspection (McGladdery et al., 1993). In the United Kingdom, while strict adherence to regulations on salmonid movements prevented the introduction of two salmonid rhabdoviruses, the lack of regulation on ornamental fish resulted in the release of spring viraemia of carp virus (SVCV). France, on the other hand, had a surveillance programme mandated by decree to control IHN, but due to lack of compensation for ordered stock destruction, the surveillance and control measures became essentially ineffective (de Kinkelin and Hedrick, 1991).

Each experience leads to modification of relevant codes and practices, but bearing this in mind, how can countries with fewer resources keep up, let alone comply effectively? Thus, although many

A fundamental component of any education or extension service is effective information communication. For disease information, this is particularly critical, since misinformation to farmers or consumers can easily lead to panic, resulting in inappropriate treatments or market closures. For educational purposes, any disease screening information should include good pictorial or illustration of procedures, and diseased and normal (healthy) comparative examples. Many books and other educational media give detailed text on pathogens and diseases with illustrations of extreme or advanced cases (e.g. Diagnostic Procedures for Finfish Diseases by Tonguthai et al. (1999); Australian Aquatic Animal Disease - Identification and Field Guide by Herfort and Rawlin (1999); EUS Technical Handbook by Lilley et al. (1998); Handbook of Shrimp Pathology and Diagnostic Procedures for Diseases of Cultured Penaeid Shrimp (Lightner 1996b). The most significant lack, therefore, is in the area of early detection - when more subtle clues may be the first “tip off”. These should be included in training material, along with how to follow initial clues to get more accurate and confirmed diagnosis. Well-illustrated guides for training also span the range of languages and education levels operating at the farm/site level of the industry - sadly, such texts and other developing countries develop and/or enforce national aquatic animal health legislation and regulatory frameworks, these often meet with limited success.

Education, training, and extension services

There has been an increase in the number of diagnostic laboratories, universities and other institutions offering fish and shellfish health short- and long-term training courses. However, this number has not matched the needs of the rapidly developing aquaculture sector, especially in the developing regions of the world, where most aquaculture activity takes place. Some education programmes have a strong academic component, but lack disease diagnosis and/or management experience. Some programmes aim at specialized disciplines (e.g. bacteriology, immunology, policy-planning etc.) and, although specialists are important, multidisciplinary approaches and practical field training are also required.

information media are still rare.

Another fundamental barrier to gaining access to information technology (e.g. computers, software, Internet connection, access to commercial abstracting services), is cost, which may be prohibitive to many researchers and fish health workers from less-developed countries (Arthur, 1999). This is another area that should be borne in mind when designing education and information packages meant to reach remote, rural and underdeveloped regions.

Special considerations for health management in rural, small-scale aquaculture

As noted in the Introduction, it is increasingly recognized that inadequate aquatic animal health management is a risk to the livelihoods of rural people involved in small-scale aquaculture and enhanced/stocked fisheries (DFID/FAO/NACA/GOB, 2000). Aquatic animal health problems impact resource-poor aquaculturists, fishers and their dependants more severely than elsewhere, through loss of production, income and assets.

The degree of impact may vary, but a common factor is inadequate knowledge and support for all production systems. For example there is frequently a lack of:

- appropriate national policies and enforceable regulatory frameworks to prevent entry of pathogens with live aquatic animals and their products;
- extension services which can respond quickly to the needs of remote or poor producers;
- research that directly addresses immediate or baseline farmers' needs;
- opportunities for farmers to improve production skills and options; and
- development programmes which include enhancement of sustainable aquaculture approaches.

It is necessary to improve the understanding of the risks, impacts, and their avoidance within the context of rural livelihoods. Aquatic animal health management should be included in efforts to integrate aquaculture and enhanced fisheries into overall rural development programmes.

Such an environment gives strong, healthy juveniles or seed, optimum growth opportunity and thus, optimum physiological strength to combat opportunistic health challenges. Other farm-side strategies that can boost baseline health management are proper nutrition (in the form of appropriate feeding regimes and proper storage of feed products), good site selection, proper stocking density, age-class separation and separation of stocks from different sources. Waste management is another critical area for maintaining site health. Small decisions, like land disposal of mortalities and waste materials, control of garbage blowing onto sites etc., can all prevent a build up of irritant agents which weaken the stock in the face of a health challenge. Over-riding all these farmside strategies is the need for vigilant and regular monitoring. Early detection of health problems is the ultimate key to the best opportunity for control - this is no different from any other disease situation, including humans! Wherever possible, aquatic animals showing lesions or aberrant behaviour (including feeding) should be isolated immediately for investigation. If they are harbouring an infectious agent, this will reduce

What can be done to improve health management and reduce disease risks?

Communication

An effective health management programme must cover all levels of aquaculture activity, from the production stock to the international level. However, the success of such a broad-reaching programme pivots on a continuum of open communication and multidirectional information exchange and feedback.

At the district level, the communication network starts with good planning and siting of aquaculture farms, effective extension services, organization of farmer cooperatives, and local fisheries officers trained in health management and field-level disease surveillance and reporting. Isolated farms, especially those with links to other production facilities, must be included in extension service support networks and should have access to personnel trained in health management.

Role of the private sector (aquaculturists, industry associations, cooperatives and other stakeholders)

At the production level (farm or its proliferation throughout the system and help reduce its chances of establishing reservoirs for re-infection.

A critical component of stringent farm-monitoring is consistent and accurate record keeping. Hindsight can be fuzzy when it comes to the "first appearance" of problems. Feed and growth records are excellent sources of information that can help pinpoint the start of disease problems and, possibly, isolate their source. Depending on the size and type of farm operation (tanks, ponds, open-water cages or lines), record keeping can range from simple (regular monitoring of growth, site or weather conditions) to more detailed recording as outlined in Table 1.

Such records are invaluable for determining the source or nature of a disease outbreak, assisting in accurate and rapid diagnosis, and providing appropriate intervention and control measures.

The private sector (farmers and service providers) should also play an important role in:

- developing national aquatic animal health programmes and effective codes of practice;

aquaculture site) the primary requirement to maintain good health is a good growing environment (water quality, easily monitored, manageable predation/fouling, security from weather extremes and unrelated human activities).

Table 1: Aquatic animal health record keeping options

aquatic stocks species, numbers, origin, age classes, distribution on site	**management practices** continuous stocking, all-in-all-out, closed operation, stocking densities etc.
nutrition live food/manufactured food, source of food, feeding practice, change of feed	**yields** monitor per pond, per farm, per species
farm/site lay-out inflow/outflow, connection of ponds via water, new ponds, sites upstream	**unusual events** land- and water-use activity, run-off, spills, extreme weather events etc.
normal survival rates and mortality data affected sites, cages, ponds etc. (distribution pattern), along with approximate percentages/ numbers	**abnormal growth or spawning events** dates, species, site distribution (random, focal point, isolated, spreading)
clinical signs behavioural or appearance (lesions, colour changes, fin/appendage loss, ectoparasitism)	**site conditions** weather, salinity, temperature, turbidity, plankton blooms, predation activity etc.

- participating in joint strategies;
- complying with legislation developed to protect aquatic animal health; and
- providing the field information and observation required for early and effective disease control.

Another area where the private sector has a significant role is in working with governments, universities and other institutes to communicate research needs. Where government needs to be open to private-sector input on aquatic animal health control policies and legislation, the private sector should be equally open to government on industry practices which can be modified to improve health and sustainability.

Role of diagnostics and research

The purpose of diagnostics, as previously discussed, is to establish the cause of unfavourable health and recommend effective mitigative measures. When doing disease diagnostic work, the focus should be on the population (and not the individual animal) and production-based indicators of disease, on intervention based on identification, and on prevention rather than treatment. The purpose of research, on the other hand, is to better understand the mechanism of disease processes, in order to provide more effective means of disease management through accurate

Both research and diagnostics work best when conducted in close association, and both are necessary to ensure that optimal diagnostics and health support for farmers are kept up-to-date and readily available. To achieve this, there should be an improved linkage between farmers, researchers and diagnosticians such that:

- farmers identify and report disease concerns to diagnosticians;
- diagnosticians identify the disease problems which require research; and
- researchers examine and advance resolutions to these problems and transfer this knowledge back to the diagnosticians and farmers.

There is an urgent need to bridge communication gaps between researchers and farmers in many countries (both developed and developing). This is slowly being achieved through scientist participation in industry workshops, as well as greater industry participation in many scientific fora. Many of the latter include sessions aimed specifically at industry concerns, e.g. the most recent meeting of the National Shellfisheries Association, held in Seattle (March 2000), included a special workshop on green crab invasion of shellfish beds along the Pacific coast. The Asia Pacific Economic Co-operation (APEC) is promoting industry participation in projects also dealing with aquatic animal health.

diagnosis, prevention, control and treatment. In addition, research is often required to establish the cause of emergent disease or confirm the diagnosis of known diseases.

Table 2. Three levels of disease detection and diagnosis (FAO/NACA, 2000)

Level	Site	Activity	Requirements
I	Field	Observation of the animal and the environment Clinical examination	Investment in training, access to information – little or no equipment required. (Site access may require boat or negotiation of cooperation with culture site managers/employees). Investment in training and basic equipment; access to information required.
II	Laboratory	Parasitology Bacteriology Mycology Histopathology	Significant investment in training, equipment and running costs. Access to current information required.
III	Laboratory	Virology Electron Microscopy Molecular Biology Immunology	Considerable investment in training and equipment and considerable running costs. Access to current information required.

Recent examples include the APEC FWG 02/2000 "Development of a Regional Research Framework on Grouper Virus Transmission and Vaccine Development" held in Bangkok, Thailand in October 2000 and APEC FWG 03/2000 "Trans-boundary Aquatic Animal Pathogen Transfer and the Development of Harmonised Standards on Aquaculture Health Management" - a joint APEC/FAO/NACA/SEMARNAP Expert Consultation held in Puerto Vallarta, Jalisco, Mexico in July 2000, where industry representatives provided valuable interaction with scientists and policy-makers.

One on-going research issue that directly pertains to aquatic animal health is the development of standardized methods for disease diagnosis and pathogen screening, along with regular evaluation of their effectiveness compared with other diagnostic methods. Appropriate application(s) for detection and diagnosis of priority diseases/disease agents also need to be certified (Walker and Subasinghe, 2000).

Considering the wide range of resource expertise and infrastructure required (training, facilities etc.) for disease diagnostics, a phased approach for its establishment and implementation is recommended for countries which currently lack such resources. FAO/NACA (2000) recommends the promotion of three levels of diagnostics according to existing resources (see Table 2). The different levels provide a

The three levels do not exist in isolation but constitute a continuum of activities building on each other, with Level I constituting the essential foundation. The levels are specific to a given disease and not for the entire laboratory capability. Many countries which lack Level I, but have Level II or III capacity, are still highly encouraged to reinforce or establish Level I capability. This is necessary to ensure optimum monitoring feeds into the established diagnostic service/research support infrastructure.

Reference laboratories and collaborating centres of expertise are crucial to the successful implementation of any aquatic animal health programme. Aside from providing generalized support services, confirmatory diagnosis, facilitating research and acting as contact centres for advice and training, they standardize, validate and assist in the quality control of development and research programmes.

Role of professional societies in aquatic animal health management

There are a number of regional and international societies, and in some countries, national broad-scale application to disease detection and diagnostics where countries can move from one level to the next as capacities are improved and as resources become available.

societies/networks, that focus mainly on aquatic animal health (e.g. the European Association of Fish Pathologists (EAFP), the Fish Health Section of the Asian Fisheries Society (FHS/AFS), the Fish Health Section of the American Fisheries Society (AFS/FHS), and the Japanese Society of Fish Pathology (JSFP)).

In addition, subject-specific professional groups and, more recently, formal associations of farmers, all share a common goal of assisting in highlighting and researching resolution options for pressing aquatic animal disease problems. Scientists and researchers have an important role to play as knowledge producers, while farmers and policy decision-makers play an essential role in ensuring that the knowledge produced is applicable and effective for their needs. Involving potential users (e.g. farmers, particularly via on-farm level trials of research findings) in research projects at the earliest opportunity is also desirable. Mechanisms by which scientific findings are integrated into policies

- husbandry-mediated prevention rather than treatment, especially prophylactic treatment (NB this does not include vaccination) - the treatment philosophy stems from agriculture-based situations which work in significantly more controllable isolation than most aquatic animal production systems. This is particularly important for developing country aquaculture, where financial resources for chemically mediated production are sparse.
- linkage of ecological and immunological expertise - biology and veterinary science specialize in these areas, but

on aquatic animal health need to be identified and reinforced. While industry-science exchange has improved in many countries over the last ten years, the gap persists between policy and regulatory planners, licensing authorities and enforcers. A step in the right direction is the DFO Canada initiative to review all current legislation pertaining to aquaculture and seek both industry and science feedback into simplifying the system (cutting out duplication, loopholes, significant errors and inapplicability) and Australia's AQUAPLAN, as previously mentioned.

Education, training, extension and related services

There is a need for well-trained personnel in a wide variety of disciplines within the aquatic animal health sector. This is especially apparent for diagnosticians and effective extension biologists in much of the Asia-Pacific and Latin American regions. Diagnosticians who are knowledgeable on a variety of diagnostic techniques, as well as practical field-level health control and disease prevention measures, are particularly needed. Bearing in mind these needs, another fundamental factor affecting the efficacy of education, training and extension services is a global need to bridge the traditional gap between veterinary science expertise and aquatic biology. Both both have different approaches, which should be considered complementary rather than conflicting. A good example of linkage is the OIE Fish Disease Commission. The OIE is a veterinary-based organization, however, the Fish Disease Commission was established by, and includes, aquatic pathology biologists as well.

Long-term planning for establishing a strong aquatic animal health infrastructure and capacity should be a priority. Unstable health services with discontinuous/transient expertise weaken basic health services. Expertise, by definition, is based on experience. If such experience is fragmented then new recruits lack "mentor" guidance. Bearing in mind the acute nature of many disease situations, having a stable health support network which is "ready to go" should be a primary consideration for the aquaculture industry (at the local, national or even international level).

Other areas that may be considered include the following:

- a system for certification of aquatic animal health professionals, including quarantine and inspection officers;
- integration and/or

apply to aquatic animal health management and address critical areas without spawning all.

Fundamental paradigms, which need to be reconsidered, include:

- increased emphasis on aquatic animals in traditional veterinary courses, especially in countries with well-established industries. This is developing slowly in some countries, however, terrestrial emphasis still appears to be the only option within many veterinary school curricula.
- client confidentiality - this cannot outweigh reporting of disease emergence in an open-water or flow-through circulation farm/site production system. Industry Code of Conduct protocols or government disease control/eradication measures must have priority for immediate action.

strengthening of aquatic animal health subjects in veterinary and fisheries curricula (as noted above);

- vocational-level courses that provide more hands-on practice (over and above university degrees which specialize in research/academic qualifications); and
- inclusion of risk analysis, contingency planning, communications networking etc. in support of aquatic animal health control, within both vocational and academic courses on aquaculture.

Role of national governments

National governments need to show firm commitment to regional/international agreements or policies by implementing stable national aquatic animal health action programmes. They should also establish effective regulations, with the support of enforcement and monitoring policies. Where possible, financial assistance or alternative compensation options for farmers should also be available in the event of production losses or eradication programmes. Furthermore, a functional domestic or national legislation - a major commitment on the part of responsible administration - is a major prerequisite for meeting international trade regulations/guidelines. Governments also need to strengthen the knowledge-base (especially science) upon which policy decisions are made. They should also establish good relationship with industry stakeholders through open communication to determine the most cost-effective solutions to health problems and, once established, such cooperation and trust must be sustained.

An overview of national requirements are:

- resources to support one or more team(s) of health professionals and specialists

Role of agencies at regional/ international levels

At the regional/international levels, a regional mechanism for building joint strategies and approaches is required on:

- standardized techniques for disease diagnosis and screening for specific pathogens;
- codes of practice for reducing aquatic animal health risks;
- responsible and transparent reporting systems;
- accreditation of regional aquatic animal health reference and resource laboratories; and
- mechanisms for regular monitoring and evaluation of regional/international agreements.

Regional and international agencies play a critical role in supporting regional programmes, setting directions, and providing transparent consultation and information exchange mechanisms that allow other potential cooperators to determine the conditions for their participation. Cooperation must be designed to respond in a cost-effective manner, avoiding duplication of efforts, competition for, and maximized use of limited resources. International assistance to countries seriously affected with aquatic animal diseases is necessary because with a solid communication infrastructure linking national and farm-level expertise, with up-to-date information and technology;

- strong national policy directives/regulations and legislation covering diagnostic services, disease management and control plans (including contingency plans for emergency disease outbreaks);
- surveillance and reporting systems, health management and extension services training, education and public awareness programmes for policy-makers, farmers, national and field officers, and market consumers;
- a system to establish good communication links and provide for appropriate consultation with stakeholders (e.g. farmers, industry, academe, research institutes, other interested groups); and
- active participation by committed political representatives in regional/international programmes aimed at aquatic animal health agreements, in order to keep pace with changes in disease knowledge, status and related trade issues.

persistence of uncontrolled/unmonitored disease poses a risk to neighbouring countries and trading partners.

Conclusions

In this new millennium, the demand for aquatic animal production will continue to grow (see Regional and Global Reviews, this volume). The role of aquaculture in meeting this increasing demand, with both high quality and diversity production, will play an important socio-economic role in providing livelihood opportunities and economic security for all aquaculture regions of the world. The current trend to meet this demand through expansion, intensification and diversification will continue to provoke the emergence and recurrence of disease challenges. How industry, government and other stakeholders rise to meet these challenges will dictate how aquaculture survives and achieves true sustainability. The options are not always easy.

The varying levels of political, economic and social development among countries, the transboundary nature and commonality of many major disease problems, and the need to harmonize approaches all complicate effective cooperation and consultation. However, all levels of management and the different sectors involved have to do so in order to make the most effective use of limited resources - this being one aspect of global productivity which appears to be sustained below industry requirements. The current situation offers a big challenge and an opportunity to all concerned but, if maintained at the present level, major epidemics will continue to threaten, break out and impact the ultimate goal of aquaculture sustainability.

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Nutrition and Feeding for Sustainable Aquaculture Development in the Third Millennium

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Hasan, M.R. 2001. Nutrition and feeding for sustainable aquaculture development in the third millennium. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 193-219. NACA, Bangkok and FAO, Rome.

ABSTRACT: Over the last decade, the world has witnessed spectacular growth in the aquaculture industries of many developing countries. It is unequivocally agreed that global aquaculture production will continue to increase, and much of this will occur in the developing countries of Asia and Africa, through the expansion of semi-intensive, small-scale pond aquaculture. Nutrition and feeding play a central and essential role in the sustained development of aquaculture and, therefore, fertilizers and feed resources continue to dominate aquaculture needs. This paper reviews a number of specific issues in the fields of aquatic animal nutrition and feeding which are critical for sustainable aquaculture production in both industrialized and developing countries, e.g.: nutrient requirements of fish and their supply under practical farming conditions, availability and supply of feed resources and their implication on development of aquafeeds, forecasting of demand and supply of marine resources, and maintenance of environmental quality and sustainability of aquaculture systems. While discussing the nutrient requirement of fish under farming conditions, the possibility of accessing existing databases on nutrient requirements is examined, along with their application for establishing general nutritional principles. Particular emphasis is placed on understanding the contribution of naturally available food in semi-intensive aquaculture and its role on the development of on-farm feed management strategy. Other issues such as nutritional effects on immunocompetence and disease resistance of fish, understanding of broodstock and larval nutrition, role of nutrition on fish quality, and development of regional nutritional databases for aquaculture development are also discussed. Recommendations for improvement of nutrition and feeding protocols in support of sustainable aquaculture development in the third millennium are also made.

KEY WORDS: Aquaculture, Feeding, Aquafeeds, Nutrition.

Introduction

Over the last decade, spectacular growth has taken place in aquaculture. Most production in developing countries is realized from pond-based or open-water extensive, improved extensive and semi-intensive practices using polyculture farming technologies. In contrast, the bulk of high-value freshwater and marine carnivorous finfish in developed countries is produced by intensive farming systems using high-cost nutrient inputs in the form of "nutritionally-complete formulated diets".

It is unequivocally agreed that global aquaculture production will continue to increase, and much of the increased production in developing countries of Asia and Africa is likely to be achieved through the expansion of semi-intensive, small-scale pond aquaculture. Nutrition and feeding will play an essential role in the sustained development of this aquaculture. Therefore, it is imperative that fertilizers and feed resources continue to be produced and refined. Sustained development of aquaculture, however, must take into account and ensure that the needs of competing users are

Nutrient requirements and supply under practical farming conditions

Growth, health and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrient, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Supply of inputs (feeds, fertilizers etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved.

Complete data on nutrient requirements are only available for a limited number of species. Although dietary protein and lipid requirements and carbohydrate utilization are relatively well investigated for several fish and shrimp species, data on the requirements of micronutrients such as amino acids, fatty acids and minerals are only available for the most commonly cultivated carnivorous and selected omnivorous fish species. Available data on nutrient requirements for various fish species are presented: protein (Tables 1 and met, and that environmental integrity is protected. Therefore, sustainable aquaculture management should address allocation of inputs based on local circumstances, and balance maximizing profitability with social and environmental costs.

This paper will review a number of specific issues in the fields of aquatic animal nutrition and feeding that are critical for sustainable aquaculture production in both industrialized and developing countries. Some of the major issues are:

- availability and cost of feed resources and development of aquafeeds;
- increasing competition for resources with other users (e.g. agriculture and livestock industries);
- forecasting of local and global market supply and demand; and
- maintenance of environmental quality and sustainability of aquaculture systems.

Aquaculture development is also confronted with the choice between using established culture of herbivorous/omnivorous species under extensive or semi-intensive systems or developing more intensive systems to meet increasing production demands. Similarly, issues and conflicts, such as the demand for food verses availability of marine resources, productivity verses environmental quality, and choice of species verses biodiversity, warrant critical examination.

2), amino acids (Table 3), essential fatty acids (Table 7), minerals (Table 8) and vitamins (Table 10).

Table 1 shows the protein and energy levels resulting in maximum growth for a few species of juvenile fish. The data show that the protein requirements for different fish species range from 28 to 56 percent of dry diets. Apparently, marine and freshwater carnivorous species require 40-55 percent dietary protein, while most freshwater omnivorous and herbivorous species require 30-40 percent of their dry diet to be made up of protein. Like finfish, most crustaceans studied to date have rather high protein requirements, ranging from 30 to 60 percent of the dry diet (Table 2).

Lipids are primarily included in formulated diet to maximize their protein sparing. There is convincing evidence that the degree of unsaturation does not appreciably affect digestibility or utilization of fats and oils as energy sources for coldwater or warmwater fish (Steffens, 1989). Carnivores like trout have natural diets rich in triglycerides and can adapt to high fat diets (upper limits have yet to be defined). Dietary lipid levels as high as 35 percent has been reported in some salmonid feeds (New, 1996). The maximum levels for other freshwater fish appear to be lower. In general, 10-20 percent of lipid in most freshwater fish diets gives optimal growth rates without producing an excessively fatty carcass (Cowey and Sargent, 1979).

Table 1. Dietary protein and energy levels resulting in highest growth rates in various fish species (% of dry diet)

Fish species	Crude dietary protein (%)	Gross dietary energy (kJ/g)	Protein to energy ratio (mg/kJ)
Chinook salmon (*Oncorhynchus tshawytscha*)	40-55		
Coho salmon (*Oncorhynchus kisutch*)	40		
Sockeye salmon (*Oncorhynchus nerka*)	45		
Rainbow trout (*Oncorhynchus mykiss*)	40-45 40 45	19.1-20.8	20.5-22.5
Estuary grouper (*Epinephelus salmoides*)	40-50	14.3	35.1
Gilthead bream (*Pagrus auratus*)	40	22.5	17.7
Red sea bream (*Pagrus major*)	55		
Largemouth bass (*Micropterus salmoides*)	40	18.3	21.9
Smallmouth bass (*Micropterus dolomieui*)	45	18.4	24.4
Striped bass (*Morone saxatilis*)	47-55	24.8	22.2
Plaice (*Pleuronectes platessa*)	50		
Puffer fish (*Fugu rubripes*)	50		
Yellow tail (*Seriola quinqueradiata*)	55		
Japanese eel (*Anguilla japonica*)	44.5		
Snakehead (*Channa micropeltes*)	52		
African catfish (*Clarias gariepinus*)	40	18.6	21.5
Asian catfish (*Clarias batrachus*)	30		
Channel catfish (*Ictalurus punctatus*)	35-40	11.5-16.9	20.3-22.2
Pangas catfish (*Pangasius sutchi*)	25		
Green catfish (*Mystus nemurus*)	42		
Stinging catfish (*Heteropneustes fossilis*)*	27.7-35.4		
Common carp (*Cyprinus carpio*)	31-40.6	12.8-22.7	15.3-29.6
Indian major carp (*Labeo rohita*)**	34-36	15.5	18.6
Tilapia (*Oreochromis aureus*) fingerling	34-36	13.4	20.5
Tilapia (*Oreochromis aureus*) fry	56	19.3	27.5
Tilapia (*Oreochromis mossambicus*)	40		
Tilapia (*Oreochromis niloticus*)	30		
Tilapia (*Tilapia zilli*)	35	21.8	16.0
Red tilapia (*Oreochromis* sp.)	34.4		
Tilapia hybrid (*O. niloticus* X *O. aureus*)	30-35	17.3	30.3
Grass carp (*Ctenopharyngodon idella*) fry	41-43		
Grass carp (*Ctenopharyngodon idella*) fingerling	23-28		
Mullet (*Mugil capito*)	28		
Milkfish (*Chanos chanos*) fry	40	15.3	26.3

Source: Data were adapted from Hepher (1990), Tacon (1990) and De Silva and Anderson (1995); *Akand et al. (1989); **Akand et al. (1991) and Hasan et al. (1996)

fingerling			
Mullet (*Mugil capito*)	28		
Milkfish (*Chanos chanos*) fry	40	15.3	26.3

Source: Data were adapted from Hepher (1990), Tacon (1990) and De Silva and Anderson (1995); *Akand *et al.* (1989); **Akand *et al.* (1991) and Hasan *et al.* (1996)

Carbohydrates are the least expensive form of dietary energy and are frequently used for protein sparing in formulated diets. Fish and shrimp vary in their ability to digest carbohydrate effectively (New, 1987). The utilization of dietary carbohydrate has also been found to vary with the complexity or chemical structure of the carbohydrate source used. Channel catfish (Ictalurus punctatus) and Kuruma shrimp (Penaeus japonicus) appear to utilize complex carbohydrates more readily than simple sugars (NRC, 1983; New, 1987) The ability of carnivorous fish species to hydrolyse or digest complex carbohydrate is limited due to the weak amylolytic activity in their digestive tract, thus for species such as trout,

Table 2. Dietary protein levels resulting in highest growth rates in prawn and shrimp

Species	Crude dietary protein
Prawn	
Macrobrachium	35-40
Shrimp	
Penaeus indicus	30-40
Penaeus aztecus	40-51
Penaeus setiferus	28-32
Penaeus merguiensis	34-42
Penaeus monodon	34-46
Penaeus japonicus	40-57
Palaemon serratus	30-40

Source: Tacon (1990)

Luquet (1989) further suggested that extensive research on the determination of quantitative amino acid requirements does not seem to be a priority, as indirect approaches provide a rather accurate estimate of requirements. Table 4 summarizes the range of essential amino acid requirements that have been determined for a variety of species of finfish.

Dietary lipids provide essential fatty acids (polyunsaturated fatty acids, PUFAs) that fish, like all animals, cannot synthesise but require for the maintenance of cellular function. Plant oils are starch digestion decreases as the proportion of dietary starch is increased. For salmonids, carbohydrate digestibility also diminishes with increasing molecular weight (Steffens, 1989).

In general, warmwater omnivorous or herbivorous fish species such as common carp, channel catfish and eel have been found to be more tolerant of high dietary carbohydrate levels. Furuichi and Yone (1980) compared the utilization of carbohydrates by common carp, red seabream, and yellowtail. Growth retardation and low feed efficiency were noticed in common carp fed diets containing over 40 percent dextrin, red seabream fed over 30 percent dextrin, and yellowtail fed over 20 percent dextrin. Studies of common carp (Takeuchi et al., 1979) and channel catfish (Garling and Wilson, 1977) have shown that carbohydrate levels up to about 25 percent of the diet are utilized as effectively as lipids as an energy source.

generally rich sources of linoleic series fatty acid (n-6) and with the exception of linseed, conopher seed and hempseed oils, contain little or no linolenic series fatty acid (n-3) (New, 1987; Tacon, 1990; Table 5). Linolenic series fatty acids are found in terrestrial animal fats only in trace amounts and are common only in marine oils, highly unsaturated fatty acids HUFAs (20:5n-3, 22:5n-3, 22:6n-3) are virtually restricted to this source (Steffens, 1989; Tacon, 1990; Table 6).

Dietary essential fatty acid (EFA) requirements of the most commonly cultivated fish species are presented in Table 7.

All studies on finfish to date have shown that they need the same essential amino acids as most other animals (Table 3). The requirements for individual amino acids are fairly consistent between species, although variability is apparent both between species and between studies on the same species. A large part of the variability may be explained by differences in the methods used by various workers. Luquet (1989) pointed out the rather close agreement between amino acid requirements for coldwater fish (rainbow trout) and those of warmwater fish (channel catfish) when expressed in absolute terms and not as the percentage of the protein content.

Table 3. Quantitative essential amino acid requirements of certain fish species

Amino acid	Chinook salmon	Rainbow trout	Japanese eel	Channel catfish	Common carp	Tilapia*
Arginine	6.0 (2.4)	3.5 (1.4)	4.5 (1.7)	4.3 (1.0)	4.3 (1.6)	4.20 (1.18)
Histidine	1.8 (0.7)	1.6 (0.6)	2.1 (0.8)	1.5 (0.4)	2.1 (0.8)	1.72 (0.5)
Isoleucine	2.2 (0.9)	2.4 (1.0)	4.0 (1.5)	2.6 (0.6)	2.5 (0.9)	3.11 (0.87)
Leucine	3.9 (1.6)	4.4 (1.8)	5.3 (2.0)	3.5 (0.8)	3.3 (1.3)	3.39 (0.95)
Lysine	5.0 (2.0)	5.3 (2.1)	5.3 (2.0)	5.1 (1.2)	5.7 (2.2)	5.12 (1.43)
Methionine	4.0 (1.6)[a]	1.8 (0.8)[c]	3.2 (1.2)[e]	2.3 (0.6)[g]	3.1 (1.2)[i]	2.68 (0.75)[k]
Phenylalanine	5.1 (2.1)[b]	3.1 (1.2)[d]	5.8 (2.2)[f]	5.0 (1.2)[h]	6.5 (2.5)[j]	3.75 (1.05)[l]
Threonine	2.2 (0.9)	3.4 (1.4)	4.0 (1.5)	2.3 (0.5)	3.9 (1.5)	3.75 (1.05)
Tryptophan	0.5 (0.2)	0.5 (0.2)	1.0 (0.4)	0.5 (0.1)	0.8 (0.3)	1.00 (0.28)
Valine	3.2 (1.3)	3.1 (1.2)	4.0 (1.5)	3.0 (0.7)	3.6 (1.4)	2.80 (0.78)
Crude protein (%) in the diet	40.0	40.0	37.7	24.0	38.5	28.0

Requirements are expressed as percentage of dietary protein.
Values in parentheses indicate requirements as percentage of dry diet.

[a] In the absence of cystine, with 1% cystine in the diet, methionine requirement was 1.5% of the protein;
[b] In the absence of tyrosine, with 1% tyrosine in the diet, phenylalanine requirement was 4.1% of the protein;
[c] Diet contained 0.4% cystine;
[d] Diet contained 0.8% tyrosine;
[e] In the absence of cystine, with 1% cystine in the diet, methionine requirement was 2.4% of the protein;
[f] In the absence of tyrosine, with 1% tyrosine in the diet, phenylalanine requirement was 3.2% of the protein;
[g] In the absence of cystine;
[h] In the absence of tyrosine;
[I] In the absence of cystine, with 2% cystine in the diet, methionine requirement wa s 2.1% of the protein;
[j] In the absence of tyrosine, with 1% tyrosine in the diet, phenylalanine requirement was 3.4% of the protein;
[k] Diet contained 0.54% cystine;
[l] Diet contained 1.79% tyrosine.

* *Oreochromis niloticus*

Source: Steffens (1989) and Lall (1991)

It is apparent from this table that marine fish (i.e. red seabream, sea bass, yellowtail, turbot, plaice) have exclusive requirement for HUFAs (20:5n-3 and 22:6n-3), while freshwater or anadromous species require a higher proportion of C18 fatty acids within the n-3 series.

In general, coldwater freshwater (i.e. salmonids, ayu) fish have an exclusive requirement of n-3 series PUFA (18:3n-3, 20:5n-3, 22:6n-3) in their diet, while warmwater freshwater fish require both n-3 series and n-6 series PUFA (i.e.carps, eel) or the n-3 or n-6 series (tilapia).

All fish studied to date appear to require EFA (n-3 or n-6) at about one to two percent of the diet by dry weight. At present, there is no firm quantitative information on the dietary EFA requirement of marine shrimp or freshwater prawns. The information available at present is more suggestive than conclusive, however, as with fish, it is believed that n-3 series fatty acids have a higher EFA activity than n-6 series fatty acids in shrimp and prawn (NRC, 1983; Tacon, 1990).

Determination of dietary mineral requirement of aquatic animals has been complicated by the fact that they have the ability to absorb minerals from the surrounding water in addition to the food ingested. The dietary requirement of a fish and shrimp species for a particular element thus depends to a large extent upon the concentration of the element in the water body (Steffens, 1989; Hepher, 1990). At present, (De Silva and Anderson, 1995). As a result, the data obtained from studies of salmonids, common carp or channel catfish (Table 10) are usually applied to other species while formulating the complete diet for intensive culture. While natural food is usually rich in vitamins, this may not be the case with supplementary feed. Vitamin deficiency mainly appears, therefore, in intensive culture systems, where supplementary feed is the major, if not the only, source of feed (Hepher, 1990) or where formulated complete feed is the only source of feed.

Given the large variety of species under culture, it is not practical to undertake extensive studies on nutrient requirements and utilization of each species. If we critically examine the existing there is little information concerning the contribution of waterborne elements to the total mineral balance of fish or shrimp. Further, aquatic animals' absorption of minerals is largely influenced by variations in response to salt regulation or osmotic pressure. As a result, freshwater fish have greater demands for adequate mineral supplies than marine fish and shrimp.

Minerals available in feed ingredients are not always sufficient to meet the fish's requirements. Some of the minerals may be leached during the processing of the food (Hepher, 1990). Moreover, many of the feed ingredients may be rich in particular minerals and deficient in others, or only partially available to the animal consumers. Dietary mineral requirements of five fish species are presented in Table 8. However, the information on mineral requirement is not complete and sometimes highly variable. Cho and Schell (1980, adapted from Hepher, 1990) summarized the requirement of 16 minerals (Table 9) for fish. Apparently the summary was prepared from available data for different fish database on the nutrient requirements of different fish species, a tolerable generalization of nutritional requirement for different species groups can be made. The available literature indicates that the some of the nutrient requirements of major cultivable fish species can be generalized into four broad groups:

- marine carnivores (e.g. yellowtail, red seabream, sea bass, salmon, trout, grouper);
- freshwater carnivores (e.g. snakehead, eel, goby);
- freshwater omnivores (e.g. tilapia, catfish, common carp, Indian major carps, shrimp); and
- freshwater herbivores (e.g. grass carp, silver carp).

Table 4. Summary of essential amino acid requirements of fish

Amino acid	Requirement (g/100g protein)
Arginine	3.3-5.9
Histidine	1.3-2.1
Isoleucine	2.0-4.0
Leucine	2.8-5.3
Lysine	4.1-6.1
Methionine a	2.2-6.5
Phenylalanine b	5.0-6.5
Threonine	2.0-4.0
Tryptophan	0.3-1.4
Valine	2.3-4.0

[a]Requirement varies depending upon the amount of cystine in the diet;
[b]Requirement varies depending upon the amount of tyrosine in the diet
Source: De Silva & Anderson (1995)

species and should thus be considered as suggestive. Since much of the mineral requirement is supplied by the food, partial mineral supplementation may be sufficient to meet dietary needs.

Although the pathologies related to vitamin deficiency in fish are well investigated, quantitative dietary vitamin requirements of fish and aquatic animals are probably the least studied area in fish nutrition. The vitamin requirements of the majority of species of fish in culture have not been determined

Table 5. Average fatty acid composition of the major oilseed and plant by-product oils

Plant lipid	Fatty acid	% of total fatty acids
Castor oil	Ricinoleic acid	91 - 95
	Linoleic acid	4 – 5
	Palmitic & stearic acid	1 - 2
Cocoa butter	Oleic acid	30 – 40
	Stearic acid	35
	Palmitic acid	25
	Linoleic acid	2 - 4
Coconut oil	Lauric acid	44 - 52
	Myristic acid	13 – 19
	Palmitic acid	7 – 10
	Caprylic acid	5 – 10
	Capric acid	4 – 10
	Oleic acid	5 - 8
	Stearic acid	1 - 3
	Linoleic acid	1 – 3
Conopher seed oil	Linolenic acid	65 – 72
	Oleic acid	10 – 13
	Linoleic acid	10 – 12
	Stearic acid	3
	Palmitic acid	2 – 3
Cotton seed oil	Linoleic acid	40 – 55
	Palmitic acid	20 – 25
	Oleic acid	18 – 30
	Stearic acid	2 – 7
Groundnut oil	Oleic acid	42 – 72
	Linoleic acid	13 – 28
	Palmitic acid	6 – 12
	Arachidic & higher sat. acids	5 – 7
	Stearic acid	2 – 4
Hempseed oil	Linoleic acid	45 – 65
	Linolenic acid	15 – 30
	Oleic acid	14 – 16
	Saturated acids	4 – 10
Kapok seed oil	Linoleic acid	33
	Oleic acid	30
	Palmitic acid	23
	Stearic acid	1
	Cyclopropene bearing fatty acids	13
Linseed oil	Linolenic acid	30 – 60
	Oleic acid	13 – 26
	Linoleic acid	10 – 25
	Stearic & palmitic acids	6 – 16
Maize (corn) oil	Linoleic acid	34 – 62
	Oleic acid	19 – 49
	Palmitic acid	8 – 12
	Stearic acid	2 - 5
Neem oil	Oleic acid	49 – 62
	Stearic acid	14 – 19
	Palmitic acid	14 – 15
	Linoleic acid	8 – 16
Niger seed oil	Linoleic acid	51 – 55
	Oleic acid	31 – 39

Table 5. (Continued). Average fatty acid composition of the major oilseed and plant by-product oils

	Saturated acids	9 - 17
	Lauric acid	46 - 52
	Myristic acid	14 - 17
	Oleic acid	13 - 19
	Palmitic acid	6 - 9
	Capric acid	3 - 7
	Caprylic acid	3 - 4
	Stearic acid	1 - 3
	Linoleic acid	0.5 - 2
Olive oil	Oleic acid	65 - 86
	Palmitic acid	7 - 20
	Linoleic acid	5 - 15
	Stearic acid	0.5 - 3
Poppy seed oil	Linoleic acid	65
	Oleic acid	25
	Saturated acids	6 - 10
Rapeseed oil	Erucic acid	2 - 45
	Eicosenic acid	9 - 15
	Linoleic acid	9 - 15
	Linolenic acid	2 - 7
	Saturated fatty acids	3 - 6
Rice bran oil	Oleic acid	40 - 50
	Linoleic acid	29 - 42
	Palmitic acid	13 - 18
	Stearic acid	1 - 3
	Linolenic acid	0.5 - 1
Safflower oil	Linoleic acid	78
	Oleic acid	13.5
	Palmitic acid	6.6
	Stearic acid	1.8
Sesame oil	Oleic acid	37 - 50
	Linoleic acid	37 - 47
	Palmitic acid	7 - 9
	Stearic acid	4 - 5
Soybean oil	Linoleic acid	52 - 60
	Oleic acid	23 - 34
	Palmitic acid	7 - 14
	Stearic acid	2 - 6
	Linolenic acid	2 - 8
Sunflower oil	Linoleic acid	55 - 70
	Oleic acid	15 - 30
	Palmitic & stearic acids	5 - 15

Source: Tacon (1990)

The nutrient requirements shared among different species generally include protein, lipid, amino acid and water-soluble vitamins. Further, carbohydrate utilization by closely related species or species groups falls within a narrow range. Similarly, the differences in the requirements of most of the micronutrients, such as amino acids, vitamins, minerals and fatty acids show marginal variation between cultured species (De Silva and Anderson, 1995).

Therefore, general nutritional principles can be applied, and reliable data from closely related species can be utilized as and when appropriate. The use of such nutritional strategies will strengthen sustainability of the production system as a whole.

A large proportion of aquaculture in many developing countries is carried out in rural areas, where farmers adopt extended extensive or semi-intensive farming practices.

Table 6. Major polyunsaturated fatty acid (PUFA) contents of various lipids (% of lipid)

Lipid source	Total saturated fatty acids	Total unsaturated fatty acids	Total PUFAs	n-6 series fatty acid	n-3 series fatty acid	18:2n-6	18:3n-3	18:4n-3	20:4n-6	20:5n-3*	22:5n-3*	22:6n-3*
Soybean oil	15.1	80.7	57.6	50.8	6.8	50.8	6.8	-	-	-	-	-
Cottonseed oil	26.1	69.6	50.7	50.3	0.4	50.3	0.4	-	-	-	-	-
Corn oil	17.7	82.8	58.1	57.3	0.8	57.3	0.8	-	-	-	-	-
Sunflower oil	10.9	83.9	49.7	49.4	0.3	49.4	0.3	-	-	-	-	-
Sesame oil	15.2	80.5	40.5	40.0	0.5	40.0	0.5	-	-	-	-	-
Groundnut oil	17.3	77.8	31.0	31.0	-	31.0	-	-	-	-	-	-
Safflower oil	9.5	86.3	73.8	73.3	0.5	73.3	0.5	-	-	-	-	-
Lard	39.5	54.9	11.4	10.0	1.4	10.0	1.4	-	-	-	-	-
Beef tallow	48.2	46.6	4.3	3.7	0.6	3.7	0.6	-	-	-	-	-
Mutton tallow	48.5	43.0	7.5	4.8	2.7	4.8	2.7	-	-	-	-	-
Chicken fat	32.6	63.1	17.6	16.5	1.1	16.5	1.1	-	-	-	-	-
Herring oil	21.5	73.9	13.9	2.1	11.8	1.7	0.6	2.0	0.4	4.4	1.0	3.8
Menhaden oil	33.3	62.3	28.5	3.0	25.5	2.0	1.0	2.4	1.0	12.5	1.7	7.9
Cod liver oil	17.3	77.1	25.1	3.0	22.1	1.8	0.7	1.6	1.2	8.9	1.6	9.3

*Highly unsaturated fatty acid (HUFA)

Linoleic acid = 18:2n-6;
Linolenic acid = 18:3n-3;
Arachidonic acid = 20:4n-6 (eicosatetraenoic acid), 20:5n-3 (eicosapentaenoic acid);
Clupanodonic acid = 22:5 n-3 (docosapentaenoic acid), 22:6n-3 (docosahexaenoic acid)

Source: New (1987)

Table 7. Dietary essential fatty acid requirements of fish (% of dry diet)

Fish species	Level of requirement (% of dry diet)								
	18:2n-6		20:4n-6		18:3n-3		20:5n-3		22:6n-3
Cold water- freshwater									
Rainbow trout					1.0	or	1.0	or	1.0
Coho salmon					1.0				
Chum salmon	1.0	and			1.0	or	1.0	or	1.0
Ayu					1.0	or	1.0		
Warmwater- freshwater									
Channel catfish					1.0	or	0.50 – 0.75		
Common carp	1.0	and			1.0				
Tilapia zilli	1.0	or	1.0						
Oreochromis niloticus	0.5 – 1.0	or	1.0						
Japanese eel	0.5	and			0.5				
Marine									
Red sea bream							0.5	and	0.5
Sea bass								1.0	
Yellow tail								2.0	
Turbot								0.5 – 2.0	
Plaice								1.0	

Source: Tacon (1990) and Lall (1991)

Table 8. Dietary mineral requirements of various freshwater fish species g/kg or mg/kg dry diet)

Mineral	Rainbow trout	Japanese eel	Channel catfish	Common carp	Tilapia
Microelements					
Calcium (g/kg)	0.3-3.0	0.3-3.0	4.5	0.3-3.0	7.0
Phosphorus (g/kg)	=6.0	=6.0	4.2-4.5	=6.0	4.5-6.0
Magnesium (g/kg)	0.4-0.7	0.4-0.7	0.4-0.7	0.4-0.7	0.4-0.7
Sodium (g/kg)	Max 1.6		0.026*		
Microelements					
Iron (mg/kg)	R	170	30	200	
Copper (mg/kg)	3		5	3	
Manganese (mg/kg)	12-13		2-3	12-13	
Zinc (mg/kg)	15-30		200	15-30	
Cobalt (mg/kg)	0.05				
Selenium (mg/kg)	0.2-0.4	0.3-0.5	0.25	R	R
Iodine (mg/kg)	0.6-2.8				

R = Required
Source: Steffens (1989); Lall (1991); *Wilson and El-Naggar (1992)

Although information concerning the nutritional requirement of many of these cultivated fish species is well established, most has been generated from laboratory-based controlled feeding trials and, hence, is useful mainly for the formulation/production of nutritionally complete feeds for intensive culture systems. Such data may be less applicable to farming conditions where nutrition is from natural food supplies or supplemental artificial feeds. Natural productivity of the water body generally plays an important role in these production processes.

Nutrition and feeding of finfish and crustaceans in semi-intensive pond-farming systems are complex and poorly understood. Little or no information exists on the dietary requirements under farming conditions for many of the species cultured. To a large extent, this is due to the difficulties of quantifying the contribution of naturally available food organisms to the overall nutritional budget of pond-raised finfish or crustaceans (Tacon, 1993). In order to maximize cultivation production, there is an ongoing need to develop basic understanding of nutrient dynamics, specifically the role of fertilization and natural productivity.

Such under-standing will allow us to ensure that cost-effective diets are developed that take into account nutritional requirement differences between species, natural productivity of the water bodies and the location-specific availability of inputs.

There is evidence that even minor modifications of different inputs into semi-intensive systems can bring about major changes

Table 9. Summary of mineral requirements of fish

Mineral	Requirement (per kg dry diet)
Calcium	5 g
Phosphorus	7 g
Magnesium	500 mg
Sodium	1-3 g
Potassium	1-3 g
Sulphur	3-5 g
Chlorine	1-5 g
Iron	50 -100 mg
Copper	1-4 g
Manganese	20-50 mg
Cobalt	5-10 mg
Zinc	30-100 mg
Iodine	100-300 mg
Molybdenum	trace
Chromium	trace
Fluorine	trace

Source: Cho & Schell (1980, adapted from Hepher, 1990) in terms of growth, reproductive performance and overall productivity of the system (De Silva and Davy, 1992; Veerina et al., 1993; Bjerkan, 1996; Tacon and De Silva, 1997; Miaje et al., 1999). Since feed and fertilizers represent about 60-80 percent of the total cost of aquaculture production, understanding feed management strategies and their implementation is of major importance. Although there are many examples of how improved feeding strategies can be successfully implemented using simple indigenous techniques (Tacon and De Silva, 1997), further studies and research are necessary.

Method of feed presentation, feeding rates and frequency are three areas where much improvement can be made. In many semi-intensive systems, supplementary feeding is based on fish biomass. Environmental factors and natural foods, which are known to influence food consumption and fish growth, are seldom considered. In addition, no precise schedule(s) or table(s) for most cultured fish are available.

Table 10. Dietary vitamin requirements for rainbow trout, channel catfish and common carp (mg/kg dry diet unless specified)

Mineral	Rainbow trout	Channel catfish	Common carp
Vitamin A (IU)	2000-15000	5500	1000-20000
Vitamin D (IU)	2400	500-4000	NR
Vitamin E	30-50	50-100	80-300
Vitamin K	10	10	NR
Thiamine	1-12	1-20	NR
Riboflavin	3-30	9-20	4-10
Pyridoxine	1-15	3-20	4
Pantothenic acid	10-50	10-50	25
Niacin	1-150	14	29
Folic acid	5-10	NR or 5	NR
Vitamin B_{12}	0.02	0.02	NR
Choline	50-3000	400	500-4000
Inositol	200-500	NR	200-440
Biotin*	0.8	0.1	1.1
Ascorbic acid	100-500	NR or 100	R

NR = Not required;
R = Required
Source: Lall (1991); *After Hepher (1990)

Table 11. Feeding frequencies required for promoting optimum growth and feeding efficiency in different species of fish

Fish species	Optimum feeding frequency (feeds/day)	Initial fish size (g)
Cyprinus carpio	3	0.2
Chanos chanos	8	0.6
Oncorhynchus mykiss	2	7.6-15.0
Epinephelus tauvina	1	70.0
Heteropneustes fossilis	1-2	4.5-9.0
Ictalurus punctatus	2	-
Channa striatus	1	0.7
Clarias lazera	Continuous	0.5
Oreochromis niloticus	1	6.8

Source: Chiu (1989; in *De Silva and Anderson, 1995*)

Feeding rates or ration size need to be determined by pond ecology (which varies considerably with season), in addition to fish biomass. Maximum benefits from supplemental feeding can only achieved if the diet is ingested in its entirety, and supplied to fish or shrimp at a rate compatible with the quantity and quality of natural food available in the pond. It has often been advocated that feeding regimes should reflect the feeding habit of the species under wild conditions (Tacon, 1993). The majority of feeding tables recommended by feed manufacturers for use within semi-intensive farming systems are hypothetical and set irrespective of dietary composition, pond fertilization rate, natural food availability, stocking density and standing crop (Tacon, 1993). The benefits of increasing feeding frequency have also been well documented Villalon, 1991;

In most semi-intensive systems, particularly small-scale rural operations, supplemental feeds are dispensed in powdered form (De Silva, 1993). There is increasing doubt about the efficiency of this form of feeding, since there appears to be significant wastage and individual fish face difficulties ingesting sufficient quantities of each of the constituent ingredients to obtain a nutritionally balanced meal. In cyprinid polyculture, farmers often use “feeding bags”, which are suspended at a number of locations, the perforated bottom touching the water surface (Tacon and De Silva, 1997) to increase the feeding efficiency. Although there has been no scientific evaluation of the efficacy of this feeding method, most farmers believe the returns are higher than with hand broadcasting.

Similar but somewhat modified

Sumundra, 1992). These authors reported reduced leaching and feed loss, improved growth and feed efficiency for shrimp through increased feeding frequency. Table 11 presents a summary of experimental data available on feeding frequencies at which optimal growth was observed in different finfish species. The variability in the feeding frequencies shown in the table is probably more indicative of uncertainty of results, rather than of the biological variability per se (De Silva and Anderson, 1995). Nevertheless, it emphasises the importance of feeding frequency in aquaculture. The optimum feeding rate and frequency of presentation must, therefore, be determined for individual feeds and farms by carefully monitoring feed consumption, growth and feed efficiency over several growing seasons (Tacon, 1993).

feeding methods are used by the farmers of Andhra Pradesh in India. They keep the powdered feed mixture in perforated polyethylene bags suspended by wooden poles at a number of points around their ponds. Fish browse on the feed through the perforations and within two to three hours most of the feed in the bag is utilized. This method results in minimum wastage of feed and helps the farmers to apply medication effectively through feed (Veerina et al., 1993). In carp farming systems in Bangladesh, supplemental feeds are dispensed in both wet dough balls and in powdered dry mixture form. More recently, Miaje et al. (1999) demonstrated that both pelleted and dough forms of supplemental feed, comprised of mustard oil cake, rice bran and wheat bran, appear to be more suitable than powdered feed for Indian major carps and Java barb in polyculture.

Several other supplementary feeding techniques, ranging from manual feeding by placing floating feed items into a floating or fixed-surface bamboo frame to simple demand feeders, are practised in different parts of the world. However, in many cases, hard data are lacking on the efficiency of these feeding techniques (Tacon and De Silva, 1997). In semi-intensive aquaculture, there is a need for further research in these directions.

Several other techniques have been reported to maximize use of supplementary feed in semi-intensive farming systems. De Silva (1985) advocated the adoption of a mixed feeding schedule with alternate high and low protein diets. Adoption of such mixed feeding techniques using feeds already available appears more cost effective and feasible than developing new feeds (De Silva, 1993). Furthermore, protein-rich diets (more expensive) diluted with carbohydrate-rich diets (less expensive) (Hepher and Pruginin, 1981) as well as use of a limited number of diets with improved nutritional value (Hepher, 1990; Sumagaysay et al., 1990) may offer significant economic advantage by reducing the overall feed cost in intensive aquaculture practices.

Nutrition and health

A large number of research studies have been carried out to quantify the nutrient requirements of fish and

Thus although these studies have generated a significant amount of information on pathology in relation to nutrient imbalance and the presence of toxic and antinutritional factors in feed ingredients, the possible effects of macro- and micronutrients on immunological parameters have mainly been overlooked. Nutrition and farm management strategies play critical roles in fish health and disease outbreaks within intensive farming systems and, to lesser extent, in semi-intensive farming systems (Tacon, 1997a). However, it must be emphasized that nutrition and farm management should not only satisfy the dietary nutrient requirements of the farmed species for maximum growth but also for increased immunocompetence and disease resistance. There is a growing need to take immunological parameters into account in nutritional studies on aquatic animals. This is especially important, since fish appear to depend more heavily on non specific defence mechanisms than mammals (Kaushik, 2000).

The effects of vitamins C and E are well documented, but several other nutrients and feed additives, including other vitamins (vitamin A), trace elements (Zn, Cu, Se, Mn, Fl), essential fatty acids and carotenoids have also been reported to play important roles in the immune response of fish (Devresse et al., 1997). While the application of vitamins, essential fatty acids and other micronutrients has shown conclusive evidence of a role in shellfish (Alliot et al., 1974; Jauncey, 1982; Daniel and Robinson, 1986; Akand et al., 1989, 1991a,b); De Silva et al., 1989; Borlongan and Parazo 1991; Ellis and Reigh, 1991; Borlongan, 1992; Koshio et al., 1993; Castell et al., 1994; Habib et al., 1994; Hasan et al., 1994; Mourente et al., 1995; Querijero et al., 1997; Hossain and Furuichi, 1999, 2000; Ngamsnae et al., 1999). Another area of research that has received significant attention in aquaculture nutrition is the use of plant and animal by-products as fishmeal substitutes in fish feed (Atack et al., 1979; Dabrowski and Kozak, 1979; Higgs et al., 1979; Capper et al., 1982; Jackson et al., 1982; Tacon et al., 1984; Wee and Wang, 1987; Davies et al., 1989; Wee and Shu, 1989; Fowler, 1990; Gallagher, 1994; Kaushik et al., 1995; Habib and Hasan, 1995; Stickney et al., 1996; Brunson et al., 1997; Hasan et al. 1997a, b) Unfortunately, the major emphasis of these studies was on optimizing growth, feed efficiency and general health condition. sustaining the immune function of fish in laboratory trials and in intensive commercial aquaculture operations, their influence on the defence mechanisms of fish reared under semi-intensive culture conditions (where ecological factors also influence diet) remains to be determined. It is perceived that natural food production in semi-intensive culture conditions should supply enough of these nutrients to meet the fish immune response requirements (Dickson, 1987; Castell et al., 1988; Castille and Lawrence, 1989; Hepher, 1990; Trino et al., 1992; Tacon, 1993).

In recent years, probiotics (non pathogenic, opportunistic bacteria of the genera Bacillus, Lactobacillus, Streptococcus) and natural immunostimulants (yeast, glucans) have shown promise for increasing disease resistance in fish and shellfish. As a result, there has been a growing interest in the use of immunostimulants as prophylactic agents to minimize the risk of disease outbreaks. The large number of commercial immunostimulants on the market clearly reflects this interest; however, the results obtained to date have not always been consistent and these products are still less effective than vaccines (Devresse et al., 1997).

There is, therefore, a clear need to improve the stability of immunostimulants, micronutrients and oral vaccines, especially under subtropical and tropical culture conditions, as well as nutritional information related to effective use of vaccines and/or chemotherapy, before adopting new immunostimulation techniques (Lall pers. comm). Further, improving health through proper nutrition would not only reduce the need for chemotherapeutants, but also help avoid major disease outbreaks.

Toxic and antinutritional factors (blocking effective nutrient assimilation) present in plant ingredients, nutritional imbalances of formulated feed, adventitious toxic factors and toxic compounds formed during feed storage and processing etc., can all severely affect the health status of cultured species and lead to increased susceptibility to disease. Although information on these aspects is documented, and appropriate precautions during feed formulation and processing can minimize the risk (Devresse et al., 1997; Lall pers. comm), there is a need for further research to develop better strategies to minimize such toxicity effects.

Nutrition and fish quality

Fish is a highly nutritious food, containing high amounts of proteins with high biochemical value for humans. In addition, it is a very good

Recent work on salmonids showed that product quality can be tailored by modifying the dietary composition, and a more nutritious fillet can be produced (Kaushik, 2000). However, more research has to be done on this field, giving adequate consideration not only to nutrient bioavailability but also to postharvest quality control.

Aquafeed and the environment

Given that feed is the biggest source of nutrient loading in fish and shrimp aquaculture production, clear understanding of its impact is essential for sustainable development, either intensive or semi-intensive. This will help reduce negative impacts and improve predictability of environmental effects. Present knowledge and understanding of the environmental impacts of aquafeed needs further refinement; however, it is generally acknowledged that these impacts can be reduced by feeding fish with more environmentally friendly diets, developing better feeding strategies and by a sound farm management. Interrelationships among various factors and strategies in dealing with environmental pollution and aquafeed are schematically shown by De Silva and Anderson (1995). The authors advocated a holistic approach and noted that fish nutritionists can no longer be formulators of nutritionally wholesome diets, but need to consider fresh strategies in diet development source of polyunsaturated fatty acids (PUFA) known to be beneficial in preventing cardiovascular diseases, breast and colon cancer, psoriasis etc. (Kaushik, 2000). Highly unsaturated fatty acids (HUFA) present in marine fish oil are medically proven to be beneficial against inflammatory disorders and ischaemic heart disease by modifying arachidonic acid/prostaglandin pathways (Sargent, 1992). Fish also contain micronutrients such as iodine, selenium and fat-soluble vitamins (A and D) that have positive effects on human health. In many developing countries of the world, small fish are eaten whole and thus contribute calcium, phosphorus and iron to the human diet.

Improvement of feed and nutrition in aquaculture may give us the opportunity to further improve the nutritional quality and benefits of the fish consumed. Nutritional value, colour and appearance, smell and taste, texture and storing capacity may all be affected by the quality of nutrition and feed provided during culture.

and feed cost reduction.

In developed countries, where intensive farming of carnivorous fish species is primarily dependent on a supply of nutritionally complete, formulated diet, mitigation of negative impacts of aquafeed through development of more environmentally friendly diets is considered to be a major challenge. Potential pollutants from aquafeed are phosphorus and nitrogen, as well as organic matter. Alvarado (1997) describes the flux of nutrients from a gilthead seabream farm, where fish under intensive production were fed commercially extruded bream diets (Fig. 1). It was shown that 180 kg of solids, 13 kg phosphorus and 105.4 kg of nitrogen were released to the environment through excretion and by uneaten feed to produce 1000 kg of fish. Thus lowering the amount of nitrogen and phosphorus in feed as far as possible will be one of the most efficient ways to reduce pollution effects.

Further, more environmentally friendly diets can be produced by developing diets with reduced food conversion ratios (FCR), e.g. by improving palatability and digestibility of raw ingredients.

The precise requirements for protein, amino acid and energy for each species and stage of development, as well as strain, need to be refined. It is also acknowledged that nutrient requirements change as the intensity of culture changes. The digestibility of nutrients is not precisely defined in many commercial feeds, and current research shows that feed performances and digestibility can be increased with the use of enzymes that enhance plant protein use, and by use of extrusion technology. Therefore, continued research on processing techniques and additives and enzymes for improving feed performances and digestibility are required, for example, on optimization of protein/energy ratios and amino acid profiles to reduce nitrogen excretion.

Improved knowledge of feeding strategies has also helped improve feed utilization and reduce the FCR and waste, thereby reducing negative environmental impacts (Alvarado, 1997). Examples of improved feeding strategies range from:

- sophisticated computer-controlled feeding devices for intensive commercial production of high value marine fish;
- increased feeding frequency;
- adjustment of feeding rate based on pond productivity; and
- use of supplemental feed in pelleted or dough form, as opposed to powdered form, in semi-intensive aquaculture systems.

In addition to the potential for environmental degradation by waste aquafeed, therapeutant misuse should not be overlooked. Medicated feeds are often used indiscriminately during disease outbreaks in hatcheries, nurseries and farms (Hasan and Ahmed, 2001). Although some of these drugs are unstable in water and do not cause any major problem, others are very stable and can precipitate development of bacterial strains that are resistant to these drugs. Furthermore, use of multiple, related, drugs can result in development of bacterial strains that are highly resistant to a wide range of drugs (Alvarado, 1997).

Figure 1. Characteristics of Ewos extruded bream diests, and nutrients loading (kg) per ton of fish produced (adapted from Alvarado, 1997)

Protein %	47
Phosphorus	1
FCR	1.8
Digestibility (%):	
Dry Matter	90
Crude Protein	82
Crude Fat	88
Nitrogen-free	75
Phosphorus	40

Feed	1800	kg
Phosphorus	18	kg
Nitrogen	135.4	kg

↓

Fish:	1000	kg
P in fish (0.5%)	5	kg
N in fish (3%)	30	kg

↓

To the environment:

P in faeces:	10.8	kg	N in faeces:	24.4	kg	Solids:	180.0	kg
P in water:	2.2	kg	N in water:	81.0	kg			
Total P:	13.0	kg	Total N:	105.4	kg			

Thus several factors and strategies have to be carefully monitored, and alternative strategies developed, while dealing with aquafeed and environmental pollution.

Broodstock and larval nutrition

It is well recognized that adequate nutrition has an important role to play in the reproductive success of all animals, including fish. There are a number of aspects of reproduction that can be affected by nutritional status:

- the time of first maturity;
- the number of eggs produced (fecundity);
- egg size; and
- egg quality as measured by chemical composition, hatchability and larval survival (De Silva and Anderson, 1995).

During the last decade, increased attention has been paid to the role of different components of broodstock diets. It has been shown that essential fatty acids, vitamins (A, E and C), trace minerals, -carotene and other carotenoids can affect fecundity, egg quality, hatchability and larval quality (Kaushik, 1993; De Silva and Anderson, 1995; Izquierdo and Fernandez-Palacios, 1997), and that the amino acid requirements of broodstock are apparently similar to those for optimal growth (De Silva and Anderson, 1995). Results of these studies also indicate that there exists

Some interesting short-term effects of nutrients on broodstock have also been described in red seabream. It has been reported that specialized diets given immediately prior to, or during, spawning of red seabream affected the composition of the eggs. Pigments such as -carotene, canthaxanthin or astaxanthin resulted in marked improvement in the percentage of buoyant eggs. Therefore, there is a need to define different stages of broodstock nutrition for appropriate management. Nutritional requirements of broodstock can further differ depending upon the phase of reproductive period. These periods are generally distinguished as:

- the period from commercial size to broodstock size;
- immediately prior to, or during, spawning; and
- post-spawning.

Formulation of complete diets should, therefore, take into account the stage-specific, as well as species-specific nutritional requirements of the broodstock. Nutritionists and the feed industry should also consider the options for developing three types of broodstock diets:

- conditioning diet,
- reproduction diet, and
- recovery/maintenance diet.

The broodstock conditioning diet should be formulated as an optimized growout diet to meet the full nutritional requirements of the species great species diversity in nutritional requirements affecting reproduction. Apart from common carp, most of these studies have been carried out for marine carnivorous fish species (De Silva and Anderson, 1995; Izquierdo and Fernandez-Palacios, 1997); thus relatively little is known about broodstock nutrition of freshwater omnivorous/herbivorous fish species. Therefore, there is an immediate need to learn about the nutritional requirements for broodstock maintenance and reproduction for most of the commercially important freshwater fish species. Clearly defined broodstock nutrition is not only necessary for high-value fish cultivated under intensive aquaculture, but could also significantly enhance production success of species grown under semi-intensive farming conditions. Another aspect that has received little attention to date is the nutrition of male broodstock. Possible improvement of sperm quality through dietary manipulation deserves further consideration.

In a study continued over a period of eight months prior to spawning, Watanabe et al. (1984a) found that EFA (n-3 PUFA)-deficient diets in red seabream produced eggs with significantly lower survival and high levels of larval deformity.

from commercial to broodstock size in maximal synergy with the environment. The reproduction diet used before or during spawning should meet the needs for maximal reproductive performance (spawning success and fecundity), gamete quality, and vertical transfer of nutrients and biologically active substances to offspring. The recovery/maintenance diet should assist recovery from reproductive exhaustion and reconditioning for the next reproductive cycle.

The nutrient requirements of all animals vary throughout their life cycle. Complex morphological and physiological changes invariably modify feeding and nutritional requirements. Finfish, nutrition during the embryonic stage is provided by the yolk sac and oil globules. The transition from an endogenous to an exogenous food supply, which marks the onset of the larval stage, is one of the most critical phases of the lifecycle and is the period when much of the mortality of hatchery-reared stock occurs (De Silva and Anderson, 1995). In spite of the clear importance of nutrition in influencing the survival, growth and development of larvae, however, relatively little is known about the absolute nutrient requirements of these stages of aquatic animals.

It is generally acknowledged that the feeding behaviour of larvae has a dominant role in larval nutrition, e.g. the larvae of many fish species will not take an artificial diet. There are also species that will take an artificial diet, but this must be supplemented with live zooplankton to satisfy all nutritional requirements. In some species, provision of microparticulate diets in addition to live food enhances both growth and survival rates (Kanazawa, 1991a).

In recent years, a considerable amount of research has been devoted to study of the nutritional requirements of marine fish larvae. Comparison of the biochemical composition of eggs and larvae at different stages, pattern of loss and conservation of nutrients during starvation and feeding experiments that control live-prey or microdiet nutrient composition are some of the most frequently used methods to study nutritional requirements of marine fish larvae (Izquierdo and Fernandez-Palacios, 1997). Live foods constitute the main diet for marine fish larvae, but a single live food species is often unable to satisfy the complete nutritional requirement of the species under culture. Since many finfish are reared on a single type of live food at any one time, a number of studies have been conducted to investigate the effect of enriching live

Culture of most marine fish and shrimp larvae, at least during early ontogenesis, still relies heavily on the supply of live food items (brine shrimp, rotifers and microalgae). This dependence on live food is already causing concern, due to the lack of resources and increasing production costs. Efforts are underway to find alternatives, such as other sources of live prey, partial replacement/supplement of live prey and development of microparticulate diets for larvae. Much research effort is also being invested in establishing nutritional limiting factors, early use of artificial diets and reduction of the weaning period, for many marine fish larvae (Alami-Durante and Meyers, 1993; De Silva and Anderson, 1995; P. Lavens pers. comm.)

For most hatchery-reared marine and freshwater fish and shrimp larvae, development of complete artificial diets for rearing, or reduction of length of weaning from live food, is of immense importance for further development of aquaculture of these species. Determination of absolute nutrient requirements of fish larvae of commercial importance is also an essential prerequisite before any attempt is undertaken to formulate/develop an artificial diet. The necessity to utilize diets with optimum stability and good physical characteristics in water, along with food organisms with various nutrients. Results indicate that larval fish require diets with a high protein content (Kanazawa, 1991b, Kissil, 1991; Cho and Cowey, 1991; Luquet, 1991) and sufficient amounts of essential fatty acids (Lavens et al., 1991). The live foods that have been most intensively investigated, with respect to their nutritive suitability are brine shrimp (Artemia spp.) and rotifer (Brachionus plicatilis). Artemia is low in the essential fatty acids eicosapentaenoic acid (C20:5n-3, EPA) and docosahexaenoic acid (C22:6n-3, DHA); thus simple methods of bioencapsulation have been developed to incorporate particulate products into brine shrimp nauplii. The nauplii consume particles of a desired composition prior to being offered as prey for fish larvae. The nutritive value of rotifers is made suitable by culturing them a suitable medium such as -yeast, and by feeding with a mixture of homogenized lipids and baker's yeast or marine alga (Chlorella spp.), all of which are rich in n-3 polyunsaturated fatty acids. While it is generally considered that eicosapentaenoic and docosahexaenoic acids are important fatty acids in the nutrition of larval fish, the specific fatty acids required vary between species (De Silva and Anderson, 1995).

enhanced attractability, are clearly recognized. Attractiveness is an especially critical factor for optimum ingestion of the diet and is a crucial component for accurate evaluation of the nutritional value of the particular formulation. Other aspects that need to be addressed for the development of larval diets are improvement of digestibility of microparticles and diet quality through supply of requisite nutrients, e.g. exogenous digestive enzymes. Another approach is incorporation of feeding stimulants, especially amino acids, to dry diets. Research on the physical behaviour of particles in the water column and controlled leaching of components also deserves further attention. Although much of the potential for manipulation of natural productivity to ensure production of good quality larvae under semi-intensive farming systems remains to be determined (Kaushik, 2000), the problems associated with nutrient quality of live food do not necessarily occur when larvae are reared under natural pond conditions. For example, where planktonic growth is stimulated by fertilization/natural productivity, as in the case of rearing of Chinese carps (De Silva and Anderson, 1995), the range and suitability of natural foods enable the cultured organisms to obtain all nutrient requirements without further supplement.

Demand and supply of marine resources for aquafeeds

It is envisaged that world annual fishmeal production will remain static at 6.5 million mt over the next decade. World annual fish oil production will remain around 1.24 million mt during next decade, although this is expected to fluctuate due to El Niño. To keep pace with global aquaculture production, a marked increase in use and production of formulated feed is foreseen for the next 25 years (Tables 12 and 13, Fig. 2) (Barlow, 2000). High quality fishmeal and fish oil are the major dietary ingredients for the production of formulated feed. It is, therefore, predicted that the requirement for these will increase from 2,115 to 3,262 million mt for fishmeal and from 0,708 to 1,308 million tonnes for fish oil between 2000 and 2025, to support today's intensive aquaculture industry (Table 14, Figs. 3 and 4) (Barlow, 2000).

While the demand for fishmeal for the aquaculture industry will increase, it is projected that there will be a drastic reduction in the use of fishmeal for the poultry industry (Barlow, 2000) (Fig. 4) and, as a result, aquaculture will have sufficient fishmeal to 2020 and beyond. It is also predicted that sufficient fish oil will be available to year 2010, although fluctuations caused during El Niño may create

Since marine fish oil is rich in n-3 PUFA and the major source of unsaturated fatty acids in compound aquafeeds - an essential dietary nutrient for all marine carnivorous finfish and crustacean species (NRC, 1993) - the feed industry should look for possible substitutes.The demand for fish oil could be reduced by using vegetable oil or a blend of fish oil and vegetable oil as a source of unsaturated fatty acids (n-3 and n-6). With the exception of strictly carnivorous fish species, fish are able to use C18:2n-6 or C18:3n-3 and convert them into corresponding HUFA: C20:4n-6 in the case of n-6 series, and C20:5n-3 or C22:6n-3 in case of n-3 series. Gene research on marine carnivorous fish to acquire the capability to elongate C18:3n-3 deserves further consideration (see Dunham et al., this volume).

Alternative protein sources: plant and animal by-products

Fishmeal and fish oil are the most widely used dietary components of commercially produced high quality fish/shrimp feed throughout the world. Fishmeal and oil are preferred for commercial feed production because of their unique balance of protein (amino acids) and lipids (long chain n-3) in a highly digestible energy dense form. Substitution with other ingredients, especially those of temporary shortages. However, beyond this period, there will be a shortfall of marine oil for aquaculture feed (Table 14, Fig. 4).

plant origin, is likely to compromise nutrient balance and fail to match the energy concentrations achieved using fishmeal and oil. Nevertheless, the high costs of these ingre-dients have severely restricted their use, especially in semi-intensive aquaculture systems.

Table 12. 1999 prediction of global aquaculture production ('000 tonnes) in 2000, 2010 and 2025

Species	2000	APR *	2010	APR	2025
Carp	13,983	10	36,268	2	48,812
Tilapia	974	10	2,526	5	5,251
Shrimp (marine) + crabs	1,034	5	1,684	5	3,501
Salmon	876	6	1,569	6	3,760
Marine Fish[1]	856	5	1,394	5	2,898
Trout	450	5	733	5	1,524
Catfish	371	5	604	5	1,256
Milkfish	379	2	462	1	536
Other marine fish[2]	105	20	650	5	1,351
Eel	216	2	263	1	305
Total	**19,244**		**46,153**		**69,194**

*APR- Annual percentage rate of growth;
[1]Bass, bream, yellowtail, grouper, jacks and mullets;
[2]Flat fish including flounder, turbot, halibut, sole, cod and hake.
Source: Barlow (2000)

Table 13. 1999 prediction of global aquaculture feed production in 2000, 2010 and 2025

Species	% of feed			Feed use per t produced			Feed requirement ('000t)		
	2000	2010	2025	2000	2010	2025	2000	2010	2025
Carp	25	50	75	2	1.5	1.3	6,991	27,000	47,592
Tilapia	40	60	80	2	1.5	1.3	779	2,106	5,461
Shrimp	80	90	95	1.8	1.6	1.4	1,489	2,425	4,656
Salmon	100	100	100	1.2	0.8	0.7	1,051	1,255	2,632
Marine fish[1]	60	80	95	1.8	1.5	1.2	923	1,670	3,304
Trout	100	100	100	1.3	0.8	0.7	585	586	1,067
Catfish	85	90	95	1.6	1.4	1.3	505	761	1,551
Milkfish	40	75	85	2.0	1.6	1.4	303	554	638
Other marine fish[2]	100	100	100	1.2	0.9	0.8	126	585	1,080
Eel	80	90	95	2.0	1.2	1.0	346	284	290
Total							13,098	37,226	68,271

[1]Bass, bream, yellowtail, grouper, jacks and mullets;
[2]Flat fish including flounder, turbot, halibut, sole, cod and hake.
Source: Barlow (2000)

Agricultural (animal and plant) by-products and wastes of agro-processing industries are widely available in most parts of the world and many are traditionally used as feed for farm animals. Of these (Table 15), the major conventional feed ingredients used as protein and energy supplements for fish, to date, are:

- meat meal, meat and bone meal mix, poultry by-product meal, blood meal (animal origin); and
- oilseed cakes, pulses, cereals and cereal by-products (plant origin).

Considering the increasing

Lower performances are attributed to toxic and nutrient-uptake blockers in plant ingredients and the inherent essential amino acid deficiencies of most plant proteins (Kaushik, 1989; NRC, 1993; Hasan et al., 1997b; Tacon, 1997b). Nevertheless, opportunities exist for use of these by-products as fish meal for most fish and shrimp grown in less intensive systems.

Considering the improved extensive and semi-intensive farming systems practised by most small-scale fish farmers of Asia and other developing countries, where fish and other aquatic animals are able to fulfill part of their nutritional requirements from naturally available food in the system (Tacon, 1993), ingredient quality similar to that of fish meal is probably not necessary for most farmers.

cost of fishmeal and doubt concerning its long-term availability, much research has been carried out on the use of plant and animal by-products as fishmeal substitutes (Dabrowski and Kozak, 1979; Jackson et al., 1982; Tacon et al., 1984; Wee and Wang, 1987; Davies et al., 1989; Fowler, 1990; Gallagher, 1994; Kaushik et al., 1995; Stickney et al., 1996; Brunson et al., 1997; Hasan et al. 1997a). Although some animal by-products have shown similar nutritional values to those of fish meal for many fish species, it is generally felt that there is currently no realistic alternative to fish meal or fish oil, because of the high levels of high quality protein and lipid required for cultivation of the fast growing carnivorous fish species. Replacement of fishmeal with plant by-products does not generally achieve the desired level of growth and other performances required for culture of fish and other aquatic animals (Higgs et al., 1979; Tacon et al., 1984; Stickney et al., 1996; Alexis, 1997; Brunson et al., 1997; Tacon, 1997b).

Figure 2. 1999 prediction of global aquaculture and aquaculture feed production in the years 2000, 2010 and 2025 (Source: Barlow, 2000)

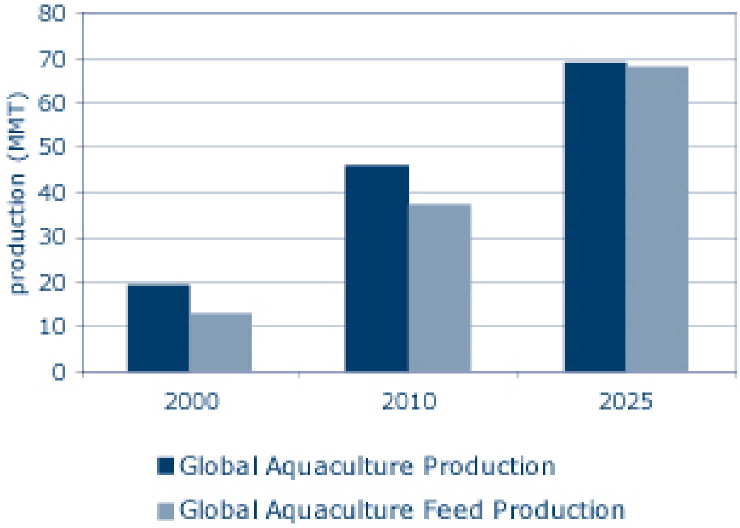


Table 14. 1999 prediction of global use of fishmeal and oil in aquaculture in 2000, 2010 and 2025

Species	% Fishmeal inclusion			Fishmeal requirement ('000t)			% Fish oil inclusion			Fish oil requirement ('000t)		
	2000	2010	2025	2000	2010	2025	2000	2010	2025	2000	2010	2025
Carp	5	2.5	0	350	675	0	1	0.5	0.5	70	135	238
Tilapia	7	3.5	2.5	55	74	136	1	0.5	0.5	8	11	27
Shrimp	25	20	15	372	485	698	2	3	3	29	73	14
Salmon	40	30	25	454	377	658	25	20	15	283	251	395
Marine fish[1]	45	40	30	415	668	991	20	15	10	185	251	330
Trout	30	25	20	176	147	213	15	20	15	88	117	160
Catfish	3	-	-	15	-	-	1	1	-	5	8	-
Milkfish	12	5	5	36	28	32	3	2	2	10	11	13
Other marine fish[2]	55	45	40	69	263	432	10	12	10	13	70	108
Eel	50	40	35	173	114	102	5	10	8	17	28	23
Total				**2,115**	**2,831**	**3,262**				**708**	**955**	**1,308**

[1]Bass, bream, yellowtail, grouper, jacks and mullets;
[2]Flat fish including flounder, turbot, halibut, sole, cod and hake.
Source: Barlow (2000)

Table 15. Gross nutritional composition (% dry matter) of major conventional feed ingredients that have a potential to be incorporated into aquafeed

Feed ingredients	Nutritional composition (%)				
	Protein	Lipid	CHO	Fibre	Ash
Animal origin					
Fish meal	60-75	5-20	1-4	1-3	10-25
Meat meal	55-60	2-10	19	2-3	15-18
Meat & bone meal	48-50	10-14		3-4	30-35
Poultry by-product meal	60-65	12-15	4-6	2	16-17
Poultry offal meal	53-75	17-40			3-7
Poultry feather meal	80-90	2-6	<1	<1-4	3-14
Blood meal	80-90	1-3	4-7	1-2	5-7
Silkworm pupae meal	55-75	15-30	5-10	4-6	3-7
Plant origin					
Oilseed meal and cakes					
Sesame, mustard, linseed, rape, copra, palm kernel	20-40	2-15	20-55	8-20	6-15
Soybean, cotton, groundnut	45-60	1 -7	20-35	4-15	6 -9
Cereal by-products	6-17	4-15	34-65	10-30	4-18
Cereal grains (barley, maize, rice, wheat, sorghum)	5-14	1-9	>75-80	2-10	2-5
Pulses (groundnut, lupin, all types of beans)	18-45	1-8	30-70	1-16	4-12
Root crops (potato, cassava)	2-10	1-3	70-90	1-4	2-6
Leaf meals	11-30	2-7	38-65	10-20	4-19
Single cell protein (yeast, algae)	45-70	1-14	14-40	<1-9	7-14

Source of data: De Silva (1999); Habib and Hasan (1995); Hasan and Akhteruzzaman (1999); Hasan and Amin, (1997); Hasan and Das (1993); Hasanet al.(1985); Hasanet al(1988); Hasan et al. (1989); Hasanet al. (1990); Hasanet al. (1991); Hasanet al. (1994); Hasanet al. (1997a); Hasanet al. (1997b); Mahtaet al. (1994); New (1987); NRA (1993); NRC (1983)

Figure 3. Projection of demand of fish meal for fish and other animal feed industry (adapted from Burlow, 2000)

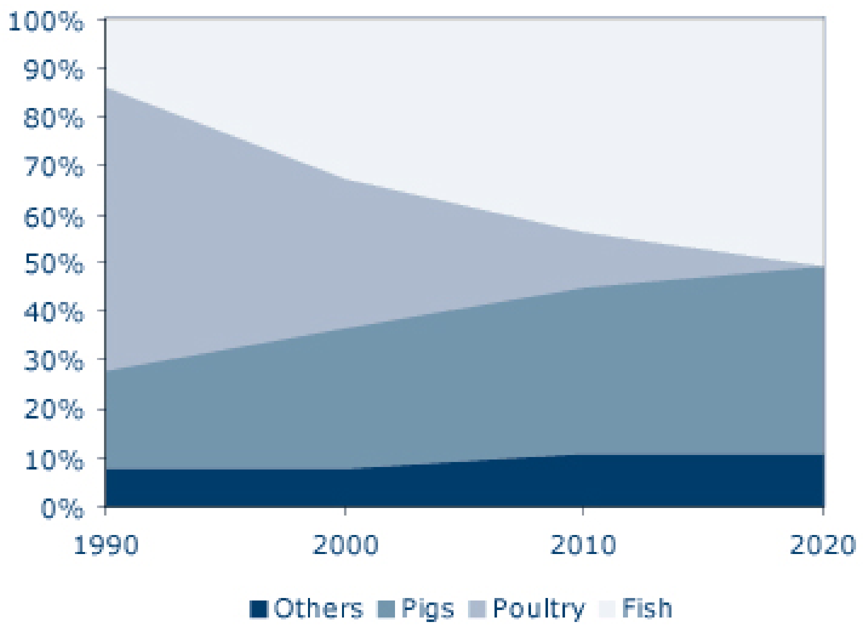
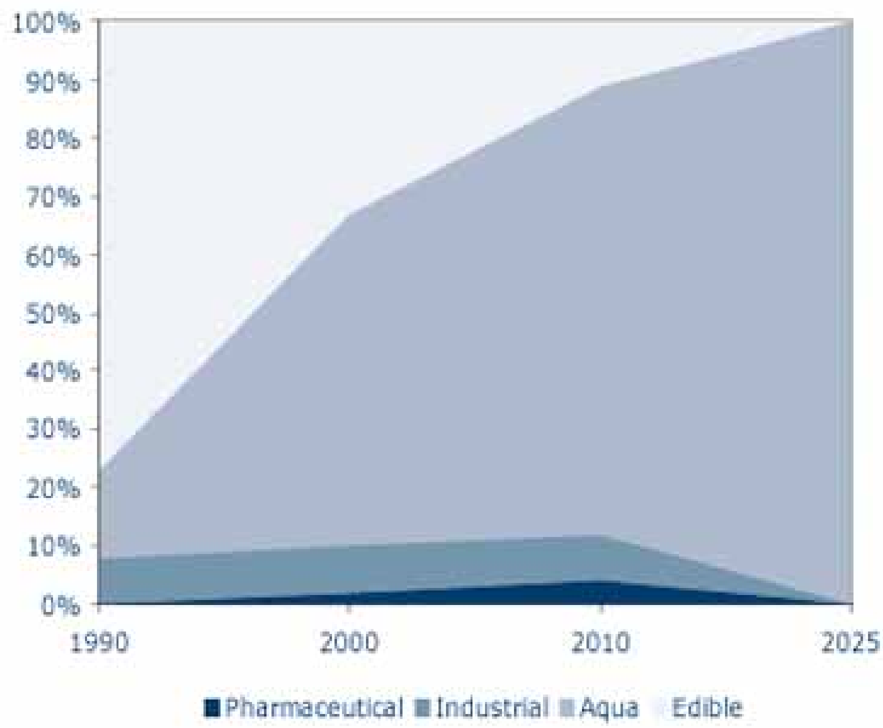


Figure 4. Projection of demand of fish oil for aquaculture and other use (adaped from Burlow, 2000)



More relevant research emphasis would be on the "appropriate utilization of these ingredients as supplemental feed" rather than "evaluation of

- nutritional composition (quantity, quality and bioavailability of protein, lipid, carbohydrate, vitamin and mineral) of feed ingredients;
- their suitability for incorporation into practical diets; and
- results of experimental work on the use of these ingredients in fish feed.

Further, there is evidence that the use of many of these ingredients can be enhanced by simple processing techniques. For example, cooked starch is more useful to many omnivorous and herbivorous fish than raw starch. Many shrimp farmers in Andhra Pradesh, India cook their ingredients before use. Cooking has been reported to increase the digestibility and increase feed efficiency (Hasan and Amin, 1997). So information on simple processing techniques and palatability to the target species, along with storage and preservation, seasonal and regional variability in proximate composition etc., will all lead to more efficient utilization of these feed ingredients.

In contrast to semithese ingredients as fishmeal substitutes” (De Silva, 1993, 1999). Improved information is needed on:

intensive aquaculture practices, demands for fish meal and agricultural by-products of high quality are expected to increase, keeping pace with the dynamic developments in intensive aquaculture of carnivorous fish species in industrialized countries of the world. This will require greater availability of quality feeds. Quality of alternative protein/energy sources, be it animal or plant, has to be ensured by appropriate evaluation and screening, starting from safe and careful collection, processing using optimum technologies and maintaining efficient quality control systems. Likewise, consumers expect effective tracking and safety control systems in their final choice of foods.

Mention may be made about the spread of bovine spongiform encephalopathy (BSE), the dreaded mad cow disease. The World Health Organization (WHO) has recently concluded that BSE may be spreading worldwide through international trade in animal feed. Meat and bone meal are two of the animal by-product meals widely used as fishmeal substitutes for fish farming in different parts of the world. It is, therefore, imperative that production, sale and use of all plant and animal by-products be based on sound science, true documentation, realistic risk analyses and clear labelling, to ensure food safety. Appropriate documentation and clear labelling will also improve consumer confidence and freedom of choice.

Development of regional database for aquaculture development

The costs of feed ingredients and farm input are increasing, while market costs for the major cultivated finfish and crustacean species have remained static or are decreasing.

It is, therefore, likely that increased aquaculture production will be from herbivorous/omnivorous aquatic animals in developing countries of Asia and other parts of the world. Aquaculturists could reduce current dependence on natural marine resources to farm carnivorous finfish and marine shrimp through the use of low-cost, locally available, alternative feed ingredients. Research into the appropriate utilization of these feed supplements in semi-intensive aquaculture, however, is still required. There is little information on their availability and abundance, especially in many developing countries. In addition, development of intensive poultry, dairy and other livestock industries is likely to intensify the competition for nutrients and feed resources. A reliable database of agricultural feed resources is thus an essential prerequisite for planning sustainable aquaculture development. A national agricultural feed survey would create a database of feed resources and enable national aquaculture development strategy planning. Further, the establishment and/or strengthening of national and regional fertilizer and feed ingredient databases, and information systems, will enable projection of major agricultural by-products throughout the world that may benefit the aquaculture feed industry.

Conclusions

Over the last decade, the world has witnessed spectacular growth in the

Recognizing the current importance of fish meal and fish oil within industrially compounded aquafeeds, while lack of fish meal is not foreseen in the next 25 years, there is a risk that a lack of marine oils may occur in the short term (5-10 years). With the expansion of intensive aquaculture, aquaculturists must carefully assess the impact of nutrient loading in the aquatic environment and use both science and judgement for reducing such impacts. Furthermore, a careful balance between environment, health/disease resistance and feed use should be maintained, so that the system does not deteriorate and negatively impact market value and consumer confidence.

Use of formulated feed and fishmeal has no clear future in semi-intensive aquaculture in developing countries of the world. Nevertheless, further intensification of commercial aquaculture will take place, even in developing countries, for shrimp and carnivorous freshwater species, with the same potential as mentioned above for an overall shortage of conventional feed ingredients. Alternative feed ingredients should be sought at the same time as improvement of pond management and manipulation of pond productivity. Use of nutritionally complete formulated diets will, however, continue to play a dominant role in hatchery and nursery production.

Recommendations

aquaculture industries of many developing countries. As a result, aquaculture has been contributing significantly to food security and poverty alleviation. It is anticipated that global aquaculture production will continue to increase and further contribute to these needs. Nutrition and feeding play a central role in sustainable aquaculture and, therefore, fertilizers and feed resources continue to dominate aquaculture needs. Much of the increased aquaculture production in developing countries of Asia and Africa will likely be achieved through expansion of semi-intensive, small-scale pond culture, thus feed and fertilizer resource availability, as well as cost, could be the major bottlenecks for such development.

In intensive aquaculture of marine carnivorous species, fish meal and fish oil will continue to be the major ingredients in the near future, although there may be scope for some use of animal by-products as alternative protein sources.

Improvement of nutrition and feeding for sustainable aquaculture development can be achieved thorough:

- increased understanding of the dietary nutrient requirements of cultured species, including their application to practical culture conditions;
- developing species-specific broodstock diets that allow complete domestication and maximal reproductive and larval quality;
- better understanding of larval nutritional requirements, in order to develop suitable compound diets, which will further reduce the need for live food;
- improving the understanding of the aquaculture farming systems (extensive, semi-intensive or intensive; closed or open culture systems) and the potential nutrient loads and losses to the environment, to maximize nutrient retention efficiency;
- understanding and monitoring the dynamics of nutrient flows and sinks within pond-based farming systems;

- improving the efficiency of resource use in aquaculture through use of appropriate agricultural and fishery by-products/wastes and nonfood-grade feed materials;
- developing feeding strategies based on renewable feed ingredient sources where production can keep pace with the growth of the sector;
- better understanding of nutrient bio-availability and interactions of commonly used feed ingredients;
- better understanding of nutrient modulation of disease resistance;
- improved strategies to minimize toxicity of nutrients and other compounds of feed origin;
- promotion of "good aquaculture feed manufacturing practice" and "good on-farm feed management";
- recognizing the importance of feed and consumer concerns over food safety issues (irrespective of the culture system), including the need for traceability of feed materials and production methods; and
- considering the effect of diet on product quality and the positive nutritional characteristics of the final product in terms of human nutrition, e.g. omega-3 fats, iodine, selenium, vitamins A and D.

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Strategic Review of Enhancements and Culture-based Fisheries

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ABSTRACT: Enhancements are interventions in the life cycle of common-pool aquatic resources. Enhancement technologies include culture-based fisheries, habitat modifications, fertilization, feeding and elimination of predators/competitors. Enhancements are estimated to yield about two million mt per year, mostly from culture-based fisheries in fresh waters where they account for some 20 percent of capture, or 10 percent of combined capture and culture production. Marine enhancements are still at an experimental stage, but some have reached commercial production. Enhancements use limited external feed and energy inputs, and can provide very high returns for labour and capital input. Moreover, enhancement initiatives can facilitate institutional change and a more active management of aquatic resources, leading to increased productivity, conservation and wider social benefits. Enhancements may help to maintain population abundance, community structure and ecosystem functioning in the face of heavy exploitation and/or environmental degradation. Negative environmental impacts may arise from ecological and genetic interactions between enhanced and wild stocks.

Many enhancements have not realised their full potential because of a failure to address specific institutional, technological, management and research requirements emanating from two key characteristics. Firstly, enhancement involves investment in common-pool resources and can only be sustained under institutional arrangements that allow regulation of use and a flow of benefits to those who bear the costs of enhancement. Secondly, interventions are limited to certain aspects of the life cycle of stocks, and outcomes are strongly dependent on natural conditions beyond management control. Hence, management must be adapted to local conditions to be effective, and certain conditions may preclude successful enhancement altogether. Governments have a major role to play in facilitating enhancement initiatives through the establishment of conducive institutional arrangements, appropriate research support, and the management of environmental and other impacts on and from enhancements.

KEY WORDS: Aquaculture, Culture-based Fisheries, Enhancement, Development, Floodplains, Reservoirs, Coastal Zone

Introduction

Definition and rationale

Enhancements may be defined as limited technological interventions in the life cycle of common-pool aquatic resources. Hence, enhancements combine attributes of aquaculture (intervention in the life cycle of aquatic organisms) and capture fisheries (exploitation of common-pool resources) in a unique way.

The rationale for enhancement is that, under certain conditions, limited technological interventions can substantially increase the utilization by man of natural aquatic productivity. Stocking of hatchery-reared seed fish, for example, can increase the yields of desired species where natural productivity is high but recruitment is limited. Habitat enhancements can have similar effects. Because enhancements rely largely on natural aquatic productivity, they require little feed or energy inputs, and can provide high returns from limited investments. Hence, enhancements provide opportunities in particular for resource-poor sections of inland and coastal aquatic resource users. Moreover, introduction of enhancement technologies may facilitate institutional change and more efficient and sustainable

Contribution to global fisheries production

The global contribution of enhancement to fish production is difficult to ascertain, because yields tend to be assimilated into the statistics of either capture fisheries or aquaculture production. There is little doubt, however, that enhancement yields are dominated by culture-based fisheries for freshwater and diadromous species. Annual yields in this category are likely to be around 2 million mt, including 1.3 million mt from Chinese reservoirs (Huang et al., 2001), 0.4 million mt from salmon in the North Pacific (Shaw and Muir, 1987; Kaeriyama, 1999; Knapp, 1999), and 0.18 million mt from Indian inland waters (Sugunan, 1995 and pers. comm.). Culture-based fisheries for food and recreation are well-established components of aquatic resource use in Europe (e.g. Mattern, 1999) and in North America, where state fisheries organizations expend an average of 19 percent of their budgets on stocking (Heidinger, 1999; Ross and Loomis, 1999). Overall, the estimate of 2 million mt per year suggests that culture-based fisheries for freshwater and diadromous organisms account for about 20 percent of recorded capture yields, or 10 percent of combined capture and culture in this category (total yields 7.5 and 21.2 million mt, respectively) [FAO, exploitation of common-pool resources.

Technologies

Enhancement technologies may involve, e.g.:

- stocking to create culture-based fisheries, i.e. fisheries based predominantly on the recapture of stocked fish;
- stocking to enhance or supplement self-recruiting populations;
- habitat modification to improve levels of recruitment and/or growth;
- elimination of unwanted species;
- fertilization; and
- combinations of any the above

Enhancements may involve introductions or transfers of organisms. However, introductions aimed at the establishment of capture fisheries do not constitute continued interventions in the life cycle of the organisms, and are not considered as enhancements in this review.

1999a]).

Enhancements of marine organisms are still being carried out primarily on an experimental or pilot scale, but hatchery production of marine organisms for stocking indicates considerable efforts (A.F. Born, pers. comm.).

A number of marine enhancements have entered commercial-scale production: for example, culture-based fisheries for scallops (Patinopecten yessoensis) in Japan now yield about 0.2 million mt/year, and the technology is being adopted elsewhere (Dao et al., 1999; Kitada, 1999).

Contributions to fish production by enhancement initiatives, other than culture-based fisheries, are poorly documented. However, it has been estimated that brush parks (acadjas) account for 12 000 mt or 40 percent of the inland fisheries production of Benin in Africa (J. Moreau and P. Laleye, pers. obs.). Similar systems are in use in other African and Asian countries (Kapetsky, 1981; Solarin and Udolisa, 1993), and there is evidence to suggest that habitat enhancement using indigenous technologies is more widespread in tropical inland waters than previously realised (Neiland and Ladu, 1997; U.W. Schmidt, pers. comm.).

Unique production systems

As defined above, enhancements are unique production systems. Technological interventions may be limited and relatively simple (e.g. stocking of seed fish), and the degree of management control over enhancement outcomes is inherently limited. This is a consequence of both the limited nature of interventions in ecosystems not managed primarily for fish production, and the common-pool (non private ownership) nature of the resource. Common-pool resources are exploited jointly by separate users, where resource use by one individual subtracts from the resources available to others and exclusion of users is difficult (Ostrom, 1990). Under such circumstances, the actions of resource users are difficult to predict, let alone control.

A useful framework for the analysis of enhancements is shown in Figure 1 (adapted from Oakerson, 1992). Outcomes are determined by the physical/biological nature of the resource and technology on one hand, and by the combined actions of resource users on the other. The latter The development of enhancements usually involves modifying technology and institutional arrangements in the light of outcomes, a process illustrated by the dashed arrows in Figure 1. Within this process, resource users and managers will be guided by their perceptions of outcomes in terms of a wide range of attributes, and the values they attach to these (Lorenzen and Garaway, 1998).

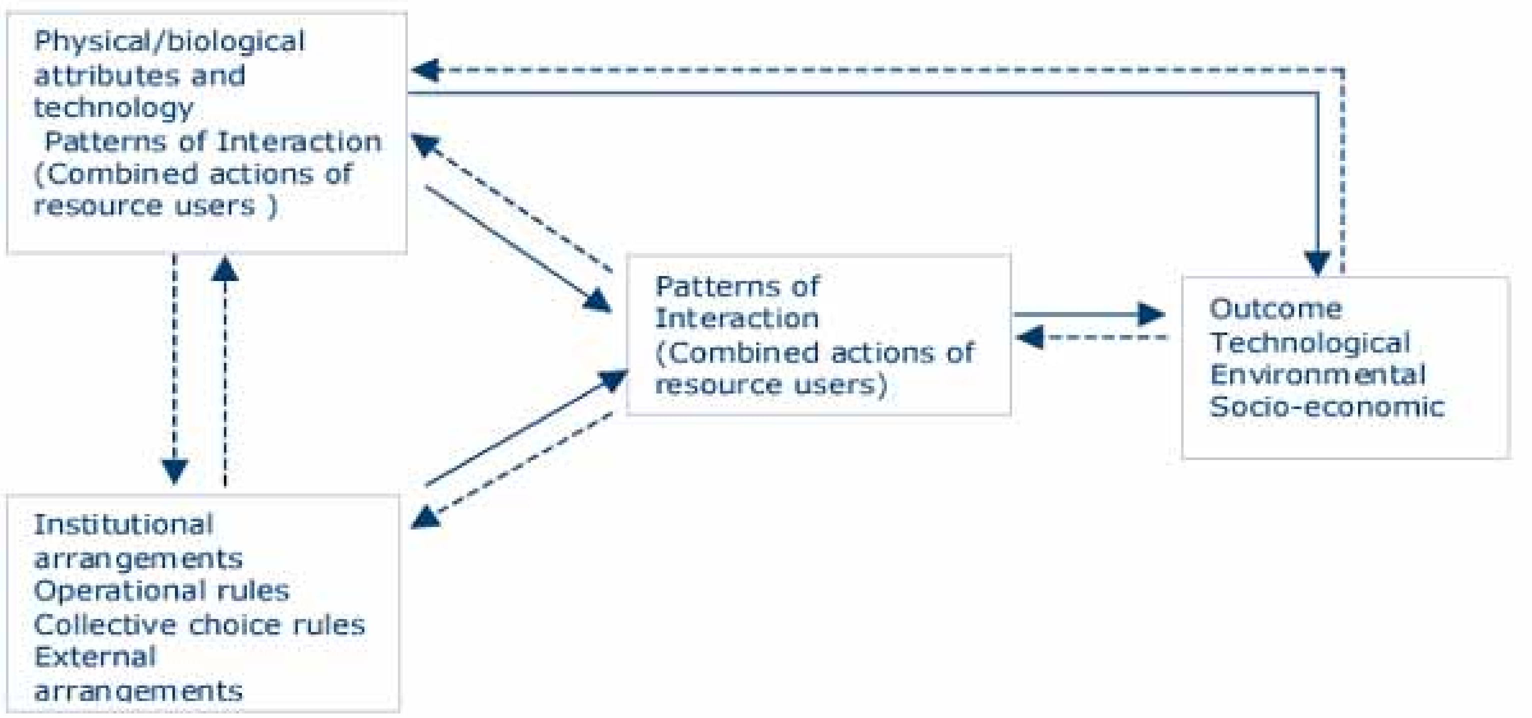
Resource management agencies and scientists may influence the choice of intervention and interact with institutional arrangements at various levels. However, our ability to predict and influence outcomes will remain somewhat limited, and strongly dependent on our understanding of the overall production system (Lorenzen and Garaway, 1998). This implies firstly a need for managers and scientists to develop a broad-based understanding of enhancement systems. Secondly, because predictability of outcomes is inherently low, strategies for developing new enhancements must be process - rather than outcome - oriented.

In the following, we review firstly the

are also known as patterns of interaction, being determined by the individual users' choices, as influenced by the physical/biological nature of the resource, and by the institutional arrangements governing resource use. Institutional arrangements consist of the operational rules for resource use, conditions of collective choice which determine how operational rules can be made, and external arrangements pertaining to rules and conditions of collective choice. In normal resource use, the nature of the resource and technology and the institutional arrangements are fixed and together influence the actions of resource users and ultimately the outcomes (solid arrows in Figure 1).

opportunities and constraints relating to enhancements, and secondly the process of developing enhancements. We then consider the future role of enhancement and current trends, before outlining requirements and opportunities for supporting the sustainable development of these production systems. We close with a set of key recommendations.

Figure. 1 Framework for analysing common pool resource systems. Modified from Oakerson (1992).



Opportunities and constraints

Opportunities for, and constraints to, enhancement must be understood in terms of a range of attributes that are important to various stakeholders, for example, yield, economic benefits and their distribution, environmental impacts, and institutional sustainability (Cowx, 1994; Lorenzen and Garaway, 1998). Opportunities and constraints would best be identified by reviewing outcomes of enhancements under a wide range of natural and human conditions, but in practice this is precluded by the fact that very few enhancements have been comprehensively evaluated (Cowx, 1994). Hence, we rely on a combination of theoretical considerations and experiences from enhancements that have been assessed with respect to at least some attributes.

Aquaculture techniques as a basis for enhancements

Many enhancements operating

Thus different objectives for enhancements may call for different seed production strategies. For example, culture-based fisheries may benefit from genetic selection for traits linked to the return rate or growth (Jonasson, 1995). Conversely, programmes aimed at supplementing natural stocks must make every effort to maintain the genetic makeup of the natural populations (Bartley et al., 1995; Munro and Bell, 1997).

Technological effectiveness and efficiency

Depending on the enhancement technology used, there are various measures of technological effectiveness and efficiency. Effectiveness may be measured in terms of recapture rates of stocked fish or increases in yield. Efficiency relates to optimal use, within given constraints, of inputs to produce the desired outputs, and is more difficult to assess than effectiveness.

Culture-based fisheries

today have a basis in “indigenous” technologies, such as the transfer of wild-caught juvenile fish from rivers to small reservoirs, as practised in China and India (Lu, 1992; Sugunan, 1995), or the construction of brush parks in Africa (Welcomme, 1972). Nonetheless, it is clear that development of efficient hatchery and nursery techniques for the Chinese and Indian major carps was a precondition for expansion of culture-based fishery production to current levels. Much emphasis is now placed on the development of seed production techniques for marine fish and invertebrates, and this is likely to create new opportunities for enhancements in coastal areas (Munro and Bell, 1997; A.F. Born, pers. comm.).

An important question in this respect is to what extent enhancements benefit from specific seed production techniques which differ from those used for aquaculture. The large-scale inland enhancements in Asia rely on seed produced for both purposes. Conversely, much research into marine stock enhancement is aimed at producing seed with desirable characteristics specifically for enhancement (Munro and Bell, 1997).

Culture-based fisheries, where yields are based predominantly on the recapture of stocked fish, can be effective in increasing yields where natural recruitment is lower than the environmental carrying capacity. This may be the case in certain modified ecosystems (e.g. reservoirs), or where intensive harvesting has reduced spawning stocks to very low levels. However, chronic recruitment limitation can also arise naturally, e.g. in seasonal and/or isolated freshwater bodies, or in marine habitats with poor connectivity to spawning sources (Doherty, 1999). By decoupling recruitment and natural spawning, culture-based fisheries also allow manipulations of population structure to increase production in a way that is unattainable in self-recruiting stocks. Where resource requirements of different size groups overlap (e.g. many planktivores and detritivores) and fish are marketable below their normal size at maturity, large and somatically unproductive size groups can be replaced by high densities of somatically productive smaller fish, thus increasing production from the given resources (Lorenzen, 1995). Hence, culture-based fisheries can, under certain conditions, increase yields over and above the level achievable from self-recruiting populations of the same species.

There are many examples of culture-based fisheries that have been effective in increasing yields of desired species: carps in small water bodies (Amarasinghe, 1998; Hasan and Middendorp, 1998; Lorenzen et al., 1998a; Nguyen et al., 2001), medium-size reservoirs (De Silva et al., 1991; Lu, 1992; Li and Xu, 1995; Lorenzen et al., 1997; Phan and De Silva, 2000), or floodplains (Ahmad et al., 1998); coregonids in lakes (Salojaervi, 1992); and scallops in coastal environments (Kitada, 1999). In all of these cases, the stocked species were either absent before enhancement or their abundance very much reduced by overfishing. The remarkable success of culture-based fisheries in Chinese reservoirs, which are reported to have raised average yields from 150 to 750 kg/ha/year (Huang et al., 2001), is based on the stocking of riverine major carps that are unable to reproduce successfully under the lacustrine conditions of reservoirs, but can make good use of the available food resources.

Unfortunately, the effectiveness of culture-based fisheries varies widely between locations, and the reasons

Stock enhancement

Where stocks have been depleted by overfishing, there may be a choice between stocking to develop a largely culture-based fishery while maintaining high exploitation rates, or supplementation stocking combined with more restricted harvesting to rebuild natural spawning stocks more quickly than would be possible through harvest restrictions alone.

Culture-based enhancement of self-recruiting populations aims to increase recruitment to the spawning stock, as well as to the fishery. The goal of enhancing, or at least maintaining natural recruitment to a population implies a need to restrict exploitation to levels that maintain an adequate spawning stock.

As in the case of culture-based fisheries, stock enhancement can be effective when natural recruitment is limited to levels well below the carrying capacity for the recruited stock. Where this limitation is temporary, enhancement measures should also be temporary in nature.

for this are not well established. High mortality of stocked fish is frequently a key limitation. A comparative analysis of stocking experiments (Lorenzen, 2000) showed that mortality of stocked fish may be slightly lower, or up to an order of magnitude higher than the average for wild fish of the same size. Optimization of seed production and release strategies can, however, significantly reduce such mortality (Bilton et al., 1982; Wahl et al., 1995; Munro and Bell, 1997; Leber, 1999).

The potential production of culture-based fisheries is strongly linked to ecosystem productivity, as clearly shown in comparative studies (De Silva et al., 1992; Lorenzen et al., 1998a; Hasan and Middendorp, 1998). Optimizing management regimes, so that the given production potential is utilized efficiently, remains a key challenge in the management of culture-based fisheries. The assessment of stocking and harvesting regimes requires quantitative information on density-dependent population processes (Peterman, 1991; Lorenzen, 1995). At present such information can only be obtained by (active or passive) experimental management, but further development of population dynamics theory and meta-analyses (joint analyses of data from several enhanced stocks) may reduce the need for experimental management

Such interventions can be effective where the causes of temporary recruitment limitation are easily established, e.g. in small water bodies affected by drought (Van der Mheen, 1994). Because stocking is unlikely to be effective when natural recruitment matches carrying capacity, recruitment must be assessed in time to produce the required additional seed fish (Munro and Bell, 1997; Giske and Salvanes, 1999).

The effectiveness of releasing cultured juveniles for stock enhancement is particularly difficult to assess. It depends on regulatory processes at different life stages that are poorly understood in broad terms, let alone for specific fisheries (Botsford and Hobbs, 1984). In the absence of detailed information, however, comparative studies provide some guidance for management. Studies on coregonids and tilapias suggest that there is little benefit from stocking lakes with established populations of these species (Salojaervi and Ekholm, 1990; Quiros and Mari, 1999), but definitive conclusions require further studies of higher statistical power.

in the future. So far, few culture-based fisheries have been analysed comprehensively, and it is likely that stocking and harvesting regimes are often suboptimal.

Habitat enhancements

A wide range of habitat enhancements is being carried out in inland and marine fisheries, using traditional and recently developed technologies (Williams et al., 1997; Cowx and Welcomme, 1998; Morikawa, 1999). The effectiveness of these measures has often proved difficult to evaluate due to the time scales involved in responses, the levels of natural variation in natural habitat and recruitment, and institutional impediments to monitoring and evaluation (e.g. Kershner, 1997; Munro and Bell, 1997). As a result, little scientific guidance can be given for choice of habitat enhancement approaches.

A common and effective habitat enhancement approach found in tropical Africa and Asia is the construction of brush parks, such as the acadjas in West African lagoons.

Stocking for culture-based fisheries and stock enhancement/supplementation may affect wild populations through the transmission of diseases, increased competition and predation, and genetic interactions (Cowx, 1994; Blankenship and Leber, 1995; Munro and Bell, 1997; Bartley, 1999; Subasinghe et al.,. This volume). These issues are particularly important where stocking is aimed at rebuilding populations and the proportion of released animals is high relative to the remnant wild stock. Where stocking involves introduction or translocation of species, there are additional concerns, such as hybridization with native/established species, habitat alterations, changes in the trophic functioning of ecosystems, and the introduction of exotic parasites and pathogens (Courtenay and Stauffer, 1984; Moyle et al., 1986; Arthington, 1991; Carvalho and

Brush parks provide substrate for periphyton (micro-algae growing on submerged surfaces) production and protection from certain predators, in addition to serving as fish aggregation devices. In the lagoons of Benin, production from brush parks has been estimated as 1.9 to 5.6 mt/ha/year (Welcomme, 1972; P. Laleye pers. obs.), substantially higher than the average of 0.29 mt/ha/year achieved in open waters of the lagoons (J. Moreau and P. Laleye, unpubl. data). Similar results have been reported from Nigeria (Solarin and Udolisa, 1993).

Indigenous technologies, i.e. habitat enhancements developed by resource users in developing as well as developed countries, have long been neglected by research and urgently require attention.

Environmental impacts on and from enhancements

Enhancements are limited interventions in the life cycle of aquatic species, and therefore remain closely linked to the wider aquatic ecosystem. This implies the potential for significant environmental impacts, both on and from enhancements. In both cases, impacts can be positive as well as negative.

Hauser, 1995; Moreau, 1999; Subasinghe et al., This volume). These risks are now widely recognized, and there is general agreement that proposals for introductions must be carefully evaluated using frameworks such as the International Council for the Exploration of the Sea (ICES)/European Inland Fishery Advisory Commission (EIFAC) code of practice (Turner, 1988; ICES, 1995; OIE, 2000) and equivalent regional guidelines.

Environmental impacts from a broad range of inland enhancements have recently been reviewed by the Food and Agriculture Organization of the United Nations (FAO, 1999b). Impacts of habitat modifications have received relatively little attention, but the example of brush parks suggests that such impacts can be significant constraints to the sustainability of enhancement initiatives. The high density of brush parks in some areas prevents circulation of the water and results in high rates of sedimentation (Anon., 1994; J. Moreau and P. Laleye, pers. obs).

Most impact assessments focus on the negative effects of enhancements. However, enhancement can have direct and indirect positive impacts:

Agricultural and industrial demand for fresh water has led to water scarcity and pollution, as well as habitat fragmentation and loss of biodiversity. These factors, along with increasing land degradation and forest loss in some areas, may impact on the potential for future aquatic resource enhancement in inland and coastal aquatic systems (FAO, 1999a).

- Hansson et al. (1997) found pikeperch stocking in the Baltic has helped to sustain ecosystem functioning despite very high fishing pressure on top predators.
- Lorenzen et al. (1998b) showed that fishing restrictions introduced in conjunction with tilapia stocking in Laos created refuges for wild stocks.

Although the beneficial effects in both cases could have been achieved through reduced fishing pressure alone, it is doubtful that this would actually have happened.

When considering the overall impact of enhancements, it is, therefore, important to consider the direct as well as indirect effects, and to evaluate these against realistic alternatives.

Because most information on environmental impacts of enhancements is based on theoretical considerations, or on generalizations from case studies, it remains difficult to predict under

Enhancements are frequently associated with institutional change, including arrangements for access to resources. Examples are community management of culture-based small waterbody fisheries in Thailand and Laos (Chantarawarathit, 1989; Garaway, 1995, 1999), leasing of seasonal water bodies to individuals in India, and granting of exclusive rights to particular social groups in Indian reservoirs (Peters and Feustel, which conditions any particular impacts might occur, or what their magnitude would likely be. More comprehensive impact assessments of operational enhancements are urgently required to provide a better basis for decision making.

Economic and social benefits

Many effective enhancement technologies have proven financially viable (Sreenivasan, 1988; Hansson et al., 1997; Ahmad et al., 1998; Lorenzen et al., 1998a; Garaway, 1999; Kitada, 1999). Some enhancements offer very high returns to cash investment and labour (Hansson et al., 1997; Lorenzen et al., 1998a; Garaway, 1999). Full economic evaluation of enhancements requires knowledge of opportunity costs, e.g. possible loss of yield from other (non target) wild stocks. Unfortunately such evaluations are rare.

Many enhancements appear to play a niche role, in that they provide types of benefits that differ from the benefits obtained from either capture fisheries or aquaculture. For example, small waterbody fisheries in Southeast Asia often provide community income (Garaway, 1995, 1999), and seasonal reservoirs in Karnataka (India) are leased by farmers who are not otherwise 1998). Concerns about the socio-economic consequences of such restrictions have been voiced, e.g. by Somnasung et al. (1991) and Samina and Worby (1993), among others. However, investigations in small waterbody fisheries (Garaway 1995, 1999) have shown that communities are often capable of adapting management systems to minimize any negative effects of access restrictions and avoid potential conflicts. This may be different where resource users are very heterogeneous in terms of wealth and power, and resources are perceived as highly valuable (e.g. the floodplains of Bangladesh (Ahmad et al. 1998); or West African lagoons (J. Moreau and P. Laleye, pers. obs.)). In such cases, external regulation of resource use (e.g. by government) may be required to avoid non equitable allocation of resources. However, government regulation may in itself contribute to non equitable outcomes, for example the Kerala reservoirs, where fishing rights were reserved for members of certain castes, turning all other fishers into poachers (S. Kumar and W.D. Hartmann, pers. comm.).

Institutional sustainability

Enhancements require significant and often regular inputs, such as stocking or the maintenance of habitats. To sustain such inputs into involved in fishing or aquaculture, but appreciate the high returns to small investments provided by culture-based fisheries (K. Lorenzen, pers. obs.).

Marketing problems affect some enhancements, such as the seasonal tanks in Sri Lanka which are concentrated in certain areas and harvested over a short period of time (De Silva, 1988). In many cases, enhancements contribute marginally to markets dominated by the capture fisheries or aquaculture, and thus enhancement production has a limited impact on prices. Market interactions between fisheries enhancement and the rapidly growing aquaculture sector can have a significant effect on the financial viability of enhancement initiatives. The expansion of salmon farming is a case in point - it led to a decline in prices that affected the viability of salmon stock enhancement (Boyce et al., 1993).

common-pool resources, conducive institutional arrangements are required. Under open-access conditions, technically effective enhancements attract additional effort into a fishery. If the result were rent dissipation, individual fishers would be no better off than before and would be unable and unwilling to contribute to the costs of enhancement. Hence, institutionally sustainable enhancements are usually associated with access restrictions.

In Chinese (and some other) culture-based reservoir fisheries, management responsibility has been vested in reservoir authorities who have exclusive rights to the fish stocks. This has allowed management authorities to sustain the inputs that have made Chinese reservoir fisheries the most technically successful enhancements worldwide.

Box 1. Design principles illustrated by long-enduring common-pool resources institutions (Ostrom, 1990).

- Boundaries of the resource and those who can use it are clearly defined.
- Appropriation and provision rules are adapted to local conditions.
- Collective-choice arrangements allow participation of resource users in designing operational rules.
- Rule monitors are the appropriators or at least accountable to them.
- Sanctions are graduated.
- Low-cost conflict resolution mechanisms exist to solve disputes.
- Rights of user-communities to devise institutional arrangements are not challenged by external government authorities.

Most other enhancements developed in common-pool resources have been sustained through continued government subsidy. Such systems remain particularly vulnerable to political changes, as illustrated by the collapse of culture-based fisheries in Sri Lanka following withdrawal of government patronage in 1990 (Amarasinghe and De Silva, 1999).

However, there are many examples of enhancement activities sustained by resource users, either independently or in cooperation with governments (Pinkerton, 1994; Garaway, 1995, 1999; Garaway et al., 2001; J. Moreau and P. Laleye pers. obs.). Given the worldwide trend towards reduction of government subsidies and direct support (e.g. Barbosa and Hartmann, 1998), future enhancement approaches will rely increasingly on the sustainability of resource-user and cooperative institutions. Ostrom (1990) identified a set of design principles associated with long-enduring

It has long been recognized that crises such as stock collapses can provide the impetus for collective action and co-management (Sen and Nielsen, 1996; Pomeroy and Berkes, 1997). Experience from Laos and elsewhere suggests that opportunities for enhancement can play a similar facilitating role. The potential for enhancement initiatives to precipitate or re-enforce user-led resource management should receive wider consideration in inland and coastal aquatic resources management.

A move away from government implementation of enhancements must not be misunderstood as meaning that governments have no role in aquatic resource enhancement. At the very least, governments have to recognize the rights of resource users to organize and make management decisions (Point 7 in Box 1). Moreover, governments are in a privileged position to support enhancement initiatives through the provision of research and extension services, the resolution of conflicts and the management of environmental impacts. Unfortunately, these opportunities are often not realised due resource-user organizations for the management of common-pool resources (Box 1). Results of institutional studies on enhancements are broadly consistent with these design principles, indicating their value as indicators of enhancement potential and for guiding institutional development (W.D. Hartmann, pers. comm.; Middendorp at al., 1996; Garaway 1999).

The introduction of new enhancement technologies can provide strong incentives for collective action by resource users where users themselves invest in the technology and conducive conditions exist (Box 1). This has been demonstrated in small waterbody fisheries in Laos, where stocking precipitated rapid proliferation of community management systems (Garaway, 1999; Garaway et al., 2001).

to differences in perceptions and objectives, lack of communication, poor focusing of research support and other institutional factors (Smith et al., 1997; Lorenzen and Garaway, 1998).

The process of developing enhancements

Enhancement is a process, not an event. Large technological and institutional uncertainties and lack of management control preclude a blueprint approach to the development of enhancements. An effective process approach is crucial to the success of enhancement initiatives, and will eventually lead to a higher degree of predictability and control.

Initiating enhancements

Enhancements may be initiated by resource users, government organizations, or a combination of both. Resource users often initiate enhancements where investment requirements are moderate and benefits are likely to accrue to those who bear the costs. Habitat enhancement, such as brush parks or trap ponds, has traditionally been initiated and implemented by resource users (Welcomme, 1972; U.W. Schmidt, pers. comm.; K. Lorenzen pers. obs.). Likewise, where seed fish are readily available, resource users often initiate culture-based fisheries in small water bodies (Lorenzen et al., 1998a; Garaway, 1999). Such enhancements may proliferate as a result of direct extension between users, either locally, as in the case of small waterbody fisheries in Laos (Garaway et al., 2001), or over longer distances through itinerant fishers, as in the case of acadjas (J. Moreau and P. Laleye, pers. obs.).

Large-scale enhancements often involve substantial investments and a lower chance of recovering costs, and have generally been the preserve of government-led initiatives. Also, where breakthroughs in aquaculture technology, such as hatchery production, are required, there is likely to be a degree of involvement from governments and development

Providing technological inputs

While certain enhancement approaches rely on indigenous technologies (e.g. brush parks), others require inputs, such as seed fish, that traditional users of aquatic resources may find difficult or impossible to provide. Therefore, many government-initiated enhancement programmes make provisions for seed production in government hatcheries or the development of private hatchery capacity (Ahmad et al., 1998). In the longer term, this function may be taken over by the private sector, e.g. most village-based Thai enhancement initiatives now obtain their seed from private operators, as opposed to government hatcheries which dominated supply in the early stages of development (Lorenzen et al., 1998a). Demand for seed for enhancement alone may be too restricted or uncertain to stimulate the development of private seed production. However, where aquaculture development stimulates seed production, this may in turn facilitate enhancement initiatives, and sales for enhancement may then account for a significant share of the total income of seed producers. Hence, aquaculture development and enhancement using cultured fishes are often implicitly linked. It is likely that a more explicit consideration of this link will lead to further synergies, as with giant clam agencies at the outset.

The decision to initiate enhancement is usually based on perceived opportunities, but may also stem from dissatisfaction with current management outcomes and the belief that enhancements will, at least, not do much harm. The assessment of enhancement potential requires both technological and institutional considerations. In the past, fisheries scientists and managers placed most emphasis on technological considerations, whereas resource users tend to be concerned mostly with institutional considerations (Garaway, 1999). Some general frameworks for the assessment of technological potential have been developed (e.g. Cowx, 1994). However, specific decision rules for the assessment of local potential are as yet available only for certain species and geographical areas (e.g. EIFAC, 1994; Heidinger, 1999). Hence, in many cases it is not yet possible to assess the potential of enhancement technologies without pilot-scale intervention.

culture (Bell, 1999).

Developing effective and efficient management systems

Where enhancement initiatives have been taken, the key challenge is to make them as effective, efficient and sustainable as possible under local conditions. This challenge has two components: (a) to identify locally optimal management approaches, and (b) to achieve the implementation of these by resource users through adequate institutional arrangements (see Fig. 1).

Uncertainties regarding local conditions and ecological and institutional dynamics are generally too large to allow optimal management regimes to be identified at the outset of new enhancement initiatives. Hence, management must be modified in the light of outcomes, through an adaptive approach that treats management as essentially experimental. Adaptive approaches are a constructive way of dealing with uncertainty and lack of control, and have developed independently in fields such as natural resource management and public administration (Walters, 1986; Rondinelli, 1989).

In practice, such approaches are implemented in a variety of ways. In resource user-led enhancement, users may experiment with both technical and institutional variables, albeit not necessarily in a very systematic way (Garaway et al., 2001). Formal adaptive approaches are increasingly being used in government-led enhancements to address technological uncertainties (e.g. Bilton et al., 1982; Blankenship and Leber, 1995; Leber, 1999). In many programmes, however, lack of monitoring and evaluation precludes adaptive improvement (Cowx, 1994).

The evaluation of enhancement management and adaptive strategies requires the use of quantitative models. Population dynamics models that incorporate sub models of key density- and size-dependent processes enhance comprehensive evaluation of management regimes. Such population models have recently been developed for certain culture-based fisheries and stock enhancements (Lorenzen, 1995, 2000, 2001, Lorenzen et al., 1997; Giske and Salvanes, 1999; Barbeau and Caswell, 1999). Purely a great deal of management information. The wider use of powerful analytical frameworks, such as population models or IAD, will further enhance the scope for comparative studies.

Eventually, analyses are likely to improve the predictability of enhancement outcomes to such a degree that the need for adaptive management is reduced and a more programmed approach becomes possible. This has already been achieved for some enhancements (Cowx, 1994; EIFAC, 1994; Heidinger, 1999).

Managing environmental impacts and risks

A number of frameworks have been developed to minimize environmental risks and manage impacts from enhancements. Key documents include the Codes of Practice and Manual of Procedures for the Consideration of Introductions and Transfers of Marine and Freshwater Organisms (Turner, 1988), the ICES Code of Practice on the Introductions and Transfers of Marine Organisms (ICES, 1995), the Code of Conduct for Responsible Fisheries (CCRF) empirical models (i.e. models not incorporating any mechanistic understanding of population dynamics) can be used to assess certain aspects of management, provided that empirical data provide sufficient contrast in the variable(s) of interest. Empirical models have been used most commonly to assess stocking densities in smaller inland water bodies (e.g. De Silva et al., 1992; Hasan and Middendorp, 1998; Welcomme and Bartley, 1998; Lorenzen et al., 1998a). Geographic information systems (GIS) provide new opportunities for integrating geographical information into the analysis of enhancement (e.g. Kapetsky, 1998).

Institutional analysis and design (IAD), a conceptual framework for analysing common-pool resource systems (Ostrom, 1990), has emerged as a powerful tool for the assessment and improvement of management institutions. The approach has great potential in the management of enhancements, and has already been used by W.D. Hartmann, pers. comm., Middendorp et al. (1996), and Garaway (1999). Wider application will require training of fisheries management staff and/or increased involvement of social scientists in fisheries development.

Comparative analyses of enhancement outcomes under different local conditions and (FAO, 1995), and the corresponding guidelines for aquaculture development (FAO, 1997).

When assessing and managing environmental impacts on and from enhancements, it is usually necessary to consider the environment beyond the enhanced fishery, i.e. at the catchment (De Silva, 2000) or coastal zone level.

Co-management

Whether initiated by resource users or government, enhancements often develop towards some form of cooperative management. Resource user-led enhancements may require government intervention to resolve conflicts or regulate environmental impacts. The expansion of indigenous acadjas in West Africa, for example, has resulted in a level of conflict that has prompted government regulation and ultimately the development of a co-management system (J. Moreau and P. Laleye, pers. obs.). On the other hand, government-led initiatives have proved difficult to sustain unless resource users assume a degree of management responsibility and contribute to costs. A need for cooperative management may be evident even where government involvement in enhancements is limited to regulation to prevent negative impacts.

management regimes hold the key to resolving technological, ecological and institutional uncertainties. Even simple comparative studies using empirical regression models can provide

Where inputs to enhancements are easily available to resource users, such as seed fish in areas with a well-developed aquaculture industry, effective regulation may be almost impossible without cooperation of resource users. Indeed, uncontrolled stocking is widely perceived to be a problem by resource managers in developed countries (Cowx, 1994; Li and Moyle, 1999).

Co-management implies a sharing of management responsibility between resource users and government, but the term has been applied to a wide range of arrangements (for reviews see Sen and Nielsen, 1996; Pomeroy and Berkes, 1997). To achieve effective co-management, a number of issues need to be addressed in the areas of:

Co-management, in the strict sense, implies an element of self-governance by resource users. The design criteria given in Box 1 provide an indication of the conditions under which self-governance can realistically be developed. In general, governments need to create a conducive legal arrangement to allow self-governance to develop. Decision making in co-management involves different levels, i.e. operational rules, collective choice rules and external arrangements. Exactly how and by whom decisions at the different levels are made is a key problem to be resolved in the design of co-management systems. Many of the more detailed frameworks for enhancement decision making (e.g. Cowx, 1994) provide comprehensive and rational guidelines which can be implemented only where management bodies have effective

- communication,
- objectives of stakeholders,
- facilitation of self-governance,
- decision making, and
- monitoring and enforcement.

Effective communication between stakeholders at different levels (resource users, local decision makers, scientists etc.) is crucial to the success of co-management. Participatory appraisal and action approaches have been developed and used successfully in many contexts (e.g. Chambers, 1992; Pido et al., 1996), and their wider application to co-management of enhancements is likely to generate substantial benefits. For a further analysis of communication issues in management involving multiple stakeholders (Bilio, 1997; M. Bilio, pers. comm.).

Co-management requires a degree of congruency on objectives and in perceptions of management issues and expected outcomes among the stakeholders. In practice, both are often lacking. In Laos and Thailand, for example, government objectives for small waterbody enhancements were geared towards increasing yields and community cohesion through communal aquaculture. However, in both cases, communities focussed primarily on increasing efficiency of resource use (i.e. high returns to cash investment and labour). In Thailand, communal aquaculture hegemony over resource users. Since this is unlikely to be the case in many practical situations, decision-making frameworks must be adapted to local arrangements. Lorenzen and Garaway (1998) discuss broad requirements for a co-management approach to the implementation of enhancement initiatives.

Monitoring and enforcement of rules is a key element of any active management system for common-pool resources. Ostrom (1990) points out that where self-governance arrangements exist, rule monitors (enforcers) must be accountable to the self-governing institutions. This is relatively easy to achieve in clearly delineated systems under the control of a single body, such as for small water bodies (Garaway et al., 2001). Where this is not the case, however, governments have to play a greater role in monitoring and enforcement. This may lead to problems, unless government enforcers are also accountable to the self-governing institutions. In medium-sized reservoirs in Brazil, for example, rules are laid down by a fisher congress, and the agreement is submitted to the federal environment agency for ratification. In this case, the government agency favours generally applicable and easily controllable rules to the myriad of locality-specific regulations was abandoned in favour of selling fishing day licenses to individuals, while in Laos a communal harvesting system persists, but is marred by incentive problems. In both cases, government organizations have been slow to recognize resource user's objectives and perceptions, and to adapt their extension and research support services accordingly (Garaway et al., 2001).

emanating from the participatory process. Thus, enforcement of rules by the agency is largely lacking, and this is seen by the fishers as a key problem jeopardizing co-management. Difficulties in enforcing rules are the most important cause for changes in community rules (Barbosa and Hartmann, 1998; W.D. Hartmann, pers. comm.).

The future role of enhancements

Enhancements can be technically efficient and generate socio-economic as well as environmental benefits provided that a conducive physical and institutional environment exists, and that appropriate technical and institutional measures are developed. Although dominated by both capture fisheries and aquaculture, in terms of output, enhancements are an important "niche" form of aquatic resource use. Enhancements can provide:

- benefits to sections of the

In inland waters, where enhancement technologies are reasonably well developed and natural conditions (e.g. boundaries of resources) are conducive to the design of enduring institutions, a rough estimate puts the global contribution of enhancement at 20 percent of capture production.

In the marine environment, natural conditions are more limiting with respect to technical effectiveness and institutional design, and the potential relative contribution of enhancements to catches is likely to be lower than the 20 percent achieved inland. Nonetheless, a contribution to marine catches of

population who cannot benefit from, or develop, proprietary aquaculture;
- food and income from under-utilized, new or degraded aquatic ecosystems, with a minimum of feed or capital inputs;
- a wide range of socio-economic and environmental benefits, including community income from small water bodies that is difficult to obtain through other management systems; and
- incentives to improve the management of common-pool aquatic resources.

In the medium term, the contribution of enhancements to fisheries production and their wider benefits are likely to increase in both absolute and relative terms, due to:

- increasing demand for aquatic products, combined with increasing modification of inland and coastal aquatic ecosystems, in many developing countries;
- full development of new enhancement technologies, primarily for the coastal marine environment;
- increasing availability of hatchery-reared juveniles for a wide range of aquatic species, which have a strong potential to facilitate enhancement

several percent (i.e. several million mt) of the total appears feasible, and is likely to be achieved with species of importance to coastal economies. Both inland and coastal enhancements stand to gain in efficiency as a result of better research support, with corresponding increases in socio economic benefits.

Recommendations

For enhancements to achieve their full potential and provide benefits on a sustainable basis, improvements are required in both policy and research support.

Principles

- Development of institutional arrangements to manage common-pool aquatic resources and sustain investment in them is crucial. Usually there will be a strong element of co-management where user organizations play an important role, frequently facilitated by various interest groups.
- Government organizations have an important role in enhancement initiatives through creation of supportive institutional arrangements and research. A key factor in this role is creation of conditions

initiatives in areas where these are currently limited by lack of seed; and
- improved management of enhancements resulting from better understanding of resource population dynamics, institutional requirements and research support needs.

A quantitative estimate of global enhancement potential is difficult to give. Examples such as the culture-based fisheries in Chinese reservoirs or Japanese scallop enhancement suggest considerable potential, but there are both natural and institutional limitations to the expansion of enhancements (Kapetsky, 1998 and this review).

under which resource users can actively support and have management responsibility for enhancement.
- Government needs to strike a balance between facilitating initiatives and regulating environmental impact on and from enhancement.

Approaches to management and development

- Government involvement, including research, planning and implementation, should be guided by the principles of participation and empowerment of resource users.

- Management and policy support for enhancements must be based on a production systems approach, integrating analyses of institutional arrangements, ecology, technology, marketing and socio-economics.
- Information and communication systems should be established to facilitate

This would involve:

- training and capacity building in appropriate methods of institutional and technical analysis, e.g. Institutional Analysis (IAD), population dynamics, empirical modelling and Geographic Information Systems (GIS);
- regional data collection and

management and development, as well as regional and inter-regional cooperation.
- Government and other "supra-level" organizations should support development through comparative analyses, and facilitate adaptive learning.
- Development of enhancement initiatives should be integrated into watershed-level planning.
- Development of enhancement projects should follow international codes of practice on conservation and sustainable use of biological diversity, appropriate for local conditions. Key elements of these codes include: environmental impact assessment, responsible use of introduced species and genetic resource management.

Research needs

- Determination of the interactions between technological and institutional factors affecting the outcome of enhancement initiatives, and further development of adaptive learning approaches to deal constructively with uncertainties.
- Determination of the biological, ecological and genetic dynamics of enhancement and development of appropriate dissemination using agreed, standard methodologies; and
- regional data analysis and workshops to identify conditions conducive to enhancement initiatives, appropriate policies and management interventions.

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methods to assess technological management regimes.
- Comprehensive and quantitative assessment of environmental risks and impacts of enhancements in relation to complete watersheds.
- Consideration and evaluation of a wide range of enhancements and local resources (including indigenous technologies), and development of new enhancement approaches.

Opportunities for regional cooperation

Key opportunities for regional cooperation arise from pro-active approaches to regional comparative studies, including identification of key opportunities for learning and designing programmes for data collection and analysis.

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Systems Approach to Aquaculture Management

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ABSTRACT: The topics covered in the Conference on Aquaculture in the Third Millennium, from highly technical sessions on genetics and feeds, to non technical policy sessions on the role of different stakeholders and institutions, reflect the wide range of factors and issues relevant to modern-day aquaculture development. The "systems approach" recognizes the diverse factors affecting aquaculture and is a multifactorial and multidisciplinary approach that attempts to analyse how different factors affect aquaculture and develop solutions to problems based on an understanding of how aquaculture systems operate. The systems approach is fundamentally a multidisciplinary approach that can be used to solve problems and identify opportunities for development. This analytical approach has been shown to contribute to identification of key research issues, development of better management solutions, improvement of business efficiency, design and testing of new aquaculture systems and more effective extension and education, among others. This paper discusses the systems approach to aquaculture, provides examples of the relevance and use of the approach in aquaculture development, and recommends areas for further study and follow

up actions.

KEY WORDS: Aquaculture Management, Systems Approach, Aquaculture Development, Asia

Background

Introductory remarks

The varied topics covered in these Proceedings of the Conference on Aquaculture in the Third Millennium, from highly technical sessions on genetics and feeds, to nontechnical policy sessions on the role of different stakeholders and institutions, reflect the wide range of factors and issues relevant to modern aquaculture development.

The "systems approach" recognizes this diversity of influences on aquaculture development, and is a multifactorial and multidisciplinary approach. It uses an understanding of how aquaculture systems operate to analyse how different factors affect aquaculture and develop solutions to problems that are identified. This analytical approach has been shown to contribute to identification of key researchable issues (Edwards, 1998; Smith, 1999), development of better management solutions, As social, economic, policy and institutional issues are all important – at some level – in a systems approach, the paper also provides a link between the Conference's farming technology and policy sessions and closes with some suggestions for discussion on future directions. This paper was developed from discussions and contributions made by panel members and participants during the Conference on Aquaculture in the Third Millennium. The recommendations presented here represent a consensus of recommendations adopted in the final plenary session of the Conference.

Aquaculture systems and sustainability

Sustainable development and sustainability are complex issues that are difficult to define and apply to aquaculture. The "systems approach", however, can assist understanding of these issues, as they relate to aquaculture improvement of business efficiency, and design and testing of new aquaculture systems, as well as to more effective extension and education.

The analysis and understanding of aquaculture systems can occur at different "levels":

- the organism and its surroundings;
- the production unit;
- the economic enterprise;
- the farm, watershed or coastal areas;
- the national sectoral level, or even
- the international level.

The boundaries chosen for the system of interest may be physical entities, political borders or organizational structures. In terms of this paper, the focus is on the following systems: the farm; the farm and its local environment; and the national level, recognizing the fact that there are critical interactions between these different levels.

This paper is intended to be complementary to the earlier papers in this technology session which focused on the individual components of the system – such as feed and nutrition, health, seed and genetics – and emphasises understanding of how these development.

The term sustainability has been defined in various ways but perhaps the most widely used is based on the definition of "sustainable development" in the Brundtland report: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". An even more succinct definition is that of the International Union for the Conservation of Nature (IUCN): "sustainable development improves people's quality of life within the context of the Earth's carrying capacity". These definitions contain two key concepts: meeting the present and future needs of the world's people, and accepting the limitations of the environment to provide resources and to receive wastes for the present and for the future. The Food and Agriculture Organization of the United Nations (FAO), in particular, recognized that increased capacity at the national level is required to achieve sustainable development by including the need for "institutional change" in definitions of sustainable agricultural development (FAO, 1995). The recognition that institutions are important highlights the need for education and training, effective institutional arrangements and a individual components interact within the wider context of aquaculture systems. It first looks at our current understanding of aquaculture systems and management strategies based on a systems approach, with an emphasis (as in this session) on farm-level management practices.

legal and policy framework to underpin sustainable development of agriculture, and indeed aquaculture.

Sustainability is commonly split into three separate components: social sustainability (SS); economic sustainability (EcS); environmental sustainability (ES). Whilst social sustainability criteria are difficult to define, the definition of economic and environmental sustainability are providing a basis from which management options can evolve in aquaculture projects.

To take sustainability to a more practical level requires consideration of environmental, social and economic issues in aquaculture development. Thus, the approach to sustainability implies a systems approach.

There are general guidelines available on the different issues to consider. The Code of Conduct on Responsible Fisheries (CCRF), adopted by the FAO Conference in 1995 (FAO, 1995) in particular, identifies a number of key issues.

However, there are a wide range of culture species, culture facilities and management practices in use, and thus a very wide range of farming systems.

Key factors to be understood in the functioning of a farming system are the technologies of production and social, economic and environmental aspects. At the technology level, feeds, feed additives and fertilizers, water quality, seed quality and availability, chemoterapeutants and other chemicals, disposal of wastes

The Code sets out principles and international standards of behaviour for responsible practices, to ensure effective conservation, management and development of living aquatic resources while, at the same time, recognizing the nutritional, economic, social, environmental and cultural importance of fisheries and aquaculture, and the interests of all those involved in these sectors. The Code's Article on Aquaculture Development (Article 9) contains provisions relating to aquaculture, including culture-based fisheries. Fundamentally, the Code recognizes the importance of activities that support the development of aquaculture at different levels:

- the producer level;
- the local area, i.e., the farm and its integration into local area management and rural development schemes;
- the national institutional and policy environment; and
- international and transboundary issues.

The Code identifies many key principles in development of management strategies based on an understanding of aquaculture systems – from the farm to national and international levels. It also provides a basis for a systems approach.

that may adversely affect human health and/or the environment, and food safety of aquaculture products all require consideration. It has also been emphasised that a better understanding of the microbial populations in aquaculture systems, their interaction with the health of the farmed animals, and their role in maintaining a healthy aquatic environment are required.

The systems approach at the farm level can be used to understand and improve the efficiency of use of key natural resources – particularly water, nutrients, land, seed and financial resources. When focussing on the mix of all sustainability criteria through a systems approach, we have to deal with such factors as: appropriate densities, production and husbandry systems geared to the animal's health, maintaining ecological balance within the pond or other growout habitat, and provision of optimal social and economic benefits. It is inevitable that impacts on natural resources will become an increasingly important issue in the new millennium, and the systems approach can be used to analyse and develop the solutions required for more sustainable use of natural resources.

A wide range of management systems is already employed in

The systems approach

Farm level

There is a lot of information on aquaculture farming systems, and various definitions are available, such as the level of intensity of management and output, and degree of integration with other on-farm activities. A considerable literature exists on integrated (agriculture-aquaculture and vice versa) farming systems (Edwards, 1998 and “Farming species and systems” in these proceedings).

aquaculture operations with varying degrees of success. Given that aquaculture systems range from small, relatively self-contained farms for subsistence, to large-scale commercial units for trade purposes, variable success is hardly surprising. Thus, a “one-size fits all” approach is unlikely to be successful. A systematic approach to production management, however, allows the farmer to manipulate and control production inputs that will result in more efficient, cost-effective production and minimize excessive outputs with negative environmental impacts. There is a tremendous body of information on site selection, farm construction and design features, aquatic animal health management, broodstock and seed production and care, production techniques, the use of appropriate feeds, feed additives and fertilizers, water and sediment management, including effluent control, and other topics (e.g., Chanratchakool et al. 1998; FAO/NACA, 1995; Pennell and Barton, 1996).

The challenge is to optimize dissemination and use of such information and experience.

The systems approach can also be used for aquatic animal health management. Here the emphasis needs to move more towards management procedures, policies and products that can prevent or effectively eradicate significant pathogens, prevent re-infection through contaminants, and manage diseases in an environmentally sustainable manner. Subasinghe et al. (1998) provide a discussion of the role of the systems approach in aquatic animal health management.

The local level

The systems approach at the local level recognizes that individual farms cannot be seen in isolation, and that there are many interactions between an aquaculture farm and the external environment – including environmental resources and local communities. Furthermore, there can be significant cumulative effects where there are large numbers of farms crowded in small areas.

Environmental interactions with aquaculture arise from a wide range of inter related factors including availability, amount and quality of resources; type of

The future of integration of aquaculture into local ecological and social systems requires more focus on local area development planning. Fortunately, increasing attention is being given to such issues, particularly in coastal areas. Integrated coastal management (ICM) is a process that addresses the use, sustainable development and protection of coastal areas, and according to GESAMP (1996) "comprehensive area-specific marine management and planning is essential for maintaining the long-term ecological integrity and productivity and economic benefit of coastal regions". ICM is made operational through such activities as:

- land use zoning and buffer zones;
- regulations, including permitting to undertake different activities;
- nonregulatory mechanisms;
- construction of infrastructure;
- conflict resolution procedures;
- voluntary monitoring; and
- impact assessment techniques.

More participatory approaches to planning of aquaculture development will also be given attention with the move towards integrated development planning (see S. Sen, this volume). Practical experience in implementation ICM species cultured; size of farm; culture systems management; and environmental characteristics of the farm location. Environmental interactions are not limited to impacts of aquaculture on the environment, but include environmental impacts on aquaculture and impacts of aquaculture on aquaculture. Perhaps less well known or documented are the many ways that aquaculture can contribute to environmental improvement, for example mollusc farms' desedimentation or improved nutrient turnover (Hatcher et al., 1994), or water storage on small-scale freshwater farms.

At the local level, social and institutional interactions are also important and need to be better understood, for example:

- participation of, and benefits to, rural communities;
- institutional support through extension services;
- access to information etc.

A systems approach attempts to understand these linkages and develop management strategies based on such understanding.

for aquaculture is limited, which is in large measure because of the absence of adequate policies and legislation and institutional problems, such as a lack of unitary authorities with sufficiently broad powers and responsibilities, as well as limited training and education of people concerned.

In inland rural areas, increasing attention is being given to integration of aquaculture into rural development and special area management plans. Increasing emphasis is also being given to promotion of aquaculture for poverty alleviation (see Haylor and Bland, this volume). Such an approach requires emphasis on immediate social needs and people's livelihoods (and how aquaculture might meet these needs and contribute to improved livelihoods) rather than a technology/aquaculture driven approach. The emphasis on aquaculture for development, rather than development of aquaculture may lead to some fundamental changes in the approach to promotion of aquaculture in the coming years.

National, regional and international levels

At the national level, government policy, and institutional and human capacity are most important in providing a strong foundation for aquaculture to develop in a su (Insull and Shehadeh, 1996).

These issues are covered extensively in the Conference's policy session and are not discussed in detail here, except by recognition that most community and farm activities are influenced by national-level policy, legislation and institutional support. For example, the level of aquatic animal disease affecting small-scale producers or enhanced fisheries is related to national policies for quarantine and movement of live aquatic animals, which affect the risk of exposure of small-scale producers to serious aquatic pathogens (DFID/FAO/NACA/GoB, 2001). Inter- and intra-country trading patterns and movement of aquatic animals also affect these risks. International conventions (e.g. the Convention on Biodiversity), trade and consumer preferences, all clearly impact aquaculture development at a local level.

Application of the systems

A systems approach to management has more potential for success on the typically diverse small-scale farms in developing countries. This approach includes analysis of the resource-base of the farm, and the farmers' perceptions of their needs. The role of institutions in promoting the development of aquaculture can also be analysed using such an approach. The role of national institutions (government and non governmental agencies) as primary facilitators of aquaculture and the necessity of capacity building in order to facilitate the systems development approach should be recognized. International and regional agencies can support such capacity building.

Environmental management systems

Environmental management systems are also starting to evolve for some forms of aquaculture, as well as more formal environmental

approach

Some examples of systems approaches presented during the Conference are given below.

Small-scale farmer research and extension

The systems approach has been widely used in the promotion of sustainable development through small-scale integrated aquaculture (Edwards, 1998). He emphasises that most scientists focus on technical aspects of aquaculture, resulting in the impression that the major constraint facing aquaculture development is a shortage of technical knowledge, overshadowing the developmental and educational constraints. The most important constraint to aquaculture development is dissemination of existing knowledge, whether derived from research or indigenous technical knowledge of farmers also affect these risks. The limited capacity of developing-country institutions in education, research and development compounds this fundamental failing. Research should follow farming systems research and extension methods in which inter-disciplinary teams work with farmers to evaluate and develop both production systems and extension methods that are appropriate to the local conditions

management systems (EMS). EMS is a complex approach with little direct application to small- and medium-sized farms, however, EMS principles provide useful guidance for improving environmental management of aquaculture production systems (H. Dixon, pers. comm.).

EMS assemble management policies, programmes and practices designed to identify links between industry, urban and developmental activities, and consequent pressures on the environment. An effective EMS for aquaculture should establish indicators of changes in the environment, including land, water and aquatic resources. Policies and practices responding to the changes are implemented with continuous feedback to reduce/mitigate any environmental impacts. These indicators should make clear links between environmental impacts and aquaculture activities. The indicators should also reflect positive and negative impacts of environmental influences on aquaculture, as well as visa versa.

EMS provides a possible systematic approach to motivate aquaculture to better organize priorities and projects to identify problems and potential impacts before they occur, as well as meet environmental and business goals.

of farmers and their resource base.

This process also assists compliance with national environmental laws and regulations. A successful EMS provides the means by which aquaculture can identify causes of environmental problems and prevent them, thus saving money to repair or mitigate after the damage has been done.

According to H. Dixon, key benefits of an EMS include:

- improved environmental performance,
- reduced liability,
- competitive advantages,
- improved compliance,
- reduced operational costs,
- enhanced consumer trust, and
- increased access to capital.

H. Dixon considers that formulating an institutional framework for environmental management systems of aquaculture should:

- be simple to implement, clear and comprehensible to all involved, including the public;
- consider the needs of all

E. Hempel considers that in high technology salmonid aquaculture, the “software” of aquaculture (people) is more important than the hardware or “technology”. There are many facts and variables, so in order to understand and manage the system, things have to be simplified – “systematized” –. The approach emphasised by E. Hempel involves:

- understanding and identifying the system of concern within the farm enterprise/business;
- simplifying the system by identifying only key system variables;
- for each person working at different levels of the organization, identifying the

stakeholders;
- consider individual abilities and resources;
- be financially flexible and not inhibit the activities it is designed to address; and
- be based on sound scientific information, quantifiable and effective.

Codes of Practice

The technical methods, management systems and practices needed for minimizing impacts are being increasingly incorporated into more formal "Codes of Practice", notably in more commercially oriented and intensive shrimp and salmon farming. Several aquaculture organizations, for example, the Marine Shrimp Culture Association of Thailand, the Global Aquaculture Alliance, the Australian Prawn Producers Association, the Irish Salmon Growers Associations and others have taken the FAO Code of Conduct a step further and formulated Codes of Practice (COP). These COP contain principles for preventing or mitigating negative environmental and social impacts through use of "best management practices" (BMP). They are currently for voluntary adoption and consist of documented guidelines available to farmers. Much needs to be done towards their implementation, such

key system variables to monitor;
- reducing the number of variables to the minimum – e.g. dissolved oxygen, food conversion ratio (FCR), cash flow, and set limits/standards; and
- monitoring and responding to changes that exceed the set limits.

E. Hempel also emphasises that effective management based on a systems approach requires assigning of responsibilities within an aquaculture business to monitor and respond to changes that occur. He also emphasises that the system may change with time, and that management has to be flexible to respond to such changes. He further considers that the systems approach to business and management is important to improving the performance and profitability of farming, and is relevant at all levels of aquaculture, from small-scale farms to the largest business.

Institutional use of a systems approach

A systems approach can also be used to define institutional responsibilities in aquaculture. For example, in western Australia, according to C. P. Rogers' presentation during the "Systems as the development of operational manuals and support programmes. Furthermore, the extent to which COP will be fully adopted by farmers under self-regulation and the environmental consequences of their adoption remain to be determined. Implementation is a very important issue for the new millennium, particularly for small-scale farmers.

Improving profitability of aquaculture operations

The systems approach is directly applicable to the business of aquaculture, through the use of a structured, systematic approach to operations and business management.

session" of the Conference on Aquaculture in the Third Millennium, NACA/FAO, 2000) a systematic analysis of institutional responsibilities was useful to establish the key points for decision making in allocation of land and water resources for aquaculture development. This helped streamline permit processing. He also emphasised that a systematic evaluation of management processes can be valuable in identifying institutional responsibilities at both government and private-sector levels, as well as for promotion of small-scale aquaculture.

Implications of systems approach for future aquaculture development

Aquaculture can be socially, environmentally and economically sustainable and, contribute to the production of food and rural development, provided appropriate farming systems and management practices are adopted.

The multidisciplinary and multisectoral systems approach recognizes that technical, economic, social and environmental issues, as well as institutional factors, have to be considered in the process of development and management of aquaculture. The systems approach attempts to understand the way the system operates and the interactions between different components, and serve as a basis for better management. This multidisciplinary approach requires different skills and, as such, also needs cooperation among different disciplines and information exchange among different stakeholders. The application of a systems approach to aquaculture has several implications for a more analytical and structured approach to aquaculture development.

There is a need for better information on aquaculture systems

There was a consensus in the Conference discussions on the need to develop and evaluate meaningful indicators of resource use efficiency to better define environmental interactions with aquaculture and improve management decisions. Research is required to develop and evaluate meaningful indicators of resource use efficiency useful to management decisions.

Institutional strengthening in the private and public sectors is another critical issue that must be addressed. The systems approach recognizes that national institutions (government and non governmental agencies) are the primary facilitators of aquaculture development in their countries. However, national institutions involved in the promotion of aquaculture need to increase their capacity and reinforce emphasis on multidisciplinary approaches. This will require a shift away from traditional “top down” and “technology focused” capacity building and extension approaches, towards an approach that is interactive and responsive to farmer needs.

As emphasised above, much aquaculture research to date has focused on technical questions, leaving the impression that the major constraint facing aquaculture is a shortage of technical and promotion of more effective information exchange between stakeholders. Information requirements include social and environmental interactions at the farm level, development of better practices targeting important environmental and social impacts, and seeking incentives for farmers to adopt better farming practices.

Development of suitable indicators is also another important factor. For assessing natural resource use by aquaculture, recent research has emphasised the “ecological footprint” (Kautsky et al., 1997). The aims of the authors to develop a “sustainability” index are to be commended, however, there are a number of problems with the models promoted so far (Roth et. al., 2000), including:

- their static and dimensional (area) nature;
- the difficulties of incorporating economic and social values into the approach;
- the emphasis on biophysical factors;
- the lack of the footprint and ecological capacity to accept multisectoral or multiple uses;
- the lack of inclusion of ecosystem services (such as absorption capacity for discharge of nutrients into coastal ecosystems); and
- difficulties in making knowledge. This detracts from the attention needed for development and basic aquaculture education (Edwards, 1998). Another important constraint to aquaculture is dissemination of existing knowledge, whether derived from research or the indigenous technical knowledge of farmers. The limited capacity of many developing countries’ national institutions in education, research and development concerning the promotion of aquaculture compound this problem, and require serious attention in the new millennium.

Examples of the systems approach mentioned during the panel discussions included:

- its application to small-scale farmer research and extension;
- the development and application of best management practices to improve environmental management on commercial aquaculture farms;
- improving the profitability of aquaculture operations through the use of a structured, systematic approach to operations and business management; and
- the institutional use of a systems approach to assist in effective decision making at a

comparisons between different locations and systems.

regulatory/planning level and within the aquaculture industry as a whole.

Recommendations of the Bangkok Conference

The following recommendations were adopted by the Millennium Conference:

That a multidisciplinary and multisectorial and systematic approach be taken in the development of aquaculture and aquaculture research. Applying a systems approach allows the proper understanding and analysis of problems and opportunities, and the development of solutions based on the understanding of how systems operate. The systems approach involves basically seven steps:

- state the problem;
- identify the system;
- classify and describe the system, boundaries and key factors;
- analyse the problem;

There is a need to communicate practical examples where the systems approach has been used and to incorporate the problem identification and solving systems approach into educational and training programmes.

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- propose solutions;
- test the solution; and
- implement and disseminate knowledge to solve the problem.

Codes of Practice, and the Best Management Practices incorporated into such codes offer an opportunity to improve management. These need to be developed further and applied in real situations as a practical basis for the operating system. Special attention needs to be given to:

- implementation of Codes of Practice;
- the need for continual fine tuning to take account of new information and technology;
- a role for farmers in implementation (there should be greater participation by farmers and other end-users to provide feedback and fine-tune systems management practices); and
- the effectiveness of self-regulation.

There was a consensus on the need to develop and evaluate meaningful indicators of resource use efficiency to assist in understanding environmental interactions with aquaculture and improve management decisions. The use of the "ecological footprint" model as a tool was discussed, and it was

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Aquaculture Products: Quality, Safety, Marketing and Trade[1]

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ABSTRACT: The growth of aquaculture has led to significant changes in how its products are perceived and marketed. In becoming an important contributor to the markets for seafood, aquaculture is increasingly subject to safety mechanisms and controls, such as the statutory hazard analysis critical control point (HACCP) methodology in certain developed regions. As both safety and trade regulations are harmonized at international levels, quantitative risk assessment and traceability will become integral components of aquaculture management. Developing countries have increased their share of the seafood export market to nearly 50 per cent of global trade, a significant portion being represented by aquaculture products (shrimp, salmon, molluscs, etc.), a percentage that should increase with the continued expansion of the sector. The long-term viability of aquaculture development will be market driven, accounting for consumer demand and the capacity to adapt to the structure and legislative demands of the target markets. Important externalities will affect the production sector in achieving its goals, including the topics of sustainability, traceability and interactions with the environment. The development of schemes of best practice that incorporate the addressing of such issues, alongside quality schemes and safety management, will aid the production sector to achieve its goals. Discriminatory tariffs on trade should be avoided, particularly given the increasing importance of aquaculture as an export-earner and contributor to food security. The sectoral response to such developments must include a

better understanding of the complex issues faced by the production and marketing of consumer food products within highly competitive markets, where the assumption of responsibility is essential, both for the product and the actions taken to produce it.

KEY WORDS: Aquaculture, Safety, HACCP, Trade, Marketing, Tariffs, Export

Introduction

At a global level, aquaculture is one of the fastest growing food production sectors (9.6 per cent/yr in the last decade), a fact that will ultimately change the way that fish is perceived as food. A key element of this observation is the change in the supply opportunities for fish and fish products from a wild source to a cultured one.

Aquaculture product expansion has placed increased requirements on quality and food safety by consumers and regulators. There are few questions about the evident nutritional benefits of consuming fish but, by the end of the 1980s, developed countries arrived at the conclusion that classic fish (and food) inspection procedures, based on the analysis of samples of the final product and on generic hygiene measures, were not

International agreements on food safety

While there is no common agreement on food or fish safety at the international level, agreements do exist on food trade that have implications for food safety and quality matters. The important one regarding food safety is the Agreement on the Application of Sanitary and Phytosanitary and Measures (SPS) (GATT, 1994), which introduces two very important concepts. The first is that "to harmonise sanitary and phytosanitary measures on as wide a basis as possible, Members (countries) shall base their sanitary or phytosanitary measures on international standards, guidelines and recommendations, where they exist...
(Article 3)".

enough to provide the necessary level of protection to consumers. A preventive system called HACCP (hazard analysis critical control point) was adopted, and governments started to shift their regulations to HACCP-based systems. If one word has to be chosen to explain HACCP, it is "prevention."

An important point within the global market is the growing importance of international agreements that involve food (and fish) safety aspects. About 40 per cent of all fish produced are traded internationally, which means that there is a search for common criteria that facilitate or permit clear rules for compliance. The tendency is, therefore, to move towards the harmonization of national regulations, meaning that such regulations could assure an equivalent level of food protection to consumers. This is a relatively easy concept to understand, but very difficult to implement and validate in practice. In turn, this increases the importance of internationally accepted guidelines, recommendations and standards, such as those of the Codex Alimentarius. The provisions related to food trade of the General Agreement on Tariffs and Trade (GATT) Agreement compound this tendency, and all of these aspects are interlinked.

The same agreement establishes that, regarding food safety, "international standards, guidelines and recommendations" to be taken as reference will be those "established by the Codex Alimentarius Commission (CAC) relating to food additives, veterinary drug and pesticide residues, contaminants, methods of analysis and sampling and guidelines of hygiene practice".

The second important point of the SPS Agreement is the adoption of the criterion that risk assessment shall be the basis for determining the appropriate level of both sanitary and phytosanitary protection. In this case, the SPS Agreement imposes a strong condition on national regulations that have not yet accommodated this criterion. Current HACCP-based regulations include a "hazard analysis" step, but risk assessment, which should be a part, is performed only qualitatively, and regulations do not refer to risk assessment explicitly. It is clear that the future development and evolution of regulations will be in this direction.

All developed countries and a large number of developing countries have taken up regulatory HACCP-systems. These concern the safety of fish and fish products, which include products from aquaculture, The extent of regional and international trade in aquaculture products is difficult to analyse because trade in many aquaculture products is not yet well documented in all of the main producing countries. Aquaculture contributes primarily to domestic consumption but, at an international level, important trade has developed for a number of aquaculture products, and this has been one of the principal driving forces for aquaculture development in many developing and developed countries.

and it is assessed that approximately 65 per cent of the total international fish trade is performed under such regulations. The greatest exception concerns the Japanese market, which accounts for about 24 per cent of the total fish market (demand), but which has no HACCP regulations as yet.

Fish safety in the European Community

The Member States of the European Community (EC) are subject to both European and national legislation, and considerable developments in laws affecting aquaculture have occurred in the last decade. These are separated into two clear sections that concern the final product and the aquaculture process.

As a general conclusion, one can say that such regulations are structured around a core principle that defines the HACCP-based system, and that this basic principle is complemented by a number of regulations that can be defined as “regulatory standards”. Each species and product may be defined within a “family” of regulatory texts that outline the minimum requirements for each particular case or procedure.

The HACCP-based regulation for fish and fish products in the EC introduced the concept of "own health checks" (HACCP in terms of the EC regulation relative to fish products), and it is the Council Directive 91/493/EEC that laid down the health conditions for the production and the placing on the market of fishery products. EC aquaculture production follows Council Directive 91/67/EEC, which concerns conditions of stock health and health management and which, in practice, generated a "family" of regulations. For instance, Council Directives 93/54/EEC, 95/22/EC and 95/70/EC have successively amended Directive 91/67/EEC. This "family" of regulations is aimed basically at controlling fish diseases; they are only, in a second instance, complementary with the HACCP-based regulations aimed at preventing human diseases. The regulations related to aquaculture production do not imply accomplishment of the fish safety regulations, however. Although there are no contradictions between either regulation "family", their complementarity and coordination will surely increase with time.

Fish safety in the United States of America

The basic regulation in the United States of America, which makes Fish and fish products from aquaculture are included, either explicitly or implicitly, in such HACCP-based regulations. However, whereas the HACCP system is well defined for processing steps or procedures once the fish has been harvested, the application of the HACCP system to the entire aquaculture production chain is not so clearly established within the regulatory environment. Developments in this area can be anticipated.

Further evolution of the fish safety regulations may be expected with the introduction of new technical, scientific and operative knowledge and, in particular, regarding mandatory quantitative risk assessment.

All matters that relate to safety, quality and trade rely on the ability to identify and trace the product, but the traceability of food remains as an enormous problem to be solved. In its broadest sense, a traceability system would provide and allow access to all information concerning a product. In the case of aquaculture, this could mean following the history of a production batch from the final point of sale back to the hatchery. This would mean assuring knowledge of the steps encountered in distribution, packaging, processing and harvest, mandatory the implementation of the HACCP system in fish and fish products, is that of the United States Food and Drug Administration (FDA,5).

This regulation does not mention fish obtained from aquaculture specifically, but this source is included implicitly in the definition of "fish" ("where such animal life is intended for consumption") and in other paragraphs of the regulation (e.g., when "drug residues" is listed as one of the possible hazards to be accounted for). However, the regulation is specifically centred on processing, and does not apply to aquaculture production in itself.

including the growing conditions, the feeds and therapeutic agents used, the broodstock parentage and any other relevant information.

Clearly, such a huge amount of information cannot be encoded physically with the product, but needs to be accessible via coding and linking to appropriate databases. The ability to trace and isolate a problem with a product is essential to any safety system, but the concept of traceability is much more than this, since it affords assurance, generates trust and, very importantly, can allow the use of important information for marketing and sales. Information is a new measure for adding value and will increase in importance.

Aquaculture and trade

International seafood exports reached US$48 billion in 1998 (provisional FAO data), up from US$36 billion in 1990, but down slightly from the figures for 1996 and 1997. The share of developing countries in seafood exports grew from 43 per cent to 49 per cent between 1990 and 1997, giving net receipts of foreign exchange that rose from US$10.2 billion to US$15.8 billion.

The rapid growth in aquaculture production has made the sector important to the economy of many developing countries, and it has become either an important source of supply, or the main supplier, in the case of some products. For these farmed products, production fluctuations have had a significant impact on price trends. In general, however, aquaculture products have helped to stabilize traded supplies and to bring down prices over the years. Furthermore, several species that were once considered to be high-value luxury products have now become more abundant through aquaculture production, lowering prices and expanding markets.

The extent of regional and international trade in aquaculture products is difficult to analyse because trade in many aquaculture

Shrimp is already the most traded seafood product internationally, with about 25 percent or 800 000 mt coming from aquaculture (FAO, 1999a). Since the late 1980s, farmed shrimp has tended to act as a stabilizing factor for the shrimp industry. Therefore, the major crop failures in Asia and Latin America during the past few years (caused by disease problems) have had a significant impact on overall supply, demand, prices and consumption trends.

The major markets are Japan, the United States of America and, to a lesser extent, the EC, while the largest exporters of farmed shrimp are Thailand, Ecuador, Indonesia, India, Mexico, Bangladesh and Vietnam. Demand for shrimp is expected to increase in coming years, where Asian markets, such as China, the Republic of Korea, Thailand and Malaysia, will expand as local economies recover and consumers' demand more seafood. This trend is already reducing the availability of shrimp to traditional importers and will eventually put upward pressure on prices if supplies do not increase.

Trade in crab species has also increased with growing aquaculture production (1997: 165 000 mt). Especially important have been the exports of China (19,000 mt in 1998) to Hong Kong SAR China and products is not yet well documented in all of the main producing countries. Furthermore, because international trade statistics do not distinguish between wild and farmed origin, the exact breakdown between fisheries and aquaculture in international trade is open to interpretation.

This situation will change gradually, as aquaculture associations emerge in the main producing countries and start to keep records, and in response to various trade regulations that distinguish between farmed and fished origin (e.g., for shrimp).

Traded aquaculture products

In 1998, the main internationally traded products from aquaculture were shrimp, salmon molluscs and seaweed. Other species showing strong growth are tilapia, seabass and seabream.

Crustaceans

Marine shrimp is the most prominent product from aquaculture in international trade, and aquaculture has been the major force behind increased shrimp trading during the past seven to eight years.

Japan (INFOYU, 1999).

Finfish

In terms of total aquaculture output, finfish ranks first, with 49 per cent of the total production from aquaculture, of which the major part are carp species, which are consumed locally in the producing countries (mainly China and India). As opposed to shrimp, finfish aquaculture trade appears to be split between species having a high traditional demand and a "quality" image (e.g., salmon, seabass etc.) and convenience products (mainly fillets) of "cheaper" fish species (e.g., tilapia). The following species are the main products that are seen as being important in international trade:

Salmon: International trade in farmed salmon has increased from virtually nothing to more than 600 000 mt (1999) in less than a decade. The traded species are mainly Atlantic salmon and, to a much lesser extent, coho salmon, which accounted for 87 per cent and 12 per cent of 1997 salmon production, respectively (FAO, 1999b). The growth seen in trade has mirrored that of production, reflecting the fact that this activity is concentrated in a few countries that have limited domestic markets (Norway, Chile and the United

Kingdom).

Norway, whose main market is the EC, is the main exporter of Atlantic salmon. On the other hand, Chile, whose principal markets are Japan and the United States, is the main exporter of coho salmon and the second largest exporter of Atlantic salmon (FAO, 1999b; FAO, 1999c; Kontali Analyse, 1999).

As production volumes have increased, so has competition within the market and costs and prices have been driven down. At the current price levels (+/- US$4/kg CIF [Cost, Insurance and Freight) Europe), salmon has become a relatively medium-priced product in international seafood markets.

Trout: Trout is traded internationally at a much lower level than salmon, with exports reaching 135 000 mt in 1998 out of a total production of 463 000 mt. (FAO, 1999b). However, trout production is split, approximately equally, between portion-size production and large trout, and

Tilapia has become the third highest imported aquaculture product, by weight, in the United States (1998 imports of 28 000 mt), after shrimp and salmon. United States imports rose 14 per cent by quantity in 1998 (NMFS, 1999). In the long term, tilapia prices are expected to decrease, and this should lead to greater exports to the United States, as well as to Europe, which is seen presently as being undeveloped as a market for tilapia.

Seabass and seabream: In Europe, the marine fish farm industry of the Mediterranean has focused on the production of European seabass and gilthead seabream, and it intends to copy the success of salmon growers. Production reached almost 90,000 mt in 1999 (FEAP, 1999), of which nearly 90 per cent was exported from the country of origin, mainly to Italy and Spain. The principal exporter was Greece, which exported about 70 per cent of domestic production. Italy was, for where 70 per cent of global production is in Europe. Consumption, particularly of portion-size fish, is concentrated in trout-producing countries, but Norway, Chile and Finland have been able to farm particular qualities of large-sized, heavily pigmented trout for the Japanese market, primarily as a replacement product for coho salmon. Japanese trout imports reached 60 000 mt in 1998 (Japanese Marine Products Importers Association, 1999).

Tilapia: Tilapia species have also shown a tremendous growth in output (production of 946 000 mt in 1997), and although international trade is limited, it is growing. This is observed especially between Latin America (Costa Rica, Ecuador and Colombia) and the United States, as well as between Asian producers (Taiwan Province of China, Indonesia and Thailand) and the United States and Japan. There is also modest trade between the EC and producers in Jamaica, Israel and Zimbabwe. The biggest exporter, Taiwan Province of China, supplies Japan with high-quality tilapia fillets for the sashimi market and ships frozen tilapia to the American market. Taiwan Province of China now exports about 35 per cent of its domestic tilapia production and supplies 80 per cent of the United States tilapia imports (1998). Thailand and Indonesia

a long time, almost the exclusive market for Greek production. However, as a result of market development efforts, some 15 per cent of Greek exports are now going to "new" markets (e.g., the United Kingdom, Germany, France etc.), and the share of these markets is expected to grow. It is not to be ignored that trade in live fingerlings is made from hatcheries in Italy, Spain and France to farms in Greece, Malta, Croatia and elsewhere.

As output of seabass and seabream has grown, market prices have more than halved between 1990 and 1999, dropping from US$16/kg to less than US$5/kg today. The rapid saturation of the market and the speed of the parallel decline in prices (down 50 per cent in five years, compared to the ten years for a similar drop in the case of Atlantic salmon) is attributed to several factors:

- the much smaller traditional market for these species (southern Europe), compared to Atlantic salmon;
- lack of diversified products;
- inadequate marketing and market development; and
- absence of technological advances (e.g., genetic improvement, efficient feeds and feeding strategies etc.) that could significantly

export less than five per cent of their production (Dey and Eknath, 1997). Vietnam has also recently entered the world tilapia market, and China exported 500 mt to the United States in 1998 (NMFS, 1999).

improve productivity.

The substantial drop in prices should help to open new markets and expand existing ones, provided that acceptable profit margins can be sustained in production through improvements in productivity, diversification of products and intensified marketing efforts.

American catfish: American catfish is now the fifth most consumed fish species in the United States, measured at 0.4 kg/capita edible weight in 1998 (NMFS, 1999). Exports are limited, as production targets the domestic market, but some exports have started to Europe. The reason for the success of catfish is similar to that of tilapia: consumer demand for white, easy-to-prepare fillets.

Seaweed

Farmed seaweed production has increased in the last decade (6.8 million mt in 1997) and is now 87 per cent of total seaweed supplies. Most of the output is used domestically for food, but there is

Live seafood

The cultural preferences and growing affluence in Asia indicate a clearly positive long-term trend of live seafood commerce. The live seafood market is largely restricted to the restaurant trade and to consumers with a relatively high disposable income. Major market expansion is anticipated due to demand in China, but is also expected in Malaysia, Singapore and Taiwan Province of China, as well as in parts of North America with large Chinese communities. The potential for aquaculture to supply the market is promising. The sector is already supplying large amounts of shellfish and limited quantities of grouper, crabs growing international trade. China, the major producer, has started exporting seaweed as food to the Republic of Korea and Japan. The Republic of Korea, in turn, exports some quantities of Porphyra (red seaweed) and Undaria (brown seaweed) to Japan (1998 exports of 26 000 mt). Chile produces over 100 000 mt, and is responsible for some 75 per cent of global production of Gracilaria sp., which is used for agar manufacture.

Significant quantities of Eucheuma (red seaweed) are exported by the Philippines, Tanzania and Indonesia to the United States, Denmark and Japan. Total EC imports of seaweed in 1998 amounted to 58,000 mt, with the Philippines, Chile, Indonesia and Australia as the biggest suppliers.

Molluscs

International trade in molluscs is limited when compared to total output, with less than 10 per cent of production traded. The major importing markets are Japan, the United States and France, while major exporters are China and the Republic of Korea. The contribution of these farmed products to trade is uncertain.

Oysters, followed by clams, scallops and mussels, lead farmed mollusc production, but international and other species. Technological developments in the culture of preferred live food species will increase the contribution of aquaculture to supplies (Riepen, 1997).

Seed supplies

There appears to be significant regional and international trade in the seed of cultured aquatic organisms, mainly from aquaculture sources, but this is poorly documented at present in most instances. Mention has been made above of the regional trade of fingerlings for Mediterranean seabass and seabream, but there is also international trade in wild glass eels (e.g., the recent development of large purchases of European eel elvers by China), “eyed” (fertilized) eggs of salmon and trout, the postlarvae of various cultured shrimps, Indian and Chinese carps, and others. There is also limited trade (in terms of quantity) in broodstock. Documentation of trade in seed and fingerlings will improve gradually as a response to concerns about the spread of pathogens and the movement of genetic material. One would anticipate that the concerns of traceability will also support such documentation.

Issues affecting future

mollusc trade concentrates on scallops and clams (fresh and frozen). Total fresh and frozen scallop imports have grown from 28 000 mt in 1985 to 65 000 mt in 1998, reaching US$510 million. Clam imports have risen from 33 000 mt to 152 000 mt in 1997, valued at US$257 million. Mussel imports have shown a downward trend after a peak of 175 000 mt in 1992, but have bounced back to 188 000 mt worth US$220 million. Oyster imports have grown from below 10 000 mt in 1985 to 28 000 mt (US$112 million) in 1998.

trade in aquaculture products

The long-term viability and sustainability of aquaculture development, particularly in respect of commercial aquaculture, will be market driven, taking into account not only the consumer’s requirements but also the structure and legislative demands of the target market, be it local or international. Some of the key issues that need to be addressed are mentioned in the following sections.

Externalities

Environmental and social concerns can influence markets for consumer goods and have already influenced farmed shrimp exports to North America and Europe in recent years. There is a growing desire for knowledge of what is being consumed, a position that, in some cases, is accompanied by accountability for consumption.

The importance of attaining

Quality and safety

With growing concern about food safety, increasing efforts have been undertaken to improve the quality of food that is placed in the market, which evidently includes aquaculture. International codex standards cover aquaculture products, and the introduction of mandatory HACCP requirements for exports to the United States of America and the EC in 1997 has already had a great impact on sustainable aquaculture with no or limited negative externalities will force many exporting countries to adopt more sustainable production practices. The introduction of eco-labelling schemes will further accentuate this trend. Where aquaculture is perceived as a non-traditional food-producing sector, it will have to further establish its credentials for sustainability, particularly when compared to fisheries and crop agriculture. This consideration requires to be extended to safety assessments, based on risk assessment and the precautionary approach, before entry into production of new or exotic species, including the potential use of the products from modern biotechnology.

Awareness of environmental and welfare issues is increasing, particularly in the developed countries, where purchase decisions can be influenced by adverse publicity or a lack of information. As livestock farmers, aquaculture producers are increasingly required to act responsibly and in line with standards expected of the activity. While such topics are partially addressed by the Food and Agriculture Organization’s Code of Conduct for Responsible Fisheries (CCRF), it is increasingly recognized that standards applicable to international trade in trade in several aquaculture products.

Some countries have developed comprehensive HACCP plans for selected aquaculture products; for example, the United States now has plans for catfish, crayfish and molluscs. In other countries, individual aquaculture producers have undertaken voluntary certification (ISO 9000) for control as well as marketing purposes. Such certification appears to be increasingly required for entry into markets such as multiple retail stores.

Alternative efforts include the development of industry-led quality schemes, which require government approval, to which individual producers can adhere. These schemes have controllers and strict operating procedures and conditions, serving to provide products of high quality and known origin.

In the field of HACCP, focus is increasingly on risk assessment by the operator, and this issue will put further institutional demands on exporting countries.

The effects of bovine spongiform encephalitis (BSE - mad cow disease) in cattle, the debate over genetically modified organisms (GMOs) and the increased aquaculture require harmonization. At national levels, safety and quality management systems including Good Agricultural Practice (GAP) and Good Manufacturing Practice (GMP) should be developed and put in place in order to assure the production, distribution and sale of aquaculture products that are safe to consume and of high quality. Such measures require active and competent professional associations, working hand in hand with government, in order to be successful.

The collection, analysis and dissemination of relevant information should be facilitated in order to enable producers and industry operators to make informed decisions and to ensure consumer confidence in aquaculture products.

awareness of toxin presence in the environment and food have contributed to a higher consciousness of the consumer to the quality and content of food in general, especially in the developed countries. Actions to assure best practice, including traceability throughout the entire supply chain, are seen as being inevitable for assuring both the credibility and the sustainability of the aquaculture sector. This should not just apply to the aquaculture production process, but also include the feed content, particularly where additives and the potential use of GMO components are concerned.

Sales and marketing

Attaining and maintaining consumer confidence requires considerable effort. It is no longer satisfactory to believe that production of a "high value" aquaculture product is a guarantee for the producer's long-term success.

Aquaculture history shows how technical success for rearing a “high-value” product incites production expansion, which leads to price drops or crashes. There are many different opinions as to the “whys” and “wherefores” of these circumstances, and market saturation is often given as the answer. There are, however, other explanations.

The long time required between investment in stocks and financial returns from sales can force producers to sell too early or at low prices, simply because of current cash needs, a circumstance that is punctual and rarely accompanied by marketing efforts. Such situations lead to market surpluses and price crashes in circumstances where better financial and production planning could assist.

The geographic dispersion of the activity and the relatively small amount of production per unit mean that there are a high number of sellers to markets that have few buyers (in number), a situation that gives keen competition and an advantage to the buyer. In addition, the aquaculture sector is relatively young and spends little money on marketing and promotion, particularly at the producer end of the scale.

Aquaculture produces perishable

For fish and fish products, these changes have had, in many markets, a profound impact on both the demand for products from aquaculture and the production sector itself. Modern distribution channels have developed buying criteria with precise requirements for quality, portions and sizes, price and delivery times that often can only be met by aquaculture producers. This explains, to some extent, the success of products such as Atlantic salmon, which is prevalently sold through super- and hypermarkets in European markets. This has led to the virtual disappearance of the specialized fishmonger in certain developed countries and has imposed significant changes on the profession, in operating, marketing and organizational skills.

An example of this is the demand for packaged products, even for fresh, gutted fish. The demand now focuses on fixed weight packs (so that no individual weighing is required), particularly for processed products, using modified atmosphere packing (to assure freshness and a longer shelf-life) and where the sale price is attached prior to despatch to the supermarket. These conditions mean that, for the aquaculture producer to be capable of attaining this market, access to approved processing and packing facilities products with a short shelflife, particularly where products are sold fresh, meaning that distribution skills and production planning (to avoid surplus supplies to markets at specific times of the year) have to be honed to meet market demands.

The need for improved marketing and distribution skills is evident in many individual cases, where the grouping of producers under cooperative structures or as producer organizations is seen as being a response to such criticism.

The creation of efficient marketing systems, in which prices and costs are determined by supply and demand, moving to assure economic efficiency and sustainability, should be facilitated. The use of economic incentives and disincentives should be used to rectify market failure and the unsustainable use of resources.

Distribution channels

The growing market share of multiple retail stores (super- and hypermarkets) in the distribution of foodstuffs has significantly changed patterns of production, supply and distribution.

has become an essential part of working, as opposed to an option.

Labelling should follow the recommendations and codes of practice that are in line with the international requirements of the World Trade Organisation (WTO) and the Codex Alimentarius, demonstrating full traceability.

Tariffs

Despite steady reductions in customs tariffs on both fish and aquaculture products in recent years, tariffs and import licenses continue to represent barriers to trade in many countries. This is especially the case in many fast-growing economies in Asia, but important markets such as Japan, the European Union and the United States of America all give competitive advantages to domestic producers of many species, especially in the case of processed products. On the other hand, producers in the developed markets argue that they are subject to higher levels of control and imposed regulatory investments that increase their production costs.

Average tariffs on imports from developing countries are now estimated at 4.8 per cent, a cut of 27 per cent from previous levels (FAO, 1995). The long-term trend, with growing membership in the WTO, will lead to further tariff reductions. The multilateral trade negotiations, which were to have started in late 1999, now show some delay in taking off, but could also have a large impact on future trade in fish and aquaculture products.

Measures that are taken to protect human life, animal life and health, the environment and the interests of consumers are increasingly seen as being potentially discriminatory, either in the nation of origin or in the exporting nation, depending on the point of view and the legislation in question.

Food security

Aquaculture is an important source of seafood, and the major part of the total output from aquaculture is consumed internally by the nations that produce, providing employment and an important nutritional contribution to society. Aquaculture has also become a

The complex nature of the activity and its diversity mean that increased interregional and international cooperation should be encouraged, particularly in the fields of safety, quality and trade, where accent should be given to promoting a harmonized sectoral approach to the issues of concern.

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significant source of foreign currency for many developing nations, since the products exported are usually the more valuable ones destined for markets in the developed world. These revenues allow the countries to import other less costly protein and, as such, aquaculture plays an important role in food security, even where significant proportions of the output are exported.

Conclusions

The circumstances of producing and marketing fish and seafood produced from aquaculture are changing quickly. Technological advances have brought new species and higher productivity to the sector, which has developed to become an important contributor to national and international markets. Consumer demand for specific products, combined with good business opportunities, has contributed to the rapid development and restructuring of certain aquaculture subsectors, notably those concerned with export to developed countries. The industrialization of production and processing, alongside increased consumer awareness and legislative actions, has imposed quality and safety standards that are becoming requisite rather than optional. Sustainability and environmental friendliness are also factors that

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are being linked to sectoral acceptability and, hence, influence quality, marketing and trade issues.

outlook, March 4, 1997.

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[1] This review is based on the Plenary Lecture IV- “International trade: issues and challenges” and the presentations and recommendations of the Session III – “Aquaculture products: quality, safety, marketing and trade” of the Conference. This manuscript was compiled by Mr. Courtney Hough.

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Aquaculture Development: Financing and Institutional Support[1]

The Editors

Anon, 2001. Aquaculture development: financing and institutional support. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 259-263. NACA, Bangkok and FAO, Rome.

ABSTRACT: Aquaculture development during the decade preceding 1997 fostered an increase in annual production of about 200% to over 36 million tons overall or 28% of total global fish production, according to FAO statistics. This represents an average annual production increase exceeding 17% over that period. A rough estimate of investment that was required to achieve this increase is about US$75 billion in Year 2000 dollars. The funds for this development were provided from private sector investments, grants, loans, and governmental subsidies. The investment supported expansion of production facilities, research (including monitoring), disease diagnosis capacity, feed production, hatchery development, processing facilities, market channels, education, training, technical assistance, etc. Although much of the expansion can be attributed to private sector investment, there was also direct participation by local communities; national, private, and multilateral banks; governments; multilateral and bilateral agencies; non-governmental organizations; aquaculture associations and cooperatives; aquaculture research institutes; universities, and technical schools and colleges. Often, more than one and, in many instances, several of the above institutions have collaborated on the implementation of aquaculture development programs, using the relative strengths of each to its best advantage. Based on this experience and the comparative advantages of current activities that involve multiple agency collaboration with the receiving communities/households, it is expected that this trend will continue in the future. If aquaculture production continues to increase at the same rate that it did in the 1990s, the yield from aquaculture will equal that of marine capture fisheries by 2005 or a further increase of close to 250%. This would, however, require more intensive, co-ordinated institutional support and direct community involvement for sustainable results. The rapid increase in supply

could also have significant impacts on market prices that would need to be effectively forecasted to assure that the investments are viable as was witnessed for some aquaculture products in some countries in the 1990s. The rapid development would also require close attention to potential environmental and social impacts and their prevention or mitigation.

Financing and investment principles

Increasingly, international assistance is geared to poverty alleviation. This requires development programmes to adhere to the principles of sustainability, social acceptability and environmental soundness over and above the traditional principles of technical feasibility and financial and economic viability.

To achieve rapid and sustainable aquaculture development would require more intensive, co-ordinated institutional support and direct community involvement. Continued rapid development will require close attention to potential environmental and social impacts and their prevention or mitigation. Defining the roles of government and the private sector including civil society, and the identification

Priority-setting exercises are important mechanisms but an understanding of the livelihood objectives of the poor and their own strategies for achieving those objectives should precede these. This would mitigate the tendency to look at problems from a viewpoint other than theirs and then proffer or impose solutions to these problems. Further, the constraints to development are not always issues for or answered by research. An FAO/NACA study on development research constraints and priorities has identified weak or lacking institutional support, and lack of enabling policies as the major constraints to the application of technology for aquaculture development. However, in many cases, technological solutions were ineffective due to research-setting activities failing to consider the circumstances of and overlooking the participation of the beneficiaries; such research of responsibilities that enable each one to complement the others' efforts is crucial to mustering support or commitment to development projects. Donors would like to see national policies that clearly express the roles and responsibilities of various stakeholders preferably made through consultations among them. More important, it would assure investors and farmers that their projects are supported and their investments protected.

Priority and agenda setting

- Grass roots/rural community needs should be reflected in national priorities;
- Understanding of development bottlenecks should be improved.
- The aquaculture sector should be a key advocate for research and development needs;
- Development outcomes should be defined – such as production for domestic consumption, increase in rural incomes and employment, and increase foreign exchange earnings while concurrently assuring product quality for exports.

There is a growing trend towards projects thus had little relevance to the actual needs of the rural poor. One key area that has been overlooked is the need to formulate low risk technical options for poverty reduction. Using research as a vehicle for advocacy for aquaculture development would thus entail raising the R and D capacity of the country and improving the research priority setting mechanism so that the national R&D agenda incorporates strongly the views, and addresses the needs, of the poor. Among Asian countries, high productivity increases have in the past made government planners aware of the importance of aquaculture, which prompted them to include aquaculture in government policies and plans. This has also resulted in increased investments on the management of the sector and on technological development by governments. It also stimulated increased investments on aquaculture projects by both government and the private sector. Trends are now towards R & D and policies that address social and economic as well as environmental objectives. This was in large measure prompted by the environmental problems and social conflicts that aquaculture was seen to generate, as well as the basic shift from aquaculture development to aquaculture for development with emphasis on the social better governance, accountability, and more stakeholder participation. An important question is how can the importance of aquaculture gain appropriate consideration in national policies and planning.

A mechanism is needed to set national social and economic development priorities for aquaculture that includes and reflects the needs of the rural poor.

objectives of the country. In the end, it is good governance marked by accountability and transparency that ensure that development projects are implemented better and embraced and supported by the people.

Allocation and use of resources

- Private Sector - Major player; includes national companies, trans-national corporations, and entrepreneurs;
- Public Sector - National, regional, bilateral and multilateral institutions;
- NGOs;
- Cooperatives.

Significantly, the investments on aquaculture development are increasingly originating from a mix of sources. The trend is that financing from private sector is on

Institutional support and co-ordination

- Capacity building and access to credit by the rural poor are essential;
- Local research and strengthened training are mobilized;
- Competence of extension services for sustainable development strengthened and maintained;
- Appropriate technologies, knowledge, and skills made available to businesses, farmers and communities.

the rise and becoming dominant, even as donor and external funds are decreasing relative to the overall amount of investment. National sources that include development and commercial banks, private investors, farmer cooperatives, and governments themselves are becoming a more significant player in aquaculture development funding. NGOs are also moving from a solely advocacy role to providing support services. Nonetheless, smallholder access to credit remains limited, due in part to the interest on so-called bankable projects, which are invariably commercial-scale or -oriented activities. There is therefore a need to focus or direct more development assistance to address poverty. And this suggests greater scrutiny of aquaculture from the environmental, social and good governance perspectives.

Some issues on the allocation and use of resources would include effectiveness of the financial delivery mechanisms, how can these be strengthened; the future role of NGO's in the delivery of services including credit; and, along with globalization, how nations could benefit from increasing mobility of international venture capital.

An important consideration in the use of resources is stakeholders' There are two ways of looking at the issue of institutional capacity. One is that the probability of success of an investment project becomes better with well-developed institutional mechanisms. The other is that it is usually in areas that have poorly developed policy, institutional support and regulatory systems that are in greater need of development support. One key area that has increasingly been overlooked is the provision of credit and training in its management for the rural poor under fair market terms that improves profitability, broader access to markets, and, thereby, sustainability. Often, traditional credit institutions do not have the experience or capacity to evaluate aquaculture proposals and need to develop linkages to fisheries/aquaculture departments, agencies, or institutions to hire technical specialists to be able to assist in the assessments. Mechanisms to meet collateral needs often required for micro-credit/loans also need to be explored and researched, particularly for the rural poor who are often precluded from formal sources of funding due to collateral requirements. Examples along the lines of the practices of the Grameen Bank in Bangladesh may be a good starting point for many countries. Accordingly, for the provision of credit, the range of involvement in the process. Primary stakeholders should be enlisted as partners with government in decision-making processes. This requires well-organized and informed stakeholders that are willing to share responsibility for planning and management of the aquaculture sector or of a development project.

options need to be explored among the institutions (banks, government finance systems, credit unions, cooperatives, NGOs, etc.) need to be considered as to whether they are the more appropriate agencies.

Support to improving research and extension capacities on technical aspects have, in the past, been substantial in many countries so that there is now, in most developing countries the critical mass of skilled R & D personnel, and fairly well developed management systems and infrastructures for research and extension.

The UNDP/FAO project that established the Network of Aquaculture Centres in Asia-Pacific also strengthened national centres for R and D, which took part in regional cooperation on research and development. The NACA project strategy was to achieve increases in yields as well as improvements in productivity by the application of known and adaptation of better technology. The consequences of noticeable

Ways to increase stakeholder involvement include the creation of an enabling environment, which legalized and encouraged stakeholder involvement; development of decision-making processes and mechanisms to include stakeholders and development of the institutional capacity and aspirations of stakeholders to participate in the decision-making processes. It is essential that the local and national increases in fish production included a higher profile of aquaculture in national development plans and therefore more investments from governments, private sector and external sources in aquaculture development projects, including further research. With this enhanced research capacity from a technological and production focus, the Asian regional development programme for aquaculture gradually shifted towards, and expanded to embrace the social, economics and environmental dimensions of development, spurred largely by problems in these areas that impacted on aquaculture or which aquaculture development and expansion were seen to create. This broader focus required institutional and legal frameworks to govern aquaculture development. Thus the trend in development assistance has been to build or strengthen institutional capacities of technical line agencies for the most part, though more is needed on the finance side. On the other hand, research capacity (if not the overall capacity, at least in a number of critical competencies, as in social and economic research) has been static; missing, such as the case of improving credit accessibility; or possibly declining in some regions or countries, so that it would be crucial to revisit this issue from the points of view of stakeholders own the development agenda. (Editors' note: an elaboration of this and related issues is found in the review, "Involving Stakeholders in Policy" by Sevaly Sen in this volume).

Although much of the expansion can be attributed to private sector investment, there was also direct participation by local communities; national, private, and multilateral banks; governments; multilateral and bilateral agencies; non-governmental organizations; aquaculture associations and cooperatives; aquaculture research institutes; universities, and technical schools and colleges. Often, more than one and, in many instances, several of the above institutions have collaborated on the implementation of aquaculture development programs using the relative strengths of each to its best advantage. Based on this trend and the comparative advantages of current activities that involve multiple agency collaboration with the receiving communities/households, it is expected that this trend will continue in the future.

The key to obtaining the maximum development impact and desired results from investments (be they grants, loans, or direct investments) is effective co-ordination and cooperation among

(i) national support; (ii) donor assistance and (iii) South-South cooperation.

What is required to achieve the needed capacity?

- Increasing donor cooperation and co-ordination;
- Strengthening institutions and access to funding to meeting demand;
- Increasing information exchange and communication capacity.

The management of a development project is a complex undertaking requiring the co-ordination of various efforts and even harmonizing often-differing views or interests from all legitimate stakeholders. Clearly, the sum of the capacities of various stakeholders would not make any impact on development if these were not co-ordinated or they did not cooperate. Cooperative involvement occurs when primary stakeholders act as partners with government in the decision-making processes. Much depends on the commitment of government for stakeholder involvement in policy, planning and management processes, the tasks to be undertaken, political and social norms in the country and the capabilities and aspirations of the stakeholders themselves.

donors to address all needs at the local level. Governments know that external support should mainly provide the catalyst to development or to a development process, not to serve as substitute to national resources and efforts. On the other hand, donors and other assistance agencies have been working on several approaches aimed at co-ordinating diverse assistance. One of these approaches was exemplified by the NACA project, and now the NACA organization, by which a regional programme provided coherence and direction to various sources of assistance. A recent example, designed to focus various externa as well as local assistance to address poverty, is the Sustainable Aquaculture for Poverty Alleviation (SAPA) strategy of Vietnam. A third, example, at the regional level, is the regional initiative called STREAM (for Support to Regional Aquatic Resources Management), which provides a platform for cooperation among various organizations, agencies and institutions to address livelihoods development among poor rural dwellers dependent on aquatic systems for livelihood. (Editors' note: The keynote paper, "Regional and Inter-regional Cooperation for Sustainable Aquaculture Development," by Lennox Hinds and G.B. Bacon (in this volume) provides an interesting and detailed

Increasing stakeholder involvement requires overcoming any constraints associated with these critical issues.

rationale and strategies for effective cooperation among donors and recipients).

A key element to improving capacity to manage development activities is information and communications support. Firstly, an information system is integral to the monitoring and evaluation system, secondly, it enables a quick response mechanism to urgent needs by the participants, thirdly it facilitates exchange of experiences and lessons learned, and fourthly, a strong development support communications facilitates the search for or design of solutions to problems, and improves the effectiveness of training and other capacity building efforts. An effective blend of traditional media and the new information technology would be desirable.

As a final word, the attribute of these and, no doubt of successful cases or other promising approaches, is that institutional and financial assistance to aquaculture development drawing their

Multiple projects increase the costs of development assistance and place a significant burden on national resources. A program approach makes it necessary for donors to more effectively cooperate and collaborate with each other. Ultimately this needs to occur within comprehensive frameworks. There is thus a need for donors to adopt more cohesive approaches and procedures.

Recommendations of the session

The session panel comprised Cornelia Nauen, Ron Zweig, Richard Fuchs, Barney Smith, Kirsten Bjoru, Simon Bland, Jeanenike Dahl-Kristensen, Lennox Hinds, A.M. Jayasekara, Jia Jiansan, Hassanai Kongkeo, Alessandro Piccioli and Malcolm Sarmiento. The recommendations are as follows:

coherence and relevance from viewpoint of local needs.

Summary of the session

Private sector funding makes a major contribution to aquaculture development, while public sector finance is important and can fill niches of capacity building and institutional development. Applied research and farmer access to knowledge are identified as areas needing particular attention. International development assistance is becoming increasingly directed towards poverty alleviation and needs to adhere to basic principles of social equity, including gender, environmental sustainability, technical feasibility, economic viability and good governance. The level of risk is important when supporting initiatives to address poverty elimination.

- Private sector funding makes a major contribution to aquaculture development, while public sector finance is important and can fill niches of capacity building and institutional development.
- Applied research and farmers' access to knowledge and credit are identified as areas needing particular attention.
- International development assistance is becoming increasingly directed towards poverty alleviation and needs to adhere to basic principles of social equity, including gender, environmental sustainability, technical feasibility, economic viability and good governance.
- The level of risk is important when supporting initiatives to address poverty elimination.
- Multiple projects increase the costs of development assistance and place a significant burden on national resources. A program approach makes it necessary for donors to more effectively cooperate and collaborate with each other. Ultimately this needs to occur within comprehensive frameworks. There is thus a need for donors to adopt more cohesive approaches and procedures.

[1] This manuscript was compiled by the editors of this volume, using the panel discussion notes prepared during the conference, recommendations of the panel and the technical contents from the relevant section of the Report of the Conference on Aquaculture in the Third Millennium.

Part IV - Aquaculture Development Trends

Current Status and Development Trends of Aquaculture in the Asian Region

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Kongkeo, H. 2001. Current status and development trends of aquaculture in the Asian Region. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 267-293. NACA, Bangkok and FAO, Rome.

ABSTRACT: The past 20 years have seen Asian2 aquaculture evolve from a traditional practice to a science-based activity and grow into a significant food production sector, contributing more to national economies and providing better livelihoods for rural and farming families. Aquaculture used to be regarded as an infant in comparison with crop and livestock husbandry and capture fisheries. It has since matured into a better-organized economic sector characterized by more state patronage but also a stronger private-sector participation, in most parts of Asia. Asia dominates the world in aquaculture production and the sector is extremely diversified in species, technologies and farming systems employed. Many governments place priority on aquaculture development, however there are various threats and constraints to its growth. Asia's contribution to total world production in 1997, following the International Standard Statistical Classification for Aquatic Animals And Plants (ISSCAAP} grouping, was: finfish -89 percent; crustaceans (marine) - 80 percent; freshwater crustaceans - 94 percent;

molluscs - 88 percent; aquatic plants - 98 percent, and miscellaneous animals and products - 99 percent. The region provides 91 percent of global aquaculture production. In 1997, the combined aquaculture production was 32.63 million mt valued at US$41.95 billion, an increase of 144 percent and 117 percent in weight and value, respectively compared to 1988. Aquaculture production in the region has been growing at a rate nearly five times faster than landings from capture fisheries, and its share of total fisheries landings in the region increased from 32 percent to 50 percent between 1988 and 1997.

The two major influences on Asian aquaculture development policy are the recent broadening from technical and economic objectives towards social objectives for aquaculture development that include poverty alleviation, livelihood development and food security, and the links made between sustainable aquaculture practices and trade. An increasing recognition of the importance of small-scale, socially oriented aquaculture is happening, and recent initiatives have been made at the regional level to focus governments and regional organizations on this issue. The role of the fish farmer is changing from merely raising fish to being a part of a chain for the production and delivery of safe, high quality products to the consumer. The link made to production practices and their impact on the environment, on one hand, and trade, on the other hand, has been reflected in recent regional and national programmes.

KEY WORDS: Aquaculture, Fish Farming, Asia, Development, Development Trends

Introduction

The past 20 years have seen Asian aquaculture evolve from a traditional practice to a science-based activity and grow into a significant food production sector, contributing more to national economies and providing better livelihoods for rural and farming families. During the period 1988-1997, Asian aquaculture production grew from 13.4 to 32.6 million mt (APR [Annual Percent Rate of growth] 11 percent), increasing its value from US$19.3 billion to US$42 billion (APR 9 percent).

Aquaculture used to be regarded as an infant when compared with crop and livestock farming and capture fisheries. In most parts of Asia, the activity has matured to become a clearly defined economic sector that is better organized and characterized by state patronage and strong

Figure 1. Contribution of Asia towards total world aquaculture production by weight (FAO, 2000)

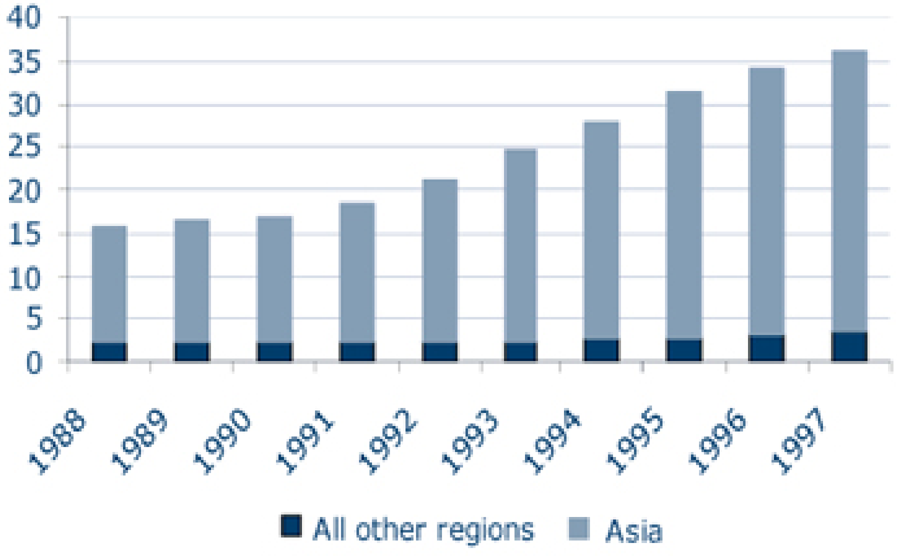
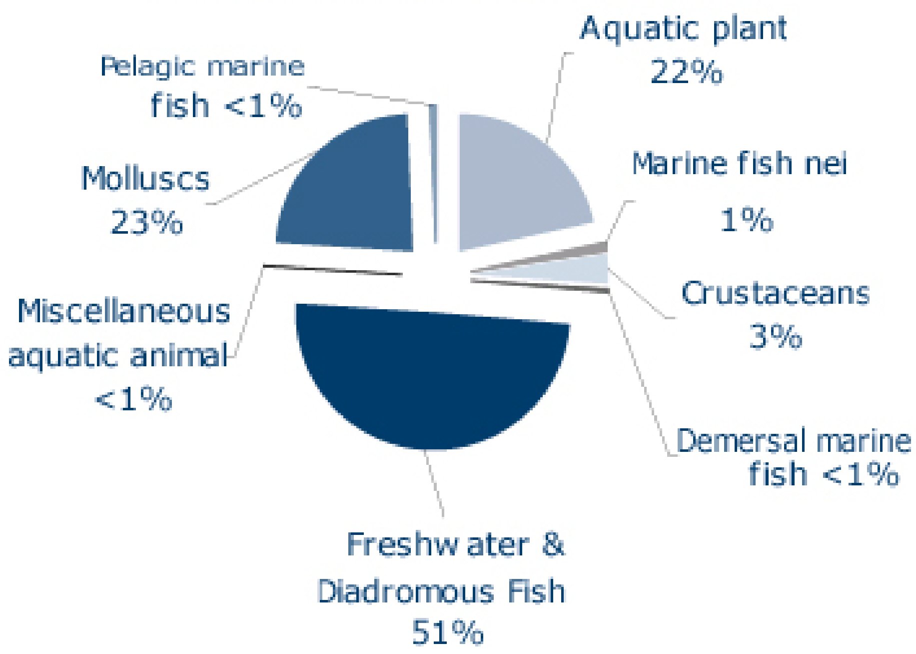


Figure 2. Aquaculture production in Asian region in 1997 (FAO, 2000)

Total 1997 production 32 633 348 MT



By the same token, India merits the same focus. Nevertheless, analysis of the overall regional private-sector participation. Many changes have occurred alongside the sector's development. Aspirations for higher yields through technological innovation have been tempered with concerns for sustainability. Economically, the drive for higher profits has been qualified by schemes to distribute benefits fairly. As a commodity industry, the purposes of producing more food, earning higher incomes and improving economies have been expanded to include ensuring food security, alleviating poverty, and promoting social harmony and prosperity.

These shifts in outlook, not confined to aquaculture and prompted by global and social forces, occurred in the last part of the previous century. It is in the midst of these changes that aquaculture status serves a useful purpose, particularly in trying to identify regional opportunities and actions.

Asia's contribution to total world production in 1997 (Fig. 1), following the International Standard Statistical Classification for Aquatic Animals And Plants (ISSCAAP) grouping, was: finfish - 89 percent; crustaceans (marine) - 80 percent; freshwater crustaceans - 94 percent; molluscs - 88 percent; aquatic plants - 98 percent, and miscellaneous animals and products - 99 percent.

development in Asia finds itself at the beginning of the new millennium.

The status of Asian aquaculture

Asia dominates global aquaculture production. This simple statement covers, however, the extreme diversity encountered within the sector, not only in the species reared and the technologies and farming systems employed, but also in the role and objectives of aquaculture development in different countries, the priorities placed by governments and the threats and constraints to its growth.

These considerations, in addition to the wide range of geographic locations, habitats and levels of national development, are important influences on how, and how fast, aquaculture will develop in the region. For these reasons, it would be better to look at the status and trends of Asian aquaculture by subregion, or on a national basis, with China[3] classified by itself as a subregion in view of the sheer size of its aquaculture.

The region provides 91 percent of global aquaculture production, where the top 10 Asian aquaculture producers are China, India, Japan, Republic of Korea, the Philippines, Indonesia, Thailand (also the top seven producers in the world), Bangladesh, Viet Nam and DPR Korea.

In 1997, the combined aquaculture production in Asia was 32.63 million mt (Fig. 2) valued at US$41.95 billion, an increase of 144 percent and 117 percent in weight and value, respectively compared to 1988. Aquaculture production in the region has been growing at a rate nearly five times faster than landings from capture fisheries, and its share of total fisheries landings in the region increased from 32 to 50 percent between 1988 and 1997.

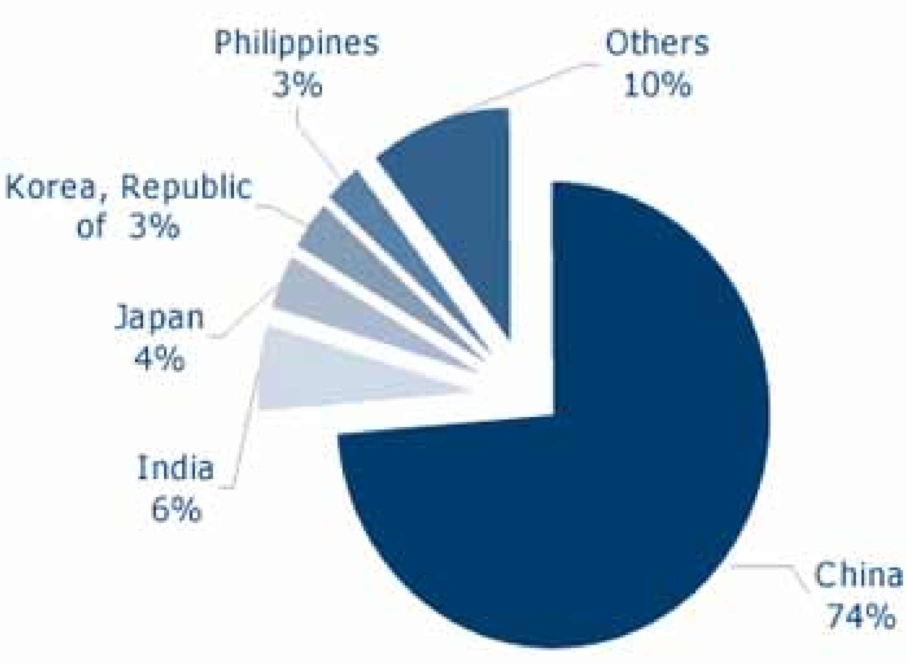
In Southeast Asia[5], freshwater foodfish species comprise almost 30 percent of the total aquaculture output, mainly from Indonesia, Viet Nam, Thailand and the Philippines. While the overall production of diadromous species has been decreasing, milkfish contributed an additional 13 percent in 1995. Rising Indonesian aquaculture has been a major contributor to the

Production by commodity groups

Finfish

Throughout Asia, the production of finfish has increased from 6.36 million mt in 1988 (having a value of US$10.1 billion) to 16.7 million mt (US$22 billion) in 1997, representing an average APR of 11 percent, while annual growth during the period 1992-1996 averaged 15 percent. In South Asia4, fish for food, mainly freshwater species, dominate production, with over 94 percent of total fish production in 1997. Freshwater and diadromous species occupy 92 percent of the subregion's total production, the remainder being crustaceans. Subregional production attained 2.2 million mt in 1997, worth US$22 billion.

Figure 3. Top five freshwater fish producing countries and their production in 1997 (FAO, 2000)



increased production of freshwater species in this subregion. Aquaculture produced 1.5 million mt worth US$3.4 billion in 1997.

China is the major finfish producer in East Asia6, where total production was 13 million mt in 1997 (Fig. 3) worth US$16.1 billion. The production of freshwater finfish in China, mainly of carp and tilapia species, was over 12 million mt in 1997, accounting for 37 percent of regional aquaculture and 34 percent of global aquaculture (Fig. 3). In recent years, diversification towards luxury freshwater species has been emphasized, including mandarin fish, freshwater crabs and prawns, eels and softshelled turtles. Nonetheless, carps accounted for 92 percent of freshwater production and represented 47 percent of national production in tonnage and 40 percent in value.

Japan produces some 322 000 mt of finfish, worth US$2.8 billion, having an average value regularly higher than US$9/kg. This is mainly due to the production of significant quantities of Japanese amberjack (138 000 mt), silver seabream (80 000 mt), Japanese eel (24 000 mt) and rainbow trout (13 500 mt).

Around 14 percent of all finfish production in the world consists of carp, more than 90 percent of which is produced by aquaculture and where 80 percent of this amount is produced by China. In most countries, carp is consumed locally and, with few exceptions, producers of Chinese and major carp species have been unable to find markets outside Asia. Carps, as a group, are not traded globally. Carp supply in China, India and countries of the CIS [Commonwealth of Independent States], will probably continue to increase steadily, at least in the near future, in response to population growth and demand.

Tilapia has spread outside of Africa, its origin, and is now a common feature of aquaculture not only in Asia but also in Latin America and the Caribbean. Producers have access to domestic markets in several Asian countries, such as the Philippines, Thailand and China, and there is also an established and rapidly expanding market in the United States that is providing additional impetus to tilapia farming in several countries.

Tilapia products are also being sold in Japan and in European countries.

Small quantities of trout are farmed in Iran, Pakistan, the colder regions of India, and in Nepal, but Japan is the largest producer with some 13 500 mt produced in 1997. Trials are starting in Thailand to grow trout in the cooler climates (northern hills) as an income generating activity and largely for the domestic market.

The production of eels is significant in China, Japan and Taiwan Province of China, where the focal point for trade is Japan, which imported 11 000 mt of live eels and 45 500 mt of processed eels in 1996. Regional production has risen from 92 000 mt (1988) to 224 500 mt (1997). However, major growth has only occurred in China (>100 000 mt over the period), production dropping significantly in Japan (from 40 000 mt to 24 000 mt) and in Taiwan Province of China (52 000 mt to 22 000 mt). Furthermore, the 1998 value of the eel output (US$314 million) in Japan was a huge drop from the 1995 peak of US$577 million, because of the decrease in quantity produced (from 29 131 mt in 1995 to 21 971 mt in 1998) and average price of the product from (US$20/kg to less than US$15/kg.

As production capacity has grown, the total volume of cultured penaeid shrimp is now close to half that produced by capture fisheries. In volume terms, the rate of increase in production of penaeid shrimp is tapering off in Asia, but one can see a significant increase in the production of freshwater crustacean species, Macrobrachium rosenbergii, mainly in Bangladesh and China.

The growth of penaeid shrimp production has been predicted to slow down in the immediate future. One of the main reasons for this short-term prediction is the slower rate of economic growth in Japan, the world's largest market for shrimp, as well as the slower economic growth expected in the other developed economies. In addition, the management of shrimp culture is not at a uniformly high level. Furthermore, the emergence of stringent environmental regulations may slow down expansion in Asia.

In South Asia, crustacean culture is dominated by penaeid shrimp, which increased from 37 000 mt in 1988 to 134 000 mt in 1997 as a result of increased production in India, Bangladesh and Sri Lanka valued at US$858 million. Growth slowed in 1997 due to disease outbreaks and India's sanctions on shrimp culture. Of note is the large harvest reported in 1997 for the disease and a shortage of elvers of Japanese eel (Anguilla japonica) have caused seed supply problems in the region and initiated the trade of elvers of the European eel (A. anguilla) from Europe to Asia, particularly, China. Recently, a resurgence in the recruitment of the Japanese elver has alleviated the situation.

Crustaceans

Aquaculture of crustaceans, mainly shrimp and crabs, yielded 539 000 mt in 1988, worth US$3.5 billion. By 1997, this had risen to 1.1 million mt (APR 9 percent), having a value of US$7.2 billion (APR 9 percent).

Shrimp production in 1997 was worth US$6.9 billion at farm gate prices to the region, representing a total of 902 000 mt. The value added through processing is also very significant, making it worth more than US$6.9 billion to the region. Penaeid shrimp is the main crustacean aquaculture product that is traded internationally but, although this is an important source of hard currency in many developing economies, shrimp are much less significant as a food source for domestic consumption.

freshwater giant river prawn (M. rosenbergii) in Bangladesh, 48 000 mt valued at US$497 million.

In Southeast Asia, the production of shrimp and prawns grew from 220 000 mt in 1988 to 562 500 mt in 1997, where Penaeus monodon (giant tiger shrimp) represented 450 000 mt in 1997 (80 percent). The decade reviewed (1988-1997) shows the phenomenal growth of this sector in Thailand (+242 percent), the world's leading producer of this species, Viet Nam (+293 percent) and Indonesia (+115 percent). After production stagnation during the late 1990s, Thailand has rebounded with production of an estimated 250 000 mt in 2000.

East Asia has witnessed significant reductions in shrimp production, where production of the fleshy prawn (Penaeus chinensis) dropped from a high of 207 000 mt in 1992 to a low of 64 000 mt in 1994, recovering to 146 000 mt in 1997. Taiwan Province of China's giant tiger shrimp production dropped from a peak of 78 500 mt in 1987 to only 5 000 mt in 1997. Overall, the subregion's production of shrimp and prawns has decreased from 246 000 mt to 163 000 mt, but has shown signs of recovery in recent years.

Other crustaceans for which production is increasing are crabs, notably in China, and after a period of decline, production of freshwater prawn is also rising with increasing outputs from China and Bangladesh.

In West Asia7, crustacean production is nominal and restricted to penaeid shrimp. In Iran it is small but increasing.

Molluscs

Mollusc aquaculture is dominated by East Asia (98 percent of the region's production), the remainder being attributed to Southeast Asia. Regional production reached 7.6 million mt in 1997, valued at US$7.6 billion, compared to the 1988 production of 2.6 million mt worth US$2.5 billion, an APR of 13 percent in volume and 14 percent in value.

Molluscs are almost always reared for sale, rather than household needs, usually being sold to markets located near the place of production. Mollusc culture in Asia was not affected much by the 1997-

These subregions provide almost all of the brown, red and green seaweeds produced in global aquaculture. While aquatic plant production almost doubled between 1988 and 1997 in East Asia, rising from 3.5 to 6.3 million mt, the contribution to aquaculture production dropped from 32 percent to 23 percent. In Southeast Asia, the pattern is different, production growing over the same period from 0.34 to 0.76 million mt, the contribution changing from 22 percent to 25 percent.

The region's total production was 7 million mt in 1997, valued at US$4.8 billion, figures that indicate APRs of 8 percent and 5 percent, respectively. The average value/kg for this group has eroded from US$0.84 to 0.68, an APR of -0.2 percent.

The highest reported global production of any cultured aquatic organism for 1997 was the kelp Laminaria japonica, totalling over 4.4 million mt. In the top 10 species, carps have consistently led production, followed by plants and shellfish (1988); by 1997, shellfish

1999 economic downturn and will continue as a source of growth in aquaculture production. Cockles and mussels are promoted as cheap sources of protein, while oysters tend to be more of a luxury item, consumed domestically and in some countries as an export item Pearl oysters are significant industries in China, Indonesia, Japan and the Philippines and to a lesser extent in India and Thailand.

Big increases in production have occurred throughout the region during the period examined, but most significantly for:

- Japanese carpet shell (China: from 186 000 mt to 1 257 500 mt);
- razor clams nei (not elsewhere included) (China: from 138 500 mt to 354 000 mt);
- Pacific cupped oyster (China: from 447 500 mt to 2 328 500 mt); and
- Yesso scallop (China: from 129 500 mt to 1 001 500 mt; Japan: from 180 000 mt to 254 000 mt)

Elsewhere in the region, oyster production has stagnated. Mussel production, in general, has declined everywhere, with the exception of the increases reported for the Korean mussel in the Republic of Korea (8 000 mt to 64 000 mt).

had overtaken aquatic plants in this position.

Comparison of the top ten aquaculture species in the Asian Region, ranked by production importance in 1988 and 1997 is given in Table 1.

One can note that the top ten species contribute two-thirds of the region's production, but that carps have displaced aquatic plants from its dominant position and shellfish production, having tripled in volume, now occupies second place in the groups containing the top species.

Table 2 provides a similar comparison, but based on the total value contributed by different aquaculture species.

Most notable is the rise to the top, from 5th place, of the giant tiger shrimp (Penaeus monodon), which contributed 9 percent of the total value of Asian aquaculture in 1997, although it is 17th in the production ranking. Thailand contributed more than half this figure, despite disease problems. The production of P. chinensis, which is predominantly cultured in China, was ranked 42nd.

While the production and contribution of the major carp species have increased

Aquatic plants

East Asia and Southeast Asia produce the bulk of aquatic plants within the region, where seaweeds, mostly brown or red, dominate the volumes reported.

significantly, the average US$ value/kg has gone down; for the examples cited in this analysis, reductions of 12-30 percent have been seen.

Table 1. Comparison of the top ten aquaculture species in the Asian Region ranked by production importance (mt) in 1988 and 1997 (Source: FAO, FISHSTAT).

	1988		1997	
	Production (MT)	%[1]	Production (MT)	%
Japanese kelp	2 072 383	64	4 401 931	100
Laver (Nori)	670 816	21		
Wakame	492 196	15		
Plants total	3 235 395	24	4 401 931	14
Silver carp	1 493 882	42	3 169 342	31
Grass carp(=White amur)	605 253	17	2 708 798	26
Common carp	712 381	20	2 015 093	20
Bighead carp	715 397	20	1 544 382	15
Crucian carp			861 950	8
Carps total	3 526 913	27	10 299 565	33
Pacific cupped oyster	1 037 008	71	2 771 613	54
Japanese carpet shell			1 272 165	25
Marine molluscs nei[2]			1 134 728	22
Sea mussels nei	429 675	29		
Shellfish total	1 466 683	11	5 178 506	16
Freshwater fishes nei	532 684	4	1 407 117	4
Subtotal top ten species	8 761 675	66	21 287 119	67
Total production	13 241 684		31 631 872	

[1] Percentages in bold are calculated on the total production, while percentages in light are calculated on the group subtotals.
[2] nei = not elsewhere included.

Most of the shrimp species have maintained or increased their US$ value/kg. During the same period, the value of the Japanese eel has halved, while certain fish species (milkfish, rohu, Japanese amberjack and tilapias) have increased.

Production by environment

If one separates aquaculture production by environment, the

Freshwater finfish, in particular the Chinese and major carps, accounted for the greatest share (48 percent) of regional aquaculture production in 1997, while aquatic plants contributed 22 percent. A key factor in the rapid rise in the production of some of the species cited has been the increased availability of hatchery-produced seed.

Main culture systems

proportion of freshwater species in total Asian production increased from 43 percent to 49 percent between 1988 and 1997, an average APR of 12 percent. Brackishwater production had an average yearly growth of 5 percent and marine production 10 percent.

The proportion of brackishwater aquaculture decreased from 7 percent to 4 percent while experiencing growth at an APR of 10 percent during the same period. Similarly, marine production had average growth of 10 percent, but its share decreased from 50 percent to 47 percent.

Inland fresh-and brackishwater ponds, tanks and reservoirs comprise the largest production areas in Asia, with some 1.99 million ha in China. Similarly, there are 147 000 ha in Bangladesh, 900 000 ha in India, 462 000 ha in Indonesia, 255 000 ha in the Philippines, 320 000 ha in Thailand and 392 000 ha in Viet Nam. Viet Nam, Indonesia and the Philippines have more brackishwater than freshwater ponds and which are devoted to shrimp culture as well as other species, such as milkfish in Indonesia and the Philippines.

Table 2. Comparison of the top ten aquaculture species in the Asian Region, ranked by value (US$) in 1988 and 1997 (Source: FAO, FISHSTAT).

1988				1997			
Species	Value ('000 $)	US$/kg[1]	% of Total	Species	Value ('000 $)	US$/kg	% of Total
Silver carp	1 528 422	1.02	7.9	Giant tiger shrimp	3 766 740	7.16	9.0
Fleshy prawn	1 496 645	7.50	7.8	Silver carp	2 923 214	0.92	7.0
Japanese kelp	1 457 322	0.70	7.6	Japanese kelp	2 873 933	0.65	6.9
Laver (Nori)	1 375 097	2.05	7.1	Pacific cupped oyster	2 864 175	1.03	6.8
Giant tiger prawn	1 324 103	6.63	6.9	Grass carp	2 489 411	0.92	5.9
Pacific cupped oyster	1 068 162	1.03	5.5	Common carp	2 138 635	1.06	5.1
Common carp	1 060 759	1.49	5.5	Yesso scallop	1 700 718	1.35	4.1
Japanese amberjack	1 039 971	6.22	5.4	Japanese carpet shell	1 661 556	1.31	4.0
Japanese eel	992 029	10.81	5.1	Freshwater fishes nei[2]	1 595 789	1.13	3.8
Grass carp	804 719	1.33	4.2	Rohu	1 484 731	2.14	3.5
Subtotal top ten	12 147 228		63.0	Subtotal top ten	23 498 904		56.0
Total value	**19 294 267**			**Total value**	**41 945 580**		

[1] Weighted average value for all Asian production.
[2] nei = not elsewhere included.

Freshwater ponds in Viet Nam, Cambodia, Laos, Bangladesh and India are generally small and used to grow food fish that are low on the trophic level. These are usually integrated with other operating systems, such as the 127 000 ha of VACs (vegetable-fish-livestock plots or gardens) in Viet Nam, and the undrainable composite-culture ponds in India.

The Network of Aquaculture Centres in Asia-Pacific/Asian Laos and Thailand, indigenous cyprinids such as Puntius spp. are more common.

Thailand's freshwater ponds are operated for a mixture of objectives. The products of school and village ponds provide food and income among poor families, and these comprise nearly 13 000 units, ranging in size from one-third of a hectare (school ponds) to 8 ha (community ponds). All in all, Thailand has a total of 247 300 ha of

Development Bank Study (ADB/NACA, 1998) found that almost all carp farming in the region is a polyculture of indigenous and (often) exotic carp species, with the exceptions of Korea and Indonesia, where monoculture of common carp was common. The carp farming systems also commonly contained other non-carp species.

There are three distinct areas of carp polyculture in Asia: South Asia has the major carps; China and cooler waters use Chinese carps, and Southeast Asia uses a mixture of exotic and indigenous carps. For example, in Cambodia, inland aquaculture ponds, comprising 122 000 farms and producing annually 196 000 mt of mostly food fish. Commercial freshwater ponds are used to raise higher-priced indigenous species, such as catfish, snakehead, freshwater prawn and tilapia. Many of the commercial entities are integrated farms.

Cambodia has the highest percentage (97 percent) of integrated farms within the semi-intensive carp production activity, perhaps a result of the introduction of this system by nongovernmental organizations (NGOs) as opposed to tradition. Thailand follows with 62 percent of farms integrated, primarily with chicken farming and tree crops.

Brackishwater ponds are generally devoted to higher-value species, shrimp being the most popular, followed by other crustaceans and diadromous species. Indonesia has extensive brackishwater ponds (385 000 ha] used for shrimp and milkfish. The Philippines has more than 250 000 ha producing milkfish and shrimp; lately, trials have been made with salt-tolerant tilapia

In 1997, China harvested almost 4.7 million mt of seaweeds, 6.5 million mt of molluscs (including scallops and abalones) and 21 500 mt of other coastal aquaculture species. The areas where mariculture is done were made up of 7.9 million ha, including shallow coasts (3.7 million ha), bays (0.5 million ha) and mudflats (3.7 million ha).

being rotated or polycultured with shrimp to determine its effects in controlling shrimp diseases. In India and Bangladesh, there is a tradition of extensive culture of shrimp in large water bodies.

The potential for integration of rice and aquaculture has long been recognized. China has shown that rice-fish systems are indeed productive and, by also using the system to nurture fingerlings, can generate additional income for rice farmers over a short period. China has 1.3 million ha applied to the paddy cum fish system and an additional 281 000 ha of paddy used for fingerling growing. China's production from the rice-fish system was 455 000 mt in 1997 or almost 500 kg fish/ha. Freshwater fish culture integrated with rice is also found in South Asia and Southeast Asia. Alternate cropping of rice and shrimp – a crop of rice in the wet season followed by a crop of shrimp in the dry season - is also found in some seasonally brackishwater deltas in Southeast Asia (notably Viet Nam) and South Asia (India and Bangladesh).

China's freshwater fishponds yield an average of nearly 5 mt/ha (9 million mt of fish from 1.9 million ha). Culture-based fisheries in open waters are likewise very productive; 880 000 ha of freshwater lakes yielded around

Culture-based fisheries in open-water systems, such as oxbow lakes, are significant in India and Bangladesh, where production yields are around 500 kg/ha for native and exotic carps. Stocking involves both native and exotic carps, although some recent stocking programmes in Bangladesh are giving more emphasis to indigenous carps due to concerns over the potential impacts of stocking of exotics on native fisheries and aquatic biodiversity.

Production losses

The first attempt, at a regional level, to quantify the effects of disease occurrence was made by NACA (ADB/NACA, 1991) in 1990. At that time, losses incurred from disease outbreaks were estimated to have been worth US$1.4 billion a year in the developing countries of Asia, and these have increased since. Reports from China suggested that in 1993 alone, shrimp diseases caused losses of US$1 billion. An ADB/NACA farm survey in 1994-1995 (ADB/NACA, 1998) indicated that for carp and shrimp farming, losses from diseases and environment-related problems were valued at around US$300 million a year. Furthermore, external influences that are associated with disease

810 000 mt of fish in 1997, and 1.56 million ha of reservoirs provided 1.16 million mt. China has also exploited the potential of canals, producing 602 000 mt of fish from 370 000 ha of these waterways. The system used within canals usually involves cages or pens.

The NACA/ADB study on aquaculture sustainability and the environment (NACA/ADB, 1998) found that only 24 percent of surveyed freshwater farms in China were integrated, reflecting farm intensification and perhaps, changes in traditional farming practices. The report cautions that this observation needs further confirmation. China's mariculture (in shallow coastal waters and bays) is likewise characterized by the integration of various species (e.g. seaweed, mollusc an cucumber within a column of coastal water) for an intensive use of the marine environment.

problems (including chemical use, environmental impacts, trade issues etc.) have yet to be properly assessed. Generally, economic losses are likely to increase in scale as aquaculture expands and intensifies, affecting both large-scale and small-scale production units.

Production trends and growth rates

A noteworthy, but perhaps disturbing trend seen in the statistics for the Asian countries/territories from 1988 to 1997 is that the average aquaculture growth (APR) has been 10.4 percent by weight and 9.0 percent by value, but production has not shown steady growth, with year on year increases varying between 1.6 percent in 1990 and 18.6 percent in 1992. After peaking at 18-19 percent in 1992-1993, the rate of increase has slowed down steadily to 5.7 percent in 1997.

This observation coincides primarily with the trends seen for Chinese aquaculture. Some countries within the region have shown production decreases, with a steady decline of production through the period. These are Japan, China, Hong Kong8, Democratic Republic of Korea and Taiwan Province of China.

A striking trend in Japanese aquaculture has been the decline in production of the major species. For instance, the yields of Japanese amberjack have declined from a high of nearly 170 000 mt in 1995 to 147 000 mt in 1998, while laver dropped from a peak of 483 000 mt (1994) to under 400 000 mt (1998). Pacific cupped oyster production has also shown a steady decline. Of the major mariculture species, only silver seabream and Yesso scallop have shown trends towards rising production.

The annual rate of production growth has been consistently higher in China than in the rest of the region, reflected by the increased rate of difference in the compared production volumes. If aquaculture values are compared, the picture is slightly different. This figure shows that the difference in value is proportionately much less than that of production, confirming the

Demand for aquatic produce

The projections for the average annual population growth rates in the region from 1998 to 2020 are:

- 0.8 percent for East Asia, growing to 1.66 billion;
- 1.6 percent for Southeast Asia, growing to 655 million;
- 1.7 percent for South Asia, increasing to 1.72 billion; and
- Iran will have 89 million and Australia 22 million.

The total equals 4 124 million people or two-thirds of the earth’s population. Just to maintain, region-wise, the supply of 17.2 kg of fish per capita (1995 average), the Asian Region would require more than 70 million mt of food fish in 2020, to be supplied from capture fisheries and aquaculture. A look at the situation by region would show differences, but all the same, the indications are for aquaculture to increasingly fill the fish supply requirements of the populations.

In China, aquaculture already contributes more than 60 percent of the total fisheries production and, in 1995, the per capita supply of fish was 22.2 kg, implying a need for 32.2 million mt by 2020 assuming a constant per capita fish supply. If the same supply proportion were to be maintained, 19 million mt would be needed from aquaculture. Southeast effects of diversification and the maintenance of value in aquaculture in the rest of Asia. Indeed, in China the APR for value has grown and shown stability from 1990-1996, dropping off in 1997. In the rest of Asia, the value APR grew steadily from 1989, but has since declined regularly from 1994 onwards, even showing negative figures in 1996 and 1997. Theses circumstances meant that Chinese production alone had a total value higher than the rest of Asia from 1996.

Asia's average per capita supply is now 24.7 kg a year; with a population of 655 million it will require 16.2 million mt of food fish. In assuming that 30 percent is to be contributed by aquaculture, almost 5 million mt of food fish need to be supplied by aquaculture.

Table 3. Population, fish consumption and aquaculture supply.

	Population in 2020 (million)	Fish Consumption (kg/capita)	Need (million mt)	Aquaculture Supply	Need (million mt)
Asia	4 124	17.2	70.926		35.685
China	1 450	22.2	32.190	60%	19.314
Rest of East Asia	210	59.0	12.390	30%	3.717
Southeast Asia	655	24.7	16.179	30%	4.854
South Asia	1 720	4.7	8.084	97%	7.800

Source: FAO, 1998; UN ESCAP, 1997; Ye, 1999; NACA, 1999 (see references).

South Asia will need a total of 8.1 million mt of food fish. In 1997, only 2.33 million mt were produced by aquaculture, 97 percent of this being food fish. If the same ratio is maintained, the South Asian Region will need 7.8 million mt by 2020.The assumptions, and forecasts based on the assumptions, are summarized in the Table 3.

With a total requirement of 35.7 million mt of cultured food fish forecast for 2020, the concern for supply is evident. Since the wild catch is stagnating and forecast to slow even further, aquaculture will have to increase its contribution beyond its current levels.

The Food and Agriculture Organization of the United Nations (FAO) predicts that global aquaculture is likely to show sustained growth in the medium term and could attain 35 to 40 million mt of finfish, crustaceans and molluscs by the year 2010 (FAO, 1998). What this analysis clearly points out is that there is now a burden on aquaculture to meet the future demand for aquatic products, especially that the continued capacity to sustain further productivity increases in all the food production sectors is facing the following threats (UNDP, 1998): losses in genetic resources and biodiversity (e.g. 4 percent of

To put this into a positive light, aquaculture must be developed in a spirit of social harmony, environmental sustainability and economic progress.

Trends and issues

International trade in aquaculture products

Information on the trade in aquaculture products is rarely separated from trade in fisheries products, making it difficult to analyse trends in the trade of aquaculture products. Comments here are therefore based mainly on fisheries products (FAO/RAP, 2000). By volume, Asia is a net importer of fishery products, mainly because of Japan’s trading patterns where an annual trade deficit (exports less imports) of more than 3 million mt has been registered since 1994. If Japan is excluded from the trade data, the developing countries of Asia would register a surplus of only 35 000 mt a year in the triennium up to 19979. The major net importers (with volumes over 100 000 mt) of fish are China, followed by the Philippines and Malaysia. The major exporters with volumes greater than 100 000 mt are India, Indonesia and Thailand. Of these, aquaculture production probably makes the biggest contribution in Thailand.

fish and reptile species are threatened with extinction); loss of aquatic habitat such as coral reefs and mangroves, and severe depletion of commercial fish stocks (25 percent of fish stocks for which data are available are either depleted or in danger of depletion, and another 44 percent of fish stocks are being fished to their biological limit). Aquatic resources are not unique in facing such degradation, as 9 million ha of land are extremely degraded, with their original biotic functions fully destroyed, and 10 percent of the earth's surface is at least moderately degraded, and the availability of safe and clean water has declined steeply to 60 percent (in 1996) of its 1970 value (UNDP, 1998). These trends, which show no signs of changing, indicate that future production of food from aquaculture will face significant challenges in access to and use of resources.

Another crucial point that should be emphasized is that the countries in this region have the highest population densities in the world. There are many issues that aquaculture has to face, but the fundamental one for Asia is that of supply and demand, which has been illustrated above. The critical concerns identified for resolution of this issue relate to social, economic, biological, environmental

In terms of financial value, the countries with developing economies are responsible for more than half of the region's fishery exports, and there is a dramatic change in the pattern of imports and exports. Exports from developing countries in Asia are mainly high-value products that are directed primarily to developed economies. In the triennium ending in 1997, Thailand was the leading exporter in the region, exporting US$2.92 billion annually, a significant portion of which was cultured shrimp. Other major exporters with more than US$1 billion of fish products per year over the triennium include China, India and Indonesia.

In terms of financial value, the countries with developing economies are responsible for more than half of the region's fishery export trade, which is directed primarily to developed economies. Between 1993 and 1996, Thailand was the leading world exporter of fish products, at annual values of around US$3.4 billion (although displaced by Norway's fishery exports in 1997).

Japan is the leading importer of fish products in the world, with a value of US$15.5 billion in 1997.

and institutional questions, which must be resolved with a minimum of conflict and most efficient use of resources.

United States absorbs about 10 percent of the total value and these two countries and the European Community (EC) (including the value of the intra-EC trade) import 75 percent (in value) of internationally traded fishery products.

Shrimp trade

In financial value, shrimp is the most important traded aquaculture commodity in Asia, and Thailand is the world's main supplier of cultured shrimp, with an output of over 200 000 mt. In 1997, the shortage of shrimp on the world market was acute; but Asia, as a whole, was able to maintain its share of the United States market, and smaller exporting countries in the region such as Indonesia and China performed well, although China has of late rarely exported any shrimp.

Mollusc trade

Mollusc exports from the region, including intra-regional trade, increased from 240 000 mt in 1988 to 335 000 mt in 1997, peaking at 380 000 mt in 1996. Important exporting countries are China, Democratic Peoples Republic of Korea, Republic of Korea, Malaysia and Thailand. The predominant products are clams, scallops and oysters.

Finfish trade

The trade in live marine fish, particularly reef fishes, has been growing steadily, spurring work on their aquaculture. Market analysis done in 1995 indicated that the total seafood market in Hong Kong and southern China, the main markets at present, was over 220 000 mt a year, within which the estimated annual demand for high-quality live reef fish was 1 600 to 1

Indian shrimp exports to Japan increased by 6.6 percent to a record 59 100 mt, while total exports in the late 1990s have exceeded 100 000 mt, of which around half were cultured. The reasons for increased import to Japan included EU restrictions on Indian seafood, which started in August 1997.

In 1997, Japanese imports of shrimp fell by 7 percent to 267 200 mt, the lowest figure in nine years, reflecting a downward trend that was apparent throughout 1997. The United States shrimp market was very strong, owing to the country's expanding economy and to the high value of the US dollar, and prices rose by 20 percent in one year. United States imports expanded by 10 percent in 1997, overtaking Japan as the world's major shrimp market for the first time.

Within the region, for markets such as China (including Hong Kong), Singapore and Malaysia, the imports of fish and fishery products for domestic consumption continued to be lower in 1997 than in 1996 due to the economic problems experienced.

Seaweed trade

Seaweed exports bring significant earnings to the Philippines, China, 700 mt. This study forecast compound growth rates of more than 12 percent, in other words, doubling every six years.

In 1997, Hong Kong consumed 28 000 mt of live fish, of which groupers represent 35 percent by weight and 50 percent by value. Tilapia, filleted or chilled, is a growing export species. Taiwan Province of China supplied half of the 50 000 mt of tilapia consumed by the United States in 1998. Other exporters of tilapia to the United States market, but as yet in small quantities, are Indonesia and Thailand.

Singapore is also a significant market for high-value marine fish, although local cage farming has mainly satisfied its domestic consumption. To meet expected growth in demand, it has initiated the move to farm marine fish in offshore deep-water cages, targeting annual production of 40 000 mt that would be supplied with fry from local hatcheries.

The breeding and growing of ornamental fish and aquatic plants is also a growing industry. The value of world trade (wholesale and retail) in these commodities has been estimated at US$5 billion, generating employment and income to breeders and growers. Singapore, Malaysia and Thailand

Indonesia and the Republic of Korea. The Philippines produced over 620 000 mt in 1997 of mostly Eucheuma seaweed, from which the colloid carageenan, which is the export product, is extracted.In East Asia, seaweed (Laminaria and Undaria) are also produced and particularly Undaria, exported.

have well established and mature industries. Countries such as Sri Lanka and the Philippines have discovered this sector fairly recently, seeing that the activity offers opportunities for rural families to earn income from cultivating freshwater ornamental fishes.

Discussion

As the Asian economies develop and become more affluent, opportunities for intra-regional trade will increase. Before the economic downturn in the region in the 1990s, intra-regional seafood trade was increasing steadily. Some countries, such as China, Japan and Singapore, continue to be significant importers of seafood within the region and, as other economies recover, these will again play a more important role in trade within the region.

As more countries within the region develop their economies, and as costs will rise in all likelihood, changes will occur in aquaculture production costs. Where the

Changes in market characteristics (consumption patterns, prices of inputs, market saturation)

Domestic regional changes will have a significant influence on the species promoted for and produced by aquaculture. China, for instance, is targeting increasingly "fine'" (or high-value) species, responding to the rising demands of a more affluent population. On a more fundamental level, increasing populations are prompting higher productivity and, hence, more intensive culture systems.

A major impact seen within this context is that China has become a major importer of fishmeal for livestock and fish feeds, as well as products are destined for export, trade privileges that have been accorded to specific regional countries may also change.

The recent withdrawal, by the European Union (EU], of trade privileges for seafood exports from Thailand to the European Community (EC), for example, has had a significant impact on the export patterns for shrimp in particular and, hence, the cost structure of that industry.

Such events will lead to increasing competition between countries within the region for access to key markets. Countries with lower production costs will take a larger share of regional exports, either directly or via third countries. This phenomenon has already occurred for certain products within key international markets, and since most countries in the Asian Region are producing and exporting within similar markets, price competition for some commodities can be strong.

Cultured shrimp, in particular, has come under threat in key export markets due to adverse publicity concerning the environmental and social impact of some aquaculture activities. Some of this publicity maybe justified, serving to highlight some of the problems in the sectoral development of most other countries relying increasingly on artificial feed formulation (i.e. carp farms in China and milkfish in the Philippines). Between 1988 and 1997, the import of fishmeal within the region increased by 66 percent (APR 8 percent) to reach 2.2 million mt. During the same period, the value increased by 87 percent, reflecting a rise in the value/mt of 12 percent. In remembering that not all fishmeal is used for aquaculture, major importers (>100 000 mt/year) are China, Taiwan Province of China, Thailand, Indonesia and the Philippines.

Economic growth, improved living standards and the higher purchasing power of local populations have seen an increased demand for food of improved quality and that is better packaged.

Inevitably, the “cost of compliance” with these demands will be imposed on the sector. For export, this situation favours countries with a well-developed infrastructure for handling and processing to the standards required, but will impose additional costs on countries wishing to develop or increase exports. However, the higher costs of processing in target export countries have led to an increase in the manufacture of value-added products in the producing countries.

aquaculture. Nonetheless, this has the unfortunate effect of tarnishing all aquaculture activities in the eye of the consumer. Efforts to provide a reasoned, balanced view of aquaculture activities and the promotion of the benefits of aquaculture products, grown in a responsible manner, are necessary.

The international marketing of Asian seafood has mainly been generic, with little attempt to develop brands or build a specific image. The use of brands or specific identifiers is much greater in developed countries, leading to a higher degree of awareness on the part of the consumer. Countries with large, integrated aquaculture producers (e.g. such as are found in Latin America or Europe) are increasingly using such marketing tools. Efforts leading to the environmental certification of seafood and/or eco-labelling will also increase this trend.

The structure of the Asian seafood export industry, particularly for those countries depending on small-scale aquaculture, incurs different levels of awareness of the present and future importance of such mechanisms in the international market. This situation could lead to Asian exporters being out-competed by those from countries that have better developed marketing "capacity".

Agreements regulating international fish trade

International rules and regulations play a major role in governing the trade of fishery, affecting aquaculture products in both developed and developing economies. Several major international agreements and codes of conduct include sections that relate to aquatic animals and their products. In the Asia-Pacific

Quality of aquaculture products

The importance of aquaculture production in Asia and in particular that of freshwater fish, most of which are sold in the domestic market, has a significant bearing on the concerns of human health associated with products from aquaculture. The most common method of producing low-value freshwater fish in developing countries, especially in low-income food deficit countries (LIFDCs), is to use a combination of fertilizer application and supplementary feed. Polyculture of species that have complementary feeding habits is a general practice, especially with major and Chinese carps. However, the patterns of production are changing rapidly, with a large increase in more semi-intensive farming.

There will be further emphasis on food safety issues in the future. In 1997, a WHO (World Health Organization)/FAO/NACA Study Group (WHO/FAO/NACA, 1999) looked into the food safety issues associated with aquaculture and concluded that there were considerable needs for information, recognizing that such knowledge gaps could hinder the development process. Education is needed to increase the awareness of potential hazards in aquaculture and their management. The Study Group Region, however, there is a wide difference in knowledge and expertise between different countries Furthermore, some countries in the region are members of organizations such as the Office International des Épizooties (OIE) and the World Trade Organization (WTO), and comply with the terms of such agreements, while others who are not signatories are obviously not bound by the terms of such agreements.

Regulatory and management frameworks for aquaculture

Agencies responsible for aquaculture development

In Asia, the primary responsibility for aquaculture production usually resides within one government ministry or department. By contrast, the management of the resources upon which aquaculture depends, particularly water and land, is normally the responsibility of other ministerial departments. This situation inevitably causes the potential for conflicts between different departments, and confusion or lack of clarity in the application of policy.

The increasing importance of aquaculture strongly argues for governments to give priority to developing clear, well-formulated, also recognized the difficulties in applying Hazard Analysis Critical Control Point (HACCP) procedures to small-scale farming systems and that food safety hazards associated with aquaculture vary by region, habitat and environmental conditions, as well as by methods of production and management.

In Asian shrimp production and processing, food safety is given increasing attention, largely because of the quality standards required by importing countries but also because of the higher profile given to environmentally friendly practices in the aquaculture sector.

implementable and realistic national and local policies for aquaculture development, based on financial, social and environmental sustainability. As the private sector is the key to successful and sustainable aquaculture development, the views of industry should be taken into account in respect of policy formulation, research and development.

Participation

The adoption of a "participatory approach" is receiving increasing attention in both aquaculture planning and management. Experience with coastal fisheries management has shown, in general, that the failure to include coastal residents in natural resource management can lead to a lack of community compliance, resulting in resource depletion and conflicts.

This situation can be particularly acute when the government's capacity to enforce laws and regulations is limited.

A promising approach to this problem is "co-management", which involves the cooperation of the local community in both establishing and enforcing local management rules, with the requisite support from government. The co-management approach has proved useful for community-based management of some coastal capture-fishery resources, but the devolution of ownership and management of resources towards local people and communities should be explored for coastal aquaculture. The need to develop effective local arrangements for management of aquatic resources will also be stimulated further in some countries by the trend towards devolution of decision-making powers to local government bodies, as in the Philippines, Thailand and Viet Nam.

It is also apparent that the views of non-aquaculture groups need to be considered when formulating policy and implementing aquaculture development; without such views and contributions, some problems relating to conflicts of interest may be too difficult to fully resolve.

Such issues are quite new, but

This consideration is driven by a variety of factors that include the following:

- greater political attention to the sector as its economic importance and potential become more apparent;
- realisation that inappropriate laws and institutional arrangements can severely constrain the sector's development;
- evidence of environmental damage and social disruption as a result of the rapid and largely unregulated expansion of shrimp farming; and
- a growing emphasis on examining production methods as a means of improving the quality and safety of aquaculture products.

While capture fisheries are generally regulated by a single government department or ministry, aquaculture is frequently regulated by many agencies under a variety of laws. In this circumstance, the formulation of a comprehensive regulatory framework for aquaculture is legally and institutionally complex. Typically, the tasks involve drafting or amending legislation that addresses a variety of issues such as land use planning and tenure, water quality and environmental there is evidence of increasing involvement of various aquaculture interest groups, including the private sector, local farmers and others, in aquaculture policy formulation. In some countries, the government and farmers have entered into discussion with NGOs and non-aquaculture groups for the formulation of management strategies. Examples have been seen in Sri Lanka, where NGOs have participated in aquaculture policy discussions, and in Malaysia, where input from various government, farming, academic and NGO interest groups was provided in the formulation of the shrimp and marine fish “Codes of Conduct”.

Legislation

In many countries, aquaculture legislation is poorly developed and frequently consists of a few articles contained within a law regulating capture fisheries. During the last few years, interest has grown to develop a comprehensive regulatory framework for aquaculture whose goals would be to protect the industry, the environment, other resource users and the consumer, and to clarify rules for resource use.

issues, fish movement and disease, pharmaceutical and chemical use, food quality and public health.

It also requires clarification of responsible authorities and the establishment of the arrangements to ensure cooperation and coordination between many different institutions that have jurisdiction over the item or issue concerned.

International developments

The adoption of the Code of Conduct for Responsible Fisheries (CCRF) by the 1995 FAO Conference (FAO, 1995) promises to provide a significant influence on the development of regulatory systems for aquaculture in the coming years. Article 9 of the Code deals with aquaculture development and sets out a wide range of relevant principles and criteria. In addition, the “Jakarta Mandate”, which was adopted by the second Conference of the Parties to the Convention on Biological Diversity in 1995, provides useful guidance regarding aquatic biodiversity and related environmental aspects that should be taken into account when developing coastal aquaculture.

During 1994 and 1995, several regional workshops10 were organized to examine environmental, legal and institutional issues associated with aquaculture. Recently, FAO published a compendium on aquaculture and inland fisheries legislation in the Asian Region (FAO, 1996). Although new national laws to regulate aquaculture comprehensively may be desirable in many countries in the region, other options are now being explored. This is because the time required to develop and pass new comprehensive legislation is likely to be several years, while the rapid development of the sector has created an urgent need for regulation. These options include the enactment of regulations that exist under existing legislation and the application of voluntary approaches such as guidelines and codes of practice.

Creating incentives to encourage compliance or disincentives for noncompliance or failure to join the scheme can enhance the effectiveness of voluntary codes of practice. One example is the policy Instead, new regulations will be incorporated under the existing Fisheries Act, and a voluntary Code of Responsible Aquaculture Practices will be introduced for cage culture and shrimp farming. These measures will be supported by incentives, and institutional structures will be strengthened to ensure the effective monitoring and continuing formulation of aquaculture policy.

Many regulatory systems could be improved by including mechanisms that are designed not only to prevent or reduce the risk of environmental harm but also to help right any damage that may occur. The Tamil Nadu Aquaculture (Regulation) Act of 1995 not only set out conditions to improve the siting and management of aquaculture facilities, but also established an “Eco-Restoration Fund”, funded partially by deposits from aquaculturists, to be used for remedying any environmental damage caused by aquaculture farms. In addition, the constitution of the Aquaculture Authority of India has been made for the regulation of shrimp aquaculture.

that was adopted in India in 1995 by the National Bank for Agriculture and Rural Development (NABARD), which was a major source of refinancing for brackishwater prawn farming in the states of Andhra Pradesh and Tamil Nadu. This policy sets out the conditions to be met before NABARD will provide credit to banks for aquaculture developments. Similarly, Malaysia is considering the requirement that aquaculture enterprises which are given preferential “pioneer” tax status must adhere to a code in order to retain the various tax incentives accorded. Clearly, there is scope for increasing the use of such conditional public and private-sector funding to encourage the application of sustainable aquaculture practices.

The Australian State of Tasmania has recently passed legislation that provides another interesting example of what can be done to address this issue. The new laws (notably the Marine Farming Planning Act [1995] and the Living Marine Resources Act [1995]) impose that the preparation of marine farming development plans must cover areas, rather than sites, and provide for broad community participation in the preparation of these plans. An environmental impact assessment must also be done, with the establishment of a marine farming zone, before site

Environmental aspects of aquaculture

Environmental issues have become of increasing concern for several reasons. The first is recognition of the increasing pressure on resources in some coastal and inland areas. More attention has been given to the impact of aquaculture on the environment in recent years, partly induced by some well publicized “crashes” within the shrimp industry. This has been accompanied by the publicity given to environmental and social issues surrounding aquaculture. This type of exposure has had a profound impact on the public’s perception of aquaculture, changing it from the “blue revolution” which would improve the availability of cheap, affordable protein to poorer people, to that of being an environmentally unsound means to produce luxury food items for consumers in developed nations.

Australia is adopting integrated farming technologies in a watershed where water is an economic resource and is at a premium (i.e. use must be paid for). This situation is in contrast to that encountered in some countries in the region where traditional integrated farming practices are reducing their levels of integration, applying less species diversification leases are granted to marine farms.

Malaysia is developing an integrated regulatory system for aquaculture, in the short to medium term, but without formulating a specific aquaculture act.

and more emphasis on high-value products.

Balanced resource use

There has to be a balanced and more efficient use of resources. Obtaining conflicts. This situation can be particularly acute when the government's capacity to enforce laws and regulations is limited.

It appears likely that economic issues related to resource use and the "polluter pays" principle will be faced, in the next few years, by aquaculturists in some countries of the region.

Minimizing negative impacts

Guidance is emerging for the application of practices for improved environmental management, and strategies have been identified for the following:

- ***Technology and farming systems***: In recognizing the importance of appropriate farming technology/system and management of inputs

There is a growing awareness that environmentally friendly aquaculture makes good business sense, and this is particularly true for commercial producers. It is increasingly important when considering the perceptions of target export markets and provides an incentive for both the industry and supporting governments to further advance the adoption of environmentally and socially responsible farming practices through appropriate standards or codes of conduct. Recognized codes of practice require further development and implementation and are becoming particularly important for aquaculture products that are traded internationally.

and outputs, special attention is given to the major resources used (i.e. feed, water, sediments and seed). At this level, management actions mainly involve farmers and input suppliers.

- ***Adoption of integrated coastal area management approaches:*** The importance of integrating aquaculture projects within existing ecological systems in coastal areas is increasingly recognized. This approach requires the consideration of proper site selection and the application of planning and management strategies that allow the allocation of resources among different users.
- ***Policy and institutional support:*** It is necessary to have a clear and supportive policy framework for aquaculture. Particular issues include aquaculture legislation, economic incentives and disincentives, actions for the public image of the activity, private-sector and community participation in policy formulation, and increasing the effectiveness of research, extension and information exchange. Policy decisions and their implementation play a strong role in influencing the

Aquaculture and environmental rehabilitation

It is well known that inland aquaculture, particularly that within integrated agricultural farming systems, can provide many positive environmental benefits (e.g. water storage on small-scale farms, efficient use of farm resources).

Perhaps less well known and publicized is the fact that coastal aquaculture, including shrimp culture, can also contribute to environmental improvement. For example, seaweed and mollusc culture can contribute to the removal of nutrients and organic materials from coastal waters. It can also provide an alternative source of income and employment for people involved in environmentally destructive fishing practices and other forms of habitat destruction. Other activities of note include the following:

- Mixed aquaculture-mangrove systems are being used to restore mangrove habitats in some countries (e.g. Indonesia's tambaks or earthen ponds, Viet Nam's mixed farming systems);
- Coral reef fish mariculture provides an effective alternative to destructive fishing practices in coral reef

management possibilities at both the farm and local area levels.

The environmental assessment of an aquaculture area, rather than targeting individual projects, is now being used to identify opportunities for minimizing the impacts of the aquaculture sector within a particular area (e.g. in a bay, an estuary or a watershed). Such applicable measures are promoted through a wide range of instruments and should be brought together within the framework of an aquaculture development plan, ideally as part of an Integrated Coastal Management Plan.

areas;

- The rehabilitation of fish populations through stock enhancement; and
- Aquaculture itself is also a technique for the effective monitoring of environmental conditions.

A recent review has suggested that aquaculture within saline inland areas can provide benefits through the use of previously degraded resources, contributing to environmental rehabilitation and poverty alleviation among communities whose livelihoods such damaged resources.

Aquaculture is also being integrated as a component of mangrove rehabilitation projects (as in the Mekong Delta) and within coral reef management activities (small-scale cage culture).

Biodiversity, genetics and aquaculture

The potential impact of farmed aquaculture stocks, especially

However, much of Asian aquaculture involves smallholder-based production of low-value species, either for personal consumption or for local sale. In the latter case, the input cost of feeds is generally negligible and, if feeds are used, they usually consist of cheap, readily available materials.

International development aid

introduced exotic species, on wild fish and fisheries has been highlighted at many international meetings. Among the potential impacts identified are a loss of genetic resources within healthy or undisturbed populations and a dilution of the wild gene pool through interbreeding with escapees from aquaculture facilities. Initiatives have been made recently to breed indigenous species for stock enhancement purposes as well as for aquaculture, but these are new initiatives and results that could guide development work are not available yet.

Aquafeeds and feeding strategies

When feeds are used in aquaculture, their contribution to production costs varies following the species and the system employed but can be as high as 50 percent of the total costs. Following concern as to the sustainable supply of fishmeal and fish oils, research has focused on identifying alternative, economically viable sources of proteins and lipids for incorporation into feeds. Improved management for more efficient feed use is another area of interest.

Some research (i.e. in Hong Kong) has taken a step further towards the development of

to aquaculture

While Asia has received much of the international external assistance for aquaculture development, FAO (1998) has reported reduced levels in recent years. However, the recent trend for such support has been through assistance given to projects having a wider scope. These include as socially oriented projects, environmental rehabilitation projects, as well as integrated area development programmes, such as the Mekong River basin development programme, and the Bay of Bengal Programme (BOBP). In many of these projects, aquaculture is a component within a broad-scale development.

For the period 1988-1995, the Asian Region accounted for 65 percent of commitments made by funding agencies and donors to development assistance (which is different from actual disbursements) and 38 percent of the projects, while Africa was the recipient of 16 percent of commitments and about a quarter of the projects. The major beneficiaries during this period (i.e. countries receiving at least 1 percent of total aid) included India, China, Bangladesh and Mexico, which all received major loans from development banks, accounting for environmentally friendly feed. Little information is available on the production of aquaculture feeds in Asia, but a recent estimate indicates a supply of some 1.9 million mt in Asia (excluding China), where 1.2 million mt were for fish and 0.7 million mt for shrimp. An estimate for China (1996) indicated a total aquaculture feed production of 5 million mt, but it was unclear if this figure also included farm-made feeds. The future prospect for fishmeal and oil for animal feeds is that global supply is expected to be stable (FAO, 1998).

A distinction must be drawn between the different feeds manufactured for aquaculture species, i.e. whether for high- or low-value species. The higher values of commodity species, or those reared for export, can justify the investment required for the manufacture, distribution, purchase and use of specially formulated feeds.

about 64 percent (about US$638 million) of external aid to aquaculture.

The two most common sources of credit for Asia's developing countries have been the World Bank (WB) and the Asian Development Bank (ADB). In 1997, WB provided US$409 million to South Asia's agriculture sector (a decrease of 26 percent compared to 1995), while the Asian Development Bank approved 632 loans, of which 10 percent went to the agriculture sector and 50 percent to the financial sector.

Other multilateral programmes that assist small farmers are the United Nations Development Programme (UNDP) (for agricultural development, including training and provision of experts) and the United Nations Development Fund for Women (UNIFEM) (provision of financial capital enabling women to establish small businesses, including aquaculture).

The United Nations Children's Fund (UNICEF), the United Nations Drug Control Programme (UNDCP) and others, including FAO, extend support to small farmer development programmes under various schemes (Technical Cooperation among Developing Countries (TCDC), Special Programme on Food Security (SPFS), Technical Cooperation Programme (TCP)). In addition, a number of donor agencies provide small-scale enterprises with development fund assistance. These include the United States Agency for International Development (USAID], the Australian Agency for International Development (AusAID), the Canadian International Development Agency (CIDA), the Danish International Development Agency (DANIDA), the Swedish International Development Agency (SIDA), the Norwegian Agency for Development Cooperation (NORAD), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), the Department for International Development (DFID, United Kingdom), the Groupe de Reflexion d'échange Technologique (GRET, France) and agencies from Belgium and the Netherlands. Assistance to research and development is also provided by the Australian Centre for International Agricultural Research (ACIAR), the Danish

The Asian Region does not possess a well-developed venture capital market that is willing to invest in new projects of potentially high financial risk. This situation severely limits the region's capability to develop and bring to the market new technologies without recourse to foreign investment.

This situation can also lead to a loss of opportunity, particularly where the fruits of research that have been achieved in the region benefit projects and investors elsewhere. Additionally, future prospects for private-sector financing are likely to be affected by the current weak economic situation in much of the region.

It is clear that many projects that were funded in the years before the economic crisis in Asia were not subject to the kind of scrutiny that would have identified high-risk investments. The banking reforms that are being undertaken in the region are likely reduce the level of financing available to aquaculture projects unless these can be demonstrated to be technically and economically viable. At the same time, the increasing costs of compliance with government regulations, as well as the trade agreements referred to, will increase the cost of entry into the commercial aquaculture sector.

Cooperation for Environment and Development (DANCED), the Japanese International Cooperation Agency (JICA) and the other afore-mentioned agencies.

Assistance by banks, private sector to aquaculture development

Private-sector investment for aquaculture development has tended to be limited to the culture of high-value species, where the systems are more capital intensive. The degree of personal involvement of the investor depends upon the scale and cost of the project. Small-scale projects may be financed directly by the owner or jointly with other investors, with the farm operating without recourse to external sources of finance. As the investment and operating capital requirements increase, it is often necessary for such entities to turn to external sources of funding (e.g. local or national banks).

For larger scale production units, particularly in cases where the investor has little or no direct control over day-to-day operations, such investment is often assessed alongside other potential opportunities. These circumstances can be quite volatile and depend on the relative performance of the investment(s). For example, the short-term nature of many of the

NGO support to projects involving aquaculture has also increased, noting that there are thousands of NGOs in Asia. National development banks have tended to give a higher priority to projects producing high-value crops, although some, like India's NABARD, the Grameen Bank in Bangladesh, Bank Pertanian Malaysia, Bank Rakyat Indonesia, Bank of Agriculture and Agricultural Co-operatives of Thailand, and the Land Bank of the Philippines and others have developed loan programmes for small projects oriented towards rural development.

The private sector has played a major role in Asian aquaculture development, although principally for commercial rearing of higher value species. Due to the predominance of small-scale farms in some countries and the rate of development of intensive aquaculture, feed companies and other suppliers have proved to be a significant source of information for farmers. Shrimp feed companies, in particular, frequently provide information and technical support as part of their customer services. Such information is usually aimed at increasing sales.

shrimp farming investments has resulted in a lot of movement of investment capital, both into and out of the sector.

Sometimes, this can lead to the widespread recommendation of inappropriate practices, such as overstocking. On the other hand, it has been customary to organize seminars, with invited independent experts, to pass on new information to farmers. On balance, the impact of this type of information transfer has been positive for the production sector. Most feed companies also provide technical support services for both their current and prospective customers, which may include checking water quality, fish or shrimp health and providing advice on the farm. Some suppliers have introduced testing services for shrimp viruses.

The creation of farmers' groups has become more common in recent years, partly as a response to the pressures put on the production sector by external sources, but also with the realisation by the farmers

They include the Asian Institute of Technology (AIT), The Southeast Asia Fisheries Development Center (SEAFDEC) (through its Aquaculture Department), the International Center for Living Aquatic Resources Management (ICLARM) (which has a sizeable research programme in the Asia-Pacific Region), the Aquatic Animal Health Research Institute (AAHRI) (a regional resource centre for fish health management and now a reference centre on epizootic ulcerative syndrome (EUS), INFOFISH, the Mekong River Commission (MRC), and the Asia Pacific Economic Co-operation (APEC) (which is collaborating in a study on manpower development for aquaculture and the grouper R & D Network). Information is shared among the organizations and most are managing a number of specific databases for development and management purposes.

that a strong professional lobby was needed to put aquaculture on the political agenda. This type of action has improved the exchange of views between the appropriate government bodies and the private sector and has also improved the awareness of wider issues among the members of such farmers' groups.

Within the region, much aquaculture investment has been, essentially, of a short-term nature. This position, when combined with the lack of local sources of venture capital, has meant that the region, with one or two exceptions, lags behind considerably in the private-sector development of new technologies. An exception to this was the establishment of a consortium of several private-sector companies for the development of a shrimp-breeding programme in Thailand. However, this might not have been established without the major involvement of a government agency that is a major shareholder in the venture. This position demonstrates the contrast with other shrimp breeding initiatives in the Americas that are mostly financed with private-sector funds, albeit using research results achieved through governmental support (universities, institutes and other public bodies).

There is a growing trend towards collaboration that focuses efforts and links or integrates different initiatives, providing wider attention to and a greater impact on development issues and problems. This approach makes better use of the available resources and is also opening opportunities for governments to decide unified positions, hence a stronger voice in relation to certain international issues, trends or agreements.

One example is a project concerning the responsible movement of live aquatic animals11 that has enabled access, collectively by 21 Asian governments, to the capabilities and assistance of OIE and FAO for promoting quarantine, health certification and a responsible approach to fish health management. Successful work would have a positive impact on both farming practices and trade. Likewise, cooperation between WHO, FAO and NACA on food safety issues has brought regional attention to the concepts and practices of managing food safety hazards that are associated with aquaculture products, an extremely important consideration for consumer protection, trade and stimulation of better management practices.

Regional institutions and their assistance for capacity building

Apart from NACA, there are a large number of organizations and agencies that are active in aquaculture development in the region.

For manpower development, many national and regional institutions and agencies provide tertiary education. Vocational and short-term technical training provide valuable support to human resources development in the region. While NACA has a large short-term training programme, a number of regional institutions, such as AIT, provide both long-term and short-term training programmes. The regional centres of NACA in India and China have expanded their cooperation with tertiary education institutes to be able to provide longer term degree-based programmes.

If aquaculture is to sustain its growth momentum within the region more effort must be focused towards the building of human capacity. To be able to respond to and to meet the increasingly complex development challenges faced by aquaculture, this effort must be directed at all levels, from the farm worker to the policy maker. At the present, a proposal for a potential cooperative regional strategy to meet these needs is

While the implementation of safety assurance programmes is well advanced in the fish-processing sector, the application of such programmes at the fish-farm level is a new approach. The application and enforcement of HACCP regulations at the production level could cause significant difficulties for Asian farmers unless major efforts are made to develop technologies and methodologies for the reduction of potential risks.

being prepared within the cooperative aquaculture education project of APEC/NACA/Deakin University.

Major shifts, changes in regional policies that influence aquaculture development

The two major influences are the broadening of the aquaculture development objectives from economic to social, which focuses on poverty alleviation, livelihood development and food security, and the links made between sustainable aquaculture practices and trade.

Poverty alleviation and food security

Throughout the region, the expressed national goals and priorities concerning aquaculture have invariably included and even emphasized social goals. The key issue concerning this topic has been in respect of the emphasis given to commercial and/or export-oriented aquaculture, on the one hand, and to the small-scale food security oriented activities on the other. Both the levels and the balance of the support given to either subsector are part of this issue. It has to be said that increasing recognition is being given to the importance of small-scale, socially oriented aquaculture. Initiatives have been made recently

Production practices and trade

The link made between production practices and their impact on both the environment and trade has been reflected in recent regional and national programmes. Some of the measures that have been started include environmental impact assessments, the development of guidelines to implement the FAO Code of Conduct for Responsible Fisheries (CCRF) and the development of policies on zoning and integrated coastal zone management (ICZM). These measures are being developed and achieved seriously and in a concerted manner.

Main impacts of other sectors on aquaculture and of aquaculture on other sectors

Impacts of the external environmental on aquaculture

These may be positive or negative. Nutrient enrichment of water bodies may provide nutrients that are beneficial to aquaculture production in some extensive culture systems (e.g. seaweeds, molluscs). However, excessive loadings with urban and industrial wastes can have severe consequences for aquaculture operations, particularly shellfish culture, when exposed to at the regional level to focus the attention of both government and regional organizations on this issue.

Environment and trade

The role of the fish farmer is changing from merely that of a producer to being an integral part of a chain for the production and delivery of high-quality food products to the consumer. Hazards can be introduced within the chain at the production stages on the farm, and these can be spread during processing and preparation. The means of assuring food safety can be difficult to determine when certain microbial hazards can cause diseases in humans but not in fish, as is the case for some naturally occurring pathogens.

contamination by toxic pollutants, pathogens and phycotoxins. Contamination of coastal waters with phycotoxins associated with plankton blooms has caused major losses in East Asia in recent years (Hong Kong and China, in particular).

With increasing aquatic pollution and the physical degradation of aquatic habitats by other non-aquaculture developments, aquaculturists face the risks of mass mortalities of farmed stock, disease outbreaks, product contamination and reduced availability of wild seed or broodstock.

Impacts of aquaculture on the environment

Many types of aquaculture can contribute positively to environmental improvement. The recycling of nutrients and organic matter through integrated farming systems has long been recognized as being environmentally sound and is still widely practised in the region. Recent developments in Integrated Pest Management (for example, through NGO interventions in Bangladesh) have shown how rice-fish culture can help farmers reduce the use of environmentally damaging pesticides. The use of wastewaters for freshwater aquaculture, mollusc and seaweed farming can recover excess nutrients, thereby reducing risks of eutrophication. In programmes for the restoration and recovery of endangered fish species and stocks, hatcheries and aquaculture systems have been used both to provide a temporary sanctuary and to increase numbers of individuals for re-introduction into the wild.

Negative impacts have been associated mainly with intensive and monoculture systems, the effects of which can include nutrient and organic enrichment of recipient waters, resulting in a build-up of anoxic sediments, changes in benthic communities and the installations. In some cases, significant losses of farmed stocks have occurred, significantly affecting financial returns. Encountering self-pollution problems at least provides farmers with very strong incentives to improve environmental management. Indeed, several regional countries have made significant changes to their management practices designed to reduce disease risks, which have apparently led to reductions in negative environmental impacts. Examples include the closed and recirculation shrimp farming systems.

Other interactions with aquaculture

There are a variety of interactions between aquaculture and other sectors, which include capture fisheries, agriculture, forestry (including coastal mangrove forests), industry, tourism and navigation. As in the case of environmental interactions, these may also be positive or negative.

In Malaysia, there is a growing interest to integrate some aquaculture operations with tourism (e.g. marine cage culture and put-and-take fishing ponds in Sarawak). Much inland aquaculture is carried out in agricultural areas and is, therefore, well integrated eutrophication of lakes. In some areas, large-scale shrimp culture has resulted in degradation of wetlands, localised water pollution and salination problems. The misapplication of chemicals, the collection of seed from the wild, the introduction of exotic species and the overuse of fishery resources as feed inputs are topics that have also raised concern in some locations.

Such problems have focused attention on the development of appropriate management strategies that, in some cases, have had trade implications for aquaculture products (mainly shrimp) traded on international markets. Thailand, for example, is now looking into a "certification" process for marketing shrimp aquaculture products that are produced in environmentally sound ways.

Impacts of aquaculture on aquaculture

This intra-sectoral issue has raised quite specific problems that have been particularly acute in intensive cage culture and shrimp culture. These concern self-pollution and the transmission of diseases that have occurred in areas where the high density of farms requires the use of water that has been contaminated by neighbouring into agricultural farming systems, adding value to the total farm output and, in some cases, making best use of on-farm resources.

In some coastal areas, some significant conflicts have arisen. For example, social conflicts have occurred between rice farmers and shrimp aquaculturists in areas of Bangladesh. Such situations, while generally not well documented, suggest that more attention will have to be given to techniques of conflict management. Given that interactions between coastal aquaculture and other sectors are likely to increase due to rising population pressures in Asia's coastal regions, more attention needs to be given to these important issues.

Australia is moving to resolve potential issues related to aquaculture "interactions" through the integration of sectoral interests. The plan is to develop a policy for integrated aquaculture development, within which the objectives would be:

- to facilitate the establishment of a primary industry sector, at a national level, which would be the Australian Integrated Agri-Aquaculture Systems; and
- to provide a strategic R&D focus for integrated agri-

aquaculture systems.

These considerations would apply to all relevant activities, agencies and bodies, primary producers and individuals/companies active in agriculture, fisheries and aquaculture.

Technological advances over the last decade

The standard that is usually set for technological development in aquaculture is livestock husbandry and, by this measure, aquaculture is way behind. The three commodities that have received intense regional R & D attention, particularly for breeding and culture techniques, are shrimp, tilapia and carps, while milkfish, seabass and catfishes have received less attention.

Genetic improvement of aquaculture species in Asia has been most advanced for tilapias and carps. Surprisingly, despite their high value, work on shrimp genetics in Asia has been confined to academic research although,

Techniques for disease diagnosis, as well as products and methodologies for prevention and control, have only recently been developed and applied in the field, largely because of the occurrence of viral shrimp diseases. The problems encountered have highlighted the importance of having healthy seed in sufficient quantities to support the development of aquaculture.

Quality concerns are also important in inland freshwater aquaculture, such as in carp culture, where genetic deterioration and poor quality seed have affected the performance of freshwater aquaculture, and in some other species, such as milkfish. Work on seed quality improvement has been relatively limited but, with few exceptions, clear guidelines on the characteristics of high-quality seed are available. In most cases, demand usually outstrips supply, at least on a seasonal basis. In such circumstances, there is little to no possibility of introducing more strict more recently, several private ventures have expressed interest in such developments. Tilapia, although an introduced species, has become widely distributed in Asia. Recent advances in selective breeding and sex control in tilapia have had a major impact on farm procedures (G. Mair pers comm.).

The topic of feed development has seen some progress, and techniques to make feeds on the farm have been widely documented, improved and disseminated.

Research on mass seed production and hatchery systems has been successful for carps, tilapia, milkfish, freshwater prawn and indigenous freshwater species. Much remains to be done for marine shrimp (particularly on broodstock development), grouper (especially mass seed production) and mangrove crab (also mass seed production).

The development of new species (particularly marine species) and aquaculture technologies is a key strategy for several Asian countries. The development and implementation of best management practices (BMP) will also require more attention, and it is considered that management of the complete farming system will become more important. A further quality demands.

Trends in public support to the sector

Following the Kyoto Conference of 1976, a major change that occurred was the increase in government support to aquaculture. Regional cooperation was enhanced and organizational structures were put in place to transform aquaculture from a traditional practice to a more science-based activity. Governments in the region have recognized the role of aquaculture as an important food provider and income earner. Government planning and development increased, elevating aquaculture to a status close to that of capture fisheries.

Active steps are now being taken to encourage the involvement of the private sector in providing services to the industry. These services include the production and distribution of seed, postharvest practices and marketing, and research and development. Governments do recognize, however, that strategic services need more support, such as central hatcheries for broodstock maintenance and development and research and development programmes directed towards the small-scale aquaculture sector.

issue is that, as a wider number of species are considered for aquaculture, research needs will increase and require more investment in R and D facilities and projects.

Resource utilization: patterns and trends

The growing scarcity of land-based resources is prompting the sector to look for alternative sites for aquaculture. Maritime countries are investigating the use of offshore waters, while other

areas of investigation include derelict water bodies and wastelands, impounded water bodies and, although not new, irrigated rice lands for rice-fish culture. Increasing interest is being paid to ofshore cage culture, and a number of countries (including Australia, Singapore, Malaysia, the Philippines and Thailand) are making serious attempts to apply this system.

India, Bangladesh and Sri Lanka are improving management systems for inland open water bodies, while China has good technology for culture-based lake and reservoir fisheries. Integration in small-scale aquaculture is being promoted for greater farm

- Increasing pollution, shortage of feeds, disease incidence, and intensification problems (health and feed).

Institutional constraints

- Weak institutional capabilities of aquaculture extension agencies, including government organizations and NGOs, also weaken the transfer of technology.
- Too many government organizations and NGOs are involved in aquaculture support services, duplicating and overlapping activities.
- Limited access of the sector to commercial credit.
- Technology transfer

productivity and to lower risks.

For a number of reasons, it appears inevitable that there will be an increase in the acreage of impounded waters in the region. Once in place, such waters need to be used for aquaculture purposes to an increasing extent, whether for culture-based fisheries, cage culture or a combination of both. Most countries recognize this to be a relatively uncontroversial way of increasing fish production through aquaculture. Culture-based fisheries have the additional advantage that the rearing process is of least environmental disturbance. Key examples can be found in China, which has substantially increased its yields from culture-based fisheries.

Main constraints and opportunities for further development for the sector

Policy constraints

- Short-term leases of the public water bodies for aquaculture development inhibits planning and development.
- Research emphasis is on short-term economic returns rather than a balance with long-term social benefits.
- Lack of or weak implementation of zoning mechanisms are weak.
- Research-related constraints, including resources, skilled researchers, facilities, coordination among institutions and workers, and poor linkage between basic and applied research and between research and production sectors.
- Weak links between research and development activities in the freshwater aquaculture sector.

Socio-economic constraints

- High investment costs.
- Land use conflicts.
  Lack of security of investments.
- Legal constraints.
- Lack of access to resources and security of tenure or user rights.
- Lack of incentives for entrepreneurs.
- Lack of adequate guidelines for responsible aquaculture.
- Lack of unified regulations on use of resources by aquaculture.

Technical constraints

- Absence of statistics and information on different types of water bodies and weak statistics and databases for aquaculture production by policies.

- Lack of clear guidelines to address issues such as genetically modified organisms (GMOs), non-trade barriers, food safety, and externalities from production and resource use.

Resource constraints

- Multiple use and multi-ownership of ponds and other water bodies.
- Limited access to public water bodies for pen and cage culture.

different farming systems.

- Lack of infrastructure for fish feed manufacture and distribution in different parts of the region.
- Lack of technology for the diversification of aquaculture systems.
- Inadequate manpower for research and extension services.
- Lack of well-trained manpower to manage or operate aquaculture projects.

- Inadequate and unreliable supply of quality fish seed.
- Lack of markets for some aquaculture commodities.
- Lack of technology for postharvest practices and value addition.
- Fish health management capacities are inadequate.
- Increasing scarcity and decreasing quality of water resources.

Financial constraints

through the assurance of food security, the alleviation of poverty, the improvement of livelihoods, and increasing the net worth of the national economies.

Strategic objectives

To achieve the mission and the development goal, the plan will pursue the following strategic objectives:

To improve aquaculture

- Lack of government resources to fund development projects.
- Lack of investment guidelines for the private sector.
- General perception of aquaculture as a high-risk or non-bankable investment.

Outlook and prospects

The issues that have been covered within this paper are the demands made of aquaculture, its ability to fulfil these demands, the threats to that ability and the opportunities to overcome these threats. These opportunities have been articulated by governments into a development plan for Asia, made at the regional workshop to formulate the Asian aquaculture development strategy for 2000-2020 conducted by NACA in September 1999. The governments envisage aquaculture to be "a major provider of food and applied to reducing societal disparities and inequities." Based on this vision, the mission will be:

- to fulfil the aspirations of all sectors of the populace, through a people-oriented approach and focusing on aquaculture for development;
- to develop aquaculture in a responsible manner and in harmony with the environment;

technology and farming systems

The continued development of farming systems and technology is essential and imperative. There is a need to improve farming technologies, to encourage integrated farming and crop diversification, and to increase the focus on improving efficiency and the optimal use of resources, achieving these through technological advancement and possible mechanization. Major challenges to meet this objective relate to securing and efficiently providing the inputs required for the different aquaculture systems.

To assure the availability of good quality seed

A major constraint to increasing the productivity of farming systems is widely recognized to be the inadequate supply of good quality seed. Emphasis needs to be placed on the importance of the role of local hatchery production, alongside quality certification and accreditation of seed and the development of strategies to further improve seed quality. The development of breeding and hatchery technology, genetic improvement and domestication are additional key objectives for securing the seed supply for major aquaculture species.

- to transform the emphasis of aquaculture from being an activity that is resource-dependent towards being knowledge-based; and
- to continue the pursuit of shared governmental objectives through regional cooperation and to strengthen the existing spirit and substance of this.

Development goal

The development objective of the plan is to improve the quality of life of the people in the aquaculture sector and to help strengthen the social and economic status of the Asian countries/territories

To improve efficiency in the use of feed and fertilizer

The efficient use of feed and fertilizer inputs, particularly through the use of readily available local raw materials, and the minimization of environmental impacts, is highlighted; fishmeal replacement, improvements in feeds and feeding technology and the development of environmentally friendly, low pollution feeds need to be tackled. Concerns over the incorporation of GMOs as feed ingredients will also be addressed.

To improve availability and access to financial resources for aquaculture investments

This objective will address the development and supply of suitable incentives for aquaculture (for example, tax credit schemes) and include the creation of a more conducive environment for adequate insurance, the provision

attention as a viable means of increasing and improving the use of inland lakes, reservoirs and river water resources.

To improve environmental management and the image of aquaculture

Improvement of farmer education and awareness, the development of long-term land tenure (to increase certainty for investors) and investigate ways of encouraging more private-sector participation in the financing of aquaculture development.

In terms of access to financial resources, schemes will be developed for the simplification of credit arrangements for farmers and improving the coordination between financial and technical agencies. The plan will pay particular attention to the small-scale farming sector.

To reduce the social and economic impacts of aquatic animal diseases

Diseases cause significant economic losses, and the prevention and control of disease will remain an important issue. The objective is the continued development and implementation of government quarantine and health certification measures; these will include monitoring and surveillance programmes, contingency planning and emergency responses, establishment of diagnostic capability and methodology standardization. The plan will encourage a shift from governmental health management and control towards preventive husbandry and on-farm health management. Focus will be given specifically to health measures that and implementation of Codes of Practices and the development of low impact farming systems are subjects that need more attention. In respect of the public perception of aquaculture, community and local authority education on aquaculture issues is needed to be able to provide a balanced picture of the environmental interactions of aquaculture. Environmental impacts on aquaculture are likely to be of increasing concern. Important issues to be addressed include:

- establishment of effective monitoring and management programmes;
- regulation of land-based sources of pollution; and
- protection of aquaculture from the adverse impacts of agricultural, domestic, and industrial activities.

To create an enabling policy environment for sustainable aquaculture

Promotion should be made for the further development of government policies that support aquaculture and its development. These should include policy issues relating to the identification and zoning of suitable aquaculture areas and sites, integrated planning (e.g. watershed, lake and coastal planning), and the provision of infrastructure, investment facilities can be used by rural farmers.

To make efficient use of land and water resources

Such a strategy needs to address the likely reduction, in most countries in the region, of the availability of water and land resources for aquaculture. The objective is to find ways to make more efficient use of water resources and to maintain the region's lead role in global aquaculture. Appropriate systems that offer good scope for increasing the productivity of agricultural land, such as integrated farming, will be developed and promoted.

In some countries, there may be scope for enlarging the sites available to aquaculture by employing unused or under-utilized areas (e.g. inland saline areas, coastal and offshore marine farming). Culture-based fisheries should also be given more and support activities.

Rather than being actively involved in production, regional governments will increasingly play the role of facilitating development through the creation of an "enabling environment" for sustainable aquaculture.

To promote responsible development of aquaculture through a progressive legal framework

As pressures increase on resource use, legal and institutional instruments are needed for the recognition of aquaculture as a distinct agricultural sector, which is integrated in resource use and development planning.

Legislation is also required for the protection of consumers through improved food safety and quality measures that meet international standards and improve aquaculture management.

To improve the human resource base to manage and operate aquaculture development

There has been substantial investment in training and education programmes but, if development needs are to be achieved, there is a continuing requirement to improve both the number and quality of human resources. A greater emphasis is required for the improvement of extension support, education and training at all levels, career planning and institutional capacity building. The previous focus on technical training will have to be increased, and emphasis will also need to be given to nontechnical training; such as the development of communication skills. The significant human resource development needs will probably be best met through improved cooperation between the providers of education and training.

To improve the flow of knowledge

Activities that improve communication and networking

To increase participation of farmer associations and the private sector in aquaculture development

The private sector will continue to play a major role in aquaculture development, but there is a need for better cooperation between aquaculturists to deal with the numerous issues, problems and constraints.

The involvement of farmers' associations on a national and regional basis and the encouragement of private-sector participation in aquaculture development will be a key component for success in the coming years.

To move towards a market-based production system

Although the regional and global demand for aquaculture products is expected to increase, it was recognized that there is a need for the sector to move towards a market-oriented approach to the activity, rather than basing development on production. One of the means of achieving this objective is to examine the existing and potential markets for aquaculture products, both within and outside the region, and investigate ways of maximizing intra-regional trade.

within the region were highlighted as an important means of developing and communicating the knowledge base of aquaculture. Advances in electronic communication, combined with specific cooperative efforts, should be used to increase the information exchange in the region.

To enhance and maintain social harmony

Stakeholder conflict concerning resource use will have to be approached through the better use of conflict management strategies; this should be accompanied by a decentralized and participatory approach to development planning and resource management.

To improve quality and image of aquaculture products

The potential role of HACCP, its application to production systems, the use of drugs and chemicals, appropriate processing and storage technology, and the nature of market/consumer demand are all topics that require investigation and elaboration. Fish handling and postharvest technology could also be improved for the reduction of wastage and the improvement of farm incomes.

For each strategic objective, indicative activities have been identified that will require different kinds of support and implementing mechanism to be achieved. The relevant recommendations of the Conference on Aquaculture in the Third Millennium will be incorporated into the Asian Aquaculture Development Strategy.

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[2] For the purposes of this review, the Asian countries are Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China (Peoples Republic of China), Democratic Peoples Republic of Korea, Hong Kong (China, Hong Kong Special Administrative Region), India, Indonesia, Islamic Republic of Iran, Japan, Laos, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Republic of Korea, Singapore, Sri Lanka, Taiwan Province of China, Thailand and Viet Nam.

[3] In this review China refers to the Peoples Republic of China.

[4] Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

[5] Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam.

[6] China, Democratic People’s Republic of Korea, Hong Kong, Japan, Mongolia, Republic of Korea and Taiwan Province of China.

[7] Afganistanh and Islamic Republic of Iran.

[8] In this review Hong Kong refers to China, Hong Kong Special Administrative Region.

[9] Average from 1995 to 1997.

[10] Regional workshops organized under the auspices of FAO and/or NACA.

[11] Project led by NACA and FAO, with additional support and participation from OIE and several international and regional agencies and national institutions.

Current Status of Aquaculture in the Pacific Islands

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ABSTRACT: Compared with fishing, aquaculture is currently of little commercial significance to the Pacific Islands, with one important exception, black pearl farming, which is virtually confined to eastern Polynesia. Elsewhere in the Pacific, considerable development is needed before aquaculture can be considered economically sustainable. Shrimp (Penaeus spp.) farming has been a focus of commercial development in several islands with varying degrees of success; tilapia (Oreochromis niloticus) aquaculture has entered the subsistence economy in some areas, and seaweed (Kappaphycus spp.) is a future commercial export prospect. The culture of other marine and freshwater species is, however, generally still at the experimental or “backyard” stage. The expansion of aquaculture in the Pacific will depend on providing better production methods for species currently being farmed, and techniques for propagating and growing the “new” species described above. These methods and techniques should be simple and flexible so that they can be adapted to the context of the Pacific Islands environment and to the market constraints (local and export markets). This approach should favour systems integrating fisheries and mariculture with low investment and operating costs and simple technical production processes. This should be done in association with pilot commercial-scale operations to test and demonstrate the economic viability of the methods proposed. This will require research combined with assistance, training and education programmes.

Pacific Island nations have many attributes that favour development of aquaculture and stock enhancement in the coastal zone. These are as follows: a great diversity of coral reef species which are in high demand, proximity to major aquaculture and seafood markets in Asia, availability of suitable growout sites in pristine habitats, geographic conditions which favour restocking and stock enhancement, a relatively inexpensive labour force, and a tradition of working with marine resources. Although these confer many advantages on the region in terms of aquaculture development and stock enhancement, there are still several constraints for such enterprises in the Pacific, which include limited domestic markets, high added-value export markets targeted, transport problems, socio-economic factors, fragile habitats, limited fresh water, and cyclones. Some of the best opportunities for aquaculture development in the Pacific are in the aquarium trade (coral reef fish, hard corals, soft corals), the live seafood markets (e.g. groupers, spiny lobsters, abalone, crabs) and the pharmaceutical industry (e.g. algae, sponges, soft corals). In all cases, the products are of high value and can be grown in small areas with relatively simple technology.

KEY WORDS: Aquaculture, Secretariat of the Pacific Community, Fish Farming, Aquaculture Development

Introduction

This review covers the insular Pacific as defined by the work-area of the Secretariat of the Pacific Community (SPC)2.

Compared to fishing, aquaculture is currently of little commercial significance in the insular Pacific, with one important exception –

The potential importance of aquaculture to pacific islands

A major problem facing most of the island nations in the Pacific is that they have relatively few opportunities to generate income (Adams, 1998). The economies of most Pacific countries are limited black pearl farming - and this is virtually confined to eastern Polynesia. Elsewhere in the Pacific, considerable development is needed before aquaculture can be considered economically sustainable. Shrimp (Penaeus spp.) farming has been a focus of commercial development in several islands over the past 30 years, with varying degrees of success; tilapia (Oreochromis niloticus) aquaculture has entered the subsistence economy in some areas, and seaweed (Kappaphyceus spp.) is considered a future commercial export prospect by the region. The culture of other marine and freshwater species is generally, however, still at the experimental or "backyard" stage.

Aquaculture is a relatively new development in the region, and in most Pacific Islands where it has been attempted; its history goes back less than 30 years. There is no fund of traditional knowledge for culturing fish and shellfish, just catching them, except in very specialized instances and areas. There is thus no great resource of aquacultural skill or infrastructure. This steep development path has perhaps not been taken into account in some development projects, which have often had unrealistic short-term aims and lacked follow-up.

due to small landmasses, few terrestrial resources and low numbers of inhabitants. To ensure further development, island nations must make the most of the one important resource they all have - the sea. Through the joint efforts of the Forum Fisheries Agency (FFA) and the SPC Oceanic Fisheries Programme, island nations are deriving major inputs to their economies by fishing for tuna, or by selling access rights to tuna, within the large maritime zones under their control. However, valuable, sustainable harvests are also possible from inshore waters and coral reefs.

The potential for increased well-being of coastal communities from the responsibleuse of their inshore marine resources arises because the inshore habitats surrounding Pacific nations support a great diversity of economically important species (Wright and Hill, 1993; Dalzell et al., 1996; Bell and Gervis, 1999). Traditionally, these animals were harvested at subsistence levels. More recently, however, development of export markets has provided coastal communities with opportunities to earn income from the inshore fisheries species. Unfortunately, the transition from a subsistence to a market economy has usually been far from ideal: chronic overfishing has occurred in some areas. In

Despite the comparatively minor penetration of aquaculture into Pacific Island economies, and despite the loss of interest by most of the international development community after many short-term project failures, several Pacific Island governments have accepted the challenge. They recognize that expansion in capture fisheries is limited, and have made substantial investments in freshwater aquaculture and mariculture, often in concert with external sources of development assistance.

Pacific Islanders cannot turn away from the sea. It is the greatest resource they have.

such places, there are now too few of the prized animals to sustain reasonable harvests. Destructive fishing methods have compounded the problem by degrading some habitats to the point where they cannot support the valuable species (McManus, 1997). Pacific Island countries now recognize that aquaculture provides one of the few long-term, sustainable, ways of deriving benefits from inshore fisheries resources (Williams, 1996). This view of aquaculture as a priority area for continued sustainable development was reinforced as part of a consensus member country statement arising from the 2nd SPC Fisheries Management Workshop in 1998:

"…Regional fisheries managers have focussed on establishing regimes to sustain inshore fisheries. This is supported by a strategy to divert demand and fishing pressure to alternative activities, mostly to offshore fishing and into aquaculture.

Development of fisheries management varies from country to country reflecting the differing stages of economic development and levels of need. In some countries the need is to encourage economic activities and to generate income for rural villages; in other countries the need is to restrict or limit fishing. Yet in other countries the need to involve all stakeholders in the management system has evolved into community-based decision-making and control. There is now broad acceptance that marine resources cannot be managed in isolation from other users, or by one government agency so that an integrated and co-ordinated approach should be taken. In many circumstances, because of the smallness of the islands, an island system-management approach is the desirable option.

Aquaculture, as an alternative activity, is still at a preliminary stage of economic development in most PIC3, but is of enormous future significance. For aquaculture to realise its full potential to the economies of PIC in a sustainable way will require a considerable degree of international support. PIC have endorsed a strategy to harness and prioritise such support at the regional institutional level. Several PIC already devote significant national resources to

- Availability of suitable growout sites in pristine habitats - coral reef lagoons create the calm conditions essential for culture of many species. The favourable environmental conditions should be the opportunity to develop green label products to get better prices on the international market.
- Geography that favours restocking and stock enhancement - most Pacific countries are small islands, or groups of small islands, surrounded by deep water. Cultured juveniles released into the inshore waters of island ecosystems cannot emigrate, and are therefore relatively easy to recapture.
- A relatively inexpensive labour force - expectations for financial return on labour are low in many Pacific countries relative to developed countries.
- A tradition of working with marine resources - coastal communities are already familiar with the basic biology of many species.

Constraints to aquaculture in pacific islands

Although the attributes listed above confer many advantages on the *this subsector and this trend will continue as benefits are realised…"*

Advantages of pacific islands for aquaculture

Pacific Island nations have many attributes that favour development of aquaculture and stock enhancement in the coastal zone. These include:

- A great diversity of species associated with coral reefs that are in high demand for:
- the aquaculture and seafood markets in Asia (e.g. napoleon wrasse, groupers, sea cucumbers, spiny lobsters, trochus, pearl oysters, giant clams, green snail);
- the marine aquarium trade (e.g. clownfish, angelfish, hard corals, soft corals, giant clams); and
- the pharmaceutical trade (e.g. algae, sponges, soft corals, sea horses).
- Proximity to the major aquaculture and seafood markets of Asia - flight times are short enough to ensure that many species can be shipped alive to Asia.

region for development of aquaculture and stock enhancement, there are also several constraints to such enterprises in the Pacific. Many of these have been identified previously by Uwate and Kunatuba (1983), Munro (1993) and Bell and Gervis (1999). They include:

- Limited domestic markets. Local markets for the fresh products of aquaculture in the Pacific are small, and with the exception of very limited opportunities in the restaurant trade, usually offer low prices. Thus any large-scale aquaculture development in the Pacific catering to the trade in seafood will depend heavily on export markets.
- High added-value export markets targeted. These are most often regional and fluctuating markets (e.g. live reef fish). Thus any aquaculture development will depend on the capacity to follow the market trends, and to fulfil the demand in time.
- Transport problems. The high cost of shipping in the Pacific adds considerably to the cost of producing and exporting aquaculture products. Poor internal transport services restrict opportunities to grow perishable products in remote locations, and limited

international air connections inhibit continuity of supply to export markets. Transport arrangements dictate that species cultured for export need to be of high value and low weight. Alternatively, the products must be non-perishable, e.g. bêche-de-mer (processed sea cucumbers) or frozen, so that they can be shipped by sea.

- Social and economic factors. Many of the smaller island nations lack the infrastructure, capital and skilled labour required to implement aquaculture, particularly where hatcheries are involved. Sustained assistance from developed countries is needed to implement and operate stock enhancement programmes until they become self-funding (Bell, 1999a). The traditional marine tenure systems in place in many countries (Ruddle et al., 1992) also add complexity to the process of negotiating access and tenure

Stewart, 1997), can be expected to change the ecosystem in favour of algae and herbivores. Such changes are likely to be unacceptable, particularly to the tourist industry. This constraint is particularly relevant to lagoonal habitats, but would not apply to locations that have good flushing to the open ocean.

- Freshwater is limited, except for the large islands of Melanesia, which have extensive river systems. Prospects for freshwater aquaculture are thus limited. Even in areas with significant to sites for aquaculture.

- Fragile habitats. Coral reef ecosystems on many of the smaller island nations have evolved in a nutrient-poor environment. Additions of nutrients, e.g.through uneaten and undigested formulated diets for carnivorous fish in cage culture (Beveridge, 1987; Landesman, 1995;

fluvial development, the indigenous freshwater ichthyofauna is generally unfavourable for economic culture and species for freshwater aquaculture have been imported.

- Cyclones. Countries in the cyclone belt can expect aquaculture installations to be damaged intermittently by large swells and strong winds.

Box 1: Aquaculture production trends from the FAO statistical database

Aquaculture in the Pacific Islands, while most species are of small commercial significance (apart from the significant black pearl culture sector, which is discussed later in the review), is a developing activity that has increased production volume nearly five-fold in the past decade. According to FAO (2000), 6 500 mt were produced in 1997, compared to 1 463 mt in 1988, representing an APR [Annual Percent Rate) of growth of 17.9 percent. The value of the 1997 production for species on the FAO database is reported as US$16.7 million, rising from US$4.7 million in 1988, an APR of 15.1 percent (figures exclude contribution from the pearl culture sector). The most significant production volumes (including plants where appropriate) for 1997 are seen in the Fiji Islands (345 mt), Guam (220 mt), Kiribati (4 652 mt) and New Caledonia (1 152 mt); these states realise nearly 99 percent of the reported volume of aquaculture production in the Pacific Islands.

These figures do not, however, reflect the differences observed within the different states. For example, eucheuma seaweed (*Kappaphycus alvarezii*) represents 70 percent of total wet weight of production in the region, concentrated in Kiribati, but whose value is only eight percent of the regional total excluding black pearls, its unit price being around US$0.3/kg. Crustacean production represents 20 percent of regional volume but 80 percent of value excluding black pearl, the main products being *Penaeus monodon* and *P stylirostris*. The production of shrimp in New Caledonia (1 107 mt) gives it the lead position in terms of the value obtained from aquaculture at US$12.2 million in 1997, equivalent to 73 percent of regional value excluding black pearl culture.

The highest increase in production rates are seen for molluscs [oysters] (APR 29.2 percent), seaweeds (19.4 percent), crustaceans [shrimps] (17.4 percent) and freshwater/diadromous fish production [tilapia and milkfish] (11.0 percent). Of the organisms cultured in the region, there has been quite a lot of variability in production throughout the decade, particularly for seaweeds and molluscs, but the growth of fish and crustacean culture has been relatively steady (FAO, 2000).

Current status of aquaculture in the pacific islands

Aquaculture systems

Profitable aquaculture of penaeid shrimps and blacklip pearl oysters has now been established in some areas of the Pacific by commercial interests. Stand-alone enterprises producing penaeid shrimps for export markets are firmly established in New Caledonia and Fiji and were so in Solomon Islands until recently. These enterprises are applying technology developed originally in Japan, Taiwan Province of China and France, and now common place throughout the tropics.

A large, sustainable, industry for culturing pearls using the blacklip pearl oyster (Pinctada margaritifera) has been established in the Tuamotu Archipelago, French Polynesia, and on a couple of atolls in the Cook Islands (Fassler, 1995). In French Polynesia, the value of cultured pearls exceeds US$150 million per year. In Cook Islands, the industry is currently worth US$5 million and is the second largest source of revenue for the country after tourism.

Blacklip pearl oysters

Small-scale culture of pearl oysters is under way in Fiji, Marshall Islands, the Federated States of Micronesia, Solomon Islands, Kiribati and Tonga. In some places, e.g. Kiribati, development is based on spat produced in hatcheries, whereas in others, e.g. Solomon Islands, development is geared towards finding ways that coastal villagers can catch and grow wild spat (Friedman et al., 1998). Current research is concentrating on assessing the economic viability of pearl farming in Solomon Islands, Fiji and Kiribati, and comparing growth, survival and pearl quality of oysters derived from wild and hatchery-reared spat.

Giant clams

Small-scale enterprises in Solomon Islands, Palau, Marshall Islands, Cook Islands, Tonga and American Samoa supply five species of giant clams (Tridacna crocea, T. derasa, T. gigas, T. maxima and T. squamosa) to the marine aquarium trade (Foyle et al., 1997; Hart et al., 1998). Production of giant clams for enhancement of wild stocks is also under way in Solomon Islands, Fiji, Cook Islands

Black pearl farming in French Polynesia and Cook Islands, and shrimp aquaculture in New Caledonia represented more than 98 percent of the total value of aquaculture production estimated in 1996 (Table 1).

and Western Samoa (Bell et al., 1997a; Bell, 1999b). Several of these countries also have the capacity to produce giant clams for the sashimi market in Okinawa, and as a live product for markets in China, Hong Kong Special Administrative Region and Taiwan Province of China (Bell et al., 1997b).

Table 1. Values (US$ 000) of aquaculture productions for coastal species cultured in tropical Pacific countries and territories in 1996 (from Bell and Gervis, 1999).

Country/Territory	**Species**									**Total**
	Pearl oysters	Penaeid shrimps	Micro-algae	Various finfish	Macro-algae	Table oysters	Giant clams	Milkfish	Sponges	
American Samoa	-	-	-	-	-	-	30	-	-	30
Cook Islands	4 500	-	-	-	-	-	-	-	-	4 500
Fiji	-	180	-	-	20	-	-	-	-	200
French Polynesia	140 000	398	-	50	-	-	-	-	-	140 448
Guam	-	121	-	13	-	-	-	100	-	234
Kiribati	-	-	-	-	114	-	-	95	-	209
Marshall Islands	75	-	-	-	-	-	60	-	-	135
New Caledonia	-	10 062	-	-	-	675	-	-	-	10 737
Palau	-	-	-	-	-	-	55	-	-	55
Federated States of Micronesia	-	-	-	-	-	-	-	-	5	5
Solomon Islands	-	170	-	-	-	-	65	-	-	235
Tonga	*	-	-	-	-	-	*	-	-	*
Total	**144 575**	**10 931**	**0**	**63**	**134**	**675**	**210**	**195**	**5**	**156 788**

ICLARM is currently conducting large-scale growout trials to test and develop these markets for T. derasa.

Sea cucumbers

Research has commenced to assess the viability of producing sea cucumbers in hatcheries for enhancement of wild stocks. There are three steps in this process: developing methods for cost-effective mass production of juveniles, learning to release the cultured juveniles in ways that maximize their survival, and evaluating the economic impact of releasing cultured juveniles into existing fisheries. Currently, the focus is on development of methods for the mass rearing of Holothuria scabra, H. fuscogilva and Actinopyga mauritiana, three of the most valuable sea cucumbers in the region. To date, ICLARM has demonstrated that H. scabra is relatively easy and cheap to rear (Battaglene and Bell, 1999), and that A. mauritiana grows relatively rapidly at high densities (Ramofafia et al., 1997). Initial research on H. scabra indicates that this species has much potential for stock enhancement.

Other species

Technology for propagating and releasing cultured juveniles of incongruous with private-sector farm ownership in many areas, unless the development is carefully managed. Tonga is currently developing a comprehensive legislative basis for future aquaculture development, whilst the Cook Islands has adapted traditional systems into a legal basis for pearl farm management. Other countries are taking a more ad hoc approach and trying to adapt land-based systems of state leases for mariculture development, or encouraging development only by traditional reef custodians.

Status by island

Production statistics for aquaculture, as might be expected from what is currently a minor, semi-subsistence activity, are almost nonexistent for the Pacific Islands. The exceptions are for black pearl farming in eastern Polynesia, and shrimp aquaculture in New Caledonia and a few other islands. The following summary is mainly non-quantitative.

American Samoa

Aquaculture is currently focused on giant clams (Tridacna derasa, T. maxima, and Hippopus hippopus). In 1996, 30 subsistence-level farmers participated in a programme of growing-out 500 clams each provided by a public green snail and trochus has been transferred to the Pacific through projects in Tonga (JICA) and Vanuatu (Austrailian Centre for International Agricultural Research, ACIAR). The Overseas Fishery Cooperation Foundation (OFCF) is also implementing a stock enhancement programme for both species in Solomon Islands. Production of the marine alga Kappaphycus is well established by coastal villagers in Kiribati and Fiji, and sponges are being cultured in the Federated States of Micronesia. Milkfish are being cultured as live bait for the tuna industry in Guam, and there is considerable interest in this activity by several other countries.

Policy and institutional framework

The independent Pacific Islands (Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu) generally lack any specific provision for aquaculture in the legislation, but many include a statement about aquaculture in national development plans.

Whilst prospects for inland aquaculture are limited by geography, the custom of communal tenure of coastal marine sector-supported hatchery (Clarke, 1997, personal communication).

Cook Islands

There are few freshwater bodies, but small lakes on three islands contain introduced eels and tilapia (not cultured though). Blacklip pearl culture started in the early 1970s at Manihiki; there were 50 farms in 1988 and over 90 in 1998. The first full-scale commercial harvest occurred in 1990 and was valued at US$0.8 million. This had risen to $4 million by 1995 to become Cook Islands' most valuable visible export. Farming has now expanded to Tongareva and a government hatchery is there. A government hatchery for giant clam and trochus has existed on Aitutaki for 10 years, but is not currently commercially sustainable (G. Matutu, 1999, unpublished data).

Federated States of Micronesia

In spite of numerous trials and projects conducted since the 1930s, there are no sustained commercial or subsistence aquaculture operations at present (Itimai, 1999). Sponge culture exists on a small scale.

areas may be

Fiji

Aquaculture was first started in 1953, when tilapia were introduced as a protein source for pig farming. The first directed efforts occurred after the United States Peace Corps and a JICA project assisted the Fiji government in developing freshwater aquaculture methods in the 1980s. Varied success was achieved with shrimp, Kappaphycus, oyster, mussel, Macrobrachium, carp and tilapia, but now major investment is promoted by the government through a Commodity Development Fund. Currently, there are three shrimp farms and hatchery; 20 milkfish ponds for longline bait; and one industrial, seven commercial and 215 subsistence farms and six hatcheries that produced 243 mt of tilapia in 1998. Eucheuma cottonii is cultured by a total of 182 farms, producing an estimated 1 500 mt in 1999. Experimental pearl farming is conducted, and there is one commercial farm that has been operating for two decades. There is

Marshall Islands

There is farming of giant clams, seaweed and pearl oysters (Te, 1999).

Niue

There is currently no aquaculture, but investigations have been conducted on the feasibility of a giant clam and trochus hatchery.

Nauru

Milkfish been farmed for at least one century, but competition from introduced tilapia (O. mossambicus) occurred in Buada Lagoon and culture lapsed. It has recently been revived, with O. niloticus and milkfish being raised in 11 ponds (F. Alefaio, 1999, unpublished data).

Northern Marianas

Aquaculture is limited to raising penaeid shrimp and tilapia (Clarke, 1997). Annual production is also a giant clam hatchery, the Naduruloulou Government Freshwater Aquaculture Research Station, the Makogai Government Mariculture Research Station, and the University of the South Pacific (USP) Aquaculture Teaching - School Teaching Ponds (E. Ledua, 1999, unpublished data).

Guam

There was an increasing trend in annual aquaculture production between 1990 and 1995 (Clarke, 1997). In 1995, aquaculture production was 205 mt valued at US$1.6, derived mainly from the farming of tilapia, marine shrimps, Chinese catfish and milkfish. The potential for the development of other species (giant clams, top shell, striped mullet and groupers) is being explored by Guam-based research facilities.

Kiribati

Eighty hectares of mikfish ponds, originally set up to provide livebait for tuna pole-and-lining, have been operating for several decades. Kappaphycus alvarezii has been cultured in the Phoenix, Line and Gilbert groups for 15 years. There is an OFCF project on sea cucumber rearing and an ACIAR project on pearl farming (T. Tekinaiti, 1999, unpublished data).

estimated at 1 250 kg for marine shrimp, 200 kg for freshwater prawns and 4 200 kg for tilapia. There are fewer than three commercial farms. The total value of products was estimated as US$25 000 in 1996.

Nouvelle Caledonie

Shrimp production achieved 1 500 mt for the first time in 1998 (Labrosse et al., in press), after disease problems which occurred in the early 1990s. The value of marine shrimp production is about US$10 million. About 45 mt of oysters (Crassostrea gigas) are produced for the local market. Experimental culture of local oyster and giant clam is also in progress (Etaix-Bonnin, 1999).

Palau

The Micronesian Mariculture Demonstration Centre pioneered giant clam culture, as well as trochus and soft corals.

Papua New Guinea

Aquaculture started 40 years ago, with several aquaculture stations along the coast and highlands to encourage subsistence culture, mainly of Cyprinus carpio. There are 300 carp farms in operation. Trout were introduced in the 1940s, and the Kotuni Trout Farm was in operation from 1973-1984. There are three newer farms, but only two are currently operating, with a production of 15 mt. A hatchery was started in 1996.

Culture of barramundi (Lates calcarifer) has been started in Madang on the site of a failed 9 ha pond originally used for redclaw (Cherax quadricarinatus), but production has not yet been established (J. Wani, 1999, unpublished data).

Pitcairn, Henderson, Ducie and Oeno

There is no aquaculture on these islands.

Polynésie Française

Pinctada margaritifera farming for black pearls is major industry. In the past, culture systems for mussel, shrimp, barramundi and oyster have been developed.

Samoa

Farming trials were conducted on

A Japanese mariculture project with the Ministry of Fisheries on Tongatapu recently finished. Currently, there is a government hatchery for giant clam, green snail (introduced) and trochus (introduced); and trials are planned for extensive Cladosiphon farming (U. Fa'anunu, 1999, unpublished data) and hatchery production of blacklip pearl oyster.

Tuvalu

There is interest in trials on tilapia culture in borrow-pits at Funafuti.

Vanuatu

Crassostrea gigas was introduced in the 1920s. There was a short-lived Macrobrachium rosenbergii farm at Santo from 1978-1983, and tilapia from New Caledonia were cultured during the early 1980s at Efate. Also at Efate, a trochus hatchery tilapia in 1954 by the SPC and on Macrobrachium in 1971 by the FAO, but were not successful. Seaweed, giant clam, green mussel and redclaw farming were also tried. A new national economic strategy promotes aquaculture, and this is being actively developed by the current AusAID village fisheries extension project using tilapia, mullet and giant clam (A. Mulipola, 1999, unpublished data).

Solomon Islands

There are two shrimp farms and several village-based enterprises rearing giant clams and hard corals for the aquarium trade and a demonstration black pearl farm in the Western Province. The ICLARM Coastal Aquaculture Centre has also developed methods for the propagation of sandfish (Holothuria scabra) and the capture and culture of wild postlarval coral reef fish for the aquarium trade. Between 1996 and 1999 there was an OFCF project on green snail & trochus (E. Oreihaka, 1999, unpublished data), but the future of the aquaculture-oriented Institute of Marine Resources of the University of the South Pacific is uncertain.

Tokelau

There is no aquaculture on Tokelau.

Tonga

was established in 1985, started up by ORSTOM continued to the present by SPADP and ACIAR. Giant clam spawning has just started. There is no commercial aquaculture (K. Pakoa, 1999, unpublished data).

Wallis et Futuna

There is no aquaculture on Wallis et Futuna.

Prospects for further development

Some of the best opportunities for development of aquaculture in the Pacific are in the aquarium trade and live seafood markets (e.g. napoleon wrasse, groupers, sea cucumbers, spiny lobsters, trochus, pearl oysters, giant clams, green snail, abalone, crabs, clownfish, angelfish, hard corals, soft corals) and the pharmaceutical industry (e.g. algae, sponges, soft corals, sea horses) (Bell and Gervis, 1999; Bell, 1999c). In all cases, the products are of high value and can be grown in small areas with relatively simple technology.

Initiatives by FAO, the World Fish Center (ICLARM), the Center for Tropical and Subtropical Aquaculture (CTSA) and bilateral donors have concentrated on establishing the culture of pearl

Aquaculture was first attempted in 1968 with the polyculture of tilapia and milkfish. From 1973-1979, various trials were conducted on shellfish (oyster, mussel, pearl oyster); these lapsed but Pteria penguin was established in the wild and may form the basis for later pearl culture.

oysters outside eastern Polynesia, developing small-scale aquaculture enterprises for other species, and providing basic training in aquaculture and stock enhancement to fisheries staff in several of the countries.

The proceedings of the workshop entitled Present and Future of Aquaculture in the Pacific organized jointly by the South Pacific Aquaculture Development Project (SPADP) and the Japanese International Cooperation Agency (JICA) in Tonga in November, 1995 (Anon., 1996) presented the status of aquaculture in the region.

The continued expansion of aquaculture in the Pacific will depend on providing better methods of production for species currently under cultivation, and techniques for propagating and growing the "new" species described above (Bell, 1999c). These methods and techniques should be simple and flexible

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enough to be easily adapted to the context of the Pacific Islands environment and to the constraints of local and export markets. This approach should promote systems integrating fisheries and mariculture, with low cost methods of production). This should be associated with pilot commercial scale operations to test and demonstrate the economic viability of the methods proposed. This will need research coupled with assistance, training and education programmes.

In recognition of these needs, three organizations (SPC, ICLARM and USP) have recently joined forces to produce a "Regional Strategy for the Development of Aquaculture". Under this strategy, SPC will be the regional focal point for aquaculture and willconvene regular meetings of island nations to identify needs, determine priorities and put organisations and individuals in touch with each other. ICLARM will undertake long-term research to devise and test economically and environmentally sustainable methods for restocking, stock enhancement and farming; and USP will developdegree and diploma course components and aquaculture vocational training, and contribute to research through higher degree programmes. The other functions necessary for the expansion of sustainable

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aquaculture in the region, e.g. marketing, legislation, environmental protection and quarantine, will be integrated progressively through association with the Strategy.

This Pacific Islands Regional Aquaculture Strategy represents an opportunity to reinforce inter-regional cooperation based on research, training and information exchanges (including cooperation through NACA with Southeast Asian countries). It may promote more investment from Asia and better conditions for access to Asian markets.

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ABSTRACT: China's aquaculture production exceeds its fish capture landings. When China adopted the reform and opening-up policies, fisheries began to take off rapidly. By the 1980s, fisheries were playing an important role in food security and became one of the most vital support industries and economic activities in rural development. Technical innovations, especially mass seed production of aquatic organisms, design and construction of commercial fish bases, expansion of coastal aquaculture and sea-farming, and intensive and high-yield aquaculture technologies stimulated a rapid increase in production; it rose from 1.68 million mt in 1980 to 21.82 mt in 1998. Improvements have been attained with expansion, increase in yield per unit area, improvement of support and production facilities, more investments in aquaculture research and development, and provision of better services to farmers. Constraints, however, are becoming more pronounced - these include increasing cost of production and biological problems, including genetic degradation of farmed species and diseases. The environmental problems have also exposed the shortcomings of the regulatory and institutional systems for fisheries.

China feeds 22 percent of the world's population but has only 7 percent of the earth's arable land, which is devoted mostly to grain production. Thus the substantial production from fisheries, especially aquaculture and enhanced fisheries, has made a significant contribution to improving the food intake and nutrition of the people. Aquaculture has also created much rural employment. Between 1980 and 1998, the additional number of people employed in the fisheries sector was 10 million; the average new entry or job creation is half a million people a year, with 70 percent going into aquaculture. To meet the demands of another 100 million people that are expected to be added to the population in the next 20 years, the fisheries development plan aims to promote the transformation of the fisheries economic system to fit the basic requirements of a market economy, and to promote science, education and sustainable fisheries development. The goal is to increase aquaculture contribution to improve the welfare of farmers and develop the rural economy.

KEY WORDS: Aquaculture Development, China, Fisheries, Planning, Fish Farming

Introduction

From 1978, when China adopted reform and open policies, fisheries were placed in the rapid development track. Fisheries have played an increasingly important role in food security, especially after the late 1980s, to become one of the most vital support industries and an increasing centre of economic activity within agriculture and the rural economy. In the past 20 years, aquaculture has developed through the popularization of different operating systems, by means of designing and constructing commercial fish bases3, and by extending large-scale intensive and high-yield aquaculture technologies. These actions have led to aquaculture

Review of the achievements and development trends

Summary of aquaculture developments

During the past 20 years, the remarkable characteristic of Chinese fisheries and aquaculture development has been that the structure of production has changed, particularly when measured alongside the rapid increases seen in production volumes. The readjustment and optimization of the structure that exploits resources has been considered to be the most important factor for both the sustainable and rapid development production rising sharply from 1.68 million mt in 1980 to nearly 21 million mt in 1997, an APR [Average Percent Rate] of 16.7 percent over this seventeen-year period. Alongside this production systems evolution and the associated increase in fish consumption, problems of regional and structural over-production, the reduction of comparative benefits and the degradation of the fisheries environment have been inhibiting factors for the further development of fisheries and aquaculture. In order to meet the demand for fish and fishery products in the new millennium based on the forecasted increase in population of 100 million people in the next 20 years, a general plan has been made for fisheries and aquaculture development in China. The plan is comprised of the following key elements:

- To promote the transformation of the economic system of fisheries, including the pattern of economic enlargement, by applying the basic requirements of the socialist market economy;
- Implementing the strategies of promoting fisheries through science and education and the sustainable development of fisheries;
- To realise the optimum of fisheries.

For a long time, capture fishery occupied the dominant position within traditional fisheries in China, providing 71 percent of total production up until 1978. The irrational pattern of increasing production by exploiting natural resources (mainly marine fisheries resources) had caused the degradation of fisheries resources, seriously limiting the potential for the sustainable development of the fisheries sector.

Following China’s reform and opening-up to the outside world, the government adopted the policy to give first priority to aquaculture development in its overall fisheries development strategy, which resulted in the significant increase of aquaculture yield and its share in fisheries production.

In the past 20 years, vast areas of inland water bodies, shallow seas, mudflats and low-lying lands have been utilized effectively for aquaculture. The geographical distribution of aquaculture farming practice in the country also extended from the coast and the delta of the Yangtze and Pearl rivers, where fish farming has been practised for centuries, to the areas with no aquaculture tradition, particularly the three northern areas (i.e. North, Northeast and composition of the different elements of fisheries production, including farming of high-valued species, intensification of pond-culture operations and industrialized development, by actively readjusting and optimizing the industrial structure and the production components;

- By treating seed production as the base, and aquatic product quality and sustainable fisheries development as the key content; and
- Industrialization of the sector as the goal, to promote the rapid development of sustainable fisheries and aquaculture in a coordinated and regulated manner in the 21st Century so as to promote agriculture and the rural economy and provide a greater contribution to the improved livelihood of the rural population.

Northwest China).

By 1998, the total area devoted to aquaculture production in China had reached 6 085 000 ha, about twice that for 1980. In the same year, aquaculture production attained 21 820 000 mt4, 12 times that for 1980, an expansion reflecting an APR of some 32 percent, a measure of growth that confirms aquaculture to have been responsible for the major part of the increment of fishery production during this period.

Amongst the major fish producing countries of the world, China is the only one whose aquaculture harvest exceeds that of capture fisheries. In 1998, the share of aquaculture in total fishery production was 56 percent as compared to 26 percent in 1978. The rapid increase in aquaculture production also significantly increased its contribution to animal protein production; the percentage of aquaculture products in the total animal products, including meat, poultry, eggs, milk etc. reached 32 percent in 1998 against 20 percent in 1985. At the same time, the diversity of aquaculture products has shown a clear trend towards providing a wide range of products of high quality. The main aquaculture species used for production have developed from a few (four major Chinese carps, molluscs and seaweed) to several dozen commercially important culture species that include fish, shrimps, crabs, seaweed and molluscs for freshwater, brackish and marine environments. Aquaculture production increasingly includes desirable high-value species that now provide a significant portion of the total output.

For a long time, the per capita consumption of aquatic products in China was lower than the world's average. During the period It is an activity that lessens the contradiction of having a large population but little land, easing the pressure of population increase and the concomitant demand for grain and meat. These observations embody the great contribution of Chinese aquaculture production to food security in China and the world.

The past two decades have shown aquaculture to be the most rapidly developing sector within agriculture, not only in terms of production, but also in the creation of jobs in the rural areas. In 1998, the total fisheries production value reached 161.7 billion Chinese Yuan5, which was about 75 times that for 1980 (2.1 billion Yuan). The increasing importance of this economic value is demonstrated by the observation that, in 1980, fisheries represented 1.5 percent of the total combined value of fisheries and agriculture, a figure that rose to 12 percent by 1998. In terms of employment within the fisheries sector, the labour force is now estimated to be some 10 million people, a figure that is rising by around 500 000 per year. Of these totals, it is calculated that 70 percent are engaged in aquaculture.

The aforementioned details demonstrate that aquaculture development has made itself an examined, the considerable increase in the availability of aquatic products has contributed to rising annual consumption figures, and by 1998, the consumption has reached 31.3 kg per capita, a figure that is 10 kg higher than the world's average. The target of resolving the problem of fish shortage in China was reached on time. In China today, the aquatic products in the market are not only available in adequate supplies, but they are also rich in variety, of high quality and have a stable price.

Aquatic products are an indispensable food for the people, and it is often said that China feeds 22 percent of the world's population but possesses only 7 percent of the world's arable land which, in China, is devoted mostly to grain production. In fact, the large quantities of aquatic products harvested from the seas and inland waters also make great contributions to improving the human diet and, consequently, the health of the population.

China produces annually more than 20 million mt of aquaculture products, most of which contain high-quality fish protein, a situation that also reflects the important fact that aquaculture is an effective industry that utilizes lands that are not suitable for crop production and converts feed with a higher important sector within the rural economy in China. The scope is growing continuously for the development of a series of related industries, business and services, such as storage, processing, transportation, fish feed manufacture and marketing, which are subsectors driven by the development of aquaculture. The sector as a whole has been playing an active role in facilitating the optimization of the restructuring and performance of the rural economy.

Utilization of resources by fisheries and aquaculture

The integrated management and utilization of natural aquatic resources has not only widened the scope of aquaculture but has also allowed steady increases in production. In the first instance, the surface and rate of use of water areas increased. China has 17 470 000 ha of inland water surface, of which some 2 980 000 ha (17 percent) were utilized for aquaculture in 1980. The figure jumped to 5 080 600 ha in 1998 (30 percent). The total area devoted to mariculture increased from 133 000 ha in 1980 to 1 004 400 ha by 1998, nearly an eight-fold rise.

conversion rate than those of terrestrial animals.

Secondly, not only has the aquaculture capacity improved, but the yield per unit area has also increased. Alongside the continuous improvements made in infrastructure, production facilities and technology extension, aquaculture's capacity has risen continuously. In 1980, the average annual yield in inland waters was 315 kg/ha; it has risen to 2 400 hg/ha by 2000, close to a seven-fold increase. Mariculture is continuing to develop away from the simpler mollusc and seaweed cultures towards diversified systems of intensive culture of multi-species. The number of species used within mariculture has now reached several dozen and includes major commercial marine animals and plants, such as fish, shrimp, molluscs, seaweed and sea cucumber.

Aquaculture techniques include rafts employed for culture of kelp, Undaria, laver, scallops, oysters, abalone, mussels etc. in the

Tremendous efforts have been made to provide on-farm technical support and extension services by fishery research institutes and technology extension stations at the provincial, prefecture, county and village levels. With the intensification of production systems and diversification of species, the contribution of science and technology has become a vital factor in aquaculture development. A comprehensive survey and tests carried out nation-wide came up with the estimate that some 48 percent of production increase was attributed to scientific and technological advancement.

Finally, aquaculture facilities have been enhanced and the investment in infrastructure increased. The rate of return on investment in aquaculture is high and continues to have good prospects. At the same time that the government invested considerable funds to construct 10 large commercial fish production bases for fish shallow sea; net cages for a variety of marine finfish; ponds for the culture of shrimp, fish, crabs and molluscs; mudflats utilized for culture of clams, ark shells, razor shells and oysters; and enclosed indoor facilities (e.g. raceways and tanks) for rearing high-value species such as mock halibut, flounder, abalone and sea cucumber. Aquaculture systems are designed for multispecies mixed cultures, as well as for monospecies culture.

At present, a multi-patterned and three-dimensional mariculture industry is developing dynamically in the shallow seas and in the mudflats, adapting to local conditions in an appropriate manner.

The third consideration is that the labour force input and employment have increased. Aquaculture is seen to give better benefits and wider opportunities for market development and thus attracts a large number of agricultural labour. It has been observed that the economic returns of a one-hectare pond are equivalent to that from two hectares of cotton or three to four hectares of paddy field. The fisheries labour force, including aquaculture, increased from 2 950 000 in 1980 to 12 374 800 in 1998, and the average per capita income of fishermen rose from 171 Yuan to production, 500 000 ha of fishponds for intensive culture were built. This effort was realised using loans from the World Bank (WB), local government investment and labour input as the contribution of the people.

In order to guarantee the smooth implementation of the strategy of "promoting fisheries by science and technology", both central and local governments have invested a tremendous amount of funds to establish a national aquaculture technical training and extension network consisting of extension stations at the central, provincial, prefecture, county and village levels. This extension system includes 37 stations at the provincial level, 206 at the prefecture level, 116 at the county level and 1 155 at the village level. Each station is equipped with appropriate instruments and training facilities. Furthermore, an original system has been established for promoting fine (i.e. high-value) species, which includes 25 specialized farms at the state level to maintain broodstock, combined with a fishery administration and environmental monitoring and protection system.

Analysis of the main experiences and lessons learnt

The important experiences in

4 323 Yuan during the same period.

Fourthly, the contribution from science and technology has increased the level of skills of workers in the sector. The capacity of workers in the sector to apply the scientific approach to fish farming has been vastly improved through technological research, demonstrations, extension and training courses.

aquaculture development, described for China, include the following:

Application of the fisheries development principle of "taking aquaculture as the key"

As China is rich in water resources and areas such as mudflats, the government proposed a core readjustment principle containing three keys – "utilize the resource rationally, make great efforts to develop aquaculture, and focus on improving quality". Through this approach, the government assured that aquaculture development became the key means to increase the supply of aquatic products. In 1985, the establishment of the fisheries development principle -

Adjustment of the cultured species profile and the reform of market-oriented aquaculture

In order to ensure the effective supply of fish products and increase the benefits from aquaculture, the local governments have paid considerable attention to popularizing the use of fine species for both stock enhancement and aquaculture purposes, thus diversifying and optimizing aquaculture species use. This has enabled inland aquaculture to break out of the traditional pattern of rearing the four principal domestic species (silver carp, grass carp, "take aquaculture as the key, let aquaculture, fishing and processing develop together, make different emphases according to local conditions" – enabled the fisheries sector to enter the rapid development phase, which was principally dependent on aquaculture expansion, forming a unique fisheries development pattern having Chinese characteristics.

Formulation of fisheries policies for development within the economic structure of the socialist market in China

The reformed and open environment in China has provided easier conditions for the development of fisheries, a circumstance that included two main policies. The first was the liberalization of right for land use and farm management. An aquaculture farm management system was adopted based on the household responsibility system as the key element, combined with a diversified operating system. In order to encourage the people to reclaim and exploit low-lying or saline-alkali land suited for aquaculture, the local governments actively established preferential policies and provided support and privileged fiscal and investment measures. These were extremely successful, arousing enthusiasm for common carp and bighead carp). Large-scale freshwater production has now been achieved for well-known high-grade species such as eels, crabs, softshell turtles and freshwater prawns. In mariculture, increased production has been seen for shrimps and prawns, marine fish species, scallops and other high-quality species. The core "single species" activities, such as kelp and mussels, have adopted a multispecies approach where a combination of fish, shrimp, molluscs and seaweed are reared.

To be able to assure a constant, year-round supply of fresh and live fish, aquaculture methodology was also reformed, including the policy of "take turns in fishing and stocking, catch the bigger and leave the smaller". This approach lessened seasonal peaks and troughs concerning supplies, thus improving the market situation and reducing overstocking as well as fluctuating prices. It is evident that aquaculture outputs and benefits have been improved with these reforms and operational changes.

Extending aquaculture technology and improving quality

Fisheries administrations have improved overall quality in aquaculture through the popularization of many kinds of involvement in developing aquaculture both within the population and industry. The second policy was the liberalization of price control by government, which allowed the price of fish products to adjust to the market, permitting the full range of advantages of unified production and sales. All policies have given a great impetus to the development of aquaculture in the country.

advanced and suitable techniques. For example, the development and extension of artificial breeding and feeding techniques allowed shrimp farming to expand rapidly to an annual production of more than 200 000 mt in the early 1990s, and for scallop to change from a high-value product to one that is readily available. The application of intensive pond systems and more productive farming systems and technology has increased average pond output from 750 kg/ha in1980 to 4 500 kg/ha in 1998.

The rate of use of water has increased through the application of fish pen and cage farming in medium-sized and large water bodies and the application of intensive farming technology (in small to medium and large water bodies. It is estimated that this factor alone has contributed to the doubling of productivity.

Integrating aquaculture with agriculture, forestry and animal husbandry has also assisted the rapid and successful development of aquaculture.

The decline in genetic quality

At present, basic work on maintaining genetic fitness, including research, genetic purification and rehabilitation, is weak, a position that could result in genetic degeneration and lead to a potential degradation of many of the productive advantages, such as growth rates and disease resistance.

The economic impact of diseases in aquaculture

Strengthening the legal framework and fisheries management

Since reform and the introduction of an "open door" policy, China has established a basic policy of "managing and developing fisheries by law". The legal system for Chinese aquaculture is based on the framework of Fishery Law. Its key purposes are to protect resources and utilize them rationally and to guarantee the rights and interests of fishermen. Further measures have been taken to improve the legal framework of Chinese fisheries and to strengthen monitoring and enforcement in order to assure its sustainable and healthy development.

Constraints to the continuous development of aquaculture

The decline of comparative profitability

In recent years, the price of freshwater aquaculture products has declined. Amongst these, one can note that the prices obtained for eel, softshell turtle, giant freshwater prawn, mitten crab and other high-value products have diminished by as much as 50 percent. The price of the more

Although statistics are incomplete, expert analysis reveals that diseases are responsible for losses of some 15-20 percent of production, which would imply an economic loss of 5-7 billion Yuan (US$525-875 million) annually.

An outline of china's aquaculture development plan for 2001-2020

Overview

The main directions for development are to:

- transform traditional fisheries into a modern activity;
- transform production activities from extensive to intensive operations; and
- Improve the quality of aquaculture products.

By taking the improvement of product quality as a core issue, increasing both production and income are the goals, where the sector will rely on scientific progress and producer skill improvements, allowing the promotion of aquaculture as an effective, healthy and sustainable sector.

The practical work to be done includes:

staple products (e.g. carps) has been more stable, but production costs have increased. Under these circumstances, it was noted that some aquaculture enterprises have encountered serious financial losses, affecting the producer's enthusiasm for development.

The promotion of skills and technology

Although the area devoted to aquaculture and its total production give China the leading position in global aquaculture, there are still great differences in basic facilities and scientific and management levels among regions and provinces. Increased skill capacities need to be promoted.

- establishment of aquaculture systems for both traditional and high-quality species;
- development of aquaculture standards and disease control; and
- fishery engineering activities for developing the potential of shallow seas and mudflats, low-lying and saline lands (along the Yellow River), large- and medium-size water bodies and paddy-field fish farming.

Production targets

The tentative target for national fisheries production for the year 2010 is 51 million mt, which represents a 24 percent increase from the predicted production of 41 million mt in 2000, indicating an APR of 2.2 percent. The total value is estimated to reach 350 billion Yuan, contributing 15 percent to that of the entire agriculture sector. The targeted per capita availability of fisheries products is estimated at 36 kg.

The demand for fisheries and aquaculture products

Both fish species and fish products will develop in different and diversified directions according to consumers' buying power, consumption habits and perceptions. According to present trends, the consumer appreciates and welcomes nutritious and safe fish products, with a particular appreciation for the highly rated species, which represent a considerable development opportunity. These include freshwater species like mandarin fish, snakehead, perch, catfish, shrimp, softshell turtle and tortoise, while marine species of interest include fish, shrimp, molluscs and seaweed.

The distribution and management of resources

The diversity encountered in respect of both production and consumption determines that the fishery resource should be utilized and exploited evenly. Such exploitation should not be that of natural fisheries (low investment, low output, light pollution, low benefit) nor should it be an industry (high investment, high output, high energy consumption and heavy pollution) that would exhaust the natural resource and degrade the environment.

The rational approach should be to take into consideration the total resource capability, the environmental capacity and social needs. On one hand, it is necessary to obtain higher fish production by enhancing the weaker points of the resource and increasing productivity. On the other hand, the production should be kept within a certain scale in order to respect the issues concerning sustainability. It is necessary to use modern science and technology to transform the traditional fishery activities into modern ones, to increase productivity using science, and to improve the productivity of water bodies and labour, and thus the yield rate of resources. This approach will realise the unification of the social, economic and

The diversity of food preferences gives a wide range of consumption patterns, which is good for both the exploitation and the utilization of natural resources. This contributes to the avoidance of the irrational exploitation of the food chain and environmental destruction and is, therefore, good for the sustainable development of fisheries.

Due consideration has been given to ensure basic fish supplies and improve the food security situation in rural areas. Fish farming is considered as the quickest and most effective way to increase fish supplies, and it has been given high priority in the national fisheries development plan in the context of rural development. The government has been extremely supportive to rural aquaculture development through its technical extension service, particularly for production of species that are low in the food chain and with a wide adaptability and high productivity. ecological benefits of aquaculture.

China has 17.47 million ha of inland waters, of which only 35 percent are used, meaning that there is still a lot of space for aquaculture development. Nearly 6 million ha have been developed, but aquaculture remains predominantly at the stage of extensive farming. There is great potential for improving the rate of resource use, increasing the productivity, the product quality and the contribution of science. For example, out of the 6 million ha of inland aquaculture area, some 2 million ha, about one third of the total area of inland waters under cultivation, constitutes 70 percent of the total inland aquaculture production. The yields obtained from pond-fish farming are highly variable, noting that the average harvest figure in China is 4 500 kg/ha, but this can reach up to 9 200 kg/ha in high-yield regions, i.e. Jiangsu, Guangdon and Zhejiang provinces. However, significant differences can also be seen within the same region, depending on economic and technical conditions, which include modifications to ponds, integrating water flow and/or equipment and scientific training.

Reservoirs constitute 31.6 percent of the inland waters under cultivation, but they also have the lowest production yields (750 kg/ha) and therefore, have great development potential. The application of cage and fish pen culture in reservoirs would not only be a measure for increasing production, but also one that can contribute to resolving problems of employment and livelihood for immigrants in these areas. The recovery of lakes from land also provides a new chance to develop fisheries along the lower reaches of the Yangtze, the Pearl and the Songhua rivers. The activities of fishery enhancement, and cage and pen culture in new open waters would not affect the ecological environment of the land returned, but could recover the agricultural loss.

In addition, the area of paddy fields is underused for aquaculture, being 1.3 million ha, which is only one third of the area considered suitable for aquaculture. Practice has shown that fish farming in paddy fields does not affect rice production, but it can provide a double harvest of both fish and

The aspirations for aquaculture development for the period 2001-2020

In the next 20 years, the emphasis of fisheries and aquaculture development in China will be to:

- meet the needs of social and economic development;
- increase the efficiency of fisheries production;
- develop and promote aquaculture, agriculture and the rural economy;
- expand and diversify production so as to meet the demand for fish and fishery products; and
- make the best use of market potential.

To realise these goals, the state will primarily support the development of six core systems and six areas of concern. The systems to be developed are:

- original and fine species diversification system;
- fishery scientific and standardization system;
- fishery technology extension system;

rice. The goal of 1 500 kg fish and 15 000 kg rice/ha is not difficult to reach. In some remote and poor areas, to develop the paddy-fish combination, along with intensive culture, would assist the employment of surplus labour and help poverty alleviation.

To sum up, even if there was no increase in the availability of land and water resources specifically for aquaculture, the full exploitation of the potential of resources now available could meet the needs of sustainable aquaculture under both economic and environmental aspects. Meanwhile, encouragement is made for the use of wastewater for fish farming and the achievement of sustainable aquaculture, policies that are supported by the provision of preferential loans, fiscal conditions and technical services for aquaculture operators.

For increasing the efficiency of the use of water resources, well-established techniques should be adopted to exploit those water bodies that are not cultivated (65 percent of the total). On the other hand, resource enhancement (e.g. cage and pen culture in open waters) would be beneficial for the development of the reservoirs, lakes and other water bodies.

Aquaculture techniques and

- disease control system;
- fishery marketing system; and
- fishery management and environmental protection system.

The six fields to be developed are the:

- vertical integration of aquaculture production in the fish culture bases;
- development of offshore and distant water fishing;
- processing of fish products and comprehensive utilization of materials;
- building of fish ports;
- building of fishing vessels and
- manufacture of fishery machinery and new technical exploitation.

The implementation of the “TWO SIXES” systems will play an important role in strengthening Chinese fisheries and aquaculture, realising sustainable and healthy development, as well as speeding up the modernization process.

The distribution of fishery resources

It is unlikely that there will be any significant increase in pond areas in view of the limited suitable land available in China.

technological applications should be reformed for some waters. For example, the extension of the use of hard, floating feed pellets could assist the elimination of eutrophication or pollution in waters that is caused by the poor management and feeding strategy.

Consequently, the emphasis is on the upgrading of pond conditions, as well as the readjustment of culture techniques and the structure of the species cultivated. The enhancement and protection of the natural resources has to be encouraged, applying cage and pen culture in other water bodies, where appropriate. The development of polyculture alongside the capacity for multispecies applications will provide opportunities for diversification and the production of high-quality species and products.

Meeting market demand through recognized consumption patterns and economic realities would also encourage diversification. The assurance of stability within the aquaculture sector will support

- research and development to transform traditional aquaculture systems, develop new culture technology systems (e.g. raceways), eliminate self-pollution and improve management systems; and research to develop applicable technologies for the culture of marine species and to guarantee the supply of high-quality aquatic products.

Strengthening technical services

In order to bring fishery technical extension into full play, it is necessary to develop different types of services for the benefit of the production sector. These include technical associations, efforts towards the production of higher value species, providing greater economic benefit and a wider market potential.

The administration of fish farming

A number of requirements has been identified to allow the efficient administration of fish farming in China, including:

- establishing, as soon as possible, a specific legal system for fish farming to guarantee the realisation of sustainable aquaculture development;
- implementing a sector support system for fish breeding, fry supply and disease control;
- optimizing the industrial structure to reconfigure production and have a rational distribution of the activity; and
- modernizing fish farming.

The plan for upgrading the national technological base

The fishery technical development trends to be seen in China in the next century have been identified as the following:

- research on bioengineering technology with emphasis on the improvement of new

mutual insurance aid and other nongovernmental service organizations that can serve the fisheries and aquaculture sectors. It is also necessary to improve the abilities for self-protection and self-development of the labor force under the conditions of a market economy.

Strengthening legal and institutional capacities

Firstly, current legislation and regulations require full implementation, where the following issues require completion or establishment:

- standards for aquaculture production;
- the code for aquaculture operations;
- quality standards for fish products;
- environmental standards for fisheries, including water quality standards; and
- standards for rearing techniques.

Secondly, aquaculture systems and technologies should be developed in accordance with accepted ecological standards. Measures to promote the application of ecological standards and “green” products that have been reared in such systems should be the subjects of research and extension, culture species or strains;

- research on the sustainable development of fishery enhancement and aquaculture in order to assure positive and rational development;
- research on disease control and production technology for aquaculture, with particular reference to molecular biology tools;

giving focus on the supply of healthy, nutritious food. These are instruments that will assist the policies adopted for readjusting the market.

Thirdly, a licensing system for the discharge of sewage drain waters into fishery environments should be implemented where sewage could only be released after approval by the fishery environment monitoring department, which would be required to demonstrate discharge standards. Financial charges would be collected from those discharging sewage, the money to be used as a management fee to assist in:

- production management,
- technical renovation,
- treatment of wastes and drainage waters, and
- cleaning of pollution to protect or recover fishery environments.

Planning to transform Chinese aquaculture into a professional industry

Aquaculture has become an industry, and it is necessary to organize farmers' associations, such as the National Collaboration Network for Eel, the Scientific Aquaculture Association, and others, in order for these to help in the management of the aquaculture sector and to coordinate the development plans for the industry. Detailed actions would include:

- collection and dissemination of updated information;
- exchange and dissemination of experiences (e.g. production techniques, marketing etc.); and
- guarantee the support and benefits of the industry.

Economic and social expectations of aquaculture

Aquaculture can effectively promote economic development and societal progress. Firstly, the basic expectation for aquaculture should be that it should be an activity to guarantee the supply of fish products and, hence, food security, thus contributing to social stability and development.

Secondly, aquaculture can create significant employment opportunities, absorb and utilize surplus rural labour, encourage women and young people to be engaged in production activities, increase farmers' income and assist in poverty alleviation. Aquaculture development can also provide opportunities for leisure and recreation through sports fishing and tourism.

Thirdly, the awareness of the needs for environmental protection and social responsibility should be heightened when developing aquaculture. It is the duty of the sector to control pollution and resource degradation and to meet the needs of current social and economic development, achieving these aims without threatening the viability of the resource for the next generation.

Fourthly, aquaculture should be developed as an economic activity that can provide significant export earnings. As the world economy becomes more and more unified, it is necessary to take advantage of resources and technology to advance the economy and improve the stability of society.

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[3] This refers to a national campaign in China in the late 1980s and early 1990s to convert low-lying and saline-alkaline or waterlogged lands that are not suitable for crop production into fish ponds for large commercial-scale freshwater fish (in some cases also for shrimp and brackishwater species) production. With the expansion of pond area to approximately 500 000 ha, a significant increase in fish production was achieved.

[4] FAO statistical data show 27 million mt because FAO counts shelled weight for molluscs and live weight for seaweed, while Chinese figures are in meat and dry weight, respectively.

[5] 1 US$ = 8.27 Chinese Yuan (exchange rate for 2000).

Aquaculture Development Trends in Latin America and the Caribbean

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ABSTRACT: Aquaculture production from the region in 1997 was 2.1 percent of the volume of world aquaculture output and 5.1 percent of value. It was 4 percent of the total fisheries production in the region. Real annual growth of production in the South American Subregion was about 20 percent. Farmed production was concentrated in salmonids (in Chile) and shrimps (in Ecuador, Mexico, Honduras, Colombia Peru, Panama and Belize), which were mainly export products. It is estimated that 90 percent of cultured shrimp and salmonids, 50 percent of tilapia and 90 percent of Gracilaria seaweed (Chile) are exported. Oysters account for about 65 percent of molluscs in the region, and freshwater fish farming accounts for more than a fifth of the total volume of aquaculture production. Tilapia culture (Colombia, Brazil, Mexico, Cuba, Costa Rica and Jamaica) has the highest growth rate. Carp production (Mexico, Cuba and Brazil) is mainly of two species and has been increasing, as has Colossoma spp. (in Colombia, Brazil and Venezuela). In recent years, diseases have had a major impact on shrimp aquaculture. Salmon production has been less affected by disease. Growout feed production is dominated by a small number of feed companies. The environment has a substantial impact on aquaculture, particularly in the coastal areas, and natural disturbances such as the El Niño episodes and hurricanes represent a major risk to aquaculture enterprises. Laws and regulations on the environment and aquaculture are complex and often unmanageable. Legal and institutional constraints exist regarding the development of export-oriented aquaculture. An important role of the state will be to improve the efficiency of the sector through the development of information systems in support of farmers and investors. Trade agreements, both bilateral and multilateral, have played an increasingly important role in international trade in aquaculture products. For instance, the Southern Common Market (MERCOSUR) Agreement has stimulated trade, promoted fair competition, increased investment opportunities and protected and enforced intellectual property. Due to the social and economic situation in Latin America, aquaculture production tends to place priority on the generation of foreign exchange. Although industrial aquaculture has generated a lot of employment in countries like Ecuador and Chile, the real potential of the region lies in the medium and small-scale rural aquaculture which strongly depends of government participation in aquaculture development. Fish culture development by small-scale companies is limited by the difficulties arising from macro-economic policies, privatization and national budget reductions. The current trend away from state involvement may actually serve to constrain such development. As Latin America moves away from "big government", rural aquafarmers will need to find alternatives to support development. With industrial aquaculture, the government is providing an enabling environment rather than taking a direct role in it. The availability of land for the expansion of export-oriented aquaculture is not a problem; for example only 16 percent of the available area suitable for shrimp culture is under cultivation. An additional 2-3 million mt of fish will be required for Latin American consumption by 2010.

KEY WORDS: Latin America, Caribbean, Aquaculture, Fish Farming, Development

Introduction

Aquaculture began in Latin America2 and the Caribbean3 in the 1940s, mainly for recreational and restocking purposes. In the 1960s and 1970s, the activity was oriented towards the production of food for local consumption and for the diversification of rural activities related to agriculture and animal husbandry. During the past 20 years, the development of aquaculture has been significant within the region. The implementation of the latest production systems and the use of new technologies have enabled the players to manage their productive resources more efficiently, enabling the sector to contribute significantly to food supply, employment and foreign currency. These factors are all of great importance to the countries in the region, and both marine and freshwater aquaculture offer a productive alternative of considerable social and economic value.

Aquaculture development

Changes in developmental processes and macro-economic policies, leaving protectionism for the conditions of the open market, have had a considerable impact on the farming systems used, management and the ability to penetrate foreign markets. The Some developed countries have adopted nontariff entry barriers that create obstacles, which limit the growth and potential contribution of commercial aquaculture in the region.

Regional macro-economic conditions which affect aquaculture adversely are numerous and include export market fluctuations, financial crises, demand stagnation, high unemployment levels, fiscal deficit, institutional reforms and regional integration processes. Obviously, these factors are of great concern to entrepreneurs who are engaged in the production process since, if they are to compete in global markets, they need to achieve their production and marketing objectives in efficient and profitable conditions.

Many Latin American countries, including Argentina, Colombia, Chile, Brazil, Ecuador and Venezuela, have experienced periods of economic recession, inflation and interest rate fluctuation. Due to these unstable and changing economic environments, it is difficult to achieve accurate economic forecasts. Furthermore, governmental restrictions, such as applied to trade terms and/or tariff modifications, can also greatly affect farming operations and production. Economic and trading information is either not available or difficult to obtain from farming combination of privatization with government spending reductions has limited considerably the performance and development programmes in rural aquaculture areas. These areas have also been negatively affected by the reduction of financial resources available from international cooperation agencies.

Increasing competition within the local market has occurred, where products of small-scale aquaculture are competing with the lower prices and higher quality of imports or large-scale domestic production. Value is now added to the products of national aquaculture, produced from extensive, semi-intensive and intensive aquaculture systems, by providing a more competitive and attractive commodity for the consumer. This has been achieved through the use of innovative technologies and capital investment and allows the domestic product to be more competitive, not only with imports on the local market, but also within target export markets.

Farm-raised aquaculture products must meet specific international standards, not only for the environmental protection of natural resources, but also for the postharvest conditions required. Such standards invariably increase production costs and, in some cases, limit the commercial potential or market scope of the products.

companies. The combination of all of these factors limits a true economic evaluation.

In the past, the entry of regional products into the international trade markets was difficult, usually because either the domestic product was substandard or the manufacturer was unable to diversify sufficiently. Currently, domestic producers are trading within the international arena, allowing them to intensify the export of finished products and to liberalize the import of required raw materials.

The further development of aquaculture in Latin America will depend on the successful application of efficient technologies, innovation, modernization and reconversion processes. It will also depend on decreasing production and labour costs, producing a high-quality product, understanding the market and obtaining an adequate return on investment.

Aquaculture production

In the decade under study, 1988-1997, aquaculture has experienced a significant growth in 21 countries of the region. Total regional aquaculture production increased from around 87 000 mt (1984) to 179 000 mt in 1988 and to 783 000 mt in 1997. During the same period, the value of regional aquaculture rose from US$344 million in 1984 to US$852 million in 1988 and had reached US$2.7 billion by 1997.

Figure 1 demonstrates the manner of the growth during the decade, showing both volume and value. Within this overall picture, there are other observations that will be

Within the region, six countries contributed 93 percent of production in 1997 - Chile (48 percent), Ecuador (17 percent), Brazil (11 percent), Colombia (6 percent), Cuba (6 percent) and Mexico (5 percent). This demonstrates significant change from the position seen in 1987 when Ecuador (48 percent), Cuba (12 percent) and Mexico (11 percent) were the dominant producers.

Regional aquaculture has concentrated on two main products, salmonids and shrimp, whose production is predominantly exported to the United States, Japan and Europe. Salmonid production in Chile (1997) comprised 32 percent (247 970 mt) in volume and 32 percent in the value of the total aquaculture production in the region. Shrimp production in Ecuador represented 17.3 percent (132 709 mt) of the volume and 32.4 percent of the value of the region.

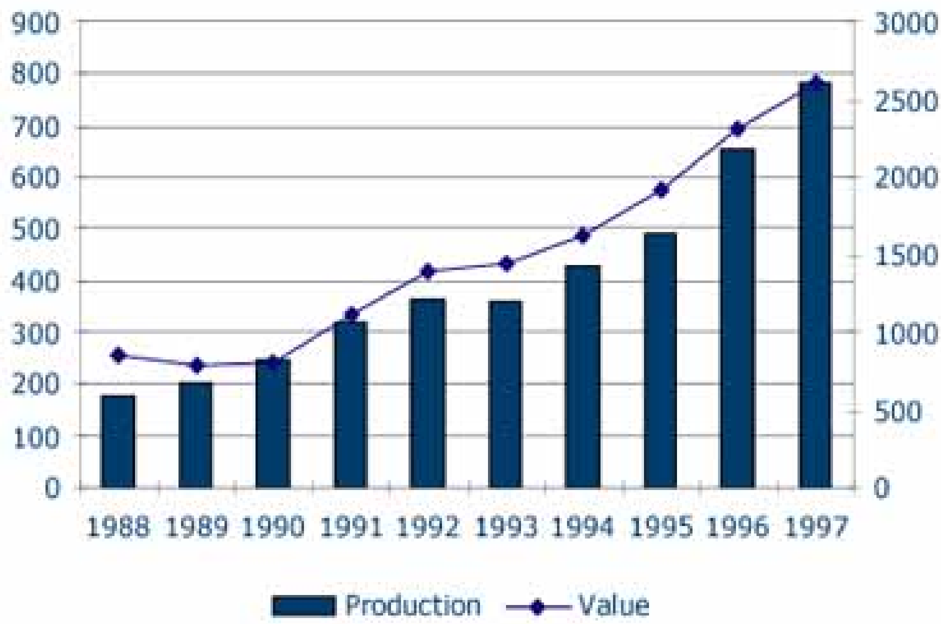
Salmon farming development has been concentrated almost exclusively in Chile, with production rates higher than any other aquaculture activity in the region. The 171 000 mt produced in 1997 represented 23 percent of world-wide production, placing Chile second after Norway.

Trout farming gave nearly 91 000 mt, or 35 percent of salmonid production in 1997 and has played an important role in the growth of developed further in this document. The APR [Annual Percent Rate of growth] for the region, representing aquaculture growth for the period under review, were 18 percent for volume and 13 percent for value. The Caribbean had lower APRs, 11 percent for volume and 8 percent for value. In 1997, the Caribbean countries provided 6 percent of the regional aquaculture volume but only 2 percent of the value, where Cuba is responsible for 92 percent of the production reported.

With the Latin American countries providing 94 percent of regional aquaculture production, one can note the importance of the activity in Chile, Ecuador, Brazil, Colombia and Mexico. For the period under study, South America and the Caribbean contributed some 80 percent of aquaculture production, while Central America and Mexico supplied 20 aquaculture in Chile, Colombia, Mexico and Peru. Between 1988 and 1997, these countries contributed 91.4 percent of the total production in the region.

In the 1990s, marine shrimp farming developed considerably in Colombia, Honduras, Mexico and Ecuador. In fact, Ecuador was the centre of shrimp farming, producing approximately 14 percent (132 709 mt) of the total world-wide production.

Figure 1. Aquaculture production in Central America (1988-1997) . (FAO, 2000)



percent (Table 1).

In global terms, while aquaculture production in the Latin American Region represented only 2.2 percent of the world's production in 1997, its contribution has doubled during the decade (1.1 percent in 1988).

The value of regional aquaculture has grown three-fold in the decade, and nearly eight-fold since 1984. By 1997, sales from South America represented 77.4 percent of the regional total, with the Caribbean providing 2 percent. During the 1990s, the export increases seen for Chile, Ecuador, Colombia and Honduras reflect the increased aquaculture production in these countries.

Table 1. Total aquaculture production by commodity for Latin America and the Caribbean, 1988-1997

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Aquatic plants	23 113	36 154	38 122	57 683	47 814	48 703	65 803	49 226	105 472	102 928
Crustaceans	91 048	91 983	103 044	137 386	152 839	131 105	147 107	163 983	164 550	201 404
Demersal marine fish	0	6	5	13	32	42	366	332	480	301
Freshwater & diadromous fish	56 860	67 935	94 719	113 516	151 301	168 209	196 349	252 756	356 063	443 248
Marine fish nei[1]	0	1	0	0	0	0	0	0	0	1
Miscellaneous aquatic animals	120	80	140	120	150	230	230	414	531	659
Molluscs	5 322	5 082	7 363	8 776	9 098	10 947	18 158	22 590	27 699	34 587
Pelagic marine fish	2 384	2 484	1 484	2 000	1 297	1 119	997	752	380	252
Grand total	**178 847**	**203 725**	**244 877**	**319 494**	**362 531**	**360 355**	**429 010**	**490 053**	**655 175**	**783 380**

[1]nei = not elsewhere indicated.

For molluscs, production has centred on oysters, scallops and mussels. During the past 10 years, mollusc production has grown especially in Chile, Mexico and Brazil, starting with 4 000 mt in 1988 and reaching 35 000 mt in 1997 (Fig. 2).

Freshwater fish farming, with 130 000 mt, represents around 17 percent of aquaculture production, where a wide range of species are of interest. Important quantities of cachama (Brazil and Venezuela), carps (Brazil and Mexico), characins (Brazil) and catfish (Brazil and Mexico) are being farmed. Twenty

In respect of aquatic plants, the seaweed Gracilaria spp. stands out (over 100 000 mt in 1997), being produced primarily in Chile. This activity has demonstrated constant growth, both in volume and value, where Gracilaria is mainly used in the agar-agar industry and is in constant demand (Fig. 3).

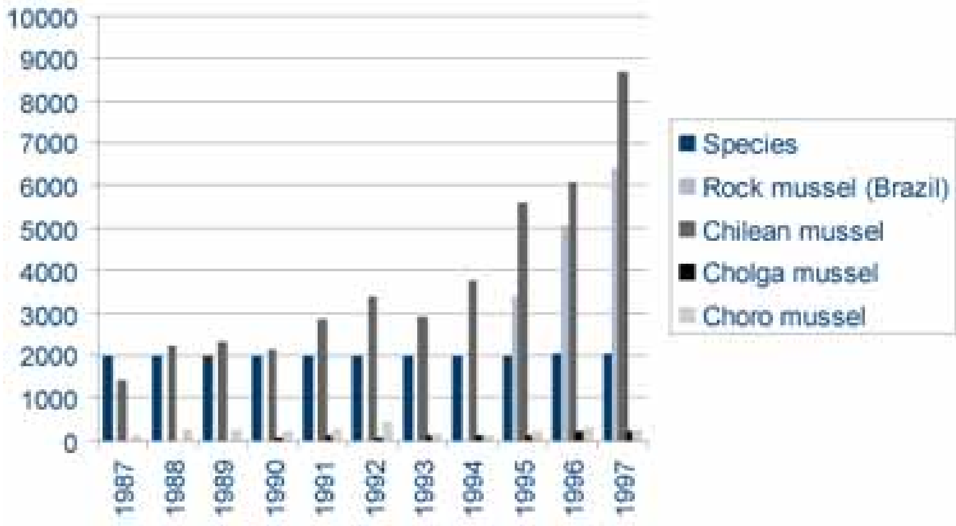
Challenges and opportunities for future development

In Latin America, aquaculture is of great importance, contributing to food production, land diversification in rural areas and coastal zones, employment and foreign currency earnings. Therefore, the factors required for the success of aquaculture are social equity, favourable environmental conditions and products that are competitive and diversified.

Within the region, remarkable changes have occurred in the social and economic development of the countries. Although local economies have benefited socially and economically from aquaculture production activities, they must also be willing and able to globalize their economies in order to meet the standards and conditions of international trade.

thousand metric tonnes of rainbow trout is farmed, being produced from eight Latin American countries. While many countries have started to produce tilapia, the main producers (Colombia, Brazil, Mexico, Cuba, Costa Rica and Jamaica) contribute 95 percent of the volume.

Figure 2. Trends in mussel production in Latin America from 1988-1997. (FAO, 2000)



Carp production in the region is concentrated in two species, silver carp (Hypophthalmichthys molitrix) and common carp (Cyprinus carpio). Production has increased in Brazil, Cuba and Mexico, where 97 percent of the farms are concentrated, providing 67 000 mt in 1997. The same growth trend can be observed for the cachamas (Colossoma spp., mainly C. brachypomum). During the past 10 years, the production of Colossoma has risen from 400 mt in 1988 to nearly 20 000 mt in 1997, mainly in Colombia, Brazil and Venezuela.

Policy makers and commercial farmers need to be aware of new trends in production, technological improvements, quality issues and marketing strategies, both in national and international markets. The further development of marine and freshwater aquaculture in the region will depend on the success of competitive commercial integration strategies in the international arena.

To be able to enter and compete in international markets, sanitary and environmental issues must be addressed in detail. These issues are outlined in the Hazard Analysis Critical Control Point (HACCP) process and the Code of Conduct for Responsible Fisheries (CCRF). These international standards require aquaculture producers to follow rules regulating production activities, postharvest practices and preservation of natural resources.

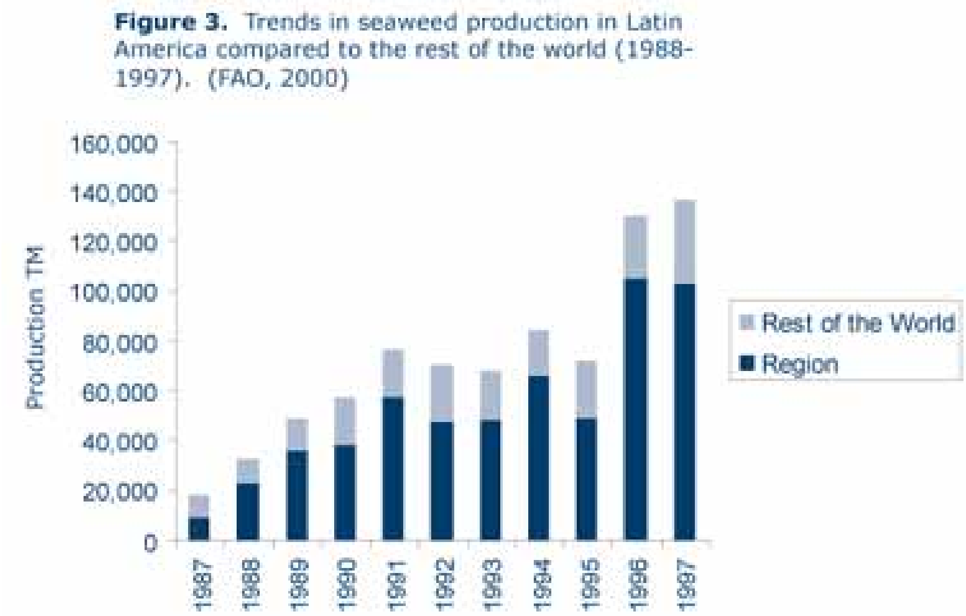
Aquaculture development review by major commodities

Shrimp aquaculture

Production and development trends

Latin America and Southeast Asia are the largest producers of farmed shrimp in the world. Since the 1970s, many investors in Latin America have put their capital and effort into shrimp production, resulting in rapid growth and expansion of the sector. The dominant shrimp species in Latin America are the white shrimp (Litopenaeus vannamei) and the blue shrimp (L. stylirostris).

Currently, commercial farms exist in 20 countries of the region. The private sector has thus played a key role in the development of shrimp culture in Latin America, which is composed mainly of small and mid-scale companies that have access to private and public capital. Additionally, these companies have been able to access technology that has allowed production process improvements, enabling improved competitiveness in the marketplace.



Commercial shrimp farms in the region vary between 10 and 500 ha in size, and most systems are semi-intensive. Management uses qualified personnel, and most operate at high professional levels. Shrimp farming, processing and marketing generate more than 750 000 direct and indirect jobs in the region, resulting in a favourable social and economic contribution. In the region, governments generally acknowledge shrimp farming to be a genuine mechanism for diversification of the economy, for generating employment in economically depressed areas and to earn hard currency. Export earnings from international shrimp sales, therefore, assist the payment of the foreign public debt.

Obtaining reliable production data can be difficult in Latin America due to a number of reasons. One example is that producers are discouraged from reporting their entire yields due to taxes imposed by some countries on shrimp production. Another factor is the producer’s fear of publicizing what he is (or is not) capable of producing. Finally, there is considerable statistical confusion between shrimp produced by aquaculture and those taken from fisheries.

The main producing countries, in order of importance (1997), are Ecuador, Mexico, Honduras, Panama, Colombia, Peru, Venezuela, Nicaragua, Brazil, Costa Rica, Guatemala and Belize. In 1997, 88 percent of penaeid shrimp production was provided by the combined production of the first five countries. Production estimates for 1998 were approximately 218 000 mt. The APR fluctuated considerably from 1988 to 1997, ranging between -15 percent and 34 percent, with an annual average of 10.3 percent.

Disease outbreaks affected the sector in most countries of the region during the 1990s. Despite these circumstances (for example, the Taura syndrome that appeared in 1993), a significant trend to increase production has been reported.

In 1997, countries in the Western Hemisphere produced over 200 000 mt, equivalent to 21 percent of global production, while Ecuador was the third largest individual producer (after Thailand and Indonesia), representing 13.3 percent. While other regional countries make less important individual contributions (none over 2 percent), their combined production provides 6.4 percent of global production.

The region possesses over 240 000 ha of ponds, which represents 28 percent of the estimated global pond surface (869 470 ha). Of note is the fact that the region's production is made by 2 percent (2

scourged Central America in October 1998, primarily Honduras and Nicaragua, causing water overflow conditions in 50 percent of the pond area. Honduran and Nicaraguan production companies incurred losses estimated to be at least US$50 million. Fortunately, the infrastructure of most farms did not suffer large damage and many are now back in production.

In Asia, WSSV has caused severe economic losses to the shrimp industry; due to the effects of the virus, China reported losses of US$1 billion in 1993, while in 1995, Thailand lost over US$500 million. At the end of January 1999, WSSV was detected in Nicaragua, Guatemala and Honduras. Later, the virus was also reported in Panama, Ecuador and on Colombia's Pacific coast. Most countries in the region have now closed their frontiers to imports of larvae, as well as broodstock. Despite great losses caused by WSSV in Central America, it is important that the industry understands that such a

617) of the estimated total number (171 450) of shrimp farms world-wide, indicating that the farms in the Western Hemisphere have a much larger surface area than their counterparts in the Eastern Hemisphere. The region has approximately 471 hatcheries that produce shrimp postlarvae for seeding, and they provide 11 percent of the world-wide total (4 189 mt). The annual productivity rate is approximately 941 kg/ha which, although varying between 727 and 3 750 kg/ha/year, is 9 percent higher than the global average of 861 kg/ha/year.

In the region, countries can be grouped into three basic productivity categories (Table 2), based on production, pond area and time (mt/ha/year):

- less than 1 mt/ha/year - includes those countries where productivity is low despite large growing areas (e.g. Ecuador, Honduras and Nicaragua);
- between 1-2 mt/ha/year - includes countries with mid-size production and medium productivity (e.g. Guatemala, Brazil, Belize, Panama and Mexico); and
- more than 2 mt/ha/year - includes countries with high productivity rates, limited production areas and relatively high production costs (e.g.

situation can be managed. It has been reported that some shrimp farms in Brazil, Ecuador and Honduras are using tilapia with shrimp in polyculture at commercial levels, in spite of the fact that many shrimp producers have considered tilapia to be an undesirable species. However, in zones severely affected by Taura syndrome, shrimp survival rates apparently improved when tilapia was included in polyculture.

Commercialization and markets

Shrimp is the main crustacean product that is traded on international markets, and Latin American shrimp production is intended primarily for the United States market, as "tails only" product. Some producers have trade contracts with European countries for the whole "head on" shrimp, while others trade with Japan. All three markets are very demanding in terms of quality and processing standards. During the past decade, Latin American shrimp aquaculture experienced significant growth and, as a consequence, the selling structures established in the 1980s changed drastically. These marketing changes, accompanied by the Asian economic crisis, confirmed predictions that prices would eventually decrease and that trading patterns with North America would have to be revised. This forecast was confirmed in 1998, when local production in the United

Colombia, Costa Rica, Peru and Venezuela).

Hurricane Mitch and the appearance of the white spot syndrome virus (WSSV) are two events that caused significant negative impacts on shrimp production in Latin America. Hurricane Mitch

States plus imports increased by 19 percent, resulting in a significant fall in shrimp prices.

Over the last 15 years, seafood consumption in the European Union (EU) grew significantly, for a number of different but complementary reasons.

Table 2. Summary of shrimp production systems used in Latin American countries.

Country	System		Yield (kg/ha/year)	Species Used
Ecuador	Extensive Semi-intensive	40% 60%	813	*Litopenaeus vannamei* (95%) *L. stylirostris* (5%)
Mexico	Extensive Semi-intensive Intensive	30% 60% 5%	708	Introduction of "super-shrimp" in the states of Sonora and Sinaloa (West of Mexico) has caused the "blue boom" in shrimp culture. Many farms still culture *L. vannamei* and some have cultured it along with *L. occidentalis* (low growth). However, some farms culture ponds with 100% of "super-shrimp". Species rotation: *L. stylirostris* by *L. vannamei* in warm season/*L. californiensis* by *L. vannamei* in cold season
Colombia	Semi-intensive	100%	3,750	*L. vannamei* (95%) *L. stylirostris* (5%) Commercial experiences with *L. schmitti* (included in programme of genetic improvement)
Honduras	Extensive Semi-intensive	20% 80%	857	*L. vannamei* (90%) *L. stylirostris* (10%)
Panama	Extensive Semi-intensive	10% 90%	941	*L. vannamei* (95%) *L. stylirostris* (5%)
Peru	Extensive Semi-intensive Intensive	5% 90% 5%	1,563 (2-2.5 harvests/year)	*L. vannamei*, as main species *L. stylirostris* occasionally
Venezuela	Semi-intensive	100%	3,500	*L. vannamei* (95%) *L. stylirostris* (5%)

A decline in red meat consumption, increased dietary awareness, strong seafood advertising and enforced controls on fishing quotas are among the factors that have combined to increase demand that is not satisfied by EU seafood production.

The EU is increasingly dependent on imported seafood products to satisfy the consumer demand for seafood, and advertising efforts, generic or specific, are increasingly required within a competitive marketplace. Access to the EU's seafood markets requires conformity to very strict

These concepts are within the origins of the programme for HACCP, a system which regulates, from a sanitary point of view, all fishery and aquaculture products entering into the United States. For the European market, this condition was made mandatory through Directives 91/493/CEE and 94/356/CEE.

With the expansion of shrimp aquaculture, concern has been raised as to the possibilities of introducing pathogens through the increased transfer of live organisms. The risks identified can affect not only shrimp aquaculture but also the natural, wild sanitary standards, which are designed for the guarantee of products of the highest quality and assure consumer protection. EU countries with the highest rates of seafood consumption include Spain, France, Italy and Germany and, combined, they import over 22 percent of global production. The EU's dependence on Latin American production has increased significantly due to the restrictions imposed on EU fisheries.

Farmed shrimp in Latin America has been recognized for its standard of quality, this being a result of the advanced technology used by the industry and the use of efficient controls to fulfil national and international sanitary regulations. With the increase of exports to developed countries, it has been necessary to maintain quality standards and to guarantee the appropriate packaging and labelling.

populations. Control measures on translocation vary with each country, but there is genuine concern in the region that farming practices in the coastal zones of one country can affect its neighbours. As a consequence, in clear recognition of this issue, producing countries have established quarantine procedures to prevent the dispersion of aquatic diseases through live transfers.

Environmental aspects

The expansion of shrimp farming has caused enormous ecological concerns in the international community. These ecological issues include the prevention and implementation of corrective measures, mangrove destruction and water pollution.

Other concerns include how farming affects native populations of wild shrimp, the length of culture periods and the salinity of agricultural grounds. These concerns have become the limiting factor for the expansion of the shrimp industry in Latin America.

Avoidance of the destruction of mangroves has become the main concern of both shrimp producers and environmentalists, but accurate information as to the sum of the mangrove forests destroyed in relation to the shrimp culture in the region is difficult to quantify. Agriculture, salt production, urbanization, wood extraction and mining are all activities that have had impacts on the mangroves.

The use of more intensive production systems has raised the level of environmental concern as to the quantity and quality of effluents generated by shrimp farms. These effluents could potentially change the water and the composition of sediment in the surrounding areas, causing biological changes in the benthic structure. The majority of shrimp farms have established mechanisms for effluent control, including measures such as water and sediment management techniques and polyculture systems using filtering organisms and biofilters. These control methods have improved the efficiency of use of feeds and fertilizers, minimizing

Diseases and pathogens

Perhaps the most important constraint in the development of the shrimp industry in Latin America in the past decade has been the appearance of infectious and noninfectious diseases. Estimates indicate that the world's production of shrimp did not increase significantly in terms of volume since 1994 due to the emergence of diseases.

Among the wide range of infectious illnesses that can occur, viral diseases caused the greatest concern for the industry, government and environmental groups. In 1989, six viruses affected the genus Penaeus while, by 1997, over 20 viruses were identified as having affected wild stock and commercial shrimp production. These pathogens have great destructive power and can be disseminated through water and/or other carrier species. This is true for the yellowhead (YHV), white spot syndrome (WSSV) and Taura syndrome (TSV) viruses.

Diseases cause an estimated loss of US$3 billion every year within the world-wide shrimp industry. In the Western Hemisphere alone, TSV caused losses of US$1 billion. In the short term, the development of appropriate pathogen diagnostic techniques and evaluation techniques for conditions concerning the effects of organic and inorganic materials that are discharged into natural systems.

Biodiversity and genetics

A main concern of environmental groups is the effect of fishing for broodstock and postlarvae in the wild, where it is claimed that wild stock depletion would impact negatively on the biodiversity of the area fished, as well as diminishing the traditional shrimp fisheries (both artisanal and industrial). At present, however, there is no conclusive evidence that proves shrimp culture to have negatively affected traditional fisheries in any country in Latin America.

Another topic of concern is the potential for alterations to the genetic pool, in a specific country, caused by the international transfer of genetic material. It is forecast that such a situation would cause or favour the introduction of diseases to native populations. Researchers who have dealt with these issues have concluded that natural postlarvae and adult populations have decreased in number over the years, but have attributed this to the changes in the macro-regional climate and oceanographic phenomena, such as El Niño.

shrimp immunity will reduce the impact of infectious and noninfectious diseases.

Efforts to mitigate losses will be helped by the application of shrimp genetic research to the commercial sector. Researchers have domesticated wild strains of shrimp through quantitative genetic selection techniques. Research has been implemented to develop genetic manipulation techniques that allow the creation of genes that are resistant to specific pathogens and which are transmissible to progeny.

Research and development

In a joint research effort between the public and the private sector, Colombia has established a US$5.8 million genetic research programme on the Colombian variety of Litopenaeus vannamei. The goals are to improve the survival and growth rate (even when TSV is present) by 12 and 15 percent, respectively.

Since 1977, the Mexican private sector has sponsored a research project to domesticate and to genetically select the wild broodstock of L. vannamei, where "Nayari", "San Blas" and "Panama" form the initial group of broodstock. The selection criteria consider the parameters of growth, reproductive behaviour and physiological index.

Other countries in the region, such as Panama, Peru, Ecuador and Brazil, have also developed plans to start programmes for the genetic selection of shrimp. In Ecuador, joint efforts made by the National Chamber of Aquaculture and a prestigious research centre are being made to promote a comprehensive study programme. This programme will study molecular markers and indicators of different immunological stages of development and also establish levels of disease tolerance for specific shrimp populations.

Between 1989 and 1990, the exotic species L. vannamei and L. stylirostris were both introduced in Venezuela. Venezuelan legislation forced the industry to close the biological cycles of both species, avoiding the need to import or use wild-caught larvae. Presently

Projections of aquaculture feed production (for shrimp and other species) for the immediate future vary considerably, reflecting degrees of uncertainty towards production statistics. Balanced, manufactured feeds normally represent 40-50 percent of the variable costs of producing marine shrimp. The use of poor feeds can cause losses to farms due to low digestibility rates, nutritional deficiencies or even inadequate use. Mismanagement of feed distribution can lead to discharging unused feed in the effluent and result, potentially, in the pollution of the surrounding ecosystem.

In Latin America, information is scarce on the nutritional requirements of the penaeid shrimps used in aquaculture. World-wide nutritional investigations have focused on Penaeus japonicus, P. monodon and L. vannamei. These species require similar nutrients, but are produced at different quantitative levels. Unfortunately, research conducted in laboratory conditions is difficult to interpret to field conditions, due to the influence of natural biota obtained in extensive and semi-intensive culture systems.

Venezuela is free of TSV.

The success of the Venezuelan industry is based on the domestication of these species, where L. vannamei is at generation 15, while L. stylirostris is at generation 20. The maturation of captive stocks without ocular ablation, and the practices of selection and cross-breeding, have allowed farmers to improve the genetic characteristics of the broodstock. Following this methodology, a line of L. stylirostris tolerant to infectious hypodermic and haematopoeitic necrosis virus IHHNV (Super Shrimp) has been developed and is currently being used very successfully in Venezuela, Mexico, Honduras, Ecuador and Colombia.

Farming technology

The expansion of shrimp farming in Latin America can be related directly to the feeding strategies adopted by the production sector. In Latin America, most of the feeds used in semi-intensive and intensive systems are commercially made. This is unlike the situation seen in Asia, where it is estimated that 50 percent of production is reared using feed products made on-farm.

Global estimates indicate a production of farmed shrimp of 660 200 mt in 1997 (FAO, 2000). In Natural biota in ponds can significantly increase the production profitability margin for farmers, where manufactured feeds contribute 23-24 percent of the nutritional requirements and the natural pond productivity supplies the rest.

Of the essential nutrients, proteins are considered to be the most important, since they represent 70 percent of a shrimp’s dry weight. However, there is controversy as to the origin of these proteins and the costs associated with their inclusion in the shrimp diet. In Latin America, there is tremendous room for improvement in the field of feed manufacture for commercial shrimp aquaculture.

Reports indicate that, at a global level, the aquaculture industry has reduced its dependence on fishmeal in feed formulation. In 1997, production of fishmeal decreased by 1.4 million mt compared to 1996, attaining its lowest production level in 15 years. Many countries in the region have focused effort on finding alternatives (partial or total) for fishmeal. As an example, Mexico is evaluating the potential use of poultry by-products (hydrolyzed feather meal, viscera meal) within diets for aquatic animals.
Fertilization is recognized as an important nutritional source for semi-intensive shrimp culture, and it is important for pond managers to

1997, the world-wide production of balanced feeds for marine shrimp farming was 1.2 million mt (assuming a feeding conversion ratio of 2 to 1) with an estimated value of US$750 million.

develop an effective management programme of improving natural productivity through the use of organic and inorganic fertilizers.

Issues, constraints and opportunities for future development

Limiting factors for the future development of the shrimp-farming sector in Latin America and the Caribbean are as follows:

- environmental issues originating as a consequence of intensification and expansion activities;
- conflicts caused by the deforestation of mangroves;
- postlarvae and broodstock harvesting from wild populations;
- climatic phenomena, such as "El Niño", causing excessive rains and undesirable conditions affecting the quality of the product (taste) resulting from the excessive growth of micro-algae;

If producers have the ability to overcome the existing limitations, then their productivity and levels of production will improve.

Salmonid aquaculture

General overview

The culture of salmonid fish was introduced into the Latin American Region as a way of diversifying traditional, rural agricultural activities. Two genera of the family Salmonidae are Oncorhynchus and Salmo, which contain the species known colloquially as trout and salmon. They make up the main fish group reared in mariculture, and have the highest commercial revenue for maricultured fish species sold internationally. While Norway is the world's leading country for farming salmonids, a position that is dominated by

- establishing control over reproductive cycles;
- predominance of L. vannamei culture (90 percent);
- supplies of Artemia;
- supplies and costs of formulated feeds;
- existing legal and institutional framework in the different countries;
- social conflicts and economic problems faced by countries;
- commercialization of products in international markets; and
- viral disease effects, particularly through the dissemination of WSSV and YHV.

Latin America has extensive areas that are conducive to shrimp culture, but accurate data has not yet been compiled for the total potential area that could be applied. Current estimates indicate that the region possesses nearly 1.5 million ha for this type of aquaculture.

In the Latin American Region, governments and the private sector recognize shrimp farming as an important activity that makes significant contributions, including:

- employment generation;
- foreign currency inflow (through exports);
- production diversification; and
- improving market networks and commercialization.

salmon production, it is followed by Chile, the United Kingdom and Canada.

Trout is farmed both in fresh water, usually to be sold as portion-size fish, and in marine conditions for the production of individual sizes exceeding 1 kg. Numerically, countries in the region tend to focus on freshwater rainbow trout (over 21 000 mt in 1997), while regional marine trout farming is limited to Chile (61 492 mt in 1997). In Latin America and the Caribbean, the salmonid sector has not reached the industrial level desired, with the notable exception of Chile. However, in recent years, new technology has been adopted for feed manufacturing and rearing techniques, improving the productivity of traditional systems.

Trout

Between 1988 and 1997, Colombia demonstrated good growth for freshwater trout production, both in terms of the volume and the value of the activity. Production increased thirteen fold, resulting in a sales value increase from US$4 million to 43 million.

Trout aquaculture in Colombia is made up of approximately 35 companies, which generate more than 2 750 direct and indirect jobs. Most production is sold locally, although significant sales have been made in export markets. In Colombia, the competitiveness of trout farming is reduced by the high cost of feeds. This is despite the fact that Colombia offers great potential for expansion of the activity, including year-round fingerling supplies and available technology.

Elsewhere in the region, the performance of trout farming has been variable, tending to reflect the consolidation of existing farms rather than the construction of new ones. Marine trout production is concentrated in Chile, and its expansion has followed that of salmon, moving from 20 mt in 1988 to 69 000 mt in 1997. Since the marine production of large-size trout provides a product that is competitive with salmon, its characteristics will be grouped with those of salmon.

Salmon

Chile is the centre of salmonid culture in the region, reaching 248 000 mt in 1997, of which 171 000 mt (69 percent) were salmon species. It is also the only country of the region that produces salmon commercially. Salmon production Rainbow trout production started to increase significantly from 1991 onwards, almost matching coho salmon in importance by 1997. In 1997, Atlantic salmon contributed 40 percent of the total marine salmonid harvest, followed by coho salmon (31 percent) and rainbow trout (29 percent). Today over 60 operating companies are dedicated to this activity. There are more than 456 concessions (authorized by government) for farming, 1 400 hatcheries and approximately 4 500 ha in production. Approximately 80 of the 186 sites in the country that are authorized for fish culture are operating at present. The salmon producers had limited access to estuaries and freshwater bodies for the fingerling stages, a position that limited the acquisition of smolts (juvenile salmon of freshwater origin comprises two main species, the Atlantic salmon (Salmo salar) and the coho salmon (Oncorhynchus kisutch). Two other species, which are produced in lesser quantities, are the king salmon (O. tschawytscha) and the masu or cherry salmon (O. masou).

Production has increased from 4 200 mt in 1988 to 240 000 mt for 1997, representing a 57-fold growth and an APR of 51 percent. This significant growth is summarized in Table 3.

Chile’s growth in salmonid farming has been due to advantages in the following factors:

- a wide geographic range of farming locations;
- high water quality and purity;
- low input and operational costs; and
- stable economic policies.

Such suitable conditions have attracted foreign investment in aquaculture from countries like Norway, the United Kingdom and Japan. During this period of almost exponential growth with a median growth rate of 69 percent per year, it is interesting to note that while coho salmon was the dominant species from 1987-1991, from 1992 onwards Atlantic salmon has been the leader.

which can adapt physiologically to the marine environment). In 1992, the granting of concessions for such activities in these water bodies was terminated, but in 1996, the position was reviewed and new allowances were made that follow reviewed operating criteria prepared by national authorities.

Farming technology and farmers

The development of the salmon industry has had a great impact on the Chilean economy, becoming an important element in the evolution of the fisheries sector. Due to demand for the product and the growth of salmon mariculture, material and equipment suppliers for this industry have increased. Generally, most companies have several concessions on land and in the sea and usually produce more than one species. In the X Region (located in the south of Chile) companies have formed an association of salmon and trout producers, the Asociación de Productores de Salmón y Trucha. This association established the Instituto Tecnológico del Salmón (INTESAL), which channels technical and production information to the production sector.

Table 3. Marine production of salmonids, 1988-1997 (MT).[1]

Species	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Atlantic salmon	165	1 860	9 478	14 957	23 715	29 180	34 175	54 250	77 327	96 675
Chinook (=spring =king) salmon	3	11	316	1 059	667	859	379	371	341	738
Coho(=silver) salmon	4 040	6 930	13 298	17 954	22 165	25 150	34 524	44 037	66 988	73 408
Masu (=cherry) salmon	0	0	29	105	68	0	0	0	0	0
Rainbow trout	20	925	1 853	1 575	13 898	20 557	30 679	40 089	52 491	69 301
Total	4 228	9 726	24 974	35 650	60 513	75 746	99 757	138 747	197 147	240122

[1]Statistical Annual Fisheries Report SERNAPESCA (1997).

During the past few years, there has been a trend for the reorganization of the large-scale companies which have attained vertical integration in the culture stages (in fresh water and salt water) and economies of scale. Many have established systems for processing and the manufacture of a range of different products. It is estimated that 65 percent of the Chilean salmon production sector has been integrated with companies that supply materials and services (e.g. feed manufacturing, processing equipment, nets, workshops, laboratories, transportation etc.). The exponential growth of the industry has generated a large number of jobs in the country, reaching approximately 15 000 positions

On-growing or fattening is done entirely in sea cages stocked with smolts of 50-100 gm that are grown up to the commercial sizes.

The technology applied at all stages allows salmon farming to be done with celerity, efficiency and quality, combining cost reduction with the minimization of environmental impacts. Nonetheless, in comparison to European practices, mechanization and equipment in Latin America continue to be inferior. European aquaculture is constantly investigating and applying new technologies, a position that is clearly reflected by the number of people required to manage a farm. In Norway, a farm of 1 500 mt is managed by six people, while in Chile the same unit directly related to the culture process.

Medium- and large-size companies have diverse and complex organizational structures. In general, the managerial levels of all companies are comprised of engineers, biologists, technicians and veterinarians, such professionals representing 10-15 percent of the company's employees. The remaining staff have limited and/or specialized skills for specific functions, such as foremen, feeders, divers, switchmen and carpenters.

The main objective in recent years has been for companies to optimize their production processes and increase productivity. New technologies and management procedures have been adopted for optimizing different components of the production process, focusing on the areas that require specific work skills, such as feeding, harvesting and net-cleaning.

Initially, in Chile, most activities relating to salmon production were done manually. Today production units require new and efficient technology to enable cost reduction and to minimize environmental impacts. Many production units use automatic feeders, fish grading/counting equipment and waste food collectors underneath the cages. Some companies have would require 12-15 people.

Commercialization and markets

Chile is the second largest producer of cultured salmonids in the world (after Norway), the primary supplier of salmonids to Japan, and the second largest supplier to the United States (after Canada). It has achieved this position in the international marketplace due to its ability to produce a competitive product, surpassing national benthic and demersal fisheries. The success of Chilean aquaculture in respect of salmonid production is due to many factors, including favourable environmental conditions, low production costs, a global market for the product and the provision of public and private investment to the sector. Access to export markets has increased as a direct result of developments in quality control, value-added products packaging and presentation, and transportation and storage facilities.

Salmonid exports from Chile

The last decade has seen revenue generated from salmon exports increase exponentially, exceeding US$500 million in 1996. Chilean products are sold primarily to Japan, the United States and Europe. Intra-regional markets are marginal in comparison to these.

Each market has specific

invested in underwater camera monitoring, predator detectors and fish pumps as a way to mechanize and systematize operations. Complementary to technological development, some have plans for genetic improvement as a means for raising productivity.

Salmon culture is done in two phases, the first being in fresh water, while the second is in the sea. It starts with the incubation of spawn, requiring land-based systems for the growth of fingerlings. At the point where the degree of maturity allows transition to sea water, the juvenile fish are put into lagoons for "smolting".

requirements regarding the size and type of product. The Japanese market favours large rainbow trout and different presentations of frozen coho salmon (filleted or whole). The United States market prefers fresh Atlantic salmon, either as filleted products or whole. Finally, the major product for the European market is frozen Atlantic salmon, although limited quantities of coho salmon and large trout are also imported.

As production and export volumes increased, many producers invested in processing plants to make added-value products. Such products include smoked fillets and canned steaks/cuts and provide product diversification and access to higher revenue markets with lower price fluctuations.

Atlantic salmon, coho salmon and rainbow trout together have given

This situation has had repercussions in the amounts of hard currency obtained for export products.

During the past few years, there has been an increased trend to produce higher quantities of added-value products, resulting in a lower demand for traditional products such as frozen and fresh-chilled products. The provision of added-value products reflects a strategic an export volume of 98 percent of production during the last 10 years. In 1988, coho salmon led exports, surpassing rainbow trout, but by 1997, Chilean rainbow trout represented 27.5 percent (44 112 mt) of the total number of salmonids exported and 26.9 percent (US$180.3 million) of the total salmonid value. In 1997, Atlantic salmon lead the way with 40.4 percent (64 740 mt) in export tonnage and 43.9 percent (US$293.9 million) in export value.

The production of rainbow trout has gradually increased to a level similar to that of coho salmon, this being due almost entirely to the rearing of large-size trout in marine systems. Culture of this species in a marine environment allows producers to reduce costs and increase the culture area. In 1997, rainbow trout represented 29.7 percent (47 697 mt) of the total volume and 26.8 percent (US$179.6 million) of the total value of exported salmonids.

Due to favourable seasonable conditions in Chile, exports such as salmon have enjoyed a competitive advantage in international markets, a fact that is demonstrated by the availability of many Chilean products in the international consumer markets during periods of limited supply from other producing countries. On the other hand, the increased availability of fresh and business approach to attract more international customers and increase sales.

The value of Chilean salmon exports to other Latin America countries and the Caribbean has increased at an average annual rate of 50 percent, while the prices mirror the international market trends, dropping to US$5.60/kg in 1997. In 1995, Chile exported 3 965 mt, generating nearly US$20 million. The number of countries buying Chilean salmon increased from seven (1987) to sixteen (1997), where Brazil, Argentina and Mexico are the principal consumers.

Issues, challenges and opportunities for future development

In the past few years, a wide range of problems have affected the aquaculture industry in the region, including:

- wide variability in price (e.g. influenced by wild salmon stocks [Canada]);
- the economic crisis in Asia (a key target market);
- dumping accusations; and
- disease effects.

There are some unresolved issues relating to using estuaries for smolt production, but the establishment of new standards for aquaculture in estuaries was made by the national frozen products of Atlantic salmon, rainbow trout and coho salmon has reduced the local demand for salmon in Chile. Due to this position, salmonids are exported regularly throughout the year, but especially in the first four months, where the highest export levels are recorded in the months of February and March. After this period, export levels drop but continue at a stable rate. This situation reflects the production cycles of coho salmon and rainbow trout, although Atlantic salmon is harvested throughout the year, maintaining a more stable production schedule, albeit increasing towards the end of the year.

In the past few years, salmon prices have decreased world-wide, due to the sustained increases in production and problems in matching supply with demand. If markets accept increased supplies without increasing demand, then product prices will decline.

authorities in 1996, following an intermediate suspension in 1992. These standards stipulate the appropriateness of the resource for aquaculture, but exclude areas that are protected by government or allocated to alternative activities, such as tourism.

Aside from the increasingly competitive nature of the international salmon market, a United States producers' group recently accused the Chilean salmon sector of "dumping" in the United States market.

The United States imports some 30 percent of its salmon demand from the region (mainly Atlantic salmon), and while this position has not yet had a significant impact, it has encouraged producers to look for alternative markets, reducing their dependence on the North American market.

Chile has made development plans to maintain, even surpass, its position as the second largest producer of salmon in the world, and an increase in authorized production units for salmon and fish culture will assist the attainment of this goal. The estimated current short-term projection for fish production alone is over 375 000 mt.

Freshwater aquaculture[4]

General overview

Fish culture was developed initially in the region for the improvement of social and economic conditions in rural areas. Between 1988 and 1997, culture systems have been intensified through the use of technology, management, equipment and adapting to export requirements. Nearly all fish farming is done in fresh water, with only nominal amounts attributed to brackishwater culture.

This increase can be attributed partly to the demands for sport fisheries ("put and take"). In order to support the strong demand for cultured fish, cages, ponds and reservoirs are all used for production purposes. Costa Rica has developed tilapia farming quickly and considerably, primarily due to the adequacy of water resources. One site has access to 12 m3/second, enabling excellent production conditions. One company generates 35 percent of all tilapia produced in Costa Rica. In Colombia, fish farming almost doubled between 1992 and 1997. Cachama culture increased significantly, rising from almost nothing to nearly 12 000 mt within the decade, all of which is sold in the domestic market. These fish are raised in intensive conditions, usually in cages, and benefit from short growth cycles (150 days) and high stocking densities (120 kg/m3.) Tilapia production contributed over 16 000 mt in 1997, mirroring regular and important increases. Total freshwater production reached 37 000 mt in 1997 (including freshwater trout).

Fish farming in Mexico has also grown, albeit slowly, with increases noted for tilapia and carps, which are destined for the domestic market. In recent years, Mexico has increased significantly its fish culture activities in reservoirs and dams. In Venezuela, fish culture is

The main species cultured in this period were tilapia, carp and cachama, a mixture of native and exotic species. Almost all for the tilapia production (94.9 percent) was derived from six countries: Cuba (42.8 percent), Colombia (19.1 percent), Mexico (13.8 percent), Brazil (8.1 percent), Jamaica (6.6 percent) and Costa Rica (4.5 percent). Carp was cultured in Mexico (41.7 percent), Cuba (32.9 percent) and Brazil (25.1 percent), while cachama was produced in Colombia (65.6 percent), Brazil (23.7 percent) and Venezuela (10.7 percent). Freshwater production has risen four fold, from 53 000 mt (valued at US$97 million) in 1988 to 203 000 mt (US$535 million) in 1997 (FAO, 2000).

Aquaculture in Latin America has experienced tremendous production changes and is viewed by governments as a significant generator of employment and foreign currency. Furthermore, investment interests see aquaculture as an interesting and productive opportunity.

In Ecuador, the development of the tilapia production sector is a direct result of diseases that have affected the shrimp industry. Fish farming in Brazil has grown significantly, moving from 14 000 mt in 1988 to over 76 000 mt in 1997. developing where red tilapia and cachama production is starting to be significant, harvests increasing by six-fold between 1992 and 1997. In the Caribbean, fish farming is focused in three islands that provide 99 percent of production. Cuba is the biggest producer, cultivating nearly 44 000 mt in 1997. Tilapia and silver carp are the dominant species. In Cuba, a strong commitment has been made to develop semi-intensive and intensive pond culture of tilapia and carps for food security reasons. Growth rate of the sector may be expected to increase markedly. Jamaica has a long history of tilapia farming, but production growth has been slow, moving from 1500 to 2800 mt between 1988 and 1997. In all countries of the region, fish farming has provided employment for women, particularly in the postharvest and processing activities.

Enhanced fisheries in Cuba and Brazil have had a significant development. Since the 1960s, Cuba has successfully developed the extensive culture of several species of tilapia and carp in its big and small artificial water bodies. Recently, hybrid Clarias (C. gariepinus x C. macrocephalus) has been introduced and stocked in many of the reservoirs with very good results. In the northeast of Brazil, an already traditional culture of native species has been developed in its many small and medium reservoirs.

Farming technology and farmers

In the region, fish farmers, can be categorized by production capacity and degree of technological advancement into three groups – industrial, semi-industrial and artisanal. With respect to tilapia culture, industrial producers contribute some 20 to 25 percent of production, while semi-industrial producers provide 25 to 35 percent and the artisanal sector supplies 40 to 45 percent. For cachama production, about 70 percent comes from semi-industrial culture and 30 percent from artisanal activities. In Colombia, cachama and tilapia are farmed together in polyculture systems, but as mentioned earlier, a true analysis of the activity is difficult to obtain due to the lack of reliable data.

Industrial farms

Businesses that were constituted for the exclusive purpose of large-scale fish culture are included within this

Semi-industrial companies often produce in small ponds or reservoirs designed for storing irrigation water. Although this part of the fish-farming sector uses primary production techniques, productivity is often increased through the use of prefabricated feeds. Production is mainly sold for local consumption. A great majority of these fish-culture systems are also integrated with other agricultural activities and cattle farming, a situation that reduces the requirement for employees and nonqualified labour. For the semi-industrial group, access to credit is subject to the financial solidity of the operator/company.

Artisanal fish farming

Rural owner/operators compose the group of artisanal aquaculture producers, an activity where production is done in private or communal ponds. Extensive, small-scale culture systems are the only ones applied, using primary title, and most are incorporated as share capital companies using local investors. These are characterized by using intensive production systems, high technology levels and the consequent high expenditure in infrastructure and operating costs. The production systems allow for large stock quantities, the use of prefabricated feeds with distribution systems and the use of high volumes of water. One of the main products within the region is the "red" tilapia, a term that covers a number of hybrid strains of tilapia having red skin colour. Currently, there is a trend to gradually increase stocking densities to improve production. Industrial farms vary in size from 0.5 to 10 ha, although some are even bigger, and have the capacity to produce large quantities of fish. Another industrial production system being used is that of floating cages. Reservoirs can provide an appropriate environment, facilitating fish-culture activities. The managerial structure is similar to other production sectors, generating employment positions in breeding, pond management and postharvest activities. Some industrial enterprises are exporting large quantities of their products. Finally, industrial aquaculture companies have better access to national and international credit, through local financial institutions, than the other production categories.

production techniques and agricultural by-products for feeds. The family is in charge of pond management and the culture of the fish, while technical advice is provided by governmental agencies, albeit infrequently. Products from this sector are consumed by the family and/or sold locally. Artisanal producers live at low economic, social and cultural levels, conditions that do not allow access to technology, information, markets or credit. This situation severely limits the artisanal producer from further development.

Commercialization and markets

Fresh fish markets have evolved considerably in the region, especially in respect of the red tilapia. Red tilapia experienced tremendous growth, stimulated by industrial investments in production in a number of countries. While there have been difficulties for aquaculture to respond to the fish size preferences of consumers, tastes and habits have changed gradually and demand for smaller sized fish has increased. This has been demonstrated in several countries (e.g. Colombia, Brazil, Peru and Venezuela), where there has been considerable demand for cachama and smaller tilapia sizes. In the domestic market, reports indicate that frozen fish (whole and fillets) has had the greatest increase, while fresh fish (notably

Semi-intensive culture systems

Semi-intensive culture systems are the usual choice for the semi-industrial producer group, which is also characterized by owner management. Technical direction and management advice is usually provided by outside specialists.

red tilapia) is sold for export. While many countries' markets have started to provide added-value products (e.g. smoked and canned fish), this is still in the initial stages of development Reports made in the early 1990s indicated that the demand for fish would grow considerably, resulting in a real increase of fish prices.

It appears now that this demand grew more slowly than predicted, a direct result of economic stagnation. During this time, fish has also come under increasing competition from pork and poultry products.

Issues, challenges and opportunities for future development

The development of fish farming by small-scale companies in the region is very limited, due mainly to economic limitations. Commercial aquaculture faces environmental difficulties, notably from the introduction of exotic species, such as tilapia, that may adversely affect native populations and the natural environment. The intensification of

include Brazil (6 600 mt), Mexico (3 000 mt), Cuba (500 mt) and Peru (320 mt), while nominal production exists in Jamaica, Costa Rica, Colombia, Guatemala, Peru, Turks and Caicos, and the Netherlands Antilles.

Scallops, including fan-shells (Pinna spp.) and vieiras (Argopecten and Chlamys spp.), belong to the Family Pectinidae, which contains approximately 350 species. Approximately 15 of these species have economic importance in international markets. In 1997, world-wide scallop culture produced 102 741 mt compared to 12 438 mt produced in the region, a figure that represents 12.1 percent of the global production and a value of US$61.8 million.

fish stocks imposes the exchange of large volumes of water which, if highly charged with organic matter, can cause eutrophication and affect the aquatic ecosystem. In tilapia culture, it is important to maintain a high genetic quality within the stock and resistance to diseases. These are the key factors that adversely affect growth, harvest size and profitability. It is also important to control the movement of live species, reducing the risk of disease outbreaks, which can be damaging and expensive to eradicate. Factors that are required for the positive and progressive development of fish farming in the region are the following:

- incorporation of technological advancements;
- modernization of companies;
- human resource training; and
- consolidated information services.

The production of carp has not increased in most of the region due to challenging environmental problems, while recent significant expansion has been reported in Cuba and in Brazil. Cachama production has also developed considerably in Colombia and Brazil, a development that was stimulated by studies conducted within the region (by Brazil, Colombia and Venezuela, in this case) on the aquaculture of their native species. Important factors in cachama

Scallop aquaculture in Chile

Two species of scallops are produced in Chile, Chlamys patagonica (in the south) and Argopecten purpuratus (in the north). The production of A. purpuratus is of the most economic significance to Chile. Historically, Chile's scallop production was a harvest activity, but due to pressure by the fishing industry, a mandate was imposed by the government in 1986 to restrict this activity. In 1980s, scallop culture (A. purpuratus) was introduced in Tongoy Bay. Soon after, Chile established new zones for the production of scallops, located in the cities of Inglesa, Salado and Chiloé (in the south).

The scallop industry in Chile has grown significantly in the past five years, in both production and exports. Currently 27 companies produce scallops, either by collecting seed from natural beds or by using seed produced from 11 hatcheries. Hatcheries are a key factor in the successful growth of this industry. There are approximately 5 500 active culture lines in northern Chile5. Due to interest from salmon producers, 121 permits have been allocated for the cultivation of scallops, but only 10 of these are producing scallops at present.

culture are the technology for fingerling production and the practices required for extensive and semi-intensive culture within monoculture or polyculture systems.

Mollusc culture

Chile is the main producer (69 percent) of molluscs in the region, harvesting 24 098 mt in 1997. Other mollusc-producing countries

Farming technology and farmers

Scallop companies in Chile have diverse organizational levels based on capital investment and production capacity. Most have large concessions (more than 50 ha) and culture only A. purpuratus, the northern scallop. In northern Chile, the scallop companies have formed the Association of Scallop Producers of Chile, whose brief is to promote, develop and protect their activities and interests. In the past few years, capital investment has allowed a restructuring of the industry, focussing on vertical integration of the production stages, hatcheries and processing plants.

The rapid growth of this sector has generated employment estimated at over 3 000 jobs.

Commercialization and markets

Towards the end of the 1970s, the private sector increased its interest in scallop culture, due to the high values obtained in the international markets. This resulted in the establishment of pectinid farming in

Frozen product is marketed in 20-40, 40-60 and 60-80 lb packs. Package weights are directly related to scallop market prices.

There are significant differences in consumer preferences within the different target export markets. For example, the Japanese market consumes the entire scallop (mantle, adductor muscle or “corn” and gonads or “coral”), the

Chile, and scallop culture has become the third largest aquaculture activity in Chile after salmonids and seaweed. In 1997, Chile harvested 11 482 mt, placing it third in global scallop production after China (1 million mt) and Japan (254 000 mt). Chile's scallop farming has developed mainly in the north and is based on technology used in Japan involving various suspended systems. This technology has three production stages: i) collection of seed, ii) intermediate culture and iii) the fattening (growout) culture. In the past, Chile's seed production had been developed in a controlled environment, working with the production technology used for Japanese oyster seed.

Most operators monitor the sexual maturation period of scallops in culture in order to determine the spawning period. This surveillance is supplemented by plankton monitoring so as to quantify the larvae and determine the optimum time to set out collectors. Scallop seed (for culture purposes) is marketed at 3.5 to 20-30 mm, packed in polystyrene bags expanded by a sponge and dampened with sea water or ice.

The intermediate culture (nursery) immediately follows seed collection, and this phase involves the sorting and selection of seed (by length) and placement in different types of European market consumes only parts of the scallop (corn and coral), while the United States market consumes only the adductor muscle. In 1997, frozen scallops represented 81 percent of the total scallop export revenue, while fresh (19 percent) made up the bulk of the remainder. Canned and dried products combined represent less than 0.03 percent. Approximately 30 companies exported scallops in 1997, double the number reported in 1987.

Issues, challenges and opportunities for future development of scallop aquaculture in Chile

The Chilean General Law for Fisheries and Aquaculture allows the development of culture activities at the lower or bottom levels of the water column for growers who already have authorization to produce at shallower water depths. Many growers have made use of this law by designing enclosures/pens that reduce production costs and increase culture activities with low investment requirements.

France reported that they would change their rule that all scallops not belonging to the genus Pecten must be called "petoncles". "Petoncles" is the name given to species of lower size and quality, reducing the sale price. Since 1996, suspended systems for a period of three to six months. The fattening (growout) process is the final stage of the production cycle. The juveniles from the nursery stage of development are harvested, sorted and re-suspended until they reach a commercial size of approximately 90 mm in length. Alternative techniques for the fattening stage are the use of lanterns and mesh bags.

Scallop production offers many products for both domestic and international consumption. Live scallops are produced primarily for the domestic market. Fresh products are marketed (with or without the shell) for domestic and foreign markets, and frozen products are packed using Individual Quick Freezing (IQF) technology (vacuum-sealed polystyrene trays) for export (5-10 lb per package). Fresh product is marketed in 10-20, 20-30, 30-40 and 40-50 lb packs.

"Coquilles de Saint-Jacques" is the official name used for Pecten maximus, the native "great scallop" on the French market.

Oysters

There are about 200 "oyster" species in the family Ostreidae, of which around 12 have economic importance. In Latin America and the Caribbean, only Chile, Mexico, Cuba and Brazil devote significant production effort towards oyster culture. In 1997, the total oyster production in the region was just over 7 000 mt (with a value of nearly US$5.5 million) compared to the 3.1 million mt produced globally.

Oyster culture in Chile

In 1997, Chile was the primary producer of oysters in the region, with a production of 4 023 mt. Two species of oyster are cultured in Chile: Ostrea chilensis (the Chilean or native oyster) and Crassostrea gigas (the Pacific or Japanese oyster), which was introduced to South America in the late 1970s. Traditionally, the production of Chilean oysters was done by artisanal fisherman who harvested the product from natural oyster beds. Most fisheries were based out of the cities of Chiloé and Las Guaitecas in southern Chile and have been characterized by high variability in production. In Chile, Pacific oyster culture was started in Tongoy Bay and was made possible by development support from the Fundación Chile. The culture of Pacific oysters has now spread to other regions, and production has grown 4 000 percent between 1987 and 1997.

The oyster industry reported US$3.5 million in exports in 1997, against US$240 000 in 1987. This increase is mainly due to the sale of Pacific oysters, which represents 90.7 percent of total exports. In Chile, there are approximately 15 companies (in the north) dedicated to production of both native and Pacific oysters. Oyster culture does not require high levels of capital investment, and producers can

Commercialization and markets

The culture of the Chilean oyster started at the turn of the century, based mainly on the use of French technology. From 1940 to 1960, the state was involved in developing new technology designed for improved seed collection and growout technology that is still used today. The most commonly used seed collector is called the "collar." Once larvae attach to this, the collar is hung vertically from a line or raft. When the seed reach approximately 10 mm, they are stripped from the collector for grow-out to market-size (>50 mm). Two methods are used for this step, suspension on long-lines (hung from rafts) or in trays placed on the sea floor. The start of Japanese oyster culture used Japanese technology, which employs hatchery systems for seed production followed by grow-out. Chile has five commercial hatcheries for this purpose, and the technology is similar to that for the production of other bivalves. This includes selection and conditioning of broodstock, spawning and fertilization, and larval and postlarval culture. The hatchery process lasts approximately 14 days, after which the oysters are settled on to collectors. These collectors are then used to hang the oysters for grow-out. Sales start when the oysters reach or exceed 90 mm in length. In the past few years, overall harvest-based oyster combine the growout stage of oyster culture with that of other molluscs, such as mussels (choritos) and scallops. Unlike other aquaculture sectors, the oyster industry does not yet have producer associations that organize and address its needs and problems. In the same vein, not many companies have integrated their production processes and are still contracting support services, such as seed production, transportation, and plant and laboratory analysis.

The Chilean oyster is produced at two levels of operation, based on annual stocking - large (>1 000 000 oysters) and small (<1 000 000). Similarly, Japanese oyster production is classified at three levels of scale: large (>3 000 000), medium: (1 000 000 - 2 000 000), and small (<1 000 000). It is estimated that this sector generates some 600 full-time and 1 000 temporary positions yearly, ranging between 50 and 100 employees, depending on the scale of operation. Organizational structure is usually simple, where the owner manages the operational unit and usually participates in the production activities. Additional professionals assist with management and the coordination of operations, while field operators and divers (with specialized skills or training) assist with manual operations.

landings have declined world-wide. Therefore, oyster culture is a viable alternative to meet market demand, and culture now supplies almost 90 percent of the world's production.

In international markets, oysters of the genus Crassostrea (mainly C. gigas and C. virginica) are the most widely sold. Oysters of the genus Ostrea (mainly O. edulis and O. chilensis) are also consumed, but in lower quantities. Oysters are marketed not only as a fresh product but also as frozen, canned and as a concentrated juice.

Between 1987 and 1997, exports of Chilean oysters grew exponentially from a value of US$171 000 to US$3.5 million, a position that is attributed mainly to the Pacific oyster, which represents more than 90 percent of the total oysters produced. Most companies sell directly to the end user, although some may operate through intermediaries for certain markets. All Chilean oysters are sold domestically, where live oysters command the greatest demand. Pacific oysters are also in high demand. Some companies sell Pacific oysters exclusively for export, while others supply both domestic and international (primarily Asia and Oceania) markets.

Issues, challenges and opportunities for future development of Chilean oyster culture

The Chilean oyster has characteristics that make it attractive to consumers in the European market. The European market includes a related species, the European oyster (O. edulis), but due to disease, harvests have been seriously depleted. This means that the Chilean oyster has marketing potential both in Europe and the United States (which also grows European oysters). Nonetheless market expansion for the Chilean oyster will require strong marketing efforts.

The Pacific oyster is cultured widely throughout the world and has experienced rapid growth. It is well-known and consumed in many different regions. In Chile, environmental factors restrict the natural spawning of this species. Consequently, further growth and development depend on obtaining stable seed supplies from hatcheries. Despite this, the Pacific oyster has good growth potential for Chile, where its biological

Seaweed culture

General overview

Gracilaria spp. is the most common seaweed used for culture in the region, and Chile produces almost all that is reported. Two Chilean companies produce more than 99 percent of the 103 000 mt harvested. Peru and Venezuela produce very small quantities. In Chile, there are two species of Gracilaria, northern "pelillo" (G. lemanaeformis) and southern "pelillo" (G. chilensis). Their production is directly related to the demands of both domestic and international markets. The demand for "pelillo" is directly related to agar use in the international market (particularly in respect of Eastern Europe).

In 1997, global production provided 137 000 mt of Gracilaria spp., showing that regional production was responsible for 75 percent of supplies, worth US$41.2 million. Chile's dominance in this production means that detailed biological studies of this algae have been an integral part of the history of the development of the "pelillo" characteristics allow culture activities to be made along two thirds of the coastline.

Mussels

Mussels (Mytilidae) are found in both hemispheres throughout tropical and subtropical regions and live in protected and exposed areas, as well as subtidal and intertidal environments. The mussel industry has attained significant importance in the international market, with production levels reaching 1.4 million mt in 1997, representing an approximate value of US$507 million. In Latin America and the Caribbean, the production of mussels is limited when compared with world-wide production (1.4 percent), reaching nearly 20 000 mt valued at US$20 million. In Latin America and the Caribbean, 99 percent of mussel production is in Chile (9 084 mt; 58 percent) and Brazil (5 840 mt; 41 percent). The main products in the region are the Chilean mussel or "chorito" (Mytilus chilensis), which is produced primarily in Chile, and the South American brown or rock mussel (Perna perna), which is the main product in Brazil. Their combined value is approximately US$17.2 million.

industry.

Gracilaria production in Chile

Chile began exporting Gracilaria in the 1960s, and production was based in the country's middle and southern zones, where there are diverse harvesting grounds. In the 1970s, due to increased demand and high export prices, production of Gracilaria expanded into the north and, at a later stage developed further in southern Chile.

In 1982, the first production reports indicated harvests of 3 000 mt of seaweed. In the mid-1980s, the combination of the "El Niño" phenomenon and an increased capture effort caused a harvest collapse and the closure of extraction areas. This situation increased the interest in cultivating seaweed. During the 1990s, seaweed production increased significantly due to the development of cultivation, and Chile became the largest seaweed-producing country in the region, dominating production.

Farming technology and farmers

Chile has 380 Gracilaria production centres, managed primarily by private companies and unions. The unions include artisanal fishermen who produce and market their products within one group. The union associations in the south are the Federation of Seaweed Farmers Unions and Organisations of Chiloé and The Union of Artisanal Fishermen Directives of Chiloé.

Most companies own their production facilities or have marine concessions for processing activities. The artisanal fishermen and unions usually own a large number of concessions. Generally, companies are completely integrated, handling transportation services and seaweed processing plants that produce agar. The companies that are located in northern Chile process dry algae and handle export operations, while in southern Chile, algae are sold to agar processing companies. Neither the seaweed production companies nor the unions have professional associations that address their needs and concerns.

There are strict requirements concerning the quality of the raw materials used for processing and in order to improve the quality of Gracilaria production, training programmes have been implemented by the unions.

Algae are marketed as three product types - wet (90 percent humidity), pre-dried (40-60 percent humidity) and dry (18-25 percent humidity). The majority of wet or pre-dried alga is sold by unions through an intermediary who, in turn, sells it to the processing plants. Private companies sell the dry alga directly to the processing plants or export it to international markets. In Chile, 100 percent of the wet alga and 80-90 percent of the dry algal products are sold domestically, the remainder being sold internationally, primarily to Japan, Taiwan Province of China and Korea. The majority of production is thus for the domestic market.

Generally, algal production in Chile meets required industry standards for agar production, not only domestically but internationally. Furthermore, Chile’s production of Gracilaria supports its home agar

Government programmes have started the development of training programmes for culture management, scuba diving and production.

There are many methods for the culture of Gracilaria, and most of these have been developed in Chile using direct, indirect and suspended processes. Suspended culture is done in intertidal and subtidal environments. Direct culture involves planting the algal holdfasts directly in the substratum or on the seabed. This is done by digging a furrow (using a hoe or pitchfork) and placing Gracilaria stems in the furrow. Indirect culture involves tying the algae to a man-made substrate that is placed on the ocean floor. The most commonly used substratum is called the "chululo", which is made of a polyethylene sleeve filled with sand. Suspended culture involves tying algae to a matrix line which is suspended in the sea by wooden stakes. The algae grow on these lines until ready for harvest and sale. The unions have implemented a new process of inoculating the matrix line with spores, then tying on the algae and suspending it in the sea.

Commercialization and markets

The common or market names for Gracilaria spp. vary between countries and include "orgonori", industry, which represents 33 percent of global production.

Continual price fluctuations are the main problem for stability in the Gracilaria sector. Small artisanal producers need to improve the promotion of their image to buyers, focusing on their recent technical progress, innovations, and managerial and negotiating skills. This statement notes that the plants built for the production of agar, colagar, carrageenans and alginates are using the most advanced technology available in the country.

Conclusions

During the past decade, aquaculture has developed significantly in the region, reflecting the application of new technologies and production systems that have allowed production to be more efficient and effective. In the region, aquaculture is generally perceived by both the public and private sectors to be a favourable and profitable activity.

The environment for successful aquaculture development within the region has experienced a great deal of change. This is due to changes in macro-economic policies, institutional structures, legal issues and domestic and international markets. Future accomplishments will be highly dependent upon the

"Chinese moss", "sea string" and "pelillo". The main characteristic of this alga is that it can produce agar, which is a phycocolloid used in the food, pharmaceutical, cosmetic, microbiological and paper industries.

improvement and success of the economic, social and political environment in Latin America and the Caribbean.

In respect of policies for aquaculture development in the region, one can note a general trend for a decrease in direct state participation and a shift towards providing an "enabling environment". On the other hand, there is a lack of appropriate and available financial instruments for both the support and development of aquaculture, reflecting the region's limited credit availability and high interest rates.

Rural aquaculture development is dependent on government support, and the allocation of scarce funds is based on the level of poverty in the rural community in question. As Latin America moves away from "big government", rural aquaculturists need to find other alternatives to support sectoral development. Such alternatives

Aquaculture has the capacity to meet these objectives for regional countries. The production of shrimp and salmon has proved to be a major success in contributing to foreign exchange earnings. In recent years, the rate of growth of shrimp production has slowed down, while salmon production has increased exponentially. Molluscs, primarily scallops and oysters, and seaweed products (mainly Chilean) have also been exported from the region. The rate of growth in mollusc culture has been constant due to a strong demand by both international and local (mainly for mussels) consumers. Growth in seaweed culture has been limited due to stagnant demand within the agar market. The immediate potential for other species to contribute to foreign exchange generation is limited.

include public and private joint ventures, new extension approaches, credit and market support for low-input aquaculture, and tax credits.

Small-scale and subsistence aquaculture producers have been greatly affected by decreased state participation. The combination of privatization, state budgetary reductions for investment, and reduced international cooperation programmes has made it difficult for these farmers to obtain the degree of technical assistance that is needed to support their production activities.

The region has a large number of aquatic species available for exploitation by aquaculture. Unfortunately, the lack of adequate consumer markets for fish species such as cachama, chame (Dormitator latifrons) and carp has restricted this development. Also, other candidate species have not been developed adequately, due to the need for further development and refinement of the technology required.

The countries in the region have identified six important objectives, which have resulted from aquaculture production in their areas. These objectives include:

- increased foreign exchange earnings;

Aquaculture serves a double role in employment generation. Not only does it provide direct and indirect job creation, it also achieves this in areas that have traditionally low employment. The potential for aquaculture to continue this employment contribution, especially in rural areas, will depend upon the government's participation in and assistance to aquaculture development in the region. This is particularly true for aquaculture activities that depend heavily on state economic involvement. The current trend away from state involvement may actually serve to constrain such development.

Aquaculture activities play an important role in reducing the rate of rural migration to urban city centres, a situation that creates over-crowding and social problems. The creation of opportunities for investment and increased employment in rural areas is a means of decreasing this phenomenon. While aquaculture has an important role to play in reducing such migration, it needs to be properly planned and implemented if it is to have any long-term impact.

The availability of land for the expansion of export-oriented aquaculture does not appear to be a problem within the region. For example, estimates indicate that only 16 percent of the available land

- increased employment;
- increased protein consumption;
- decreased rural migration;
- poverty alleviation; and
- increased food security.

Due to the social and economic situation in Latin America, aquaculture production enterprises have tended to focus on generating foreign exchange and employment as the main priorities, while agriculture development has addressed the problems of food security and decreasing poverty.

area suitable for shrimp culture is currently under cultivation. However, the increased use of land for shrimp and salmon farming is likely to be subject to considerable environmental pressures and regulatory constraints. For example, the availability of suitable areas and government concessions for fingerling and smolt production could potentially limit the development of this sector in Chile.

In recent years, diseases (particularly viral diseases) have had a major impact on shrimp aquaculture, occurring principally in large production areas that use low-intensity systems. This makes disease control physically difficult, resulting in insufficient profitability. This situation does not justify the significantly increased costs required for disease prevention investments. Although salmon production has been less affected by disease, the continued success of this sector will rely greatly on the ability to keep the region free from

The environment has a substantial impact on aquaculture, particularly in the region’s coastal areas. Pollution resulting from agriculture and urban activities, as well as being self-generated, has affected the environment. Also, natural environmental disturbances represent a major risk to aquaculture enterprises. The impact of the El Niño and La Niña phenomena, along with hurricanes in Central American and Caribbean countries, has caused devastation of aquaculture enterprises and state infrastructure.

diseases that currently affect salmon producers elsewhere.

Broodstock and seed supply have also represented a major constraint to production increases, not only in terms of availability, but also in terms of health management. Several major initiatives are underway to develop methods for the use of specific pathogen-free and high-health seed production. These strategies involve domestication, allowing the development of commercial breeding programmes for the establishment and maintenance of desirable traits.

The high demand for postlarvae has resulted in the development of a substantial intra-regional market for shrimp nauplii and postlarvae. This has taken place in the absence of effective regulations for governing transfer and health certification. The heavy impact of WSSV and the likelihood that its spread arose from these transfers has increased the demand for better regulation of such movements within the region.

Feed supply is one potentially limiting factor in the development of the regional aquaculture industry. For example, Artemia for postlarval shrimp production is sometimes simply not available. However, there are many Artemia-replacement products available commercially, and it is expected

Laws and regulations governing the environment and aquaculture in the region have often been complex and unmanageable. These need to be reviewed and simplified to make them more easy to implement and enforce.

Legal and institutional constraints exist regarding the development of export-oriented aquaculture in Latin America. Provisions for an “enabling environment” regarding aquaculture investment and expansion are not consistent throughout the region. The openness of regional economies to foreign investment and the profit repatriation also differs greatly between countries in the region.

An important role of the state will be to improve the efficiency of the sector through the development of information systems which will support farmers and investors.

Trade-related issues will have an important impact on the future prospects of the export sector. Producer competition and consumer demands will intensify as production increases. Trade agreements, both bilateral and multilateral, have played an increasingly important role in the international trade of aquaculture products. The Southern Common Market (MERCOSUR) agreement that exists between Argentina, Brazil, Uruguay, that their development by private companies, usually outside the region, will continue.

Growout feed production is dominated by a small number of companies. The shrimp feeds used at present are relatively inexpensive and have a low protein content when compared to the feeds used in Asia. This situation may change, particularly if there is a trend towards intensification resulting from concerns about health management and profitability of the low-density systems. Increasing competition for animal feed protein requires the development of more nutritious and digestible feeds, as well as a reduction in the animal protein requirement.

Paraguay and Chile has stimulated trade, promoted fair competition, increased investment opportunities and protected and enforced intellectual property. On the other hand, trade agreements can also have a negative affect on aquaculture markets. An example of this has been the impact of the North American Free Trade Agreement (NAFTA) on the competitiveness of Chilean salmon compared to Canadian salmon.

The cooperation of regional organizations such as the Western Central Atlantic Fisheries Commission (WECAFC), the Food and Agriculture Organization of the United Nations (FAO), the Organisation of Eastern Caribbean States (OECS), the Caribbean Community Secretariat (CARICOM), La Comisión Permanente del Pacífico Sur (CPPS) and the Organizacion Lationoamericana de Desarrollo Pesquero (OLDEPESCA) combined with the external aid from programmes (e.g. Italian and Spanish Co-operation, European Commission and the United Nations Development Programme (UNDP)) will also have a positive impact on the success of aquaculture development in the region.

Aquaculture production has demonstrated its capacity for providing great social and economic benefits for the countries in the region. The continued growth and development of aquaculture industries will play an important role in the future success and prosperity of each country in the region.

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[2] Central and South American countries of the region: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, French Guyana, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay and Venezuela.

[3] Caribbean countries of the region: Bahamas, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Jamaica, Martinique, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Trinidad and Tobago, Turks and Caicos Islands and US Virgin Islands.

[4] This section excludes freshwater trout farming, which is presented in the Salmonid section.

[5] Source: Association of Scallop Producers of Chile.

African Aquaculture: A Regional Summary with Emphasis on Sub-Saharan Africa

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ABSTRACT: The African Region consists of 48 countries and five island nations, most of which are practising some form of aquaculture, often at a very low level. Over half the countries report producing less than 100 mt annually. The largest producer is Nigeria (17 700 mt) followed by Madagascar (5 100 mt) and Zambia (4 700 mt). The 1997 combined aquaculture production of the region was 40 300 mt. Aquaculture is estimated to be 95 percent small scale, with fish ponds integrated into the mosaic of agricultural activities. Mean yield is approximated as 500 kg/ha/yr, although the range is wide, from less than a hundred to more than 10 000 kg/ha/yr. A typical scenario would be a 300 m2 pond producing 15 kg a year relying on family labour and on-farm inputs. There is little reporting of production from the region's many reservoirs, although these are often exploited by nearby populations. Commercial finfish culture is fresh or brackish water, with Nigeria, Côte d'Ivoire, Zimbabwe, Kenya and South Africa being important producers. Commercial tilapia farms report pond yields of 10 to 15 mt/ha/yr, while Clarias yields can exceed 20 mt/ha/yr. Marine shrimp culture is concentrated in Madagascar, although a few farms are found in Seychelles, Mozambique and Kenya. Mussels, oysters, abalone and seaweed are also marine cultures in some countries.

Fish consumption has been decreasing as supply decreases relative to a growing population: from 9 kg per capita in 1990 to 6 kg per person at present. The attributes of Sub-Saharan Africa include under-utilized water and land resources, available and inexpensive labour, high demand for fish and a climate that favours a year-round growing period. However, optimal use of these resources has frequently been curtailed by poor infrastructure and lack of production inputs. The potential for expansion is nevertheless considerable, but requires several enabling factors that include: a positive perception of aquaculture, sound policies at the national level, strong public institutions, availability of nutrient inputs, conducive investment policies to attract increased private-sector participation, and access to credit for commercial-scale enterprises.

KEY WORDS: Africa, Sub-Saharan Africa, Aquaculture, Development, Fish Farming

Executive summary

African aquaculture has come a long way since it was first introduced over 50 years ago. However, aquaculture development in Africa has followed a long and bumpy road. Initial high interest in the innovation of farming fish rapidly dwindled during the 1960s as over-expectations were not met and many enterprises were abandoned. Yet a positive perception of aquaculture’s potential role remained, as witnessed by the fact that delegates to the first meeting of the FAO Committee for Inland Fisheries of Africa (CIFA/R1, 1973) identified aquaculture as a priority

Five years later, FAO, assisted by other collaborators, assembled a series of aquaculture reviews from countries[3] responsible for 90 percent of the region’s aquaculture production (Coche, et al., 1994). These reviews identified major constraints on the continental level as:

no reliable production statistics; credit availability limited for small-scale farmers; very low technical level of fish farmers; unavailability of local feed ingredients; lack of well-trained senior personnel; prohibitive transport costs; and lack of juvenile fish for pond re-

area, stressing the need to further its development across the region. To this end, in July 1975, the Food and Agriculture Organization of the United Nations (FAO) organized the First [Africa] Regional Workshop on Aquaculture (ADCP/REP/75/1). This workshop recognized the importance of aquaculture and the high precedence attached to it by many governments. It was further noted:

"failures of some of the ill-conceived programmes during the early part of the century have continued to remain a major constraint in convincing the farmers and investors of the economic viability of aquaculture. Insufficient appreciation of the basic requirements of an effective aquaculture development programme and consequent inadequacy of governmental support activities, have handicapped the orderly and rapid development of the industry."

Following the workshop, there was renewed interest in aquaculture, with nearly every African country launching donor-supported fish farming projects. However, results remained below expectations.

African aquaculture was thus a topic at the 1988 FAO Expert Consultation on Planning for ***stocking.***

Today, although production from the region reflects a 60 percent increase over the previous decade (FAO, 2000), this is only 0.4 percent of the world total. In spite of this modest showing, aquaculture is now recognized as an important production system throughout the region. Some countries such as Côte d'Ivoire, Madagascar, Malawi, Nigeria and Zambia now have well-established aquaculture programmes. Commercial or industrial systems have also been established in Nigeria, Madagascar, Zambia, Zimbabwe, South Africa and elsewhere. South Africa is, furthermore, the most prominent producer of marine aquaculture products.

It is generally accepted that the potential for significant growth of aquaculture in the region exists. Labour is available and economical, while the demand for fish is high and often unsatisfied. In many areas, land and water resources are readily available and frequently under-utilized.

There is growing impetus for aquaculture to achieve this potential. As populations grow and competition for resources becomes more acute and the need for food security more critical, it is necessary that aquaculture assume its long-foreseen role as an

Aquaculture Development (ADCP/REP/89/33). This consultation concluded that output from sub-Saharan Africa was still very low; most production attributed to small-scale, semi-intensive farming of tilapia, with few large-scale commercial ventures able to demonstrate long-term economic viability. Ineffective or nonexistent policies combined with inadequate infrastructure, poor extension support and unavailability of inputs (including seed, feed and credit) were cited as major problem areas.

important contributor to increased nutritional and economic well-being. This review also attempts to analyse past experiences and elaborate valuable lessons learned that can guide future aquaculture development and allow long-awaited expectations to be met. These lessons are then used to define the opportunities, challenges and the way forward.

Some of the main challenges include the shrinking role of governments as countries are faced with varying degrees of socio-economic volatility combined with low levels of industrialization, dependence on the export of primary goods, on-going structural economic adjustment programmes and inadequate or nonexistent development policies.

The recommendations for the way forward cover three main approaches: (a) to promote a greater involvement of interest groups, including the private sector, to replace the shrinking role of the public sector; (b) to better understand the socio-economic and socio-cultural constraints affecting the adoption of fish farming; and (c) to increase subregional and regional networking.

Introduction

The region concerned by this review consists of the 48 countries4 of Sub-Saharan Africa, including five island nations. Most of these countries practice some form of aquaculture, although often at a low level.

Aquaculture for food production in Africa was introduced over 50 years ago. Tilapia were successfully produced in ponds for the first time in Democratic Republic of Congo (DRC) in 1946 (Vincke, 1995). By the end of the 1950s, there were almost 300 000 ponds in production in Africa (Satia, 1989). Raising fish for sport purposes has even a longer history, with trout introduced in South Africa between 1859 and 1896, as well as the late 1920s in Kenya (Vincke, 1995) and the 1930s in Zimbabwe. According to Vincke (1995), rice/fish farming has existed in Madagascar since the

In many cases, these projects had strong infrastructure and manpower development aspects geared to establishing effective national aquaculture services. Unfortunately, a variety of internal and external factors limited sustainable aquaculture development, albeit that some remarkable but temporal aquaculture successes were achieved. This perceived lack of long-term viability led to another era of disenchantment with African aquaculture on the part of foreign and domestic applicants. The 1990s evidenced a notable slump, as sustainability issues came to the forefront, problems magnified by deteriorating global economies. However, the end of the 1990s showed a new optimism for aquaculture development, as apparent failures of past efforts were better understood and previously unnoticed assets surfaced. The closing chapter of the millennium served as an effective sieve which separated true aquaculture practitioners/adopters from those motivated by other considerations. In the aggregate, this resulted in a core of practising fish farmers in most countries; farmers perhaps not raising fish optimally but farmers raising fish -- aquaculture had become an accepted agricultural production system and proponents of aquaculture were gaining a better understanding of how aquaculture fit and effective ways for its turn of the century. Initial production was based on fish that naturally found their way into rice fields through waters supplying these fields; these were captured and raised in cages (Randriamiaran et al., 1995).

During the early 1960s, as many colonial regimes were coming to an end and resources were becoming scarce, aquaculture develop-ment dramatically slowed (Aguilar-Manjarrez & Nath, 1998). In many areas, ponds were abandoned due to low yields, poor location and/or lack of government support (Vincke, 1995). Subsequently, aquaculture development accelerated in the late 1960s as a result of increased donor aid and technical assistance (Vincke, 1995).

The 1970s and 1980s witnessed numerous aquaculture development projects aimed at filling the growing fish supply gap with farm-raised fish and/or bolstering sagging economies with high-value aquaculture products.

promotion.

In the present context, the objectives for aquaculture development in the Sub-Saharan Africa can be identified as:

- to improve food security;
- to increase domestic fish production (import substitution);
- to generate employment;
- to promote diversification and reduce risk;
- to promote economic development; and
- improve use of resources, especially water.

Production Trends

A genuine potential for increased aquaculture production in Africa exists and is yet to be fully realised. This potential should not be overzealously interpreted as aquaculture filling the capture fisheries shortfall5 and eliminating seafood imports overnight. There is a long way to go, and the process will be time-consuming, but prospects are indeed favourable. The region produced 40 300 mt in 1997, having a value of US$102 million. The trends in aquaculture production in the Africa Region over the past decade are given in Figure 1.

Figure 1 Aquaculture production (quantity and value) in Africa Region from 1988 to 1997 (FAO, 2000)

These aquaculture development trends are analysed over a ten-year period (1988-1997), focusing on different production systems. Systems can be classified in terms of scale (size) and/or intensity. This analysis uses definitions that combine these two aspects:

- ***Small-scale*** aquaculture production systems are extensive/semi-intensive utility-oriented pond systems operated by the household and integrated to varying degrees with other agricultural enterprises. The "utility" orientation implies that risk avoidance and diversification are prime motives, as well as household food security. The level of intensity

- ***Medium- to large-scale*** aquaculture systems could also be classified as commercial systems where profit is the principle motive. Large-scale systems have been referred to as those having a water surface area of five hectares or more or producing more than five metric tonnes annually. Profit-oriented systems smaller than this are referred to as medium-scale. Medium- and large-scale systems rely on organized urban markets to move their product or may operate through brokers or middlemen.

indicates that these systems will rely primarily on on-farm inputs including organic fertilizers and simple supplemental feeds, most of the labour being provided by the family. Small-scale systems generally require minimum or no capital investment and are not mechanized. This definition covers traditional systems such as “acadjas”6 and “fish holes”7 or fences along with culture-based systems. To assist in classification, small-scale pond systems are often considered as those with a water surface area of one hectare or less, but this surface area consideration is not applicable to traditional or culture-based systems. Small-scale systems tend to be “rural”, if not in location then in the sense that they do not rely upon urban markets for their product, with most consumed by the family or sold on the pond bank.

These systems tend to be capital intensive, relying on wage labour, external energy sources and mechanization.

Small-scale fish farmers are certainly the major producer group in the region. It should be noted that there are many small-scale producers in the region whose aquaculture motives can include selling fish for profit. In a number of cases, these farmers could represent a transition from small- to medium-scale production and, for continued expansion in aquaculture industries, it is necessary that this group be supported and helped to grow through conducive policies and services that facilitate and even encourage this transition.

While more than half of the countries in the region report annual production of less than 100 mt, there are some relatively large producing nations. The largest individual producer is Nigeria (17 700 mt), followed by Madagascar (5 100 mt) and Zambia (4 700 mt). The major aquaculture products are fresh- and brackish-water finfish, where 33 250 mt were reared in 1997. The complete production from aquaculture is presented in Table 1, while the contributions of different species (by quantity and value) are presented in Table 2.

Aquaculture in the Africa is primarily small-scale rural (this component estimated at 95 percent of total production), characterized by one or more small (i.e. 100-500 m2) ponds, integrated into the mosaic of agricultural activities. Currently, mean yield from these ponds, on a regional basis, is approximated as 500 kg/ha/yr, although reported yields vary considerably, from less than 100 to more than 10 000 kg/ha/yr.

The following could be considered as a general scenario for this situation:

- 300 m2 of pond, producing +/-15 kg of fish per year;

Table 1. National aquaculture production (mt) for the Sub-Saharan Region of Africa (1988 – 1997) (FAO, 2000).

Country	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Benin	58	0	0	0	0	0	0	0	0	0
Burkina Faso	7	6	6	5	5	0	0	0	30	45
Burundi	24	25	30	50	50	55	55	50	10	10
Cameroon	167	138	106	74	57	50	48	55	55	55
Central African Republic	79	82	105	105	338	301	255	210	150	80
Dem. Rep. of the Congo	759	760	700	700	730	700	750	750	750	750
Republic of Congo	177	243	540	243	191	234	121	139	106	99
Côte d'Ivoire	170	168	100	253	306	351	117	386	1 128	450
Ethiopia	1	33	36	36	22	28	33	55	38	44
Gabon	2	2	2	3	5	8	28	39	62	57
Gambia	0	53	60	0	0	0	0	0	4	4
Ghana	427	330	360	410	430	465	500	550	550	400
Guinea	1	1	1	1	5	5	5	4	4	0
Kenya	561	972	1 236	1 178	1 136	1 145	1 385	1 302	579	199
Lesotho	30	25	20	15	17	18	18	14	14	14
Liberia	2	3	0	0	0	0	0	0	0	0
Madagascar	231	230	280	198	2 640	2 289	3 295	4 712	5 075	5 127
Malawi	215	217	197	223	223	256	226	226	235	224
Mali	17	13	13	31	40	52	100	100	60	60
Mauritius	73	82	78	86	100	110	142	176	165	118
Mayotte	0	0	0	0	0	0	0	0	1	2
Mozambique	24	24	20	19	14	10	116	37	4	0
Namibia	0	0	20	20	22	57	66	67	67	62
Niger	20	19	36	21	8	10	17	35	11	13
Nigeria	10 631	25 840	7 347	15 365	17 088	17 090	15 030	16 619	17 944	17 682
Rwanda	38	44	164	58	53	53	60	79	100	118
Réunion	33	40	32	33	23	13	9	4	4	134
Senegal	43	11	7	12	11	26	42	60	78	74
Seychelles	0	7	15	12	50	100	164	195	278	584
Sierra Leone	20	20	20	20	20	15	25	25	30	30
South Africa	1 626	2 297	3 873	5 167	4 597	4 321	4 729	3 830	3 403	4 281
Sudan	45	100	234	203	200	200	200	1 000	1 000	1 000
Swaziland	20	40	45	45	40	42	60	88	93	66
United Rep. of Tanzania	37	975	1 575	2 200	2 850	2 700	3 150	4 200	3 200	3 250
Togo	5	5	14	14	150	150	150	20	21	20
Uganda	34	42	52	63	77	87	179	194	210	360
Zambia	1 147	1 180	1 460	2 470	3 700	4 655	4 530	4 081	4 770	4 718
Zimbabwe	165	163	165	142	140	140	145	165	185	185
Grand Aquaculture Total	16 889	34 190	18 649	29 475	35 338	35 736	35 750	39 467	40 414	40 315

- family labour, involving all family members, estimated at six individuals; and
- raising tilapias and/or catfish (Clarias or Heterobranchus species) with some limited carp production, mostly Cyprinus carpio.

Considering this scenario, the Sub-Saharan Region’s ***small-scale finfish production can be estimated at 21 900 mt8.*** Extrapolating from previous descriptions of small-scale systems, this yield corresponds to the activities of 1 460 000 families, representing nearly 9 000 000 individuals involved in family-scale aquaculture.

Commercial finfish aquaculture is fresh or brackish water and is concentrated in Côte d’Ivoire (Chrysichthys, Clarias, tilapia), Nigeria (Clarias, Heterobranchus, tilapia, carp), Zambia (tilapia, carp), Zimbabwe (trout, tilapia), Kenya (trout, tilapia) and South Africa (trout).

Commercial production would be estimated at 11 350 mt. Commercial tilapia farms report yields of 10 000-15 000 kg/ha/yr, while Clarias yields reach 20 000 kg/ha/yr. There are commercial farms using cage, raceway and recirculating systems, but ponds are the principal production unit. Marine shrimp culture is concentrated in Madagascar, although there are a few farms in Seychelles, Kenya and Mozambique, as well as plans to begin raising shrimp in Gabon and Nigeria. Mollusc culture is limited to Namibia and South Africa, where the latter has regionally significant production of mussels and oysters, as well as the beginnings of an abalone industry. Seaweed culture is limited to South Africa, Namibia and Tanzania.

Table 2. Production (mt) of the major species groups for the Sub-Saharan Region of Africa (1988 -1997) (FAO, 2000).

Group	Unit	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Catfish	Tonnes	3 848.0	10 092.0	2 994.0	8 007.0	7 163.0	6 959.0	7 175.0	6 789.0	7 476.0	6 307.0
	$'000	5 264.1	12 614.2	4 800.6	12 115.8	22 082.0	21 959.4	21 994.3	20 993.2	21 277.5	17 960.8
	$/Kg	1.4	1.25	1.6	1.5	3.1	3.2	3.1	3.1	2.9	2.9
Crustaceans	Tonnes	77.0	186.0	382.0	291.0	320.0	1 111.0	829.0	1 926.0	2918.0	3 235.0
	$'000	861.0	1 693.5	3 393.4	2 794.5	2 981.8	7 334.7	6 761.6	12 346.0	19 326.0	24 266.0
	$/Kg	11.2	9.1	8.9	9.6	9.3	6.6	8.2	6.4	6.6	7.5
Cyprinids	Tonnes	3 244.0	5 067.0	1 199.0	756.0	2 945.0	2 863.0	4 189.0	4 527.0	9 763.0	7 368.0
	$'000	4 099.6	7 309.7	1 478.5	796.5	5 015.1	5 075.5	7 074.4	7 819.1	19 926.5	14 259.8
	$/Kg	1.3	1.4	1.2	1.1	1.7	1.8	1.7	1.7	2.0	1.9
Freshwater fishes	Tonnes	266.0	2 2	960.0	5 295.0	1 732.0	1 745.0	1 168.0	2 947.0	1 726.0	4 761.0
	$'000	376.8	3 889.6	1 653.7	9 784.1	4 442.3	4 398.6	2 943.7	7 184.5	4 468.0	10 644.8
	$/Kg	1.4	1.8	1.7	1.9	2.6	2.5	2.5	2.4	2.6	2.2
Marine fishes	Tonnes	41.0	35.0	41.0	263.0	820.0	723.0	928.0	935.0	16.0	6.0
	$'000	34.3	46.1	72.9	734.4	2 795.9	2 528.7	3 259.8	3 312.4	80.6	36.8
	$/Kg	0.8	1.3	1.8	2.8	3.4	3.5	3.5	3.5	5.0	6.1
Mullets	Tonnes	349.0	350.0	288.0	1 512.0	245.0	200.0	230.0	232.0	3.0	4.0
	$'000	433.7	443.0	374.4	2 116.8	367.5	300.0	345.0	348.6	5.4	8.7
	$/Kg	1.2	1.3	1.3	1.4	1.5	1.5	1.5	1.5	1.8	2.2
Plants and algae	Tonnes	250.0	860.0	1 460.0	2 085.0	3 834.0	2817.0	3 317.0	4 327.0	3 439.0	3 112.0
	$'000	774.0	785.6	883.7	982.5	1 528.0	965.8	1 029.8	1 462.2	1 469.1	714.7
	$/Kg	3.1	0.9	0.6	0.5	0.4	0.3	0.3	0.3	0.4	0.2
Shellfish	Tonnes	597.0	1 149.0	1 761.0	2 419.0	2 697.0	2 869.0	3 277.0	2658.0	2 092.0	2 993.0
	$'000	1051.1	2 021.8	2 921.2	3 752.6	3 824.3	3 724.2	3 902.8	3 709.6	3 184.8	4 667.6
	$/Kg	1.8	1.8	1.7	1.6	1.4	1.3	1.2	1.4	1.5	1.6
Tilapias	Tonnes	7 172.0	13 175.0	8 170.0	7 217.0	14 210.0	15 038.0	13 032.0	13 844.0	12 058.0	11 311.0
	$'000	9 036.0	15 164.1	9 437.9	8 893.9	23 510.0	27 383.5	27 578.8	30 474.5	31 405.2	25 513.6
	$/Kg	1.3	1.2	1.1	1.2	1.7	1.8	2.1	2.2	2.6	2.3
Trout	Tonnes	1 015.0	1 042.0	1 364.0	1 600.0	1 352.0	1401.0	1 600.0	1 282.0	923.0	1 218.0
	$'000	5 252.6	5 257.6	6 988.3	8 589.3	7 156.0	5 104.6	5 551.2	5 079.9	3 384.5	3 755.9
	$/Kg	5.2	5.1	5.1	5.4	5.3	3.6	3.5	4.0	3.7	3.1
Turtles	Tonnes	30.0	38.0	30.0	30.0	20.0	10.0	5.0	0.0	0.0	0.0
	$'000	277.6	329.8	260.4	270.0	180.0	95.0	50.0	0.0	0.0	0.0
	$/Kg	9.3	8.7	8.7	9.0	9.0	9.5	10.0	0.0	0.0	0.0
Grand Total	**Tonnes**	**16 889.0**	**34 190.0**	**18 649.0**	**29 475.0**	**35 338.0**	**35 736.0**	**35 750.0**	**39 467.0**	**40 414.0**	**40315.0**
Total Value	**$'000**	**27 461.0**	**49 555.0**	**32 265.0**	**50 830.0**	**73 883.0**	**78 870.0**	**80 491.0**	**92 730.0**	**104 528.0**	**101829.0**
Average Value	**$/Kg**	**1.6**	**1.5**	**1.7**	**1.7**	**2.1**	**2.2**	**2.3**	**2.4**	**2.6**	**2.5**

Production increases have been seen for several product groups over the decade, while others have declined (e.g. mullets, turtles, diverse marine fish). The greatest growth in production has been seen for catfish (64 percent), crustaceans (primarily marine shrimp – 4 101 percent), cyprinids (common carp – 127 percent), tilapias (58 percent), diverse freshwater fish species (1 690 percent) and shellfish (mussels – 401 percent). The increased production of Eucheuma in Tanzania dominates the data reported for algae.

Main constraints to development

The bulk of the African population is rural. The rural economy is frequently based on subsistence cropping and extensive livestock grazing. This augurs well for the potential for aquaculture development, as aquaculture is essentially an agricultural activity. However, aquaculture must compete with other crops for basic inputs such as land, water, labour and nutrients. Further growth will depend upon its ability to compete and meet related challenges of availability of feed, seed and credit, as well as ensuring an

In 1988, tilapias represented 42 percent of the region's production, but this figure dropped to 28 percent by 1997. Similarly, the contribution of catfish dropped from 23 percent to 16 percent. This demonstrates a general trend of diversification that is reflected by the increased production of other aquaculture crops. Tables 3-5 summarize and compare the contribution of sub-Saharan aquaculture to global production. Comparison is made of all aquaculture products, ish, shellfish and crustaceans.

investment climate conducive to industrial development.

The Africa Regional Aquaculture Review Meeting (CIFA/OP24, FAO, 2000) identified a number of constraints affecting the development of the aquaculture sector in Africa. Among other things, the review concluded that:

"Small-scale farmers have rural social constraints that affect their needs, priority assessments and aspirations. But these are poorly understood. These constraints are complicated further by being location and agro-ecological specific."

Additional constraints to aquaculture development are also elaborated by Satia (1989), Costa-Pierce (1991), Coche, (1994) and Coche & Pedini (1997). Table 6 categorizes and summarizes various constraints.

The following sections

Table 3. Comparison of total aquaculture production globally versus the Sub-Saharan Region of Africa (1988 – 1997) (FAO, 2000).

		1988	1997
Volume (MT)	Africa	16 889	40 315
	World	15 542 975	36 031 129
Volume ratio	Africa/World	0.11%	0.11%
Value (US$'000)	Africa	27 461	101 829
	World	24 408 967	50 703 629
Value ratio	Africa/World	0.11%	0.20%

further analyse the constraints confronting aquaculture development in the region.

Poor aquaculture development policies

Many countries have not established comprehensive aquaculture policies or appropriate aquaculture legislation that are needed to promote sustained growth of the aquaculture sector. This is in part a remnant of previous donor dependence, where a lack of such guidelines made all proposals suitable for all donors, but this situation is also due to the perception that aquaculture is technically complex and capital intensive, thus difficult to handle. Aquaculture has, moreover, often been looked at in isolation from other sectors whereas, it should be viewed as one of the many agricultural

Table 4. Comparison of finfish, mollusc and crustacean production globally versus the Sub-Saharan Region of Africa (1988 – 1997) (FAO, 2000).

		1988	1997
Volume (MT)	Africa	16 609	37 203
	World	11 664 704	28 740 669
Volume ratio	Africa/World	0.14%	0.13%
Value (US$'000)	Africa	26 409	101 114
	World	21 156 338	45 526 463
Value ratio	Africa/World	0.12%	0.22%

Table 5. Comparison of finfish production globally versus the Sub-Saharan Region of Africa (1988 – 1997) (FAO, 2000).

		1988	1997
Volume (MT)	Africa	15 935	30 975
	World	7 546 914	18 786 490
Volume ratio	Africa/World	0.21%	0.16%
Value (US$'000)	Africa	24 497	72 180
	World	13 532 710	28 329 290
Value ratio	Africa/World	0.18%	0.25%

Few fish farming traditions

Agriculture, habitually involving traditional subsistence crops, has an established base and dominates many economies in the region. On the other hand, little traditional aquaculture knowledge exists among farmers in most areas. Although fish farming existed in Madagascar since the turn of the century (the system based on rearing fish that came naturally into rice fields), techniques of producing fry did not exist until recently (Randriamiaran et al., 1995). Some traditional systems such as "acadjas" and "fish holes" also existed in African countries such as Côte d'Ivoire, Benin and Ghana, but the technology to manage broodstock and produce fry has not accompanied these production units.

enterprises for which countries must cater. Some countries like Madagascar and Mozambique are developing appropriate aquaculture policy and legal frameworks, and an awareness of the importance of relevant policies is increasing.

The poor economic situation of most countries

Sub-Saharan Africa has suffered from social and economic instability over past decades through civil unrest, drought and other natural disasters along with high population growth (Vincke, 1995). These have retarded economic growth and often created less than ideal climates for foreign and local investment. Development has also been adversely affected as trained personnel have left for other countries, reducing technical expertise and institutional memory. This economic situation has been aggravated by the fact that many countries have a dependence on primary agricultural goods that have not generated adequate foreign currency earnings due to global market fluctuations. Structural adjustment programmes have further complicated national programmes and institutions, making delivery of limited government services all the more challenging. These problems have reduced the public-sector capacity to deliver, and the aquaculture sector has suffered.

Inappropriate technologies and approaches

As aquaculture technologies did not exist in the traditional setting, these had to be introduced. Unfortunately many of these introduced technologies were inappropriate and unsuited to the needs of the intended beneficiaries. There was lack of appreciation for the prevailing social, cultural and economic factors, as well as a lack of understanding of important supply and demand considerations, including competition for most production inputs. Additionally, fish-farming development was not seen in the context of rural development, and aquaculture was considered as a separate entity from agriculture. More often than not, the external technical assistance prevalent promoted technologies they felt to be the most appropriate, as opposed to those most useful to would-be producers. Weaknesses in this top-down technocratic approach became apparent, as sustainability was lacking, and a new emphasis was placed on participation and understanding the human factors of technology adoption.

Lack of fish seed

This has been a problem constituting a serious restriction to aquaculture development. Early efforts focused on public-sector production and distribution of seed, and as a result, there is now often a government monopoly where the price of seed is subsidized to the point where private producers cannot compete. However, production from government hatcheries rarely meets demand, and many governments lack the means to effectively distribute seed to farmers. Recently, as economies continue to suffer to maintain minimum services, many government hatcheries have lost the few funds they previously had access to, and public sector supply of seed is on the decline. In its place in many countries like Côte d'Ivoire, Kenya, Zambia, Tanzania, Mozambique, Madagascar and Uganda, private seed producers are entering the market and providing better services to farmers who had become disenfranchised with excessive waiting periods for poor-quality seed coming from government facilities. Private seed production has been undertaken for some time by larger commercial companies, which have vertically integrated and have the capacity to produce their own.

Table 6. Constraints to aquaculture development for small-scale and medium- and large-scale production systems.

Issue	Category: Small-scale systems	Category: Medium & large systems
Policy	lack of clear policy	lack of clear policy
Government support	poor	poor
Research & extension linkages	weak	weak or non-existent
Research & development linkages	weak	weak or non-existent
Technical support	often inappropriate lack of flexibility	inadequate
Donor support	donor dependence	little provided to date
Credit availability	generally not available & need questionable	necessary but often unavailable or difficult to access
Seed supply	insufficient & often dependant on public sector little selection practised	generally provided on-farm monosex or hybridization practised by some farms
Feed supply	frequently inadequate quality and/or quantity supplemental feeds	generally provided on-farm complete feeds preferred
Extension systems	lack of farmer participation inadequate support few technicians	often neglect larger producers
Data collection	poor and often unreliable farms dispersed, often isolated	on-farm data generally collected but sometimes inaccessible
Information management	networking practically non-existent group formation desirable but often inadequate	poor information exchange and communications

Unavailability of feed

Although many small-scale producers rely on fertilization and enhanced natural food for their crop of fish, increases in production will require corresponding increases in nutrition; feeding more and better food stuffs. There are three components to this problem: (a) quality, (b) quantity and (c) varying

The existence of many nonfunctional government stations

In most countries, numerous aquaculture stations were built for research, seed production and training and even food-fish production. These were generally operated through donor funding and constitute an excellent example of requirements of different species. Feeds can be produced by the family, community or the industry. Family feeds tend to be of variable quality and quantity, typically dependent upon by-products available from the home and farm. Community feeds may be fabricated by local entrepreneurs, producer groups or others serving a relatively restricted geographic area. These feeds are often based on commercial agricultural by-products available in the area and may be of modest quality but of a reliable quantity. Commercially produced feeds require cost-effect inputs and the industrial means to manufacture feeds, the preference being pelletized feeds. Countries that have expanding agricultural sectors and produce surpluses are often well placed for the economical production of commercial fish feed. In Zimbabwe, the private sector is now meeting the demands of the industry. In South Africa, feed requirements are met by the private sector, while private businesses in Nigeria, Kenya and Zambia also produce commercial fish feeds. Nonetheless, in many countries commercial rations, especially pelleted feeds, are still not available unless imported. Feed remains one of the most prominent barriers to expanded aquaculture production, especially medium- and large-scale production. Unless affordable feed costs can be maintained, farm-raised products cannot compete the lack of sustainability after donor support is withdrawn. The justification for continuation or re-establishment of these facilities no longer exists in most instances. It is widely accepted that food fish and seed production are the domain of the private sector in today's environment with down-sized government budgets in many countries in the region. Furthermore, such facilities are largely inappropriate for farmer training or as nuclei for aquaculture extension as the emphasis shifts to producer groups and on-farm activities. In the final analysis, the main reason to maintain government stations is for research and maintenance of broodstock, these activities requiring a limited number of stations in any given country, at least during early development phase. For example, Cameroon has more than 30 government fish culture facilities where one or two would be adequate for research and broodstock maintenance. A reduction in stations through privatization of redundant facilities concentrate limited funds in a few stations, ensuring their satisfactory operations.

Weak extension services

Aquaculture extension services were initiated in the 1950s, but declined in many countries after independence, when technical staff with those coming from capture fisheries, unless there is significant value added through the production of luxury items.

Prohibitive transport costs and poor transport infrastructure

Transport is a key factor in aquaculture development. Feed and seed must often be transported to isolated producers, while harvests must frequently be carried to markets where profits can be optimized. Transport infrastructure in many areas is poor. Some roads are not passable during the wet season, while other areas may completely lack access for four-wheeled vehicles. Meagre infrastructure due to the mountainous nature of the country is cited as one of the major problems affecting the distribution of fry in Madagascar (Randriamiaran et al. (1995); the same applies to many other countries across the region, including Cameroon, Rwanda, Angola, Gabon and CAR.

and funds were no longer available (Vincke, 1995). These services were then incorporated into projects restarted in the 1960s through technical assistance. These projects frequently adopted a similar approach to aquaculture development: establish government hatcheries to address the acknowledged seed shortage and to serve for training farmers, while training and equipping government fish-farming extension workers to introduce and monitor the country's aquaculture programme. The result was a service dedicated to aquaculture extension which was expensive to operate; expenses for logistic support to service distant fish farmers were often excessive. In the majority of cases, these projects demonstrated little sustainability, as increased infrastructure and staff compounded financial constraints, and the resulting extension services were weak or non-existent.

Weak research institutions and their impact

Research activities were hindered by the general economic difficulties already cited. Furthermore, research agendas were often dominated by inappropriate technologies, as researchers frequently had little contact with the farm environment. The situation was aggravated in many cases by the fact that some research stations had high staff turnover, lacked comprehensive research programmes and adequate evaluation, and suffered from weak administrations. However, as aquaculture research advanced world-wide, the main impediment in the Africa Region was lack of access to current knowledge and technologies. Communications were often difficult, and restricted research budgets often precluded access to those communications systems available, while few libraries, universities or other institutions could afford subscribing to current technical literature.

Limited coordination between research and development sectors

As pointed out, in many cases the research and development efforts carried out are not responsive to the needs of targeted stakeholders. They are not demand driven. For the needs to be appreciated in

Inadequate information management systems

Access to aquaculture information is inadequate, limiting the scope, quality and utility of aquaculture research and development activities. There is a lack of information flow (networking) between institutions and countries. Although considerable valuable information is published as grey literature, this is not being collected or disseminated.

Opportunities for further growth of the aquaculture sector in sub-saharan africa

The current area under aquaculture production is estimated at 38 214 to 102 406 ha compared to the estimated available surface area of 30 million ha suitable for aquaculture and 12 million ha of floodplains also suitable for fish production. There is also a potential for cage culture, given the availability of water bodies throughout the region.

Careful planning is necessary to guide future aquaculture development and ensure that available resources are well used. Small-scale aquaculture should be developed such that it fits as an agricultural component of a broader community settings, research and development should be used to evaluate (a) those social aspects found in many rural areas that negatively affect the adoption of new technologies described by Sen (1995) as "levelling mechanisms", (b) power relationships, (c) intra-household allocation of resources, (d) the role of gender, (e) labour supply and demand and (f) marketing. It is also important to understand and appreciate the complexities of land tenure.

Few reliable production statistics

Most countries do not have effective data collection systems set in place to collect aquaculture production statistics. Yet this is critical for purposes of monitoring, evaluating the performance of the sector, and justifying the allocation of resources to the sector. This is in part due to the low priority given to the sector and the complexity of collecting data from dispersed rural farmers.

farming system and not as an secluded technology where communities will see it as a separate or added risk venture. Socio-economic diagnostic approaches to aquaculture promotion should be considered of high priority and focus on techniques that allow the full participation of communities in the identification, analysis and evaluation of projects.

There is need to facilitate the participation of nongovernmental organizations (NGOs). There are many NGOs involved in empowerment in different disciplines. The private sector has a key role in the production of fingerlings, feed and marketing, as well as possibly in providing extension support. Producer groups are essential to serve as an interface between government, private entrepreneurs and farmers themselves. These groups will empower farmers, reduce inputs costs, improve services, minimize market bottlenecks and foster efficient information exchange, including feed-forward and feed-back.

There is need to develop national policies and plans that promote the development of aquaculture and that facilitate participatory activities in the field. In the multidisciplinary approach to integrated aquaculture, there is need for strong liaison with other relevant institutions.

A strategy for aquaculture development

The Africa Regional Aquaculture Review (CIFA/OP24, FAO, 2000) developed a number of strategies for enhanced aquaculture development (Box 1). The strategies recognize that some programmes can best be implemented at a national level, whilst others can best be implemented at subregional or regional levels.

This strategy is an opportunity for governments to seriously examine aquaculture development and take advantage of the review and adopt the recommendations. Due to economic problems in most countries, there is increased need for inter-sectoral approaches to tackling the challenges of aquaculture development. Many interest groups and new However, challenges facing smallholder farmers across the region are often the same, and common approaches can indeed be applied to a broad spectrum of the region's fish-farming community.

The main strategies include farmer-to-farmer methodologies which focus on the farmer through on-farm research and demonstrations, identifying farmers with leadership potential, such that those trained will effectively train others, and encouraging the formation of farmers associations. The farmer-to-farmer approach is demanding, requiring significant resources that can involve universities and other public institutions, as well as NGOs and the private sector.

Networking

Information flow is critical. Consultative fora composed of stakeholders involved in aquaculture at the subnational and national levels, or other forms of coordination, need to be encouraged. These should have scheduled meetings to analyse problems and trends, assess supply and demand, seek solutions to pending problems and set up institutional arrangements with civil society will be needed to fill the void left by the reduced capacity of governments. Technicians and administrators must assume more responsibility to assist aquaculture in achieving its unmet potential.

Conducive policy framework

There is need to review the existing administrative and legal frameworks. This is normally a protracted process, as it needs parliamentary approval. But sector plans calling for the participation of relevant public agencies, civil society, individuals etc. may be developed by the concerned departments awaiting those elements that require legislative endorsement. In this way, existing regulations may be reviewed and revised to incorporate appropriate aspects of the Code of Conduct for Responsible Fisheries (CCRF), national consultative fora established, and prerequisite data collected.

Appropriate research and extension

There is need to mobilize research and development institutions to develop interest in aquaculture and remove prevailing impediments to expanding aquaculture production. To do this, governments should join forces with the private sector.

monitoring and evaluation systems. Interest groups could be linked through electronic media, and national information facilities could also be affiliated to have the widest impact possible. Farmers' associations and consultative frameworks will be key to future aquaculture development in Sub-Saharan Africa.

Training and extension

There is need to set up relevant training courses for technical staff, extensionists, farmers and other stakeholders. There is justification for developing a regional approach to training when promoting aquaculture development. Most countries have limited finances, and it is cost effective to centralize and meet these requirements through identified regional centres. The other advantage is that location within the region will permit the use of regional case studies as examples in the training packages.

Subregional organizations could assist with coordination of training and develop protocols to harmonize policies in the development of aquaculture. These protocols could promote synchrony of legislation, cooperation and integration of economic activities, human capacity building, information sharing, research and technology transfer, defining and promoting the role of civil society, implementing of the

Small-scale farmers have social constraints that affect their needs, priorities and aspirations. These constraints are often location and agro-ecologically specific. If differences are greater than commonalities, it can be difficult to generalize approaches to problem solving.

CCRF etc.

Box 1. Strategy implementation schedule (CIFA/OP24, FAO, 2000).

I. IMMEDIATELY
- Initiate reduction of number of government stations.
- Focus effort on selected areas.
- Promote farmers' associations.
- Promote farmer-to-farmer communication.
- Focus on a limited number of culture organisms.
- Focus on locally available inputs and existing technology.
- Improve national coordination.
- Develop demand-driven research agendas through improved linkages with development.
- Increase involvement of universities.
- Establish informal exchanges.
- Increase use of farmers' associations for collecting statistics.

II. WITHIN 1 YEAR
- Evaluate national training needs and capacity at all levels.
- Incorporate social, cultural and economic aspects into research agendas.
- Establish national information network.
- Initiate national research programme on brood stock management.
- Organize a regional feasibility study on credit for large-scale enterprises.
- Organize annual meeting of African Aquaculture Group together with FAO.

III. WITHIN 2 YEARS
- Establish aquaculture development policy, including privatization of fingerling production, focused extension and participatory approach.
- Create national Aquaculture Advisory Committee.
- Select and retain stations for research and training (government funding).
- Establish national broodstock management programme.
- Initiate regional research programme on broodstock management.
- Develop socio-economic indicators of impact.
- Promote private-sector involvement and better management through long-term lease.
- Organize regional specialized training courses for commercial entrepreneurs.
- Privatize seed supply for medium- to large-scale enterprises.
- Initiate national and regional research programmes on formulated feed quality, involving government and private sector.

IV. WITHIN 3 YEARS
- Evaluate regional training needs and capacities (centres of excellence)
- Establish regional information network.
- Revise and improve statistics collection.

V. WITHIN 5 YEARS
- Elaborate national Aquaculture Development Plan.
- Reduce by at least 50 percent the actual number of government stations.
- Revise extension structure.
- Improve understanding/knowledge of traditional systems and their potential for enhancement.
- Develop national or intra-regional practical training for farmers, extensionists, administrators and decision-makers.
- Establish regional specialized research network (centres of excellence).
- Establish national database.

Conclusions and recommendations

There is little doubt that aquaculture is now a known enterprise throughout Africa and has become well established in a number of countries, including Côte d'Ivoire, Madagascar, Malawi, Nigeria, Zambia etc. However, growth and development of the sector are confronted by numerous challenges if aquaculture is to achieve it widely accepted potential.

This analysis of the trends outlines constraints, challenges, opportunities and the potential for aquaculture development. The challenge is to increase the adoption rate of aquaculture across the region, as well as to improve production from existing producers. This challenge is translated for countries as the need to see aquaculture as a tool that has the potential to contribute significantly to food security and development. Food production will remain an overriding priority, and intensification as well as diversification in food production will constitute important approaches to development.

In a number of countries, high population density leaves little room for extending cropping of terrestrial crops. The best prospects for

- Due to the contracting role of governments following toughening economic conditions, structural adjustment programmes and weakening currencies, governments must encourage the participation of interest groups and the private sector at the national, regional and international levels, through establishing partnerships, consultative frameworks, and access arrangements to designated areas and under-utilized government facilities and by providing the necessary support services.
- Taking the above into consideration, there is an urgent need to reduce redundant government infrastructure and streamline services, concentrating limited resources on those areas that will provide the highest returns on investment.
- Promoting aquaculture as a separate and isolated farming system has given the impression to governments and smallholder farmers that it is technically complicated and has missed out on the opportunity of developing linkages with other farming activities. Integrating aquaculture with traditional cropping and livestock production systems has the

increasing production, therefore, lie in intensification and diversification. Aquaculture is one area that can still be developed and realise significant gains. It holds promise to increase food and financial security in rural areas.

As a way forward to the development of aquaculture in Africa, it is important to look at the aquaculture production systems in a regional context and with regard to regional resources, priorities and prospectives. Past efforts have successfully introduced the innovation of aquaculture, but the number of producers and overall production remain low. Several factors have been discussed that have contributed to the present situation, and these have served as lessons learned to elaborate a strategy for aquaculture development that will build on the strengths of the past, take into consideration the realities of the present and fulfil the realistic expectations of the future.

potential not only to increase fish production, but also overall farm production. In addition, nutritional levels, food security and household incomes will increase.

- On the other hand, governments need to recognize aquaculture as a distinct agricultural enterprise, in the same way as any specific agricultural commodity, and need to review existing legal frameworks, policies and institutions to address the specific characteristics and needs of aquaculture.
- There should be a focus on the farmer through on-farm research and demonstrations, identifying farmers with leadership potential and training them, so that they train others, encouraging the formation of farmers' associations.
- All levels of aquaculture production should be promoted, from small- to large-scale commercial. Each has its unique requirements, most of which can be met through increased private-sector involvement. Credit is often not a limiting factor for small-scale operations, but is an important consideration for enterprises of medium- and large-scale. Credit providers, both formal and informal,

should be educated as to the opportunities for investment in aquaculture and its potential profitability.

- Efforts must be taken to establish reliable supplies of private-sector-produced seed and feed, the private sector also assuring the distribution of these products. Furthermore, private-sector support to, or participation in, aquaculture extension needs to be examined.
- Information exchange is essential for aquaculture development, and access to existing information needs to be significantly improved. To a large part, the perceived lack of technologies is not due to the fact that the technologies have not been identified or evaluated, but because this information is not widely available across the region. Functional networks joining stakeholders from all areas of aquaculture development and research will go a long way toward fostering improved information flow.
- Marine culture is under-developed and should be expanded through careful analysis of opportunities, while ensuring the environmental soundness of any undertakings. Seaweed farming has benefited many coastal people and coastal communities in other countries could adopt this system.
- Many traditional fish-farming practices are inadequately documented. Efforts are needed to document and study local traditional practices, so that they can be adopted and improved to meet the needs of today. Indigenous fisheries enhancement strategies could be extended to other locations in Africa, especially where culture-based fisheries are being promoted.

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- Subregional organizations could develop protocols to harmonize policies in the development of aquaculture. These protocols could promote harmonization of legislation, cooperation and integration of economic activities, human capacity building, information sharing, research and technology transfer, defining and promoting the role of civil society, implementing of the CCRF etc. These organizations could also be key brokers as regards regional approaches to research and training.
- Data collection and its management need urgent attention. The need for countries to establish comprehensive data collection systems is evident - baseline data to use when elaborating development strategies and periodic data to monitor progress and growth of the industry. The involvement of producers in this activity is essential.
- Medium- and large-scale aquaculture production has the potential to expand, as more and more people are motivated to invest in aquaculture and both the local and export markets are insatiable. Governments need to provide an enabling atmosphere to promote investments in these systems.

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[5] Growth rates for marine fisheries, which account for most of the world's fish supply, decreased from 6 percent/yr in the 1960s to only 0.6 percent/yr in 1995/96, while population growth rates continue to rise (FAO, 1999).

[6] Acadjas are fish aggregators where artificial reefs composed of branches are placed in estuaries to concentrate fish looking for food or shelter. Fish may be enclosed in these areas and fed prior to harvesting.

[7] Fish holes or "drain-in ponds" are fish concentrators which collect fish from flood plains as waters recede and the plains dry. Fish can be kept in these ponds for a considerable period and fed prior to harvesting.

[8] With the exception of Nigeria, 95 percent of the region's production is considered as originating from small-scale producers; in Nigeria the small-scale contribution is estimated at 40 percent (the remaining 60 percent coming from commercial producers). Thus small-scale production is 95 percent of the regional total exclusive of Nigeria (14 820 mt) plus 40 percent of the Nigerian production (7 080 mt).

Status and Development Trends of Aquaculture in the Near East[1]

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El Gamal, A.R. 2001. Status and development trends of aquaculture in the Near East. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 357-376. NACA, Bangkok and FAO, Rome.

ABSTRACT: Aquaculture has a short history in the Near East Region. The overall aquaculture production in 1997 was below 200 000 mt, a figure that represents less than 0.5 percent of global aquaculture production. Eight of the 17 regional countries produced nearly 99 percent of the total regional aquaculture production in 1997 - Egypt (47 percent), Turkey (29 percent), Israel (12 percent), Syria (3 percent), Saudi Arabia (3 percent), Iraq (2 percent), Morocco (2 percent) and Tunisia (1 percent).

The scarcity of, and competition for water and land from other users, as well as rising input costs are encouraging culture intensification. The use of artificial feeds, aeration and fertilizers is increasing to semi-intensive levels. A recent trend is the development of the marine sector to culture high-value species. The availability of seed of some species such as seabass, seabream and shrimp, proximity to export markets, and the establishment of joint ventures have provided the impetus for rapid development of mariculture. However, freshwater aquaculture development will likely be shaped by national water and land polices. The over-riding consideration is scarcity of fresh water and land. Reduction in groundwater levels, prohibition in the use of fresh water, and competition with agriculture, the petroleum industry and tourism are major constraints that need to be resolved to facilitate expansion of the sector.

Availability of seed and feed are crucial technological constraints to future development. The high price of feed, exacerbated by currency fluctuation and high variable costs, has raised production costs. The uptake of aquaculture is also frustrated by poor legislation, especially for environmental protection and movement of aquatic animals, as well as the bureaucratic requirements for obtaining licenses and permits. Cooperation between institutions and agencies is weak. In some cases, their functions overlap or are conflicting. A widespread concern in the region is the weakness of extension services and the slow dissemination of technology.

Most of the aquaculture produce, especially tilapia, carps and grey mullet, is consumed locally. Cultured marine species are produced for export, but the competitive and high prices obtained locally and new and more costly European Union (EU) regulations have combined to discourage exports.

KEY WORDS: Near East, Aquaculture, Fish Farming, Development, Aquatic Production

Review of aquaculture production in the near east

Aquaculture development

In general, aquaculture has a short history in the Near East Region when compared to other parts of the world. The overall aquaculture production in 1997 is below 200 000 mt, a figure that represents less than 0.5 percent of global aquaculture production. The rate of growth of aquaculture development within the decade 1988-1997 ranges from almost nothing to over 60 percent in some countries.

Table 1 demonstrates that eight of the 17 regional countries produced nearly 99 percent of the total regional aquaculture production in 1997; Egypt (47 percent), Turkey (29 percent), Israel (12 percent), Syria (3 percent), Saudi Arabia (3 percent), Iraq (2 percent), Morocco (2 percent) and Tunisia (1 percent).

The data presented in this table also demonstrate the development trends, regardless of the absolute production volumes, which reflect the short history of aquaculture within the region. Nonetheless, the data indicate that significant developments are taking place within the aquaculture sector, notably for Cyprus, Egypt, Morocco, Saudi Arabia, Syria, Tunisia and Turkey.

The growth of aquaculture in Turkey has been the most impressive, moving from around 5 percent of the region's production to just over 30 percent.

Table 1 indicates the importance of both the volume and the regional contribution for each country within the region. Furthermore, within national production, there are very significant differences in the breakdown of the products, For example, the production of aquaculture in Lebanon is devoted to one species, rainbow trout (Oncorhynchus mykiss), which is also the major aquaculture product in Turkey, while gilthead seabream (Sparus aurata) represents the backbone of aquaculture development in Morocco and Cyprus. Nile tilapia (Oreochromis niloticus) and the giant tiger shrimp (Penaeus monodon) have been significant contributors to aquaculture development in Israel and Saudi Arabia.

There have been considerable changes in the structure of aquaculture in the Near East, which becomes evident through analysis of the water source used and the culture environment (fresh water, brackish and marine), as demonstrated in Figures 1 and 2.

Table 1. Aquaculture production (MT) in the Near East Region in 1988 and 1997 (FAO, 2000).

Country	Year		APR*	Regional Production	
	1988	1997		1988	1997
Algeria	304	322	0.6%	0.4%	0.2%
Bahrain	0	0	-	0.0%	0.0%
Cyprus	59	969	36.5%	0.1%	0.6%
Egypt	52 200	73 454	3.9%	64.0%	46.7%
Iraq	5 000	3 400	-4.2%	6.1%	2.2%
Israel	15 135	18 264	2.1%	18.5%	11.6%
Jordan	70	200	12.4%	0.1%	0.1%
Kuwait	8	154	38.9%	0.0%	0.1%
Lebanon	100	300	13.0%	0.1%	0.2%
Libyan Arab Jamahiriya	30	100	14.3%	0.0%	0.1%
Morocco	158	2 290	34.6%	0.2%	1.5%
Oman	-	-	-	0.0%	0.0%
Qatar	-	2	-	0.0%	0.0%
Saudi Arabia	331	4 690	34.3%	0.4%	3.0%
Syrian Arab Republic	3 040	5 596	7.0%	3.7%	3.6%
Tunisia	1 053	2 012	7.5%	1.3%	1.3%
Turkey	4 100	45 450	30.6%	5.0%	28.9%
United Arab Emirates	6	-	-	0.0%	0.0%
Yemen	0	0	-	0.0%	0.0%
Grand Total	**81 594**	**157 203**	**7.6%**		

* APR = Average Percent Rate

Figure 1. Analysis of aquaculture production (by quantity) in the Near East by culture environment (water use) from 1988-1997 (FAO, 2000).

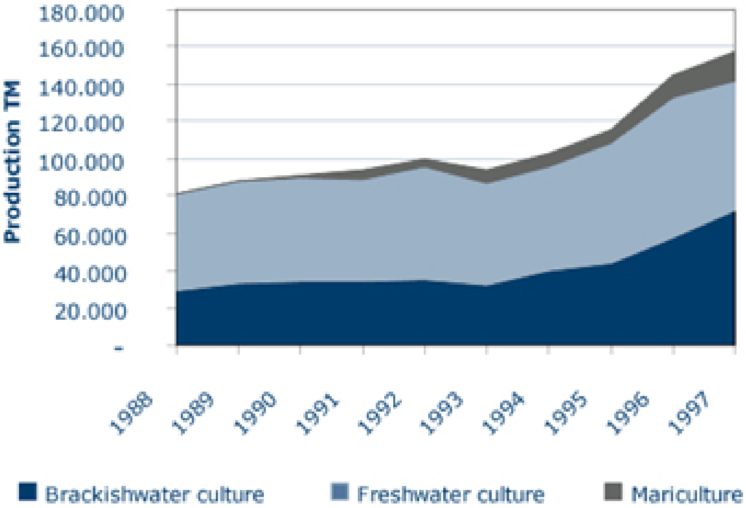
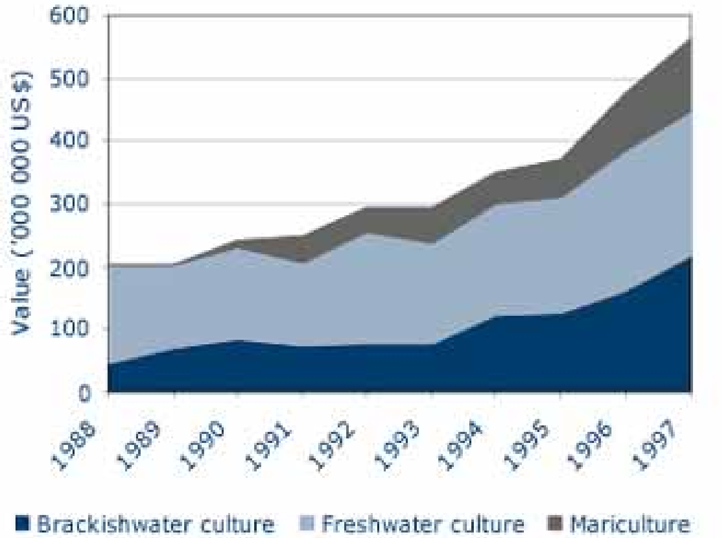


Figure 2 Analysis of aquaculture production (by value) in the Near East by culture environment (water use) from 1988-1997 (FAO, 2000).



The increasing importance of the value contributed by marine aquaculture, which has provided products of higher individual value, is noteworthy. The major contributors to the different subsectors are given in Table 2.

The data demonstrates the increasing importance of the use of brackish and marine water for production, rising from 36 percent (entirely brackish) in 1988 to 56 percent in 1997 (10 percent marine and 46 percent brackish). The APRs (Average Percent Rate) for the period were 3.2 percent for freshwater, 10.5 percent for marine and 64.6 percent for brackishwater aquaculture.

Stagnation is seen for carp production in fresh water, where a degree of substitution has been accorded (at a regional level) by tilapias. On the other hand, carp production has increased in brackish water, accompanied by tilapias, but mullets and seabream have achieved the largest growth. In the marine sector, which hardly existed in 1988, the expansion is evident, primarily for the seabream and seabass species, although one should note the growth seen for mussels and marine trout production (mainly in Turkey).

Main culture systems

Aquaculture production in the Near East Region is characterized by wide diversity, not only in regard to the culture systems used, but also in respect of the development trends and issues of concern. This position makes it valuable to summarize the status of aquaculture in member countries, highlighting important issues within the development process.

Table 2. Ranking of aquaculture species in different culture environments in the Near East (1988-1997).

Culture System	Species	Production (quantity) 1988	1997	APR	Value 1988	1997	APR
Brackish water	Nile tilapia	20 000	28 500	4.0%	30 000	58 653	7.7%
	Common carp	6 000	15 396	11.0%	6 000	22 632	15.9%
	Flathead grey mullet	2 200	16 034	24.7%	6 160	47 142	25.4%
	Gilthead seabream	294	9 802	47.6%	1 867	71 847	50.0%
Fresh water	Trouts nei[1]	1 765	32 340	38.1%	9 708	92 780	28.5%
	Common carp	37 267	25 921	-4.0%	116 194	84 914	-3.4%
	Nile tilapia	5 300	13 762	11.2%	8 622	14 023	5.6%
	Tilapias nei	5 256	8 209	5.1%	13 944	19 047	3.5%
Mariculture	Seabasses nei	5	8 660	129.0%	60	56 700	114.1%
	Gilthead seabream	62	3 031	54.1%	930	29 031	46.6%
	Trouts nei	0	2 290	-	0	7 000	-
	Mediterranean mussel	0	2 000	-	0	6 000	-
	Giant tiger prawn	2	1 681	111.3%	19	6 649	92.1%
	European seabass	3	1 218	94.9%	45	4 910	68.4%

[1] nei = not elsewhere included.

Culture technology

The technology used for fish culture varies widely within the Near East, but most production comes from earthen ponds. However, different levels of intensification are applied using extensive, semi-intensive, and intensive systems. Integrated systems that combine fish production with other types of agriculture also exist in the region, where rice-fish culture is an example of note.

The general characteristics of such systems in the region are described in the following section. It should be noted that the interpretation used in this review of what is "extensive" or "semi-intensive" has changed both with time and location.

Extensive aquaculture systems

Extensive culture is done in dam lakes in a number of Near East countries, including Iraq, Israel, Syria, Morocco, Algeria, Tunisia and Libya3, where common carp, grass carp, silver carp and sometimes tilapia are stocked. Mullets are stocked in Lake Qarun and the Rayaan Depressions in Egypt. In addition, the enrichment of natural stocks is also considered to be a sub-type of this system, where grouper, seabream and rabbitfish have been placed in waters of some countries in the region. The extensive aquaculture system applied in earthen ponds represents that of the lowest inputs throughout the production cycle and also the minimum control. Sometimes, this system is helpful in utilizing agricultural by-products that cannot be used in higher category systems.

As expected, the risk factors are at their lowest in such systems but, because of the increasing value of natural resources (especially water and land), the low productivity obtained explains the trend of

Intensive aquaculture systems

A high degree of control over the production operation is a must for the intensive system, leaving few options to Mother Nature. Nutritionally complete feeds are essential for growth, while continuous water exchange and/or supplementary aeration are usually required. Smaller ponds (than in semi-intensive farming) or tanks/raceways are used for better management. Because of the high investment and production costs, farms using "intensive" technology are developed after careful economic study and are usually applied to the raising of high-value fish, such as seabass or seabream, examples of which can be found in some countries in the region.

Cage culture represents a type of intensive system that does not require large areas of land and, in most cases, necessitates lower capital investments when compared to land-based intensive farms. Cage culture is developing moderately well in the region and could be considered to have significant promise for increasing aquaculture production in many countries. Environmental considerations are the main challenge for further development.

The integration of aquaculture with rice production is the most common type of integrated agriculture that is practised in the region (especially in Egypt), although trials with other crops have been done on a small scale.

National reviews of aquaculture in the region

Algeria

Freshwater aquaculture started in Algeria, in 1967, with the conditioning of water “upgrading” to higher culture categories that allow more efficient use of water, land and labour.

Semi-intensive aquaculture systems

As the term indicates, “semi-intensive” reflects a higher degree of intensification and greater control over the culture habitat. More feeds are used, and of better quality (especially manufactured feeds) and more fingerlings are used within a given volume of rearing system. A key result is the improved use of natural resources due to higher productivity levels. Higher investment and skills are needed to establish and operate such a system, which appears to lead the other aquaculture systems applied within the region.

bodies at Mazafran. This initial effort was followed in 1978 with a programme, supported by Algerian-Chinese cooperation, for the reproduction and culture of carps. From 1985 to 1991, 17 water bodies were stocked with fry of Chinese carps, pikeperch (Stizostedion lucioperca) and sheat (Silurus sp.), leading to a significant increase in fish production. For example, Lake Oubeira developed production of 250-300 mt of freshwater fishes, dominated by Chinese carps. Unfortunately, no data are available post-1991. In 1989, two freshwater pilot hatcheries were built for the production of fingerlings of pikeperch, grass carp and silver carp.

Trials on molluscs started in 1976 in Singa Island, Bou-Ismail Bay and Lake Mellah, but with little success. Little extensive production of mussels (Mytilus galloprovingialis) is done in coastal waters.

Bahrain

Commercial aquaculture is not done in Bahrain but, in 1979, the National Mariculture Centre was started as a pilot project, in cooperation with the Food and Agriculture Organization of the United Nations (FAO). The centre is located on Ras Hayan in southeastern Bahrain, and has the following objectives:

- to produce seed of commercially

A major factor hindering development is the application of import taxes by the export markets targeted. Nonetheless, it is believed that offshore developments will provide the main focus for future growth.

Egypt

Egypt has been the traditional leader in aquaculture production in the Near East Region. Egyptian aquaculture started with the use of traditional extensive and semi-intensive techniques. Rapid development has occurred in recent years, after aquaculture had been identified as the best answer to reduce the increasing gap between supply and demand for fish in Egypt.

important species,

- to grow fingerlings to market size,
- to train national staff on aquaculture technology,
- to assist and promote similar activities in the country, and
- to assist stock enhancement programmes through the mass production of seed/fry/ fingerlings.

The activities of the centre include studies on the nutrition and reproduction of rabbitfish (Siganus canalicatus). Growth trials have been done on rabbitfish and grouper in different culture systems and the green tiger shrimp, Penaeus semisulcatus, is also being studied. In 1994, stock enhancement trials were started using hatchery-reared grouper and seabream, where releases were made at five sites in Bahrain.

Cyprus

Aquaculture in Cyprus has a short history, production being less than 200 mt in 1992, but this reached nearly 1 000 mt by 1997. Total aquaculture production is dominated by the rearing of gilthead seabream and European seabass (Dicentrarchus labrax), and the country possesses true offshore cage-culture facilities for this purpose. The main product in 1997 was seabream, which comprised 80 percent of the total.

Cyprus also produces commercial quantities of fry for these species and has developed significant export markets, notably to producers in the European Union (EU), for these products. A small amount of rainbow trout is produced within the island (90 mt per annum).

Progress was very slow until the late 1970s, then rapid change occurred in all forms of aquaculture activity, including the development of support infrastructure (i.e. hatcheries and feed mills). This resulted in a noticeable increase in the production of cultured fish, which reached more than 73 000 mt, representing some 19 percent of the total fish production of Egypt in 1997. Production in fresh and brackish water is the main source; only 453 mt were harvested from marine aquaculture.

The majority of fish farms in Egypt can be classified as semi-intensive brackishwater farms. This type of farm is increasingly vulnerable because of the competition for land and water between this activity and the requirements of land reclamation for agriculture, and the numbers are anticipated to drop significantly.

Intensive culture in earthen ponds and tanks is now developing quickly as a response to the potential drop in number of the semi-intensive farming units. The success of this trend depends largely on the new private-sector groups (e.g. private enterprises or cooperatives) that have joined the fish-farming activity. These groups have adopted higher levels of production technology and use more responsible approaches to resource use. Private farms now represent 89 percent of the area occupied by fish farming, and most of these are individual entities, although there are six cooperatives.

A national development strategy aims to increase the annual per capita consumption of fish from the present level of 10 kg to 13 kg by the year 2017, and to ensure the availability of low-priced fish to the consumer, either from national production or from imports.

Types of Aquaculture

Extensive aquaculture

Extensive aquaculture is applied in inland lakes, rivers and irrigation canals in Egypt. Brackishwater lakes (e.g. in the Rayaan Depressions, 16 000 ha, 4 ppt salinity) are mainly stocked with mullet and carps (silver, bighead and grass carp), while Lake Qarun (23 000 ha of 36 ppt salinity) is mainly stocked with mullets (Mugil cephalus; Liza ramada and L. salina).

Stock enhancement programmes were made in Lake Quarun with sole (Solea vulgaris) in the 1960s and European seabass, gilthead seabream and green tiger shrimp in the late 1970s. These programmes were done to support artisanal fisheries and to reduce the decline in productivity, since most of the freshwater species that used to inhabit Lake Qarun had disappeared because of the increase in salinity.

The River Nile and the irrigation network of the Nile Valley have been stocked with grass carp for weed control since 1994, while black carp has been stocked since 1997. While these activities are done within the National Project for Biological Control, they provide considerable support for fisheries in the Nile Valley. Out of a total catch of more than 65 000 mt, about 12 000 mt represent the harvest of stocked grass carp. These projects are managed by the General Authority for Fish Resources Development (GAFRD) development programme and financed by both the Ministry of Irrigation and the Ministry of Public Health.

Intensive aquaculture

While not very common in Egypt, five farms are using intensive tank culture to produce 500 mt of fish per year, mostly tilapia. About 1 000 cages have been sited in the north of the River Nile, having a total volume of about 210 000 m3. Other cage sites have been developed in Lake Manzala and Lake Temsah. Current annual production of cages is above 2 100 mt.

Although irrigation authorities have not encouraged cage culture in the River Nile, because of pollution and/or navigation issues, this activity is expected to greatly expand in the coastal lagoons during the next few years, being monitored and controlled by local environmental departments. The government views the activity not only for food supply criteria, but also as a means of solving unemployment problems.

Integrated aquaculture

The importance of rice-fish culture has fluctuated according to the areas put to rice cultivation. There has been a considerable expansion in rice-fish area in the 1980s with a peak in 1989, at a time when the price for rice was not favourable and new reclaimed salt-affected land was taken under cultivation with continuous flooding and fish production. This situation changed after 1989. Rice prices increased, the adoption of high-yielding varieties led to a higher productivity, and reclaimed lands were converted to rice monoculture (Halwart, 1999). Fish production from this system peaked at 28 000 mt in 1989 (233 000 ha), reducing to 21 000 mt in 1996

Canals, ponds and lakes in the different oases in the western desert are stocked with tilapia and common carp to supply the local population with fresh fish. The first harvests were recorded in 1985.

Semi-intensive aquaculture

Semi-intensive aquaculture provides about 75 percent of Egypt's total aquaculture production (about 64 000 mt), and most farms are located in the northern or eastern parts of the Nile Delta. The water supply for these farms comes from agricultural drainage water. There is great variation in the degree of intensity, types of input, level of management and the size and type of infrastructure. This type of farming covers about 78 000 ha, while the average productivity ranges between 0.7 to 4.3 mt/ha/yr. Tilapia contributes 44 percent of the annual harvest, followed by mullets (25 percent) and carps (24 percent). Seabass and seabream contribute 3.5 percent each within the total.

and slumping to only 7 000 mt in 1997, when only 58 000 ha of rice were integrated with fish. The position in 1997 was a direct result of the abandonment of the free delivery of fingerlings to farmers. Following this situation, the Ministry of Agriculture decided to restore the policy and, in the future, production is expected to increase.

Aquaculture locations

Aquaculture in coastal lagoons

Egyptian coastal lagoons are preserved for free access to fishing, an activity that represents 31 percent of the total fish production. Fisheries are allowed in all areas, except near the sea openings.

Despite this rule, some fish farms exist within the coastal lagoons. The "Hosha" system is usually applied; this is an old practice that involves enclosing an area within a water body by dykes. Fish are attracted into the "ponds", or are stocked directly, and kept until harvest.

Land-based coastal aquaculture

Most of this activity is located in the northeast of the Nile Delta (Damyetta), the Suez Canal areas and the Sinai and

As the numbers of hatcheries increased and the requirements of the fish-farming industry became clearer, production patterns have changed slightly. Common carp still represents 49.5 percent of the total number produced (1998), where rice culture is the major recipient. A significant increase has been seen in the production of grass carp fingerlings (+283 percent) to be stocked in water canals for weed control purposes. At present, however, insufficient numbers of tilapia fingerlings are produced in governmental hatcheries focuses on the production of high-value fish such as gilthead seabream, European seabass and shrimp (Penaeus sp.).

Coastal fish farming depends on wild-collected fry as seed stock (except for shrimp farms). These farms use large, shallow ponds and have a limited water supply of mediocre quality, a factor that affects productivity. New farms in the Suez Canal and Sinai areas have established hatcheries for their own supply, as well as for others. Additional hatcheries are currently under construction. The government is encouraging coastal aquaculture to compensate for the expected decline in brackishwater yields. It is hoped to attract higher levels of corporate investment, which would imply a more developed technological activity and better management.

In-shore aquaculture

This activity is limited to only 10 cages, sited in a coastal lagoon in South Sinai, which have a total annual production of 30 mt of seabream. Nonetheless, the activity is expected to develop and expand once appropriate fingerlings are available.

Services for aquaculture (inputs)

Fish hatcheries

In order to support the needs of the growing fish farming industry, governmental freshwater fish hatcheries were established starting from the early 1980s. Currently, 14 state hatcheries produce about 90 percent of the total fingerlings produced in the country. These hatcheries are well distributed to provide their production of fingerlings to fish farms, rice fields and natural waters. Annual production was 27 million fry in 1982, reaching 306 million in 1995.

to match the need for fish farm requirements.

Private-sector hatcheries produced only 17.5 million fingerlings in 1995, representing less than 5 percent of Egypt's total production. However, these hatcheries focus on tilapia supply (16.5 million or 94.3 percent of fingerlings), a circumstance that promotes tilapia culture. This means that about 43 percent of the tilapia fingerling supply came from private hatcheries in 1995. This situation became even more pronounced by 1998, when many small and medium-size hatcheries were producing all-male tilapia fingerlings. Twenty private hatcheries produced 32 million tilapia fingerlings, while the 14 governmental hatcheries provided 18 million. These levels of production still do not meet demand. One governmental hatchery produces the postlarvae (PL) of freshwater prawn (25 000 PL/yr).

A marine governmental hatchery has been established near Alexandria to support marine aquaculture development, while several private marine hatcheries have been built recently. In 1998, about six million fingerlings were produced of seabream, seabass, red tilapia and shrimp, accompanied by an estimated 4-5 million shrimp postlarvae. Recently, a new shrimp project has started, and this includes a hatchery for production of around 200 million of P. semisulcatus.

Collecting stations

Several collecting stations, sited around the coast, distribute wild-caught fingerlings. In 1998, a total of 129.5 million were collected, of which mullets are the dominant species (99.2 percent), the remainder being seabass and seabream. The harvesting and distribution of wild-caught fingerlings

Freshwater fish hatcheries lead production statistics, where carps (especially common carp) are the major species reared.

is done and supervised by the GAFRD. While subject to seasonal fluctuation, the yields have ranged from 95.9 million (1993/1994) to 148.4 million (1989/1990).

Fish feed and fertilizers

Manure (especially chicken manure) and chemical fertilizers are used in extensive and semi-intensive aquaculture.

For semi-intensive and intensive aquaculture, supplementary feeds are used. Originally, these were pelleted cattle feed, cottonseed oil cake, wheat and rice bran, and the production and use of specifically formulated fish pellets is relatively new. Most of fish feeds produced locally have been for supplements to other feed inputs, and the quantities produced meet present needs.

Cost factors have influenced manufacturing processes, and the five feed mills (governmental and private) tend to produce fish feed of sinking (hard) pellets of 17-25 percent protein content. Pelleted feed use has expanded recently and, about 20 000 mt of formulated feeds are made annually. Some feed mills have extruders for the production of floating pellets. With the exception of fishmeal and some meat meals, all other ingredients are available from local suppliers.

However, it is of the author's view that although the existing capacity of Egyptian feed manufacture is capable, to a certain extent, of supporting the growing

The supply of tilapia fry at the appropriate time is seen as a major constraint for future development. Because of the high marketability of some marine fish and shrimp species, more attention has been given to their aquaculture potential, notably for European seabass, gilthead seabream, and green tiger shrimp. Their impact will be dependent on the success of national hatchery supplies.

The effects of the accidental entry of some species cannot be ignored. African catfish (Clarias lazera) and Nile perch (Lates niloticus) are examples of this. Because of their predatory behaviour, these species may have an impact on populations in fish ponds, especially if they are present in number and/or large sizes. Nonetheless, there is a preliminary interest in the cultivation of both species.

Introduced species

In 1934, the common carp (Cyprinus carpio) was introduced from Indonesia while the mirror carp strain was brought in from France in 1949. With the construction of hatcheries in the 1970s, more carp species were introduced. The grass carp (Ctenopharyngodon idellus) was taken from Holland in 1977 for weed control. Subsequent propagation of the species was successfully achieved. Silver industry, some types of feed has yet to match the international quality of feeds (shrimp feeds and specialized feeds for hatchery requirements are examples). Such feeds continue to be imported from Europe, the United States and Japan. Nonetheless, there is increasing adoption of formulated feeds by traditional farmers because of good productivity results.

Major aquaculture species

Indigenous species

Mullets, especially the grey mullet (Mugil cephalus), have been one the major species since aquaculture started; the market is good and fry can reach market-size within one growing season. Because of the shortage of grey mullet fry to supply aquaculture needs, M. capito stocks were used as a supplement. However, an additional nursing season is required to grow this specie to market size.

Tilapias are now the main cultured species, notably Oreochromis niloticus, O. aureus and Sarotherodon galilaeus. While Tilapia zillii is seen as undesirable, this species can “contaminate” ponds in large numbers by wild infestation or through the water supply system.

carp (Hypophthalmichthys molitrix) and bighead carp (Aristichthys nobilis) had been brought in previously from Thailand (1954) and Japan (1962). However, their contribution to aquaculture was not significant until the hatcheries were able to produce adequate quantities. Carp species now contribute significantly to Egyptian aquaculture, especially in government fish farms. Common carp is stocked in rice fields and grass carp fingerlings are stocked annually in canals and drains. The last carp species to be introduced (in 1993) was the snail (black) carp (Mylopharyngodon piceus), which is so-called because of its capacity to control snails in fish-culture habitats. Studies are being conducted to investigate their feeding habits and possible effects on the ecosystem.

Red tilapia hybrids have since been introduced, targeting better use of saline waters. The freshwater prawn (Macrobrachium rosenbergii) has been also introduced from Malaysia and Thailand in the 1980s for use in mono- or polyculture systems. The introduction of crawfish (Procambarus clarkii) is a fact, but the reasons for its presence are not clear.

Iraq

The first fish farm in Iraq was established in 1965 with an area of 2 ha. By 1995, 1 727 farms were operational, having a total area of 3 200 ha, and which produced 3 400 mt of carps (valued at US$34 million) in 1997. The potential production for such an area, if appropriate inputs (notably feeds) were available, is at least 18 000 mt of fish. Productivity per unit area is low in most fish farms, ranging from 1 400 to 2 000 kg/ha. This low productivity is attributed mainly to the shortage of adequate fish feeds.

Most fish farms in Iraq are extensive, and small farms (1-10 donems (donem = approximately 2 500 square metres)) represent more than 80 percent of the total number. The productivity of these farms is very low due to modest management systems and low input levels. Cage farming expanded in the early 1980s in Habania Lake, but was eventually abandoned for commercial production, limiting its use to research.

Israel

Israel has shown slower growth than several other nations in the region and has been displaced by Turkey as the second most important producer, following developments through the decade. Nonetheless, more than 18 000 mt were produced in 1997, represented by eight major species. Production has traditionally been dominated by the use of multipurpose reservoirs, which were responsible for 46 percent of the surface area used for aquaculture in 1995, and polyculture systems predominate. The competition for water, combined with market factors, resulted in an important shift away from the use of dedicated fish ponds (Sarig, 1996).

Key issues encountered have been to increase production efficiency, in order to reduce market prices, and species diversification, a goal that is reflected in the growth of certain species. Mullets and gilthead seabream became increasingly important contributors after the mid-1990s, while hybrid striped bass and red drum also made their appearance in production statistics at this time.

In the mid-1990s, a considerable effort was put over to investing in new infrastructure in aquaculture, particularly tilapia farming and effective over-wintering facilities (due to heavy losses in cold weather in 1991-1992). The anticipated increases of these investments started to be registered from 1995. Improving productivity to render aquaculture products more competitive in the market place and reduce imports is another core consideration of this policy. There has been a degree of interchange in production, where reductions have been seen for some "traditional" species (e.g. common and silver carp), while others have increased (e.g. seabream, tilapias, mullets). This reflects a move towards marine aquaculture as opposed to the traditional freshwater activities, noting that the species cited also have higher individual values than the freshwater species cultivated.

Jordan

Fish culture in Jordan started in 1965, following investigations to use effluent water from mirror carp to irrigate agricultural crops. The main goal was to demonstrate aquaculture viability in Jordan, accompanied by supplying carp fingerlings to farmers and stocking dammed lakes. Annual production between 1966 and 1978 was 20 000 to 30 000 fingerlings, which encouraged the establishment of carp farms. The project

Important climatic differences between the northern and southern regions, combined with increased water consumption in all areas, has meant that inland aquaculture has been given low priority, having to target brackish water and sources not suitable for agriculture or domestic use. As a general target, optimized water use (recycled city water, desalinated brackish water, recycling systems) will remain a key factor in future development. Strategies for improved water use are under examination, focusing on dual-purpose applications (e.g. within reservoirs) and/or use of recycling systems (Mires, 2000).

was terminated in 1978 for administrative reasons. There are 24 fish farms, with a total area of 13 ha, which produced 200 mt in 1997. Carp and tilapia are the main species produced. Most of the farms are very small, consisting of a few ponds that contain different species of varying sizes, and use farm by-products for feeding. Three projects exist of a more intensive nature, but none is fully operational yet. One hatchery exists in the North Shuneh region of Jordan.

Kuwait

Kuwait possesses clean, non-polluted sea water with an average temperature that gives an excellent environment for fish culture.

However, the coastline is open and unprotected from severe weather; normal conditions include strong winds, waves and currents. Kuwait has promoted marine aquaculture, adopting floating cages as the technology of choice. The natural conditions impose investment for artificial and technical protection, increasing both the construction and operating expense. Feasibility studies have indicated that a production level of 400-600 mt/yr could both support such additional costs and be profitable.

There are 65 fish farms in Kuwait that use integrated aquaculture technology, occupying a total area of about 36 000 m2, and most are operated as extensive units. The government favours farms that use higher levels of management (i.e.

Recirculated brackish groundwater tanks or ponds made from durable materials, using constant aeration/oxygenation, can be used for tilapia culture, providing fish of 500-700 gm at densities of 12-15 kg/m3. Tilapia hatcheries using established technology are profitable enterprises.

Lebanon

Freshwater fish farms were first established in Lebanon in the early 1960s, both in cold and warm water, and trout, carps and tilapia have been cultivated. There are about 40 small fish farms, mostly concentrated in the Beqaa area, culturing rainbow trout. Although the annual capacity of these farms is about 500 mt, production is only 120 mt, which using nursery facilities, growout and fattening ponds), supplying free imported feeds while more modest facilities only receive 25 percent of feed requirements; this policy is to promote more efficient and professional production.

There has been a growing interest in marine fish species, such as sobaity (Sparidentex hasta) and grouper (Epinephelus coioides), as well as tilapia spp., which can be cultured in brackish or sea water. Acanthopagrus latus has recently been spawned for the first time.

Only one marine farm exists in Kuwait, which uses intensive cage culture for local and European seabream, grouper (E. coioides) and she'em (yellow-finned black porgy, Acanthopagrus latus). Production started in 1992, aiming at around 200 mt annually.

Surface freshwater and groundwater resources are limited, and the costs of use restrict the possibilities of aquaculture development. Some 50 integrated farms exist, using higher salinity groundwater for water supply, but annual production is low (0.5-1.5 mt per well).

Techno-economic assessments of the species and appropriate aquaculture systems combined have been made to identify the positive options for development, such as integration of tilapia production with agriculture. This could take the form of integrating tilapia with vegetable crops, which are irrigated only in summer, and should yield around 1 mt fish/well (500 litres/min). A second option is to integrate tilapia with alfalfa, requiring year-round irrigation, yielding around 2 500 kg fish/well (500 litres/min). If 25 percent of the 847 operating wells were used, 530 mt of tilapia could be produced annually, imposing a need for a hatchery producing 1.5-2 million fry/yr.

is attributed to low market demand, especially for freshwater fish species, as well as difficulties in obtaining the required inputs (feeds). The Lebanese Aquaculture Center, which was established in the 1960s, encouraged the development of fish farms, supported by the Ministry of Agriculture.

Libya

Aquaculture started in 1977, exploiting dammed reservoirs made to catch rainfall. Common carp, silver carp, grass carp and catfish were stocked in these facilities. Similarly, carps were stocked in the Lake of Wadi Magnene (126 ha), while carps and tilapias have been stocked in other dams. Annual production statistics indicate that 230 mt of freshwater fish (mainly carps) are produced from 146 ha of freshwater lakes, and that production appears stagnant due to a lack of consumer demand for carps. Some 100 integrated farms have been established in the southern region, employing concrete tanks supplied with ground water, for tilapia production and using the wastewater for agriculture production.

The first marine fish farm was established in 1989 in Ain Ghazala, which has 180 ha in addition to about 500 ha of marshes. This farm acted as an enclosure to receive mullet and seabass fry collected from the lake. To support the marine aquaculture activity, a project has been established at Ain Zayyanna, targeting production of 2 million fry of seabream and seabass, as well as 400 mt of market-size fish of these species. Trials on shrimp culture have been of varying success; following tests with native and imported species, production of Penaeus japonicus postlarvae (originally imported from Egypt) had increased to about 2 million by 1997.

Experimental trials have been started on mussel culture (Mytilus edilis) in the western parts of the Libyan coastline.

Nile tilapia and red tilapia hybrids are being grown in cages in Ain Kaam Gulf, using stocks imported from Egypt.

Morocco

The first aquaculture activities in Morocco can be traced back to the 1920s, when oysters (imported from nearby European countries, such as Portugal and France) were maintained until sale during festive seasons. However, mariculture in Morocco has not advanced quickly, being limited only to coastal farming of oysters (Atlantic) and finfish (Mediterranean). Some 200 mt of oysters and 1 000 mt of seabream and seabass are cultured annually.

Mariculture has been developed through private initiatives, while freshwater fish culture was started by government authorities. In 1925, the Ministry of Agriculture established a station to repopulate naturally occurring brown trout in the waters of the Middle and High Atlas Mountains, leading to the present situation where private and government interests operate farms for the intensive culture of rainbow trout and carps. Trout (100 mt) are for local consumption, while carps (1 000 mt) are used primarily for weed control. Generally, the per capita fish consumption in Morocco is not very high (about 7 kg/yr).

There are five oyster farms on the Atlantic coast whose products are sold locally. Attempts to produce oysters and clams within the lagoons and estuaries of the Mediterranean coast have encountered technical and commercial difficulties, leading to the virtual abandonment of these activities, concentrating only on finfish (seabass and seabream) in cages. A small-scale industry for clams (60 mt) and mussels (320 mt) exists in certain sites on the Atlantic coast, where carpet-shell clams and mussels are fished and stored before sale. The large-scale production of scallops (Pactinopecten yessoensis) at Khinifiss is projected, using spat imported from Canada, where annual production is foreseen at levels approaching 2 000 mt. In regard to finfish, there are two fish farms located on the Mediterranean coast.

Three enterprises are engaged in freshwater fish farming but, due to the poor local market for these species, there is little private investment interest. Two companies that are specialized in carp production have answered the need for weed clearance in reservoirs built for irrigation and potable water supply. Only one company is involved with trout farming (100 mt/yr), which has also tested the production of sturgeon and other species, although a second project is projected to achieve the same production level.

Oman

Aquaculture is a new activity for Oman. In

Mariculture is controlled by the Ministry of Fisheries, while freshwater aquaculture is the responsibility of the Ministry of Agriculture. Mariculture initiatives have included pilot-scale mussel farming, and studies on rearing blue-fin tuna (Thunnus thunnus) have started in cooperation with Japan. Freshwater centres have investigated the hatchery production of a wide range of species, including brown and rainbow trout, pike, perch, pike-perch and black bass. The introduction of fingerlings into freshwater bodies for fishing has been promoted. Similarly, the production of carps for weed control is under governmental supervision.

Two large fish farms exist on the Mediterranean coast (at Nador and Moulouya), devoted mainly to the cage culture of European seabass and gilthead seabream, whose products are exported to markets in neighbouring European countries.

the 1980s, there were trials to culture giant tiger shrimp (Penaeus monodon), but it is believed that the Indian shrimp (P. indicus) is more promising. A large fish-farming project exists, involving the Ministry of Agriculture, national and international companies.

Qatar

Experimental mariculture started in 1988, and technical studies have been done on a variety of marine fish species within an experimental farm, but commercial aquaculture has yet to achieve significance.

Saudi Arabia

The first aquaculture project started in 1982 and, by 1996, over 95 projects were operating. In 1996, production of more than 3 500 mt of tilapia and catfish was attained. Shrimp farming started with modest yields in the 1980s, exceeding 100 mt in 1991 and over 1 000 mt in 1998.

These range from simple technology to those of intensive aquaculture. Consequently, installations range from ponds to concrete or fibreglass tanks that are land-based, using wells for groundwater supply. Feeds are made locally, formulated according to dietary requirements, and are subsidized for fish farming. Aeration or oxygenation is a common practice, but few farms are mechanized with, for example, automatic feeding systems. Food conversion ratios are normally 2-2.5 for tilapia species, and

By 1997, public investment in aquaculture maintained 15 enterprises (260 ha farms, 70 000 m3 cages). The authority has actively encouraged private-sector investment, and there are nearly 500 private fish farms with an area of 700 ha. The overall contribution of aquaculture reached about 5 000 mt in 1997.

Syria has lakes and dams, with an area of about 100 000 ha, that have been stocked with some 25 species of Cyprinidae, Mugilidae, Siluridae, Mastacembelidae, annual productivity rates for the tilapia farms range from 5 to 25 kg/m3.

Saudi Arabia is rich in marine resources, possessing a 1 600 km coastline along the Red Sea and 500 km along the Arabian Gulf. Both coasts have sheltered bays, mangrove swamps, mud flats and onshore plains that provide suitable sites for either land-based farms or for cage and pen culture. Both water quality and climatic conditions are favourable for mariculture activities. The Red Sea coast has more stable salinity (42-44 ppt) and better sea temperatures (21-31 °C) that are more suitable for marine shrimp culture than those of the Arabian Gulf (42-55 ppt and 12-35 °C).

Currently, there are three shrimp farms on the Red Sea that raise both tiger shrimp and Indian shrimp, each farm being able to supply its own needs of postlarvae. Although it was felt that the Indian shrimp holds higher promise, the tiger shrimp has given the highest yields (nearly 1 700 mt in 1988), using strains collected from the Red Sea that have a higher salinity tolerance.

The major species produced in freshwater systems are the Nile tilapia, the blue tilapia (Oreochromis aureus) and red tilapia hybrids, while common carp and African catfish (Clarias gariepinus) are also reared. All fish farms rely on groundwater drawn from surface or deep wells, and effluents are used for the irrigation of plant crops within integrated systems. Because of water supply limitations, intensive culture is the system of choice, since higher productivity (20-40 kg/m2) can be obtained, but closed and semi-closed systems (ponds, tanks and cages) are also widely used. In the southwestern region of the kingdom, three dams (Gizan, Negran, Abha) contain 1.85 billion cubic metres of fresh water, within Bagridae, Gobitidae and Cichlidae. Eleven governmental farms produce around 1 000 mt of fish and about 7 million fingerlings. The authority also owns four cage farms producing 690 mt of fish. The private-sector farms produce 3 500 mt of food fish and 15 million fingerlings.

All types of aquaculture systems exist, but most installations are based on semi-intensive practices, where annual productivity rates are between 4-10 mt/ha. These rates have been achieved through the use of better quality feeds, higher stocking densities and the maintenance of good water quality. Intensive culture is represented mainly by cage culture, where annual productivity is between 30-60 kg/m3. Carp and tilapia are the main species, while rainbow trout may be stocked once colder climatic conditions set in (December to April), following the harvest of the installations. Two farms use raceways for farming rainbow trout, producing 160 mt and one million advanced fingerlings for the “replacement” stocking described previously.

Tunisia

While oyster culture has 40 years of history in Tunisia, further developments occurred following the establishment of national centres, during 1975 to 1984. The first commercial marine fish farm was built in the 1980s, and there are now five farms having a total production target of 1 300 mt of marine fish species. Hatcheries supply 7 million fry of seabass, seabream and mullet, and annual yields of marine fish have increased from 510 mt (1988) to 800 mt (1997).

Among the problems facing marine aquaculture, the effects of toxic algae (dinoflagellates) have been notable, causing significant cage mortalities in which the Ministry of Agriculture and Water is planning to develop freshwater aquaculture.

Syria

The earliest aquaculture trials started in 1957, and the General Authority for Fisheries, established in 1974, has the responsibility for supervising and promoting aquaculture projects.

1991-1994. Plans exist for the promotion of mollusc culture through the construction of farms and hatcheries, where annual production of about 8 000 mt is targeted. The total production of molluscs (mainly Mytilus galloprovincialis), from aquaculture was around 400 mt in 1988, declining to 65 mt in 1997.

Crustacean aquaculture has been investigated, but no satisfactory results have been obtained as yet.

In 1989, a national project was launched to evaluate the appropriate fish culture technology to be used in dams, where mullet, carp and other freshwater fish species are reared. Within the country, some 14 000 ha of dammed water bodies exist. Currently, about 5 million fry are transferred annually to 12 large dams (10 000 ha total area). By 1997, fish production from these projects amounted to 700 mt, where mullet represents about 40 percent of the yield. The use of conditioned hot water springs is also being investigated, potentially for adapting to tilapia culture.

Turkey

Aquaculture in Turkey has shown almost exponential growth since 1988, increasing its annual production from 4 100 mt to over
45 000 mt. Where carp was the major product in 1988, this was rapidly

As with other regional exporters, Turkish exporters have had to adhere to the regulations concerning food safety and hygiene, conditions that have caused some problems to the sector. An export ban on national fishery products (including aquaculture) disrupted the market in the late 1990s, creating severe economic difficulties within the sector. Nonetheless, this stimulated marketing actions by the production sector in Turkey, with very positive results.

Investments have been made in the sectors of fishmeal and feed manufacture, allowing the supply of improved feeds to both the freshwater and marine aquaculture sectors, a factor that has contributed to the rapid expansion seen in the 1990s.

United Arab Emirates

The United Arab Emirates (UAE) has an extensive coastline of about 700 km, facing the Arabian Gulf on the western coast and Gulf of Oman on the east. Numerous islands and lagoons provide an overtaken by competitive products, and its production has reduced by two thirds (from 2 200 mt to 800 mt).

The main species produced now is rainbow trout, representing 63 percent of all aquaculture in 1997, while the other major species are seabass species and gilthead seabream. Some 85 percent of the trout produced is portion-size, which is mainly consumed in the local market, while the other 15 percent are large trout (over 1 kg individual size) that are produced in cages in the Black Sea. The harvest of large trout has to be achieved before high summer temperatures, an operating condition that may limit expansion of this subsector, while the portion trout market remains interesting. Very little of this product is exported, being taken up by the domestic market.

The mariculture sector continues to expand its production, which was influenced initially by an attractive European Community (EC) export market. While seabass led production in the mid-nineties, this place was taken up by seabream in the later years of the decade, partly as a result of epizootic problems. The culture of marine shrimp (Penaeus sp.) started in 1995. Finfish mariculture provided less than 200 mt in 1988, growing in size and scale to provide over 13 500 mt by 1997. A major part of this production targeted the EC market, notably in Italy.

ideal environment for marine resources. Historically, the country has strong links with maritime activities, and the government gives due importance to both agriculture and fisheries. In 1984, the Marine Resources Research Center (MRRC) was established, and experimental aquaculture is a key element of its programme. While performing a wide range of studies on husbandry and feeding research on fish and crustaceans (particularly shrimp), this has yet to be translated into significant aquaculture production.

Yemen

Aquaculture in Yemen is confined primarily to experimental work on marine fish and crustacean (shrimp) aquaculture, which is being done at the Aquatic Research Centre in Aden.

Financial assistance for aquaculture development

Aquaculture, has a short history in the region and has taken time to develop to its current level. The application of technology and improved management and husbandry systems requires investment, both in operating costs and in materials. A short review of the credit systems available within specific countries of the region demonstrates some of the difficulties faced by farmers wishing to develop their aquaculture activities.

In Morocco, preferential loans can be obtained for short-, medium- and long-term periods from a governmental bank, covering 70 percent of total project costs and requiring guarantee. An EU-Government development scheme in the northern mountain area can provide up to 90 percent, without guarantee, for as long as the project investment does not exceed US$ 280 000. No projects have yet benefited from this scheme.

Loans are, however, difficult to obtain, due to administrative delays. To date, only three projects have benefited from loans allocated to aquaculture. To facilitate obtaining loans for aquaculture development, certain suggestions have been made:

- the purpose and advantages of the credit should be made well known to the farmers;
- such credits could be associated with extension services, so that aquaculture techniques and advantages can be popularized;
- the lending banks should get further financial assistance from national or international donor agencies; and
- specialized training in credit management for aquaculture projects may be required for local banks.

In Saudi Arabia, interest-free loans are provided to farmers for the development of aquaculture projects, including the purchase of machinery and facilities. Such loans are normally extended over 10 years, with a grace period of one or two years. Moreover, the government subsidizes fish feed and farm equipment.

There is more than one credit line available for aquaculture development in Egypt, where one of the most important is the NG Aquatic Resources Activists

Constraints for aquaculture development in the near east

Aquaculture, as any other agricultural activity, is affected by different factors that enhance or inhibit its development. The factors are of a technical, economic, legislative or institutional nature. The severity of the different constraints encountered explains the gap seen between production and production capacity. The following section summarizes some common constraints encountered within the region, giving specific examples seen at national levels.

Technological constraints

Dependency on wild stock sources for seed

For example, the limitation of wild mullet fry is affecting the stocking level of dams in Tunisia and fish farms in Egypt.

Insufficient hatchery production of fish seed

This appears to be an important factor in many countries in the region, illustrating the need to apply the appropriate technology to produce seed stock for marine fish and shellfish requirements (e.g. Tunis, Algeria and Bahrain) or reduce imports (e.g. Kuwait). This was quite a big problem in Turkey, but investment in hatcheries has contributed to alleviating the requirements of wild seed. The limited availability of tilapia fingerlings of particular sizes at specific times is visibly hindering aquaculture development in Egypt.

Insufficient production of specialized fish feeds

Specialized industrial fish feed manufacture does not exist in most

Support Fund. This is a nongovernmental union that provides support to all members who work in fisheries and aquaculture. Interest-free loans can be provided to small-scale aquaculture and fisheries projects. In addition, the Government Young Graduates Support Fund can finance selected small-scale projects. A new credit line programme in cooperation with the EC, provides soft loans to aquaculture projects of varying importance.

Actually obtaining the loan is not so easy, since banks require collateral that is often beyond the ability of the small farmer, a position that is exacerbated by the perceived risks of the activity. It will take time before banks appreciate that the risk of aquaculture is no higher than that of other agricultural activities.

regional countries, due to the lack of raw materials and manufacturing technology, imposing imports as a necessity for aquaculture. Even where manufacturing capacity exists, specialized feeds for hatchery and ongrowing still must be imported. Prime suppliers of formulated feeds are the Netherlands, France and China. This situation increases direct production costs, which have to be countered by increased productivity.

Inadequacy of project conception and design

There is a clear need for an improved design capacity for aquaculture projects within the region, where specialized national aquaculture engineers are required; this would reduce the damaging effects of poorly designed and engineered projects on production.

Competition from other sectors

In Cyprus, Egypt, Tunisia and Turkey, competition in the coastal zone areas is evident, where other development sectors, notably tourism and industry, are challenging aquaculture for access to the constraints that the region is facing for aquaculture development. Furthermore, many banks view aquaculture as a high-risk venture and hesitate to give credit to commercial projects. Market limitations can also be either caused by a lack of consumer preference for the product or competition from fisheries products. Export-oriented projects have experienced the problem of adapting to export markets and their associated requirements (e.g. Hazard Analyis Critical Control Point (HACCP) surveillance). Balancing the difficulties of export (i.e. market knowledge) with the extra costs associated has been a severe hindrance for some countries.

coastal resource.

Insufficient training

This is a critical factor in almost all countries of the region, where there is a lack of skilled managerial and technical personnel to assist the development of marine aquaculture and advance technological requirements.

Inadequate water supplies

Increased salinities and expanding agricultural irrigation are but two of the factors that are restricting the availability of water to aquaculture, creating problems for aquaculture project management.

Scarcity of suitable sites

This is a clear restriction in much of the region, where there are few locations that are genuinely suitable for aquaculture project development.

Limited capacity of scientific research for technology development

Although there are several aquaculture research institutes in the region, the contribution of these institutes to real development is limited, either because of inappropriate research targets or because of the absence of effective aquaculture extension.

Economic constraints

The increased cost of aquaculture projects, particularly those based on intensive technology, poor credit resources for aquaculture, and high interest rates on credit are some economic

Other constraints

Lack of specific aquaculture policy and legislation in many countries in the region causes difficulties in aquaculture development, investment and obtaining resources. Over-all need for a cohesive aquaculture policy, within the general development framework, is essential for future aquaculture development in the region. Such policies should promote aquaculture as an activity within the overall development objectives and should consist of enforceable laws and regulatory frameworks to support aquaculture and also to protect the environment.

There are many institutional constraints too. There is often weak cooperation among agencies that are concerned with aquaculture, which can lead to overlap or even conflict in their duties. Poor cooperation between the production and research interests, particularly for applied technology, the lack of farmers groups that are capable of presenting sectoral needs to official bodies, and insufficient extension services for the transfer of research to field application are also worth mentioning.

In a region such as the Near East, one cannot ignore the problem of natural constraints on aquaculture development. Most of these constraints relate to water availability and quality, but the characteristics of the land and the climate also need to be considered. These constraints are as follows:

- water scarcity is the foremost natural constraint, leading to competition with agriculture and other societal requirements;
- scarcity of appropriate land for development;
- competition with sectors, such as

tourism, that leads to higher land prices can render coastal aquaculture unprofitable;

- decline in groundwater resources, due to over-pumping, affecting availability for aquaculture. In general, studies on the underground water reservoirs and their potential use in aquaculture appear to be largely insufficient.
- pollution of water resources, limiting use for aquaculture;
- harsh climatic conditions. The harsh climate in some countries can be a highly restrictive factor, especially in regard to water temperature, its intensity and daily or seasonal fluctuation (e.g. in Bahrain and Qatar).

Besides these, there are many constraints that are specific to different countries of the region.

Marketing of aquaculture products

Trade in fish and fishery products

Fish, shellfish and fishery products are integral within global trade, with no less than 195 countries having exported part of their production and some 180 countries having reported fishery imports in 1996. As production has increased, so international trade has continued to grow, accelerating in recent years. Part of this

Government farms tend to auction their products well in advance of harvest, while private operators depend on daily prices and demand. Cage farms harvest on demand, usually selling direct to retail. At present, most, if not all of the aquaculture products are marketed locally.

Fish marketing is a business that is almost totally private. Fish marketing regulations are concerned mainly with the quality of the product, irrespective of whether its source is aquaculture or fisheries. Egypt also imports about 25 percent of the fish consumed in the country, imports being dominated by frozen pelagic fish. The main consumers of frozen products have low incomes.

Market supply and demand factors control prices and the higher value "luxury" species, which used to be exported, now command equal or higher values to those obtained on export markets. Consequently, producers are no longer interested in tackling the demanding procedures required for export. In addition, requirements such as those demanded by the EC regulations have greatly increased local preparation costs for export products. Most aquaculture products are treated by the same legislation as applied to fisheries.

Saudi Arabia

measured growth is linked to the expansion of the world's economies, but it also reflects the increased availability, owing mainly to aquaculture production, of consumer-desired species, as well as the sustained demand for fishmeal. Another part of the increase measured is nominal, since it is due to newly reported trade between countries that were formerly within one political entity.

FAO statistics reported export volumes reaching 22 million mt in 1996, which is nearly three times the volume traded in 1976. When reconverted into the estimated live weight equivalent, this represents 40 percent of total fisheries production, a rise from around 30 percent. The following section describes the characteristics and trends for the trade and marketing of aquaculture products for some of the countries in the Near East Region. Adequate data are not available for all countries of the region.

Marketing and trade patterns

Egypt

Sales and marketing characteristics vary following the type of culture and the location. If harvested and delivered to collection points, auction sale to wholesalers remains the dominant procedure, using cooperative staff for icing, sorting and weighing.

Farm-raised tilapia is well received by certain ethnic expatriates but, in general, the local population is less welcoming. Constant prices of 11 to 13 Saudi Riyal [approximately
4.0 US$) are obtained for the preferred product, fresh fish. Retail prices are some 30-50 percent higher, and well-established networks for retail sale in the major cities have been established. At present, demand appears to be increasing, and there is no major problem in marketing tilapia produced from aquaculture.

Turkey

The aquaculture market is clearly divided into two sections, trout for the domestic market and marine aquaculture for export. While the trout sector enjoyed prices much higher than seen elsewhere (e.g. in EC nations), these diminished as production increased to important levels. Investment in added-value products has given some benefit to counter this trend. The mariculture sector had depended quite considerably on export, particularly to the southern EC nations. The EC ban on imports created great disturbance and forced this subsector to invest in a national campaign, which provided beneficial results.

Cyprus

Cyprus has promoted offshore aquaculture activities, following the lack of suitable sheltered bays and conflicts with the tourism industry, which have allowed production to develop. Fish is supplied for national demands and the tourist sector, as well as for export. Export difficulties relate, as elsewhere, to entering a competitive market while being hindered by import taxes and adhesion to EC standards. A policy of diversification and technology application is being promoted in order to render the sector more competitive.

Trade, marketing and the future

There is a clear distinction within the Near East between aquaculture development that has been made for domestic consumption, either for import substitution or for improving national supplies, and that for export, where foreign exchange earnings appear as the key motivation for the activity. The progress in marine aquaculture, primarily for seabass and seabream, reflects the latter position, usually stimulated by private investment and, in some cases, through joint ventures made with European enterprises. The dangers of over-dependence on single markets, highlighted by specific experiences, combined with the absence of sectoral marketing actions has been quite notable. In many cases, where the sector has attained a higher degree of organization, notably through the creation of professional associations, national and international marketing actions have been achieved with very positive results.

In the future, if private investment is to be stimulated and aquaculture expansion foreseen, more attention will need to be given to national actions that enable

Egypt

The aquaculture production sector in Egypt is composed of a minor public and a major private sector. Most private aquaculture activities are of a primitive form, and farmers tend to lack enough education in technical matters. Focus is on direct production costs, as opposed to sectoral development, and awareness of responsible aquaculture is weak. Fish farmers are keen to know more about the quality of water inputs and the environment within their farms, but effluent outflows and the potential for downstream pollution are of less interest. Time and effort will be required before this concept is accepted, and legal enforcement cannot guarantee the application of responsible aquaculture. However, the government can act as a positive contributor, through financing farm reforms or cancelling licenses or land-lease contracts. The government sector and well-developed aquaculture cooperatives and businesses are generally better developed, both technically and financially, where management understands the value of applying responsible aquaculture. Nonetheless, concern always exists for the higher costs anticipated in adapting to the principles. The government has applied a group of measures to prevent the negative effects of the growth of uncontrolled or irresponsible aquaculture. Among these provisions is a control measure for only licensing new farms or land-leases to projects that are environmentally friendly.

All aquaculture producers, including traditional fish farmers, are aware of the importance of monitoring water quality criteria for inflows, following problems with pollution from other activities (farming, industry etc.). Economic interests tend to outweigh environmental awareness, and many farmers argue that reinforcement of the markets instead of creating the more fragile dependence on single export markets.

Responsible aquaculture development: some case studies

The following section presents four cases concerning the concept and application of responsible aquaculture, noting the variations seen between individual countries. Overall, however, there is constancy in the negative attitude towards aquaculture from NGOs and sectors that share common resources, especially tourism.

aquaculture effluent is no worse than the agriculture drainage water used for water supply. Also, the comparison is held up that other sources of pollution are worse than the potential pollution their farms may cause, noting that chemicals or therapeutic agents are rarely used in Egyptian aquaculture.

The Ministry of Environmental Affairs operates a monitoring programme to assure that aquaculture activities are in compliance with environmental regulations. Regular analysis of water quality is done for the effluents of different activities (for example, flows into rivers, canals, drains and lakes). However, under national environmental legislation, fresh- and brackishwater aquaculture is not included within the activities that have a negative impact on the environment, and therefore, fish-farm effluents are not routinely examined.

Only farms located near the Red Sea or in protected areas receive the attention of the authorities and NGOs in regard to possible impacts on the environment.

Disease outbreaks are not common in Egyptian aquaculture, probably due to the practice of sun-drying ponds after harvest and the use of low stocking densities. On-farm surveillance is rather weak, and therapeutic advice is usually sought from public agencies and veterinary centres. The use of drugs or therapeutic agents is largely limited to the large-scale hatcheries and nurseries, whose effluents are discharged into the drainage systems.

The plan targets an increase in per capita fish consumption of 13 kg/yr, to be obtained primarily from increasing national fish production. A realistic evaluation of the capabilities and available opportunities for development was an integral consideration, and a review of national resources was made, including material and technical aspects. Providing secure job opportunities for national employment and maximizing the responsible use of all available resources are also core elements. The government developed the plan after extensive consultation with representatives of the private production sector, research and

Mortalities are disposed of by incineration or burying, depending on the scope of the incident.

National development plans have been made within the region, due to the realisation of the importance of aquaculture for achieving food security and improving fish trade patterns. The plans vary in respect of short or long-term interests. Common elements exist, such as productivity increases and better resource use, while other issues differ following national interests.

A 15-year national plan was approved, integrating aquaculture within the concept of improving national fish resources. The main features of the plan are:

- encouraging fish farming development by giving security to farm projects, especially those on leased lands;
- encouraging investment in aquaculture;
- technical and action support for the upgrading of traditional farms;
- providing adequate supplies of healthy fry and fingerlings, at reasonable cost;
- improving handling and distribution of live fish;
- support for the establishment of hatcheries for Nile tilapia;
- production of fish feeds of improved dietary balance;
- encouraging investments in marine aquaculture and intensive fish farming;
- encouraging joint-venture aquaculture developments with partners from developed countries, particularly in mariculture; and
- encouraging integrated forms of aquaculture.

other relevant bodies and organizations. It should provide more opportunities for the private sector to develop investments and actions in intensive and semi-intensive fish farming.

The development plan has been successful in both promoting and developing aquaculture in Egypt. Besides the increase in fish production, a notable qualitative improvement has been seen in the production techniques applied, especially among the less developed farms. Historically, aquaculture was limited geographically to the northern delta; Upper Egypt is now sharing aquaculture development and with great success. The precautionary approach to development was adopted within the plan, so as to avoid the anticipated negative effects of unplanned expansion on both water and land resources.

Saudi Arabia

Saudi Arabia possesses great potential for aquaculture development but, until recently, mariculture had been neglected and the expansion of inland aquaculture has been constrained by limited ground water availability. Since demand for seafood is increasing and the yield from capture fisheries has levelled off, requirements could be met from mariculture development and the improved integration of aquaculture with agriculture.

The annual water requirements of agriculture are 14 billion cubic metres and, if integrated with aquaculture before application to irrigation, considerable fish production could be achieved. Stocking the reservoirs of the Jizan, Najran and Abha regions, which hold and supply 1.85 billion cubic metres of water, could further increase the freshwater fish yield.

Diversification of aquaculture species is necessary, but the technology and seed supply for higher value species need to be made available to fish farmers. Such species include groupers, mullets, rabbitfish and penaeid shrimps. Given the scarcity of fresh water, the application of closed-system technology for water cleansing and recycling is needed. Well-defined research and development programmes are required, but there is enthusiasm for technological improvement and investment opportunities for products adapted to market demand.

Morocco

Directive plans for aquaculture development are in progress at the governmental level, but lack precision at present. While good developments are being made for the reestablishment of Mediterranean coastal waters with blue-fin tuna, a project made in cooperation with Japan, no other plans for mariculture development have been issued. The plan for inland aquaculture development (1996-1997) has two objectives:

- to increase production of fingerlings of brown trout, pike and black bass to stock for sport fisheries; and
- to increase carp fingerling supplies for control of the eutrophication seen in reservoirs and to increase commercial fisheries in dam waters.

Kuwait

With self-sufficient fish supplies being the

- In the Near East, water represents the most important item of the aquaculture planning process, simply because of its scarcity. In many cases, it is also almost impossible to modify the status of use, either in quantity or in quality. Adequate sharing of this vital resource with other activities has to be considered, so as to avoid direct competition with other sectors. All water sources need to be studied and assessed. Special attention should be given to the quality of water and whether it is really appropriate for aquaculture, noting potential changes during the growing season. Underground water should not be seen as an endless resource. These points affect the choice of aquaculture system to be applied. In countries that suffer water shortage, such as Jordan, extensive aquaculture systems could damage water availability. In Saudi Arabia, where underground water is used, integrated or intensive systems remain the systems of choice. In Egypt, only agricultural drainage water is allowed for aquaculture.

Good site selection is one of the most important factors in fish-farm planning. Awareness of the issues of competition and resource sharing is essential, while land and local climate suitability for aquaculture are indispensable attributes. Questions concerning the appropriateness of soil amendments, pond linings or appropriate cage technology are several of the issues that need to be assessed.

objective, a strategy for developing the aquaculture sector was made by the Public Authority for Agriculture Affairs and Fish Resources (PAFAAFR), and this includes developing fish culture in the Gonna Kuwait area and in the low-salinity waters of the agricultural areas. Mariculture is being developed in sea cages at a commercial level, but efforts are being made to inform farmers of the main issues, risks and responsibilities of inland aquaculture. Native fish species are interesting candidates for development, but further research is required; non-native species whose culture technology has been established could also be incorporated into future planning.

Challenges and opportunities for aquaculture development in the region

The goals of a successful development plan must be realistic and should consider all of the different elements required for achievement. Although final goals and objectives may appear to be different, most of the core requirements are common to the planning process.

Water temperature ranges determine the type and species of fish and crustaceans that can be cultured. In some countries, both cold- and warmwater fish could be grown. In the case of Syria, attempts were made to raise tilapia in the warm period followed by trout during the colder period. Extreme temperature ranges can be very difficult for aquaculture to work with, with some areas ranging from sub-zero to >40 °C within the year. The use of appropriate infrastructure and management techniques is needed. Rainfall is another important factor to consider. Heavy rainfall can cause significant damage (for example, to ponds and dykes) while also affecting salinity regimes. High evaporation rates also affect performance, increasing the salinity of brackish waters, and need to be well considered in the planning of the production process.

Selection of the right species for the right conditions is critical for successful development. The appropriate criteria relating to growth, tolerance to site conditions and marketability must be met if the farmer is to be able to rear and sell the product. Seed and fingerling supply is an important issue throughout the region. Project promotion should not be made unless there are assured supplies from hatchery sources.

There are significant national and regional differences in consumer preference. For example, even though common carp was introduced into Egypt many years ago, local consumers prefer tilapia. While rabbitfish is a favoured species in Saudi Arabia, its market position in Egypt is much lower. For shrimps, the tiger shrimp is preferred for culture, while freshwater prawns encounter market resistance. Irrespective of the perceived economic value of species that are nominated for aquaculture, the choice should ideally be based on the nature of the environment selected for aquaculture, rather than trying to adapt the environment to the species.

Aquaculture development in the region will greatly depend on the development of conducive national policies and formulation of enforceable regulatory frameworks. Such policies and regulatory frameworks should take into due consideration the role that aquaculture can play in overall national development, food security, poverty alleviation, trade and economic development. Research, education and extension will continue to play an important role in regional aquaculture development. Prioritization of research, national capacity building, institutional strengthening and other infrastructural development will be key factors in assuring success. Adequate participation of all concerned parties and stakeholders is important to ensure sustainable development and growth of the aquaculture sector in the Near East.

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[1] The Near East Region includes Algeria, Bahrain, Cyprus, Egypt, Iraq, Israel, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Morocco, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Turkey, the United Arab Emirates and Yemen.

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[3] Libya refers to Libyan Arab Jamahariya

Current Status of Aquaculture in North America

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ABSTRACT: World aquaculture production has increased at a rate of 9 percent per year since 1984, and in North America, production during this time increased at an APR [Average Percent Rate) of 3.6, comparable to that in Europe (3.9) and Asian countries [excluding China] (4.4). Aquaculture production in North America2 has shown strong growth between 1988 and 1997, increasing from 379 000 mt to 521 000 mt, representing a 38 percent increase, at an APR of 4.0. The value of aquaculture products rose even more dramatically from US$620 million in 1988 to US$1.1 billion in 1997, at an APR of 6.5 for an increase of 80 percent.

The United States dominated regional production with 438 000 mt in 1997, valued at US$771 million, while Canadian production of 83 000 mt earned US$322 million. The higher relative earnings for Canadian production reflect the dominance of Atlantic salmon, while channel catfish is the principal species cultured in the United States. In North America, the value of farmed salmon increased from US$82 million in 1988 to US$371 million in 1997, an APR of 18.3. Channel catfish production in the United States increased from 164 000 mt in 1988 to 238 000 mt in 1997, a 45 percent gain at an APR of 4.2. Production of other finfish species includes trout, sturgeon, striped bass, golden shiners and tilapia. Shellfish cultured in the region include American and Pacific cupped oysters, blue mussels, clams, crayfish and shrimp.

Production from inland freshwater systems rose from 233 000 mt in 1988 to 315 000 mt in 1997, at an APR of 3.4, while marine production increased from 45 000 mt to 209 000 mt at an APR of 4.0 during the same period. While aquaculture is rapidly expanding in North America, on a global scale the region was responsible for only 1.4 percent of total production in 1997.

In both Canada and the United States, there is strong institutional support for aquaculture and government commitments to foster industry expansion. In the United States, for example, the Department of Commerce recently established an aquaculture policy to promote the development of a highly competitive and sustainable aquaculture industry. The objectives of this 1999 policy include forecast increases in production value from the current US$900 million to US$5 billion by the year 2025, and an increase in aquaculture employment from 180 000 to 600 000 people. This is driven by the United States' need to meet increasing seafood demands and help offset the US$6 billion annual trade deficit in edible seafood products.

Competing demands on natural resources, access to fresh water and restrictions on effluent discharge are issues the industry must address in order to continue expanding into the next millennium. This will be accomplished in part by emphasising production in offshore and intensive partially recirculating systems. With capture fisheries relatively stable at around 90 million mt/yr, it is clear that the world's increasing requirements for seafood will be met through aquaculture.

KEY WORDS: Aquaculture, North America, Canada, United States

Introduction

World aquaculture production has increased at a rate of 9 percent per year since 1984 and continues to grow as the production of primary species expands and technology develops to culture promising new species (FAO, 1995). In North America, aquaculture production since 1984 has increased at an APR [Annual Percent Rate of growth] of 3.6, comparable to that in Europe (3.9) and Asian countries [excluding China] (4.4) (Rana, 1997). In 1995, the harvest of cultured shrimp surpassed that coming from the world's capture fisheries, and in 1997, farmed salmon exceeded that available from commercial fisheries. With capture fisheries relatively stable at around 90 million mt/yr, it is clear that the world's increasing requirements for seafood will be met through aquaculture (FAO, 1999).

Aquaculture production in North America3 has shown strong growth between 1988 and 1997, increasing from 379 000 mt to 521 000 mt, representing a 38 percent increase, at an APR of 4.0. The value of aquaculture products rose even more dramatically, from US$620 million in 1988 to US$1.1 billion in 1997, at an APR of 6.5 for an increase of 80 percent. The United States dominated regional production of 438 000 mt in 1997, valued at US$771 million, while Canadian production of 83 000 mt earned US$322 million. The higher relative earnings for Canadian production reflect marine production of species of higher economic value, primarily Atlantic salmon.

Production from inland freshwater systems rose from 233 000 mt in 1988 to 315 000 mt in 1997, at an APR of 3.4, while marine production increased from 45 000 mt to 209 000 mt at an APR of 4.0 during the same period. While aquaculture is rapidly expanding in North America, on a global scale the region is responsible for only 1.4 percent of total production in 1997 (FAO, 2000).

It is expected that the industry will continue to grow with strong support from both the Canadian and United States governments. The United States Department of Commerce recently established an aquaculture policy to promote the development of a highly competitive and sustainable aquaculture industry. The objectives of this 1999 policy are ambitious, and include forecast increases in production value from the current US$900 million to US$5 billion by the year 2025, and an increase in aquaculture employment from 180 000 to 600 000 people (Mieremet et al., 2000). This projected growth is based on establishing average annual increases of approximately 10 percent. Accomplishing these objectives will require significant increases in investment capital, government support and inter-agency cooperation.

The population of North America is expected to grow from 306 million in 2000 to 360 million by 2020. This would increase the annual seafood demand by 177 000 mt by the year 2010 and 360 000 mt by 2020 (Table 1). If the industry can meet the ambitious goals of the Commerce Department's aquaculture policy, new aquaculture production will easily meet the increased demand and help to offset the US$6 billion annual trade deficit (United States only) in edible seafood.

Finfish production

The channel catfish, Ictalurus punctatus, remains the dominant species to be produced in North America. Production in the United States increased from 164 000 mt in 1988 to 238 000 mt in 1997, a 45 percent gain at an APR of 4.2 (Fig. 1).

Catfish production represents 54 percent of the United States total, 75.6 percent of the North American freshwater total and 45 percent of the total North American production (Table 2).

Table 1. Projected North American population growth and estimated seafood consumption (based on estimated annual per capita consumption of 6.6 kg).

Year	Population ('000)	Projected Annual Consumption ('000 MT)
1997	297 982	1 973
2000	306 273	2 021
2010	331 995	2 198
2020	359 639	2 381

Figure 1. North American finfish production-major species (MT), 1988-1997 (FAO,2000)

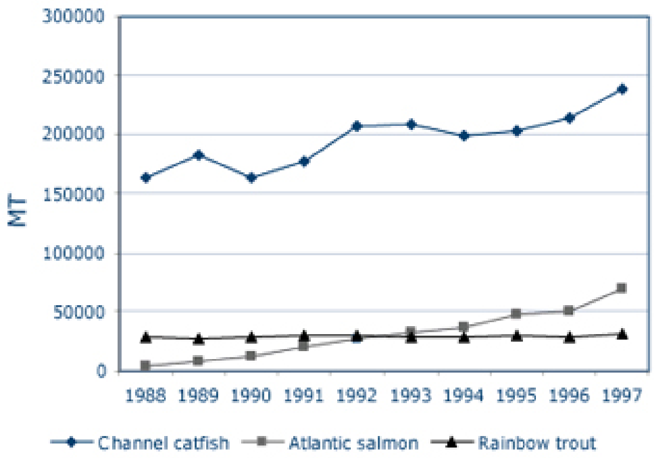
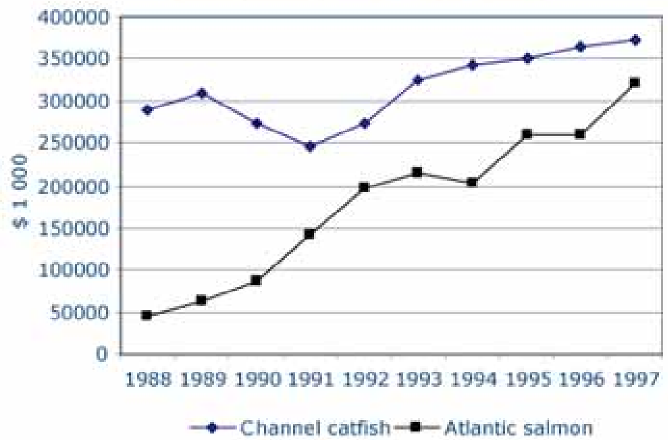


Figure 2. North American finfish value - major species ($1000) 1988-1997 (FAO, 2000)



Catfish sales generated US$371 million in 1997, up from US$290 million in 1988 for an APR of 2.8 and comprising 33 percent of the total aquaculture revenue in North America.

Salmon aquaculture contributes significantly to North American production, salmon being reared in the Northwest Atlantic (Maine, United States) and the Canadian Maritime Provinces), as well as in the Northeastern Pacific (Washington State, United States and the Canadian Province of British Columbia). Total salmon production increased from 12 000 mt to 79 000 mt between 1988 and 1997 at an APR of 23. In North America, the value of farmed salmon increased from US$82 million in 1988 to US$371 million in 1997 at an APR of 18.3 (Fig. 2).

Production in 1997 was almost equally split between the Northwestern Atlantic, with 38 000 mt, and the Northeastern Pacific, at 41 000 mt, and consisted primarily of Atlantic salmon, with smaller numbers of chinook and coho salmon (Fig. 3). In the Northwestern Atlantic United States, growers produced 18 000 mt of Atlantic salmon in 1997, compared to 900 mt in 1988, while production in the Northeastern Pacific of Atlantic, chinook and coho salmon was low at 20, 80 and 3 mt, respectively Canadian production of Atlantic salmon rose from 3 000 to 20 000 mt in the Northwestern Atlantic at an APR of 22.2, increasing in value from US$35 million to US$102 million at an APR of 12.4.

Significant Canadian production of Atlantic salmon also occurs in the Northeastern Pacific, where production rose from 80 mt to 31 000 mt at an APR of 96.6, while value increased from US$0.84 million to US$ 154 million at an APR of 78.3. Canadian chinook production in the Pacific rose from 3 500 mt in 1988 to 4 600 mt in 1997, while coho production rose from 2 700 mt to 5 100 mt during the same period (Fig. 3).

Table 2. Relative percent contribution of Canada and the United States to North American fresh total aquaculture production in 1997.

Species	Canadian production (MT)	Canadian % of species production	United States production (MT)	United States % of species production	% of North American total[2] freshwater aquaculture production	% of North American total[3] aquaculture production
Channel catfish	<1	<1	238 115	100	75.6	45.0
Cyprinids	<1	<1	1 542	100	0.5	0.3
Golden shiner	<1	<1	9 040	100	2.9	1.7
Rainbow trout	5 018	16	25 719	84	9.8	5.9
Red crawfish	<1	<1	22 332	100	7.1	4.3
Sturgeons	<1	<1	544	100	0.2	0.1
Tilapias nei[1]	<1	<1	7 648	100	2.4	1.5

[1] nei = not elsewhere included.
[2] North American freshwater aquaculture production = 314 883 mt, minor species excluded, total may be <100%.
[3] Total North American production = 521 638 mt.

In 1997, Canadian growers in the Atlantic Northeast produced 53 percent of the Atlantic salmon grown in the region, while United States growers in Maine produced 47 percent (Table 3). The combined North American production in the Atlantic represented 18.5 percent of all marine species produced and 7.3 percent of total North American aquaculture production. Atlantic salmon production in the Pacific accounted for 15 percent of marine production and 6 percent of all aquaculture production. Atlantic salmon production in the North American Region, therefore, accounts for one third of all marine production and 13.3 percent of the total aquaculture tonnage.

Trout farmers in North America produced 31 000 mt with a value of US$81 million in 1997 (Fig. 4), while freshwater trout production in Canada almost doubled between 1988 and 1997, going from 3 000 mt to 5 300 mt at an APR of 10, and the value increased from US$10 million to US$21 million at an APR of 8.3 (Figs. 1 & 4).

Marine production of rainbow trout in Canada fluctuated, but is currently around 900 mt. United States freshwater production declined slightly from 27 000 mt in 1988 to 26 000 mt in 1997 for an APR of -0.4, while value declined from US$64 to US$60 million at an APR of -0.7.

The golden shiner, the cyprinid Notemigonus crysoleucas, is produced as a baitfish and is a significant industry in the southeastern United States, primarily in the state of Arkansas. Production increased from 8 500 mt in 1988 to 9 000 mt in 1997 at an APR of 0.7, while value increased from US$52 million to US$74 million at an APR of 4 (Figs. 3 & 4).

There are a number of species cultured in the United States that reached significant production levels by 1997, rising from little or no production in 1988. The culture of striped bass is one example, where production increased from 400 mt in 1988 to 3 800 mt in 1997 at an APR of 28.5. Value increased from US$1.8 million to US$22 million at an APR of 32. Tilapia

Figure 3. North American finfish production-minor species (MT) 1988-1997 (FAO, 2000)

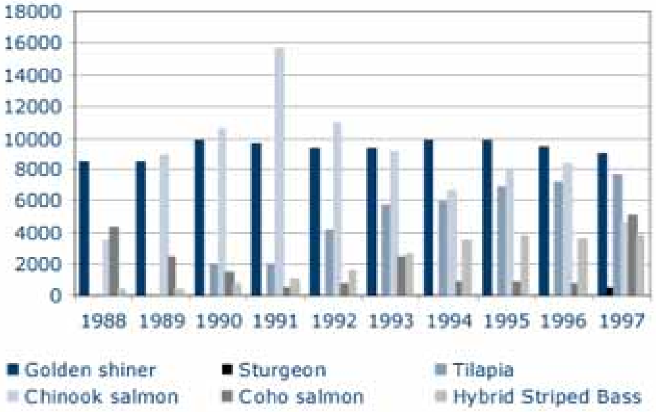
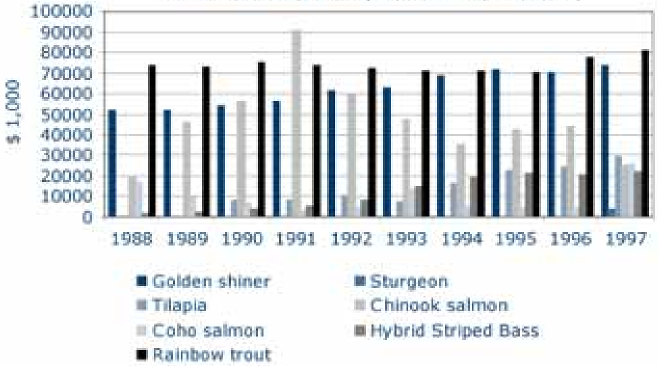


Figure 4. North American finfish value-minor species ($ 1 000) 1988-1997 (FAO, 2000)



production in North America also occurs primarily in the United States and increased from 20 mt in 1988 to 7 700 mt in 1997 at an APR of 57.6. The value of tilapia sales increased from US$70 000 to US$30 million. The culture of white sturgeon, Acipenser transmontanus, is expanding, with 1997 being the first year where substantial production was recorded and the harvest of 500 mt had a value to growers of US$3.6 million.

Figure 5 depicts the relative percentage contributions of the primary cultured finfish to North American production in 1997. Channel catfish and Atlantic salmon provided 40 and 34 percent of production, respectively. Rainbow trout and golden shiners follow with 9 percent and 8 percent, respectively, followed by coho salmon, chinook salmon and tilapia, all at 3 percent, and sturgeon at <1 percent.

A striking contrast exists between the production seen in 1988 and 1997, where catfish production declined from 77 percent to 40 percent of the total while Atlantic salmon rose from 2 percent to 34 percent during the time period (Figs. 5 & 6). Rainbow trout decreased by 4 percent while golden shiners increased by the same amount. Coho salmon, tilapia, sturgeon and hybrid striped bass production remained at low levels throughout the time period (Fig. 3).

Table 3. Relative percent contribution of Canada and the United States to North American marine aquaculture production in 1997

Species	Canadian production (MT)	Canadian % of species production	United States production (MT)	United States % of species production	% of North American total[4] marine aquaculture production	% of North American total[5] aquaculture production
American oyster[1]	1 985	100	0	0	1.0	0.40
Atlantic salmon[1]	20 310	53	18 005	47	18.5	7.30
Blue mussel[1]	11 463	89	1 354	11	6.2	2.50
American oyster[2]	0	0	63 166	100	30.6	12.00
Atlantic salmon[3]	30 793	100	0	0	14.9	5.90
Chinook salmon[3]	4 666	99	20	1	2.3	0.90
Rainbow trout[3]	214	100	0	0	0.1	0.04

[1] North West Atlantic.
[2] West Central Atlantic.
[3] North East Pacific.
[4] Total North American marine aquaculture = 206 755 mt, minor species excluded, % may be <100.
[5] Total North American aquaculture = 521 638 mt, minor species excluded, % may be <100.

Chinook salmon production was low in the specific years of 1988 and 1997, but peaked at just under 16 000 mt in 1991 (Fig. 4). Production rose then gradually declined, as Atlantic salmon became the preferred species for marine aquaculture.

Figure 5. Percent North American fish production 1997 (FAO, 2000)

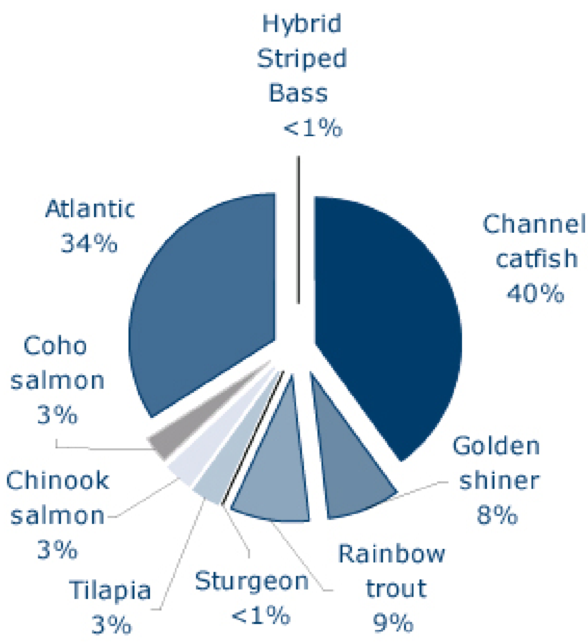


Figure 6. Percent North American fish production 1988 (FAQO, 2000)

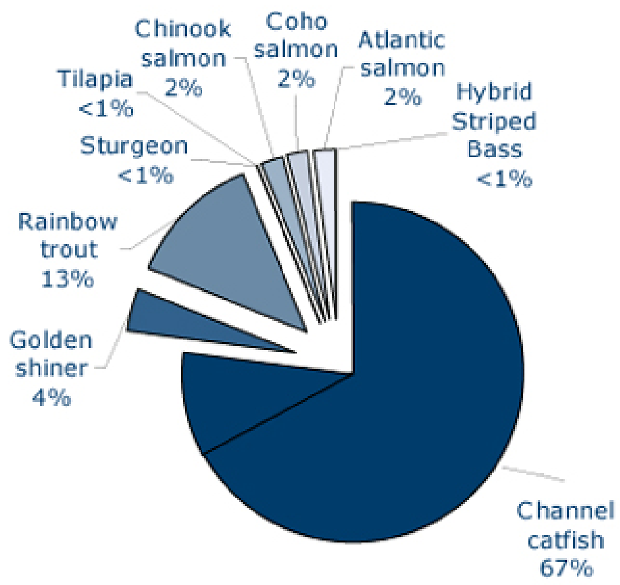


Figure 7. Percent North American fish value by species 1997 (FAO, 2000)

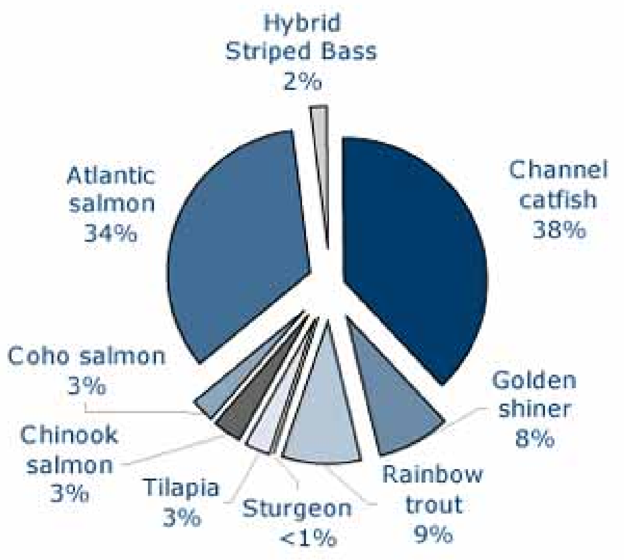
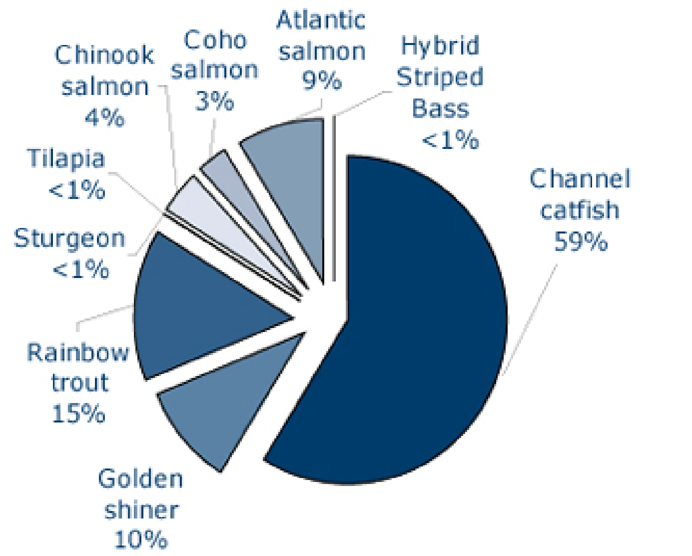


Figure 8. Percent North American fish value by species 1988 (FAO, 2000)

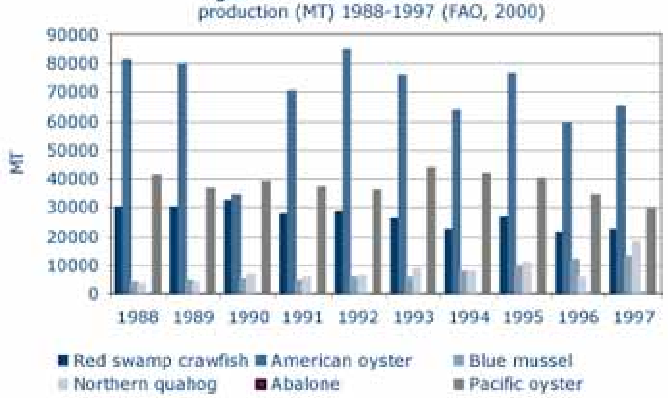


In terms of product value for 1997, catfish and salmon were comparable, representing 38 and 34 percent of total revenue, followed by rainbow trout at 9 percent and baitfish at 8 percent (Fig. 7). This differs significantly from 1988, when catfish sales generated 59 percent of total North American revenue and combined coho, chinook and Atlantic salmon sales generated only 16 percent of revenue (Fig. 8).

Invertebrate Production

The principal invertebrate products of North American aquaculture are molluscs and crustaceans. The following sections summarize these activities.

Figure 9. North American invertebrate production (MT) 1988-1997 (FAO, 2000)



Molluscs

Mollusc production in North America includes a variety of species but is centred around oysters, hard clams and mussels and includes both American and Pacific cupped oysters. Based on FAO statistical data, Pacific cupped oysters, Crassostrea gigas, are grown in the Northeastern Pacific and have declined in production from 41 000 mt in 1988 to 29 000 mt in 1997, an APR of -3.6 (Fig. 9). Revenue declined at an APR of -0.5 from US$19 to US$18 million, but price increases helped to offset the impact of production drops (Fig. 10). The United States is the dominant producer, with 25 000 mt in 1997 compared to Canada's 5 000 mt.

Growers of the American cupped oyster, C. virginica, also saw production reduce, but again, higher prices resulted in increased revenue. Production declined from 81 000 mt in 1988 to 65 000 mt in 1997, an APR of -2.4, while revenue rose from US$38 million to US$50 million, an APR of 3.2 (Figs. 9 & 10). Once again, the United States is the dominant producer, with 1997 production of 63 000 mt valued at US$47 million compared to Canadian production of 2 000 mt valued at US$3 million.

Other molluscs produced in North America include blue mussels, northern quahogs and abalone.

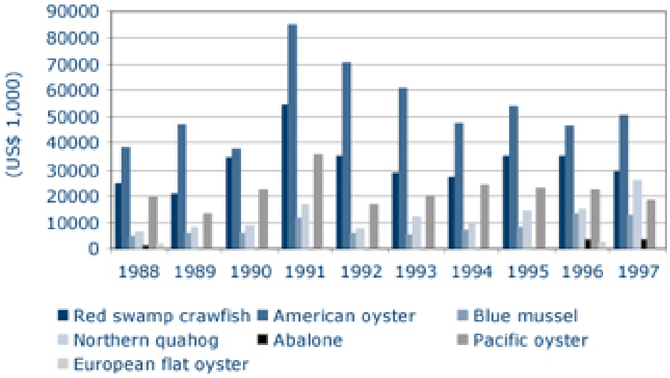


Figure 10. North American invertebrate production value (US$ 1 000) 1988-1997 (FAO, 2000)

Blue mussel production is centred in the Northwest Atlantic, where production measured 4 000 mt in 1988, rising to 12 800 mt in 1997, while value increased from US$4.3 to US$12.5 million at APRs of 13.7 and 12.6, respectively. Canadian mussel production increased to 11 000 mt in 1997 at an APR of 21, while United States production declined during the same time to 1 300 mt with an APR of -4.0.

North American production of the northern quahog or hard clam, Mercenaria mercenaria, occurs largely in the United States, with production increasing from 3 600 mt in 1988 to 18 000 mt in 1997 at an APR of 17.4. Value rose during this time from US$6 million to US$26 million at an APR of 17.4.

This increase occurred largely during 1996 and 1997, where production rose from 5 500 mt to 18 000 mt at an APR of 225, reflecting primarily the production of the newly established industry in Florida. Abalone culture is done primarily in the state of California, and the industry grew from 56 mt in 1988 to 265 mt in 1997, while the value rose during this time from US$1.2 to US$3.5 million. In recent years, both production and value have remained level.

Crustaceans

The only crustacean produced significantly in North America is the red swamp crawfish4, cultured in the southeastern United States. Production declined from 30 000 mt in 1988 to 22 000 mt in 1997 at an APR of -2.7. Rising prices enabled revenue to increase despite this trend, and the crop value rose from US$24.5 million to US$29.2 million at an APR of 2.0.

In reviewing production trends for bivalves and crustaceans between 1998 and 1997, one can see that blue mussel production tripled from 3 to 9 percent, while clam production increased six-fold from 2 to 12 percent (Figs. 11 & 12).

Production of American and Pacific oysters each dropped 6 percent, and red swamp crawfish declined by 4 percent during the time period.

Figure 11. North American invertebrate production (1997) (FAO, 2000)

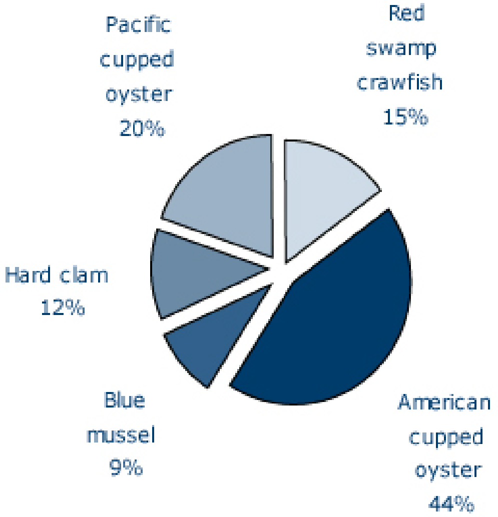


Figure 12. North American invertebrate production (1988) (FAO, 2000)

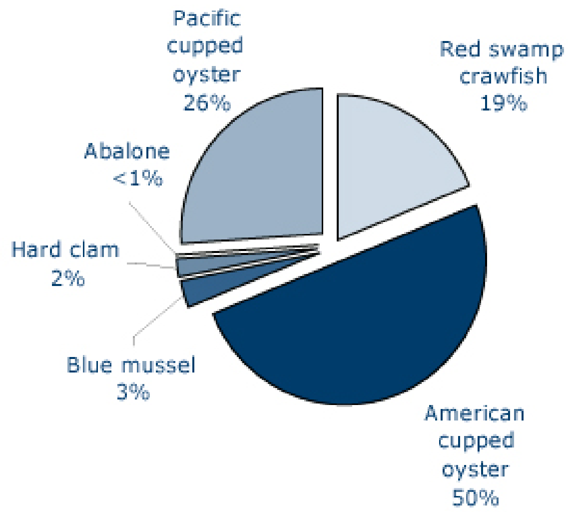


Figure 13. Percent North American invertebrate value (1997) (FAO, 2000)

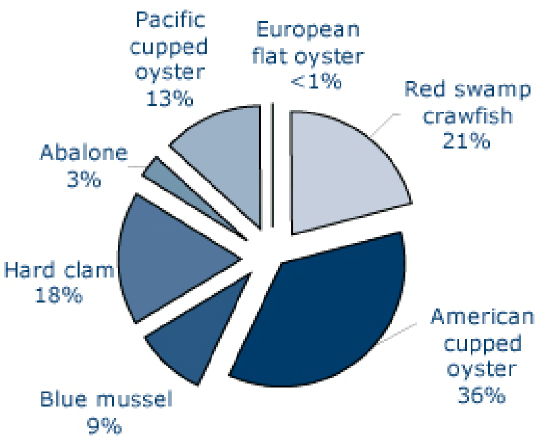
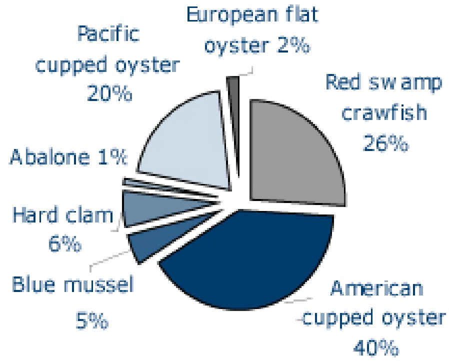


Figure 14. Percent North American invertebrate value (1988) (FAO, 2000)



A similar trend can be observed in terms of product value, where clams and mussels increased from 6 to 18 percent and 5 to 9 percent, respectively (Figs. 13 & 14), while slight declines were observed in both American and Pacific oysters.

Major species groups and regional trends

Regional reports

In North America, many aquaculture operations

The industry also requires technical support from divers, health professionals, hatcheries and business support services.

Direct employment in the Canadian aquaculture industry in the last few years is estimated at 5 200 full-time employees (FTE), with another 2 400 FTEs in supporting industries. This represents a four-fold increase over the last decade. There are currently an estimated 18 000 persons employed directly in the United States aquaculture industry.

are located in rural and coastal areas and thus provide a significant source of revenue and employment. This is important because the resource-based economies are in decline in many of these areas. This is particularly true in the Pacific Northwest area and the Canadian Maritime Provinces, where restrictions on timber harvest and reduced fishing quotas have caused economic hardship in many communities. The expanding mollusc and salmon production in these areas has allowed communities to transit from resource extraction to aquaculture production as a significant component of their economies. In a similar fashion, gill net bans enacted in several states in the United States have displaced many fishermen from their traditional livelihood. In one case along the Gulf Coast of Florida, federal job training funds were obtained and used to develop a highly successful hard clam farming industry. This industry developed over three to five years and is now producing over 150 million clams per year.

In addition to the contribution of direct employment in aquaculture production, the industry also requires significant amounts of equipment including cages and feed, boats and motors, processing equipment, packaging materials and transportation.

Canadian regional reports

There is strong government support for aquaculture in Canada at both the federal and provincial levels. At the federal level, 17 departments and agencies deliver programmes and services to the industry, and their important areas of federal responsibility are:

- research and development;
- regulation of marketed fish products;
- conservation and protection of wild fish stocks and fish habitats;
- importation into Canada and movement between provinces of live fish, eggs and dead, whole (none-viscerated) fish;
- mollusc growing water certification under the Canadian Shellfish Sanitation Programme (CSSP); and
- regulation of therapeutic drugs and vaccines.

The principal federal agencies and their responsibilities are outlined below.

Atlantic Canada Opportunities Agency (ACOA). ACOA is responsible for economic development in Atlantic Canada and views aquaculture as an important source of new jobs and a means for diversifying local economies. The agency has made partnerships with the private sector in Atlantic Canada to invest in over 500 projects involving hatcheries, growout sites, processors, cage, net and feed manufacturers, nonprofit organizations and research facilities.

Canadian Environmental Assessment Agency (CEAA). The CEAA administers the federal environmental risk assessment process for physical projects.

Canadian Food Inspection Agency (CFIA). The

Pest Management Regulatory Agency (PMRA). Products used for external treatment of external parasites, such as bath treatments for sea lice, are regulated by the PMRA. The agency has made a substantial effort to support the aquaculture sector by:

- developing a national sea lice integrated management strategy in partnership with Salmon Health, an industry-supported organization whose mandate is to ensure that Canadian aquaculturists have access to fish health management tools;
- organizing, together with the United States Food and Drug Administration Center for Veterinary Medicine (CVM), a workshop on sea lice therapeutic agents;

CFIA is responsible for handling, transport, processing and labelling of aquaculture food products. In addition, the Fish, Seafood and Production Division of the CFIA monitors molluscs for marine biotoxins under the CSSP, and tests aquaculture products for drug residues. The Animal Health and Production Division of the CFIA is responsible for regulating aquaculture feeds and licensing fish vaccines.

Environment Canada (DOE). The DOE provides scientific, technical and regulatory advice to the industry. Its water surveys of mollusc-growing areas and classification responsibilities under the CSSP are the activities that most directly affect the industry.

Farm Credit Corporation (FCC). The FCC began providing finance to the aquaculture industry in 1995 and has been an active partner since then.

Fisheries and Oceans (DFO). The DFO provides support for aquaculture development through its regional aquaculture coordinators and local fish health officers. The coordinators provide information about the regulatory framework for aquaculture in addition to guidance on federal programmes and services to assist the industry. The department conducts a broad array of scientific research and works closely with the industry in a number of collaborative projects.

Health Canada, Bureau of Veterinary Drugs (BVD). Due to the complexity and cost of obtaining approvals for the use of veterinary drugs in aquaculture, the private sector has shown little interest in obtaining such approvals. At present, the number of veterinary drugs available for use in aquaculture is very limited. To counter this situation, the bureau has made a provision for a substantial reduction of cost recovery fees for submissions for new drugs intended for minor species, including drugs for aquaculture.

- developing a project under the North American Free Trade Agreement (NAFTA) Technical Working Group on Pesticides, whereby the PMRA and CVM are cooperating in sharing data and reviews on sea lice products; and
- organizing workshops on the east and west coasts to address the assessment of potential environmental impacts of sea lice products and emergency registrations of products during sea lice outbreaks.

Human Resources Development Canada (HRDC) The HRDC assists the aquaculture sector through its Sectoral Partnerships Initiative to ensure the industry has a competent and productive work force.

National Research Council (NRC). The NRC Institute for Marine Biosciences is one of Canada’s premier aquaculture research centres. The Industrial Research Assistance Programme (IRAP), part of the NRC, coordinates and supports technical developments in aquaculture. Between 1989 and 1997, IRAP provided financial assistance to Canadian small and medium-size enterprises (SMEs) to undertake over 1000 projects in aquaculture.

Statistics Canada publishes aquaculture statistics that report production and value by province and species. The expansion of the aquaculture industry has led to an increasing demand for related statistics (DFO, 1998).

The provinces and territories have the responsibility for the majority of site approvals and for overseeing the industry’s day-to-day operations, as well as the following:

Table 4. 1997 Canadian Provincial Aquaculture Production (MT)[1]

	NFLD[2]	PEI	NS	NB	QUE	ONT	MAN	SASK	ALB	BC	CANADA
Finfish											
Salmon	613	(C)[3]	1 112	18 585						36 465	56 775[5]
Trout	14	(C)	33	550	647	3 725	5	721	3	212	5 910[5]
Steelhead	355		591								946
Other[4]											117
Finfish Total	982	94	1 736	19 135	647	3 725	5	721	3	36 677	63 842
Shellfish											
Clams										649	649
Oysters		1 432	288	265						3 650	5 631
Mussels	752	9 997	577	137	121					9	11 570
Scallops	12		16							23	51
Other	4		14		2						20
Shellfish Total	768	11 429	895	402	123					4 331	17 921
Total	1 749	11 524	2 631	19 537	770	4 250	5	721	3	41 008	81 763

[1] Statistics supplied by Statistics Canada.
[2] Province abbreviations are: NFLD = Newfoundland, NB = New Brunswick, NS = Nova Scotia, PEI = Prince Edward Island, QUE = Quebec, ONT = Ontario, MAN = Manitoba, SASK = Saskatchewan, ALB = Alberta, BC = British Columbia.
[3] Confidential (the finfish total and provincial totals include confidential amounts).
[4] Includes char and other finfish.
[5] Excludes confidential amounts.

Table 5. 1997 Canadian provincial aquaculture production value (US $ x 1000)[1]

	NFLD[2]	PEI	NS	NB	QUE	ONT	MAN	SASK	ALB	BC	CANADA
Finfish											
Salmon	1 835	(C)[3]	4 297	93 975						118 938	219 045[5]
Trout	63	(C)	110	4 056	1 868	10 748	16	2 146	8	556	19 571[5]
Steelhead	997		1 814								2 811
Other[4]											455
Finfish Total	2 895	575	6 221	98 031	1 868	10 748	16	2 146	8	119 494	241 882
Shellfish											
Clams										1 961	1 961
Oysters		2 150	696	383						2 648	5 877
Mussels	429	8 177	554	73	82					13	9 328
Scallops	36		37							117	190
Other	27		14		3						44
Shellfish Total	492	10 327	1 301	456	85					4 739	17 400
Total	3 387	10 902	7 522	98 487	1 953	10 748	16	2 146	8	124 233	259 282

[1] Statistics supplied by Statistics Canada (0.676 conversion rate to US $ used, totals may not equal due to rounding).
[2] Province abbreviations are: NFLD = Newfoundland, NB = New Brunswick, NS = Nova Scotia, PEI = Prince Edward Island, QUE = Quebec, ONT = Ontario, MAN = Manitoba, SASK = Saskatchewan, ALB = Alberta, BC = British Columbia.
[3] Confidential (the finfish total row includes confidential amounts).
[4] Includes char and other finfish.
[5] Excludes confidential data.

- specialized research, education and training;
- leasehold administration and monitoring;
- infrastructure development; and
- integrated resource planning and environmental monitoring.

A summary of 1997 Canadian provincial aquaculture species production (quantity and value) is given in Tables 4 and 5 (DFO, 1998).

British Columbia

During the time-frame examined, aquaculture has expanded dramatically in British Columbia, primarily through cage culture of Atlantic salmon and bivalve production. The marine finfish industry in British Columbia utilizes approximately one square kilometre of the 13 million square kilometres of nearshore waters adjoining the province. Atlantic salmon production in 1997 of 36,465 mt was valued at $119 million. Further development of the industry will likely proceed with the recent lifting of a moratorium on new sea cages put in place in 1995 as a result of protests by environmental groups. These groups have expressed concerns related to potential competition between escaped farmed salmon and wild stocks, disease transmission from farms to the wild, antibiotic-resistant pathogens developing on farms, benthic fouling and the loss of biodiversity in the vicinity of net pens. Concerns were also expressed over the interactions between marine mammals and net pens and the use of depredation permits.

The British Columbia government, in response to these concerns, placed a moratorium on new net-pen deployment and assigned the Environmental Assessment Office the task of developing a Technical Advisory Team to prepare a comprehensive discussion paper and make appropriate recommendations.

The Technical Advisory Team acknowledged that there was little data on which to assess the merit of the concerns raised regarding disease transmission or the impacts of antibiotics, pathogens and competition with native species. They concluded that additional information was also needed to assess the impacts of fouling in the vicinity of cages on biodiversity and adjacent

The team developed 49 recommendations that will guide the issuance of new lease tenures, and the industry will expand in concert with monitoring protocols and in accordance with the precautionary approach. There are currently about 79 active salmon farms operated by 16 companies in British Columbia employing some 2 200 people.

The British Columbia mollusc industry production is composed primarily of Pacific oysters, Manila clams and scallops, whose wholesale value was US$4.7 million in 1997. Other species being cultured include blue mussels, sea cucumbers, sea urchins, geoduck clams and abalone. There are currently 258 licensed growers utilizing 423 growing areas on intertidal and submerged lands leased from the government. Currently there are 2 115 ha of land tenured for mollusc growing in British Columbia, with about one-half used for deepwater off-bottom culture techniques, with the remainder being intertidal. The mollusc industry is a principal employer in rural areas, occupying approximately 1 000 people on a year around basis.

The mollusc industry has the potential for enormous growth in an area possessing temperate waters and an extensive coastline with many protected areas. The rural locations provide excellent water resources and, if appropriately situated, the industry is sustainable. Global markets for molluscs are strong, particularly as the Asian economies grow and develop. Current mollusc production, valued at US$4.7 million, is achieved using only 0.5 percent of the land tenured for mollusc growing in the province. A recent study by Coopers and Lybrand, Economic Potential of the BC Shellfish Aquaculture Industry (June 1997) provided the following estimations:

- The BC mollusc industry could generate revenues of US$100 million by 2006 with a land base increase to 3 500 ha.
- Industry growth could create 1 000 additional full-time jobs.
- The culture of new species could create another 165 FTEs and US$9.5 million in increased production.

New Brunswick

mollusc beds.

After reviewing the available data, the team concluded that there was not a significant environmental risk posed by the industry at current production levels, but that additional information should be obtained to evaluate concerns before issuing any new aquaculture tenures.

The New Brunswick aquaculture industry has grown tremendously over the last two decades, with a value of US$40 000 in 1979 that rose to over US$98 million in 1997.

Atlantic salmon alone represents 95 percent of this figure, with 94 000 mt valued at US$94 million, exceeding revenue from any other single agricultural export (including potatoes [US$71 million], dairy products [US$63 million] and poultry/eggs [US$59 million]). Other species cultured include trout (US$4.0 million), Atlantic cupped oysters (US$383 000) and blue mussels (US$73 000).

Newfoundland

Aquaculturists in Newfoundland in 1997 produced primarily Atlantic salmon [US$1.8million], steelhead trout [US$1.0 million] and blue mussels [US$429 000]. Other species produced include rainbow trout and scallops, and there is significant interest on the part of growers and the government to aggressively expand the industry. New species being investigated include Arctic char, Atlantic cod, flounder, eel, sea urchins and giant scallops.

Nova Scotia

In 1997, the total value of Nova Scotian aquaculture was US$7.5 million. Finfish culture dominated production, including Atlantic salmon [US$4.3 million] representing 57 percent and steelhead trout [US$1.8 million] at 24 percent. Blue mussels and American oysters were valued at US$1.2 million, representing 7.4 and 9.3 percent of the total, respectively. Other species cultured on a minor scale were scallops, clams, eels, marine plants, sea urchins, arctic char and halibut.

American oyster production in the province is valued at US$2.1 million, and a growing finfish sector culturing rainbow trout, arctic char and Atlantic salmon was valued at US$575 000.United States regional reports

Support for aquaculture development

There is strong support for aquaculture within the United States government, and the Department of Commerce recently adopted an aquaculture initiative to increase annual industry revenues from the current US$900 million to US$5 billion over the next 25 years. Federal support for aquaculture is provided primarily through agencies within the Departments of Agriculture and Commerce (Jensen et al.,1994; McVey et al., 1992). The following section summarizes the different departments, services and programmes that provide assistance to United States aquaculture.

Department of Agriculture

Agricultural Marketing Service (AMS). This agency provides assistance in developing marketing opportunities for aquaculture producers. It is also responsible for purchasing meat products in order to stabilize market conditions and supply domestic feeding programmes.

Agricultural Research Service (ARS). The ARS conducts research on aquaculture at 14 locations in the United States. Research activities are centred on genetic improvement, integrated aquatic animal health management,

Ontario

Ontario is the leading Canadian producer of rainbow trout, having commercial production of 3 725 mt with a value of US$10.7 million in 1997. Other species cultured on a small scale include tilapia, perch, walleye and sturgeon. Culture activities undertaken with walleye and sturgeon are for both production and enhancement purposes.

Prince Edward Island

Prince Edward Island is the leading producer of blue mussels in the Maritime Provinces, recording a production value of US$8.2 million for 1997, representing about 88 percent of Canadian production in the Northwest Atlantic. The remaining 12 percent of mussels are produced in Nova Scotia, Newfoundland and New Brunswick. Production occurs primarily on culture lines, and bags suspended from surface long lines that are submerged in the winter to prevent ice damage.

reproduction and early development, nutrition, production systems and environmental sustainability.

Co-operative State Research, Education, and Extension Service (CSREES). The CSREES administers federal funds for extramural research, extension and education. CSREES, through its partnership with the Co-operative Extension System, supports extension education, information dissemination and technology transfer programmes that have been critical to the development of commercial aquaculture in the United States.

Total federal extramural funding in aquaculture research programmes administered by CSREES in 1999 was US$20.2 million, which is approximately double the investment of the US$10.3 million recorded in 1987.

Regional Aquaculture Centres (RAC). Five RAC encourage cooperative and collaborative research and extension education programmes in aquaculture having regional or national application. Projects that are developed and funded by the RAC are based on industry needs and are designed to directly influence commercial aquaculture development in all states and territories (USDA-RAC, 1994).

Small Business Innovation Research Programme (SBIR). This programme exists in each department of the federal government and allows grant funding to private businesses to develop innovative technologies for the

National Sea Grant Programme (NSGP). The NSGP supports research and extension activities in aquaculture genetics, pathology, biotechnology, endocrinology, physiology, engineering, policy and economics.

Department of Health and Human Services

Food and Drug Administration (FDA). The FDA regulates and approves the use of therapeutic agents and feed additives used in the aquaculture industry. The FDA, through the Interstate Shellfish Sanitation Conference and the National Shellfish Sanitation Programme, certifies mollusc-growing waters and markets in cooperation with state health departments.

State coordination and support for aquaculture is administered through relevant state agencies and varies from state to state. Usually housed within the Departments of Agriculture or Natural enhancement of aquaculture production.

Animal and Plant Health Inspection Service (APHIS). The APHIS oversees animal importation to control pests and diseases. The agency manages depredation by migratory birds, licenses veterinary products and regulates biological control agents and biotechnology applications.

Co-operative State Research Service (CSRS). The CSRS administers grant funds to support collaborative research with state universities.

Economic Research Service (ERS). The ERS analyses production and market trends for aquaculture products and services.

Cooperative Extension Service (CES). CES staff provide for research, education and technology transfer through 74 land grant universities located in all 50 states and six territories.

National Agricultural Library (NAL). The NAL acts as a repository for aquaculture information and coordinates with other agencies to facilitate information exchange.

Department of Commerce

National Environmental, Satellite, Data, and Information Service (NESDIS). The NESDIS, in cooperation with some United Nations agencies, maintains the Aquatic Sciences and Fisheries Abstracts database.

National Marine Fisheries Service (NMFS). The NMFS supports research in marine aquaculture and fisheries and promotes the development and expansion of aquaculture production and markets.

Resources, primary responsibilities include implementation of state and federal regulations.

United States Production

The United States recently completed the first detailed census of aquaculture for 1998, where species production data for individual states have been compiled into regions, area under production, water sources and production systems (USDA, 1999).

A total of 3 252 farms were engaged in freshwater aquaculture production using 129 800 ha. In marine waters, 815 farms owned 25 973 ha of intertidal land used for aquaculture production, and 478 farms also farmed 11 522 ha of public lands leased from individual states or the federal government. The Northeast Region leads in marine intertidal and subtidal production, with 16 125 ha or 62 percent of the nation’s total marine production area. The Western Region follows with 31 percent or 8 012 ha. The Southern Region leads the nation in freshwater production with 2 253 farms utilizing 108 085 ha or 83 percent of the United States total. Data presented in Table 6 provide an overview of the primary species cultured, their value and the number of farms involved.

Of over 4 000 farms, 1 925 use ground water sources, 1 454 use surface water and 815 use salt water. Groundwater is predominantly used in the South, and ground and surface water use is roughly comparable in the other regions.

Northeast Region

Atlantic salmon and American oysters, followed by northern quahogs, dominate aquaculture production in the Northeast. Maine and Connecticut are the primary producers of salmon and oysters, respectively. In 1997, 18 000 mt of Atlantic salmon production represented 47 percent of North American production in the Northwest Atlantic. American oyster production of 63 000 mt was followed by northern quahog production of 18 000 mt.

Production systems in the region include ponds (195), flow-through raceways (98), cages and net-pens (71) and recirculating tanks (65) (USDA, 1999). Regulation and financial capital are the most frequently cited constraints to production of salmon, oysters, mussels and trout in the region. Growers of salmon, quahogs and trout also cite predation as a serious production constraint.

A number of other species are cultured commercially at lower levels in the Northeast and/or are considered experimental. These include rainbow, brown and brook trout (worth together US$8.7 million in 1998); striped bass (US$7.3 million); tilapia (US$4.2 million); fathead minnows (US$300 000) and channel catfish (US$254 000) while koi and ornamental goldfish were worth US$2.1 and US$2.8 million, respectively. Other minor species cultured are sunfish, black bass, walleye, yellow perch, golden shiners, white suckers and various carps. Researchers and growers in the region are optimistic that summer flounder will develop into a major new culture species.

North Central Region

Aquaculture production in the North Central Region involves a wide diversity of species and production systems. There are 292 production ponds, 90 flow-through raceways or tanks and 61 recirculating systems (USDA, 1999). The most significant species by gross sales in 1998 were trout (US$6.6 million), tilapia (US$4.5 million) and catfish (US$3.2 million). Sales of baitfish, including fathead minnows, goldfish and golden shiners, generated US$6.4 million, while sales of ornamental goldfish and koi exceeded US$2.8 million. Other species of commercial interest include walleye, bass and yellow perch. Approximately one half of the region's 362 farms use surface water and the remainder pumped groundwater. The majority of aquaculture producers rely on revenues from culture activities as supplementary income (Hushak, 1993).

Western Region

California, Idaho and Washington combined to produce 94 percent of the region's production in 1995. With trout production valued at US$34.2 million, Idaho is the primary trout-producing state, with 33 farms contributing 72 percent of this US$47.3 million dollar industry. This is followed by California and Colorado, with crops valued at US$4.3 and US$3.8 million, respectively (USDA, 1999). California is the leading producer of catfish and tilapia, with crops valued at US$7.6 and US$6.9 million, respectively, or 90 percent and 82 percent of the region's respective total. California also leads the region in hybrid striped bass and sturgeon production. California has seven farms that produce 85 percent of the region's baitfish, or US$2.2 million of the region's US$2.6 million total crop value. California is the only state with a significant production of ornamental fish, goldfish and koi carps, of a value of around US$2 million. Washington is the region's leading producer of net-pen reared Atlantic salmon. While Alaska has significant potential to produce finfish, it instead provides an example of how public policy can constrain industry growth. There is currently a legislative ban prohibiting finfish aquaculture as a result of opposition by members of the state's powerful fishing industry. Alaskan hatcheries do produce salmon smolts for wild stock enhancement valued at US$16 million. Finfish aquaculture in the Western Region is at times constrained by the restricted availability of broodstock and fry, a lack of new species, limited sites, a lack of capital and a restrictive regulatory climate (Fitzsimmons, 1995).

Mollusc culture in the region is dominated by Washington State, followed by California, Oregon and Alaska. Pacific cupped oyster is the leading species, with estimated production of 40 000 mt in 1998, valued at US$55 million (Pacific Coast Shellfish Growers Association, pers. comm.). Lesser production of Kumomoto, Atlantic and European oysters occurs in the same states. Other molluscs cultured in the region include Manila clams with 3 200 mt, valued at US$21 million, and the blue mussel with 680 mt, valued at US$2.5 million. Abalone are produced primarily in California, where the industry generates some US$4.0 million in annual sales.

The industry was set for expansion in the late 1980s, but an exotic sabellid worm parasite and the presence of a rickettsial bacterium that causes withering syndrome constrained industry growth during the last decade. These disease problems have been brought largely under control, and industry growth is anticipated.

Southern Region

Catfish dominates aquaculture in the Southern Region, mainly in the states of Mississippi, Alabama, Arkansas and Louisiana. These states have catfish industries valued in 1998 at US$285.4, US$58.2, US$55.3 and US$28.4 million, respectively. This represents approximately 90 percent of the 238 000 mt total production in North America, having increased from 164 000 mt in 1988. The predominance of freshwater aquaculture in the region is illustrated by the 44 000 ha of freshwater production compared to only 2 400 ha in marine aquaculture.

Ornamental fish and aquatic plants are another significant industry in the region, which is centred in south Florida and produces over 2 000 species of ornamental fish and plants. This industry is currently valued at approximately US$60 million, composed of US$48 million for ornamental fish and another US$12 million for aquatic plants.

Baitfish culture in the South is located mainly in Arkansas, where producers use 29 800 ha of ponds to produce 85 percent of the region's baitfish, primarily golden shiners, with smaller numbers of fathead minnows and goldfish. In 1998, Arkansas generated US$23 million of the region's US$27.1 million in baitfish revenue

Main markets for aquaculture products

The products of North American aquaculture production are marketed mostly within the region. In 1997, per capita consumption of seafood was estimated at 6.6 kg, down 0.1 kg from the previous year and representing a drop of 0.7 kg from the peak seen in 1987.

In the United States, the major part of production is consumed domestically, while Canada consumes around 35 percent of its production, exporting 65 percent, primarily to United States' markets. Major competition for finfish producers within regional markets comes from Chile, Norway and the United Kingdom.

Aquaculture market trends

The region's aquaculture products will face strong competition in the new millennium, needing aggressive marketing efforts to boost per capita consumption that has been relatively flat, even reducing, over the last decade. Increases in seafood consumption in North America have resulted from population increases of two to three million per year. Shrimp, tuna, salmon and catfish represent 50 to 60 percent of total seafood consumption. For these reasons, marketing efforts need to be directed at increasing per capita consumption of existing products, while product diversification should increase market opportunities.

Competition will be especially strong from the pork and poultry industries, since prices remain low and their industry associations will expand promotional efforts. These promotional efforts will market new product forms for at-home use and also for restaurant and institutional food

(Stone et al., 1997; USDA, 1999).

Culture of molluscs in the Southern Region includes oysters, mussels and clams. Clams lead with a crop value of US$22.2 million, and Florida is the primary producer, generating almost half of this. While oysters are a significant fishery in the area, aquaculture production is limited, with 24 farms generating only US$1.5 million in sales (USDA, 1999).

Crustacean production in North America is centred in the southern United States, where Louisiana leads the crawfish production, valued at US$9.1 million or 93 percent of the region's total. Texas heads penaeid shrimp production with an US$8.4 million crop that represents 89 percent of the region's production value.

service markets.

The general recovery and strengthening of Asian economies will benefit North American aquaculture producers. Japan is the largest importer of seafood in the world, and imports are likely to increase as a result of a stronger economy and higher monetary exchange rates. This trend will benefit primarily mollusc growers, who will capitalize on improving market conditions. Additional export opportunities will be tied to improving economic conditions in Malaysia, Taiwan Province of China, Hong Kong5 and Korea.

The following sections deal with specific considerations for individual species.

Catfish

Recent data show that sales of channel catfish have risen by 3.7 percent for the first eight months of 1999 compared to 1998, and that prices are stable at around US$1.54/kg. Product sales of fresh and frozen catfish are up by 3 percent, and prices for processed products have averaged US$5.15/kg. Sales of filleted products represent major growth, with sales of fresh fillets up by 9 percent while the sale of frozen fillets rose by 3 percent. Filleted sales now occupy 61 percent of the total sales.

In recent years, falling prices for corn and soybeans have enabled catfish farmers to increase gross revenue in spite of stable prices. The combination of stable prices and reduced feed costs has allowed the expansion of pond acreage and stock inventories. Currently, some 70 000 ha are being farmed (1999), an increase of 5 percent from 1998. Catfish production remains centred in the states of Mississippi, Alabama, Arkansas and Louisiana, accounting collectively for 90 percent of total production.

Inventories of market-size fish have increased (1999 data), and the combination of the robust

The average price/kg was US$5.08, a drop of five cents from the previous year.

Trout fingerling sales were 22.7 million during this period, compared to 8.33 million for the previous year. The average value was US$8.00/kg, compared to US$14.63 the previous year. The total value was US$3.78 million, up 323 percent from the previous year's US$1.17 million in sales.

Trout egg sales during FY1997/1998 totaled 330 million eggs, 10 percent less than sold the previous year. Eggs sold for US$15.36/1000, up 64 cents from the US$14.72 received the previous year.

Trout growers lost 34.2 million fish during the year, equivalent to 3 560 mt. Disease-related losses accounted for 84 percent of all losses, with predation accounting for 12 percent, and 4 percent being lost to other causes.

Tilapia

Tilapia production has continued to expand in North America, mainly in the United States. Production of around 1 600 mt was recorded in

United States economy and low unemployment has resulted in strong sales in the food service sector, the largest market for catfish products. While the United States continues to import large quantities of seafood, much of these are high-value products that should not significantly compete with catfish in the market place.

Trout

Trout production is located primarily in the state of Idaho (United States) and the Province of Ontario (Canada), although sites with suitable water sources are located throughout both countries. Rainbow trout farmers in the United States supply fish to processors (59 percent), fee and recreational fishing establishments (18 percent) and to restaurants and retailers (11 percent). For the financial year (FY) of 1997/19986, 57.1 million market-size fish were sold for a value of US$59.7 million. The total volume and value were both down by 4 and 2 percent, respectively, from the previous year. The average value/kg was US$2.38 during 1998, a rise of two cents from the previous year.

Trout farmers sold 11.6 million fish for stocking during the year, a rise of 7 percent compared to the previous year. Sales to fee-based and recreational fishing establishments, the government and other growers represented 41, 26 and 16 percent of total stocking sales during 1997/1998.

the Northeast, North Central and Southern regions of the United States, while the Western Region produced twice that amount. This represents a doubling of production in the Northeast and North Central regions, but slight declines in the South and West.

Live fish sales account for 90 percent of the domestic market, where sales are mainly made to the Asian markets on the Atlantic, Pacific and Gulf Coasts and in metropolitan areas of the Midwest. Prices were down from 1997 levels of around US$3.52/kg to US$2.20/kg in 1998. Proximity to the market plays an increasing role in farm viability, as live shipping costs from the growing regions in the Midwest to either coast are about US$1.20/kg.

Consumption was up 12 percent in 1998, and domestic production supplied approximately 20 percent of total demand. Imports, on a live weight basis, reached 42 000 mt in 1998, a 15 percent increase over 1997, and imports for the first six months of 1999 are up 26 percent from the same period in 1998. Imported products fill the gap between production and market demand and, in 1998, the dominant suppliers were Taiwan Province of China (12 600 mt of frozen whole fish and 2000 mt of frozen fillets) and Costa Rica (2 500 mt of fresh fillets). Taiwan Province of China has almost doubled exports of frozen fillets to the United States in each of the last four years.

The value of tilapia imports increased by 40 percent, to US$35.4 million, in the first half of 1999. Tilapia prices increased for all product forms in the first half of 1999, a contrast to 1997 and 1998, where prices fell in all categories. Prices for frozen whole fish increased by 15 cents/kg in the first half of 1999 to US$1.10. Imports are expected to remain strong as long as the United States economy remains solid. A weakening dollar against Asian currencies would probably lead to a softening of demand. With United States pork and chicken

In 1998, the Environmental Protection Agency and the Joint Subcommittee on Aquaculture (JSA) held a Review and Risk Assessment Workshop so as to complete a qualitative assessment of the risks associated with shrimp viruses, to evaluate the need for a more comprehensive risk assessment and to identify research needs.

The relative risks associated with shrimp aquaculture, shrimp processing and other potential sources of shrimp viral introduction suppliers benefiting from low grain prices, tilapia imports will face strong competition from these commodities.

Salmon

Salmon produced in North America is sold almost entirely on the domestic market and, to meet further demand, imports into the United States reached 53 000 mt valued at US$311 million in the first half of 1999, representing increases of 13 and 25 percent, respectively, for the same time period in 1998.

Increases were recorded in all three product categories (fresh whole fish, frozen whole fish, and fresh and frozen fillets), with imports of the fillet products and fresh whole fish each being around 53 000 mt. The value of fillet products during the first six months of 1999 totaled US$161 million and accounted for 52 percent of all Atlantic salmon imports.

The biggest change seen is that these increased imports are coming from European producers and not from Canada and Chile, who have been the dominant suppliers to the United States market during recent years. Principal European suppliers are Norway and the United Kingdom. Higher imports from these countries more than offset the slight declines observed from Chile and Canada. The decline in Canadian imports is surprising, as the weakness of the Canadian dollar relative to United States currency should have provided good export opportunities. Historically, Canada has exported around 65 percent of domestic salmon production to the United States market.

Shrimp

The future of shrimp aquaculture in the United States is linked to the extent of the distribution of nonindigenous shrimp viruses and the risk posed to both cultured and native shrimp populations. Native and cultured shrimp populations were evaluated. State management agencies will use these results to develop regulatory mechanisms for the reduction of the potential impacts of viral transmission to indigenous crustacean populations. These regulatory processes are likely to lead to the use of virus-free stocks ultimately and a combination of effluent-screening and water treatment in the short term.

The impetus for shrimp aquaculture in the United States remains strong, since US$3.1 billion of the national trade deficit resulted from shrimp imports in 1998. Of the 315 000 mt imported, frozen shrimp accounted for 86 percent, with processed products at 13 percent and 1 percent being fresh shrimp. The United States market is expected to remain strong as long as the economy is high and unemployment is low.

Red Swamp Crawfish

Crawfish imports totaled 591 mt with a value of US$1.9 million during the first seven months of 1999, representing declines from the same period in 1998 of 18 and 26 percent, respectively. China is the main supplier, but the imposition of a 123 percent import tariff has reduced 1999 imports, and further reductions are anticipated in 2000.

Crawfish exports fell 69 percent in 1998 to 810 mt as a result of increased competition and depressed markets in Scandinavian countries. This decline is a continuing trend, demonstrated by the records for the first half year’s export revenues for US$10.1 (1997), US$2.7 (1998) and US$1.9 million (1999). These reductions reflect the strength of the dollar and increasing competition from other countries, most notably China. Markets for live crawfish remain strong in Louisiana and the surrounding states, but frozen product sales face stiff competition from the Chinese product, even with the import tariff.

Oysters and clams

Oysters are marketed as live animals for the half-shell market or as shucked meat. More than 95 percent of North American aquaculture production of oysters, mussels and clams is marketed domestically. Over the first six months of 1999, total United States bivalve exports declined by 3 percent from the same time period in 1998, amounting to 1 900 mt. This trend results from the continuing strength of the dollar and problems in a number of Asian economies. The forecast is that with signs of recovery in these economies, export opportunities should begin to increase.

While bivalve exports are declining generally, some North American producers are targeting new export markets in Asia. Given the high cost of transporting live animals, Asian markets have traditionally been for shucked meats, with smaller amounts of live product going to Japan, Hong Kong, Taiwan Province of China, Malaysia, Singapore and Korea. The cost of transporting the live in-shell product is prohibitive, but some producers have recently begun shipping containers of whole frozen in-shell oysters to Asian markets where they are used in a half-shell buffet trade.

Atlantic oysters are marketed as shucked meats or the live-shell product in roughly equal quantities. Approximately 80 percent of Pacific oysters were sold as shucked meats in 1998, down from 98 percent a decade ago. This reflects the increasing popularity of half-shell oysters among consumers.

Major issues and trends

Since supplies from capture fisheries are unlikely to increase in the coming decades and the world population is currently over six billion and growing, aquaculture producers will have a significant role in producing much needed animal protein to feed future generations.

Where this occurs will depend upon:

- the availability of natural resources to support production,
- access to feeds and production technology,
- a supportive regulatory environment, and
- public acceptance of the environmental impacts that inevitably accompany any food-producing endeavour.

In North America and elsewhere, aquaculture relies on precious water resources and, as populations increase, access to good quality water and the ability to discharge effluents will become more and more restrictive. In many areas, continued aquaculture expansion will increasingly use water-recirculation technologies for land-based culture systems. These technologies will range from high technology with very little water exchange (particulate filtration, biofiltration, foam fractionation, ozonolysis and oxygenation) to less complex and cheaper technologies such as constructed wetlands, using natural biofiltration processes for treating effluent waste.

Higher technology systems will be handicapped by increased operating and production costs, and only relatively expensive products will allow implementation to be economically viable, and this in areas with a well-developed infrastructure. In North America, these systems are in operation primarily for striped bass, penaeid shrimp, sturgeon, tilapia and ornamental fish that are destined for high-value fresh or live markets. These production systems can be commercially viable, but the technology remains far from turnkey.

Since the availability of fresh water and discharge restrictions limit production in many areas of North America, the most significant production increases will occur in marine offshore production systems. In recognition of this, British Columbia (Canada) salmon growers are petitioning the government to end a moratorium on the expansion of net-pen salmon farming that was initiated in response to environmental concerns. In the United States, the Department of Commerce has adopted a new policy on aquaculture development that will encourage aquaculture production within the 200-mile exclusive economic zone. The goal over the next 25 years is to boost aquaculture revenue from the current annual value of US$1 billion to US$4 billion. The Department of Commerce is promoting aquaculture development as a means to offset the trade

- access to health management services,

deficit for fishery products, which was US$12 billion in 1994. The Canadian government is also providing strong support for aquaculture development, with the recent appointment of a Commissioner for Aquaculture Development and the convening of a National Round Table to identify constraints and opportunities for future development.

Biotechnology

Biotechnology applications to cultured fish and molluscs hold great promise for different aspects of the production process, including:

- improved growth rates,
- more efficient utilization of feed,
- enhanced immune responses to disease, and
- a wide array of other production improvements from increased yield to longer shelf life.

These improvements will come about through the use of genetically modified organisms (GMOs) produced through ploidy manipulations, gene transfer or other methods. While the use of GMOs promises great improvements in animal production, it also poses ecological risks and benefits that must be addressed responsibly. It is critically important that a science-based risk assessment be conducted prior to working with aquatic GMOs, because of the likelihood that escapes will occur and the difficulty of recapture when such an escape takes place.

The United States Department of Agriculture (USDA), with input from a wide range of experts in aquatic sciences and genetics, has developed Performance Standards for Safely Conducting Research with Genetically Modified Fish and Shellfish. Accompanied by a computer-based decision-support tool, these standards will assist the tasks of risk assessment and risk management. The performance standards were approved in 1995 by the Agricultural Biotechnology Research Advisory Committee of

Some groups in North America are beginning to call for restrictions and labelling of products that have been genetically modified or contain genetically modified ingredients.

Outlook – development trends and management

Aquaculture production in North America has great opportunities for further expansion in lesser-developed rural, coastal and offshore areas where there are fewer user-group conflicts. Such openings include the culture of bivalve molluscs and net-pen culture of a variety of finfish. Aquaculture development closer to urban areas will incorporate greater technology to recirculate and filter water, so as to reduce the burden on limited water resources and limit the volume of effluent discharges.

Current technologies for seed production, health management, feeds and culture systems are sufficient to support the expansion of the existing production sectors. Increased efficiency will be derived from continued research in these areas. For example, while feeds are available for the primary cultured species, there are numerous species for which specific dietary requirements have not been identified yet. These include striped bass, sturgeon, summer flounder, abalone and a host of other species that have been proposed as candidates for aquaculture. Refinements in diets should result in additional viable species for aquaculture, improved performance and a reduction in nutrient levels in discharge waters.

the USDA. These standards will be used in the establishment of protocols for the use of GMOs and are expected to guide evaluations of the performance and environmental safety of aquatic GMOs in the United States and abroad. This development is critically important as a mechanism to enable the safe utilization of GMOs in commercial aquaculture production.

In the past, North American consumers have been left largely on the periphery as the agriculture industry has increasingly incorporated the use of genetically engineered corn, soybeans and other commodities in efforts to improve product quality and reduce pesticide use. Recently, however, concerns over the presence of genetically modified corn and soybeans in a wide variety of food products have moved the issue to the forefront of the public's view.

There will be a continuing need for research and extension services for the support of the existing industry, and this is evident in the lack of comprehensive selective breeding programmes for many cultured species. This is being addressed partially through breeding programmes for Pacific oysters and channel catfish. Nonetheless, considerably more effort should be directed to these requirements. The significant achievements of Norwegian developments with Atlantic salmon should serve as a model for other cultured species. This promises significant gain through genetic manipulation without the controversies surrounding the use of GMOs.

Another area where North America can contribute to the future of aquaculture development is in the management, acquisition and dissemination of information. In the United States, a web-based system called the Aquaculture Network Information Center (AquaNIC) has been developed to provide access to widely dispersed aquaculture information through a central internet location.

AquaNIC houses over 8 000 publications, newsletters, photographs, slide sets, videos and directories and more than two million files were downloaded in 1998-1999 (Swann, 1999). Visits to the home page of AquaNIC average more than 5 000 per month by people from 90 countries, and more than 600 other websites provide links to the site. This ready availability of information should accelerate progress in research, education and technology transfer, while advances in real time video programming will enable long distance Internet-based training to occur.

The creation, management and dissemination of information will foster the continued expansion of aquaculture in North America and around the globe. The efficient use and sharing of information will assist in maximizing productivity and ensuring sustainable development as valuable and limited natural resources are used to produce much needed aquaculture products.

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[1] pgolin@ucdavis.edu

[2] Canada and the United States of America.

[3] Canada and the United States of America.

[4] The term “crawfish” is the same as “crayfish” e.g. in European aquaculture.

[5] China, Hong Kong Special Administrative Region.

[6] Financial (Accounting) Year for the United States; September 1 1997 to August 31 1998

Aquaculture Development Trends in Europe

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ABSTRACT: The aquaculture sector is diverse, encompassing traditional artisanal and family operations, medium-scale fish-farm businesses and multinational mariculture enterprises. Technology is likewise diverse. More than 90 percent of the aquaculture farms are small and geographically dispersed. In 1997, total aquaculture production from the region [excluding the former USSR countries) was 1.7 million mt valued at US$3.8 million, or 4.6 percent of world output and 7.6 percent of the total value. This 1997 output was 44 percent higher than that of 1988, but growth has been slowing down since 1990. Most of the production comes from mariculture, the share of fresh- and brackishwater production being only around 20 percent and 7 percent, respectively. Major species cultured are salmonids, although Europe also leads in the production of other species such as turbot, European eel, mussels, European seabass and gilthead seabream. The leaders are Norway, France, Spain and Italy, contributing together 67 percent of the region's production. Carp in earthen ponds dominates the aquaculture of Eastern and Central Europe, although the total carp production was only 5 percent of the total aquaculture output of the region.

The critical features of aquaculture as a natural resource-based sector have been recognized within the European Union (EU), but there is need to strengthen aquaculture policy in countries where aquaculture is not yet considered as an equal-right user of resources. R & D support has been concentrated on the technical aspects, so that there is a need to start to place more emphasis on environmental and social aspects, for sustainability and competitiveness. Other constraints include increasing market competition, falling or static prices, and rising production and marketing costs throughout the region. In Central and East Europe, the absorption capacity of markets has shrunk due to decreased purchasing power. Most of their products are not competitive in the export markets. For the whole of Europe, competition from relatively cheap imports from other regions is another problem. Another trend seen in European aquaculture development is lower government intervention. However, the need is seen for centralized regulations and coordinated efforts to ensure equitable allocation and sustainable management of resources and more public participation in decision-making. The development of institutional capacities still requires considerable national and international effort in Central and Eastern Europe, with special regard to quality and disease control, training facilities, training in business management and information systems. Intra-European exchange of information and collaboration among institutions has been strong in the region. There is an emerging importance of producer organizations to provide members with price and market information, as well as acting as fora to develop common policies on a wide range of issues. Regional projects in Europe supported by EU are providing examples of the important role of information networking in bringing together scientists, producers, regulators and nongovernmental organizations (NGOs) to resolve various issues.

KEY WORDS: Aquaculture, Europe, Development, Fish Production, Fish Farming

Introduction

The aquaculture sector in Europe6 is diverse, encompassing traditional artisanal and family shellfish and pond-culture operations through medium-scale fish-farm businesses to multinational marine farming companies. The applied production technologies also show great diversity. However, more than 90 percent of the aquaculture farms are rather small farms (MacAllister Elliott and Partners Ltd., 1999) that are geographically dispersed throughout Europe. The European aquaculture sector has emerged as an increasingly important contributor to the region's food production sector and has grown significantly over the last two decades. Since European aquaculture is concentrated mainly in peripheral coastal and rural regions, there are also significant socio-economic benefits of aquaculture development in Europe. Much growth has been stimulated by consumer demand, as well as technological development work, making the different and various forms of production technically and economically viable.

The percentage contribution of European aquaculture to world aquaculture production has decreased since 1988 due to the higher rate of increase seen in other regions, mainly in Asia; however, it is growing in absolute terms (Fig. 1).

Analysis of aquaculture production, demand and consumption trends

Fish forms an important part of the diet of much of the population in Europe but, while the consumption of fish per capita has remained stable in most Western European countries, the past decade has seen a decline in Central and Eastern Europe. Food and Agriculture Organization of the United Nations (FAO) statistical data (Laureti, 1999) indicate that, in 1997, the average fish consumption was 18.7 kg/yr in Western Europe but only 7.0 kg/yr in Central and Eastern European countries. The share of fish within total meat consumption may be decreasing due to increasing competition with other products (mainly poultry and pork), but it is likely to increase in absolute quantity.

For the immediate future, a moderate rise in fish consumption is expected in Western Europe, but scope

Figure 1. The contribution of Europe to world aquaculture production by quantity and value, 1988 – 1997 (FAO, 2000).

exists for a significant increase in Central and Eastern Europe. This increase will probably be slow due to the combination of economic and structural problems that have contributed to low disposable incomes for most countries in these areas.

Aquaculture as a source of food and contribution of aquaculture for human nutrition

Products of fisheries and aquaculture play an important role in European food supply. Most European aquaculture products have been perceived at some point as being high-quality or premium food but, more recently, the increased availability of some species has been accompanied by significant price reductions. Several media contributors have put forward the phrase “aquatic chicken” to describe farmed salmon.

Changes in eating habits have been significant, and general observations indicate that a decrease in red-meat consumption, a greater consumption of convenience food, and an increase in processed fish products are factors that have improved the market position of fish, although sometimes it continues to be perceived as a relatively expensive source of protein.

With the shortfall in supplies of captured fish, aquaculture has benefited from the increased demand for fish and fish products by supplying a variety of species and differentiated products.

Although competition exists between wild and farmed supplies, the extent of direct substitution is variable and depends on the species concerned. The contribution of aquaculture to food security has become and will remain important in certain regions of Europe, either directly, through consumption of the products, or indirectly, through the income and

The most important contributors are the salmonid fish (salmon and trout), demersal marine fish (seabass and seabream), carps (common carp) and molluscs (mussels and oysters). The development of the relative share of the main groups is shown in Table 2.

Salmonids

Salmonids are the major species produced (46 percent of total volume and 60 percent of total value [1997]), figures that reflect considerable change from 1988 when this group represented 27 percent of volume and economic benefits obtained by the people involved in aquaculture and its related activities.

Regional production trends

Total European aquaculture production was 1.7 million mt in 1997, having a value of US$3 840 million, representing 4.6 percent of total world production in quantity and 7.6 percent in value. Compared to 1988, Europe's contribution to global aquaculture production, while growing in absolute terms, dropped from 7.4 percent (volume) and 10.7 percent (value). The Annual Percent Rate of growth (APR) for the period 1988-1997 was 4.2 percent for production and 4.3 percent for value.

Within Europe, the European Community [EC) countries have shown different growth patterns. While providing 71 percent of regional production, representing 65 percent of value, the APR for the period 1988 to 1997 was 3.0 percent for production and 4.0 percent for value. These figures show diminished growth when

52 percent of value, demonstrating a real reduction in value (per kg) of 30 percent.

In 1988, the main product was portion-size trout (200-300 gm individual size) which attained 191 000 mt of production, equal to 63 percent of European salmonid production. Atlantic salmon production was 107 500 mt (35 percent of European salmonid production). By 1997, the position had been reversed, with salmon equalling 62 percent (473 000 mt) and trout 37 percent (284 000 mt).

Atlantic salmon - Salmon farming has been dominated by Norway throughout the decade, reaching 333 000 mt in 1997. Other major producers include the United Kingdom, Ireland and the Faeroe Islands. The rapid growth of the industry has led to circumstances where supplies exceeded established demand, leading to price crashes and economic difficulties for the production sector.

compared to the non-EC European countries, whose APR was 8.0 percent for production and 5.0 percent for value.

As far as the aquaculture production in the individual countries is concerned, the most significant producers in 1997 were Norway (23 percent), France (17 percent), Spain (14 percent), and Italy (13 percent). These four countries together contributed 67 percent of the total European production (Fig. 2).

A general key observation is that the overall value has increased at a rate exceeding that of production, but this simple statement hides complex changes that have occurred within the sector, notably in respect of the production development patterns seen for the different species.

The products of European aquaculture are diverse and cover many individual species. The relative importance of the different groups is shown in Table 1.

Figure 2. Distribution of aquaculture production by countries in Europe (1997) (FAO, 2000).

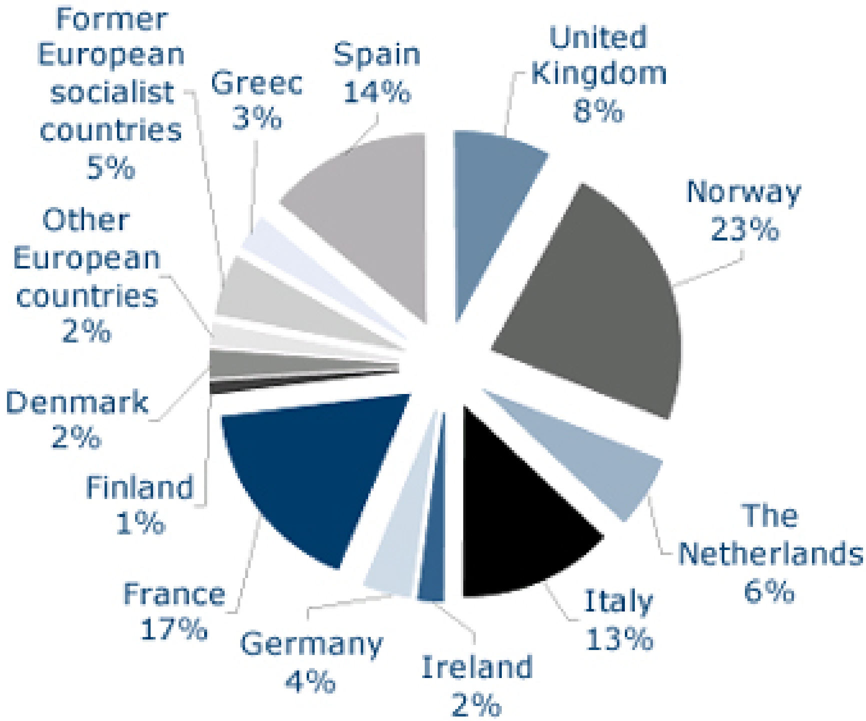

Table 1. Aquaculture production in Europe, 1988-1997 (FAO, 2000).

FAOSTAT[1] Group	ISCAAP[2] Group	1988 Quantity (MT)	1988 Value (US$'000)	1997 Quantity (MT)	1997 Value (US$'000)
Aquatic plants	Brown seaweeds	10	1	54	3
	Red seaweeds	-	0	5 008	1 764
Aquatic plants total		**10**	**1**	**5 062**	**1 767**
Crustaceans	Freshwater crustaceans	2 711	32 601	242	4 903
	Shrimps & prawns	81	1 448	353	3 019
Crustaceans total		**2 859**	**34 593**	**595**	**7 922**
Demersal marine fish	Cods, hakes & haddocks	15	60	307	921
	Flounders, halibuts & soles	157	1 465	3 048	27 399
	Red fishes, basses, congers	2 765	41 422	53 456	381 225
Demersal marine fish total		**2 937**	**42 946**	**56 811**	**409 545**
Freshwater & diadromous fish	Carps, barbels & other cyprinids	158 395	349 850	90 876	203 501
	Miscellaneous freshwater fish	6 552	28 734	8 047	28 624
	River eels	6 159	50 989	7 914	78 830
	Salmon, trouts & smelts	304 865	1 352 823	763 282	2 294 140
	Sturgeons	10	62	691	5 974
	Tilapias & other cichlids	230	1 191	280	1 106
Freshwater & diadromous fish total		**476 211**	**1 783 649**	**871 090**	**2 612 174**
Marine fish nei[3] total	**Miscellaneous marine fish**	**9**	**45**	**890**	**5 810**
Molluscs	Abalones, winkles & conchs	-	0	1 400	3 603
	Clams, cockles, arkshells	13 827	83 247	54 645	183 184
	Miscellaneous marine molluscs	-	0	430	1 978
	Mussels	506 760	349 892	513 876	318 445
	Oysters	143 268	313 776	160 223	279 840
	Scallops & pectens	331	1 243	461	2 070
Molluscs total		**664 186**	**748 158**	**731 035**	**789 120**
Pelagic marine fish total	**Jacks, mullets, sauries**	**4 253**	**8 752**	**3 559**	**14 476**
Grand total		**1 150 467**	**2 618 148**	**1 669 046**	**3 840 831**

[1] FAOSTAT = FAO Statistics
[2] ISSCAP = International Standard Statistical Classification of Aquatic Animals and Plants
[3] nei = not elsewhere included.

Table 2. Development of the relative share (in percent) of quantities of selected species groups in European aquaculture production, 1988-1997 (FAO, 2000).

Species Groups	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Salmonids	26.5	30.7	34.0	36.5	36.2	40.8	40.9	41.8	43.5	45.6
Cyprinids	13.8	13.6	11.4	10.3	10.2	8.2	7.5	6.6	5.6	5.4
Basses, redfishes	0.2	0.3	0.5	0.8	1.3	1.8	1.9	2.3	2.7	3.3
Eels	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.5
Clams, cockles & arkshells	1.2	1.7	2.0	2.9	3.0	3.0	3.9	5.1	3.2	3.3
Mussels	44.0	40.0	37.6	35.8	34.7	30.8	31.6	31.6	32.6	30.8
Oysters	12.4	11.7	12.1	11.1	11.9	12.9	11.7	10.5	10.3	9.7
Others	1.4	1.25	1.9	2.1	2.2	1.9	1.9	1.6	1.6	1.4

These situations have caused significant restructuring within the sector, reducing the number of operating companies, which are increasingly vertically integrated.

Trout - Trout farming is done commercially in 23 European states, annual production exceeding 10 000 mt in Denmark, Finland, France, Germany, Italy, Poland, Norway, Spain and the United Kingdom. The main species is rainbow trout (Oncorhynchus mykiss), although there is limited production of brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta), and growing interest for arctic char (Salvelinus alpinus).

Trout production is subdivided into two subsectors, namely that of

Carp consumption in Germany is increasingly restricted to the festive seasons, and the production cost differences have given rise to increased imports of carps and lowered production in this country.

The use of carps for recreational purposes and restocking has risen in some countries, but without making an impact on the consumer market, it seems unlikely that carp production will rise to its former levels.

Demersal marine fish

Within the demersal marine fish category, European seabass (Dicentrarchus labrax) and gilthead seabream (Sparus aurata) are the major species produced in European "portion-size" and "large" trout. While portion trout is produced solely in fresh water, large trout is grown mainly in marine conditions to a size exceeding 1 kg. Finland, Denmark, Norway and Sweden are the main producers of this product. All trout production can be classified as intensive, where raceways, tanks and cages (marine) predominate.

The recent growth seen in Norwegian trout production has been influenced by limits placed on salmon production. The vast majority of trout farms are family-owned and operated businesses, which are distributed throughout Europe. Many are equipped to do primary processing (gutting, gilling), while others have full processing facilities (e.g. filleting, smoking, preparation of patés).

Cyprinids

Five cyprinid species share the European scene, being the common carp (Cyprinus carpio), the silver carp (Hypophthalmichthys molitrix), bighead carp (Aristichthys nobilis), grass carp (Ctenopharyngodon idellus) and tench (Tinca tinca).

Carp farming is done mainly in extensive or semi-intensive pond-based systems, the latter being predominantly typical in Europe. There is a big difference in the production characteristics of aquaculture. While their natural distribution is from the south of the North Sea to the Mediterranean, Mediterranean farms dominate the production of market-size fish. Most farms hold a mixture of stock, rather than just producing a single species.

Aquaculture of these species is done using each defined aquaculture system, the best-known extensive system being that of the lagoon-based "valliculture" in Italy. Juvenile fish enter the lagoon and are grown on naturally available food; at maturity the fish leave for the sea to breed and are caught in traps. A similar system is applied in Portugal.

Semi-intensive farming involves "improved" valliculture (i.e. administration of feeds) and is usually done in coastal ponds/ditches (e.g. salt marshes in Portugal). Intensive farming constitutes the majority of European production, where the preferred technology is the use of floating cages, moored close to the coast, although ponds are used mostly in Italy, Spain and Portugal.

Hatcheries are the source of fry for ongrowing and which often have to be transported long distances to the farm sites. In 1988, production of these species totalled 2 800 mt, worth US$41 million. By 1997, 53 500 mt were harvested, having a

Western Europe and Central/Eastern Europe, the latter producing 74 percent of European cyprinid production in 1997, compared to 80 percent in 1988.

The total European production dropped from 158 000 mt in 1988 to 91 000 in 1997, the biggest reductions being seen in the early 1990s and in the major production countries. Part of the reason for these circumstances was the social and economic change occurring in Central and Eastern Europe. However, limited market opportunities have also been noted, particularly given the rising availability of other inexpensive food products.

value of US$381 million. It is worth noting that the price dropped from US$15-17/kg to US$7/kg during the period examined. Greece dominates European production, with some 62 percent of the 53 500 mt produced in 1997, followed by Italy (16 percent), Spain (8 percent) and France (6 percent).

The major market for the products of this sector is Italy, which has traditionally received the bulk of Greek production, as well as that of the growing Turkish sector.

While some markets give a preference to seabass (e.g. Italy, France) others are more disposed to seabream (e.g. Spain, Greece). These predominantly Mediterranean products have experienced difficulties in establishing a clear position in markets elsewhere in Europe.

Prices halved during the decade

Eels - Eel production in Europe is based on the ongrowing of juveniles (elvers) of the European eel (Anguilla anguilla), since no hatchery technology exists yet for artificial reproduction. Farming techniques can be divided into three main categories.

Extensive, the most ancient technique, exploits the natural examined, dropping from levels approaching US$15/kg to around US$7/kg and even lower recently (US$4-5/kg in 2000). While the gross argument for this circumstance is that increased supplies to a competitive market cause price reductions, it is a situation that mirrors similar difficulties experienced in other divisions of European aquaculture. Improvements in marketing and distribution have partially eased such circumstances, but market concentration within a few countries remains a problem.

Flatfish

Flatfish have long been of interest for aquaculture in Europe, where turbot (Psetta maxima), sole (Solea solea) and halibut (Hippoglossus hippoglossus) have been candidate species for commercial culture. Turbot is the only species that has made a significant step forward, 3 050 mt being reared in six European countries in 1997, although production is led by Spain (1 800 mt) and France (980 mt).

Intensive culture systems are required using juveniles supplied by marine hatcheries. Juvenile supply has been traditionally from northern Europe (United Kingdom, Germany) to production units sited on the Atlantic coast, usually in southern Europe. After two years, turbot

tendency of the fish to enter brackish lagoons to grow. After five to seven years (on average) the mature fish leaves the lagoon for reproductive migration and is captured by fixed devices ("lavoriero", "bordigue"). This technique is mainly used in Italy. Intensive farming uses concrete or earthen ponds for ongrowing, but requires warmer waters for growth, hence higher application in Italy, Spain and Greece. Water recirculation systems also use intensive farming criteria and have been the basis for recent developments in the Netherlands, Denmark and Sweden. Eels are held within small concrete or fibreglass tanks (+/-25 m2) and water is heated for maintaining optimal temperatures; the costs of doing this are countered by the treatment (biofiltration) and cleaning of the water for re-use. Oxygen injection and water sterilization are included in the process.

Production increased from around 6 000 mt (1988) to 8 000 mt (1997), with the Netherlands, Denmark and Spain providing the bulk of the increase. The producers using water recirculation tend to provide eels of a smaller size (under 170 gm), while those using ponds obtain the larger sizes (over 300 gm) that get better prices.

Investment in eel farming in northern Europe has increased reach market size, noting that correct pigmentation is a determinant factor for consumer acceptability. The market has posed less of a problem for this sector, since turbot supplies from the wild are low (less than 10 000 mt/yr) and the investment in production units is high, limiting the entry of investors to the sector. Production is anticipated to grow slowly with controlled expansion, a situation that should avoid weakening effects on the market.

Diverse fish species

There is a wide variety of species that can be counted within the data reported for European aquaculture, and the following section gives a brief review of the main characteristics and interest for these species:

rapidly in recent years, increasing supplies to the European market. Prices have dropped steadily and crashed at the end of the 1990s, dropping from $US11 (beginning of the 1990s) to US$5. The reasons for this appear to have been the compound result of higher elver prices and stagnant markets.

After a period of rapid investment in new production systems in northern Europe, a period of stability is foreseen, albeit with lower prices. The higher prices for elvers, increasing imports (from Asia) and the economic impact of operating water recirculation systems are factors that will continue to influence and may cause some restructuring within the sector. Nonetheless, the key issue to be resolved remains market expansion.

Catfish - Four main catfish species have been produced in Europe, the European catfish or “wels” (Silurus glanis), the black bullhead (Ictalurus melas), channel catfish (Ictalurus punctatus) and the African catfish (Clarias gariepinus). In 1997, the total combined production of these species was less than 2 500 mt.

The catfish “group” has been of interest to producers because of their fast growth rates and efficient food conversion. National approaches have also been very different. Black bullhead production was limited to Italy and has steadily stagnated, while African catfish (produced in heated-water recirculation systems) has been promoted in the Netherlands. European catfish production is spread around Central and Eastern Europe. Overall, consumer response has been weak for these species, limiting the effectiveness of promotional campaigns and continued producer interest.

Sturgeons - Sturgeon production has been of interest to producers in a number of countries, primarily as a result of investigations for caviar supply from mature fish. France (Acipenser spp.) and Italy (Huso huso) have led the way in Europe, requiring considerable stock investment because of the time required to rear the individual to maturity. It is only recently that the

Molluscs

Mussels

Two mussel species, Mytilus edulis (Atlantic, North and Baltic Sea coasts) and Mytilus galloprovincialis (Atlantic and Mediterranean coasts), are the core of over 500 000 mt of European production. There are three different culture techniques - using poles (“bouchot”), suspended ropes or bottom culture.

Pole culture: A “bouchot” is made of wooden poles, placed upright into the sea bottom. Mussel seed, collected (usually around March) either on poles (placed further out to sea) or on ropes, are transplanted onto growing poles (“boudinage”) in July. Harvesting occurs after 15 months of growth.

Suspended rope culture: For this technique, ropes covered with mussel seed are suspended either from metallic frames or from floating structures, enabling young mussels to remain under water permanently. Frames are built from metallic poles, placed upright into the ground, at water depths ranging between three to nine metres. Young mussels, placed in nylon net-bags, are grown throughout the year and harvested according to demand. Floating structures are rafts (“bateas”), saucers or longlines.

first “aquaculture” caviar was put onto the market, following nearly seven years of investment. Of additional interest, however, is the use of hatcheries and production units to supply fish for restocking; several European countries are looking at projects for the re-introduction of sturgeon into rivers and estuaries (e.g. in the Gironde area of France).

Tilapias - Tilapia species require warm water (>23ºC) for growth and commercial production. It is, therefore, only possible using a warmwater source or heated recirculation systems, a position that limits development to specific and isolated projects.

For certain species, the EC is a world leader, like turbot (100 percent), European eel (99 percent), mussels (70 percent), seabass/seabream (68 percent) and trout (54 percent). The main salmon producers are Norway, Scotland and Ireland, while the leading trout producers are France, Italy and Norway. Seabass and seabream are produced in the Mediterranean Region, where Greece is the largest producer. Carp species are mainly cultured in Central and Eastern Europe (170 000 mt and 60 555 mt in 1997, respectively), while in Western Europe carp is produced in much lesser quantity. (22 930 mt in 1997).

Bottom culture: This technique rests upon the harvesting of naturally produced young mussels and their spreading out on specially prepared growing plots and is a technique that is widely practised in the Netherlands.

European mussel production has fluctuated during the decade, with wide variations of harvests in Spain, the Netherlands and Germany during the early 1990s. After dropping to around 380 000 mt in 1993, production has recovered to former levels (514 000 mt in 1997). Where the value/kg started the decade at US$0.7, it dropped and stabilized at US$0.6 by the end.

Sectoral expansion has been seen in Greece, Italy, the United Kingdom and the Netherlands, while Spanish production has dropped by over 20 percent during the period.

Pollution of intertidal mussel-growing areas has been a problem, and increasing environmental concerns can affect use of the coastal resource, a factor that could inhibit further development.

On the other hand, demand is quite stable and supplies seem to be under control, partly due to improved management of production aspects.

The mussel has not always been perceived as a safe food, and EC legislation was implemented during the decade to address this aspect. Furthermore, sectoral advertising and marketing campaigns have been initiated and more consumer-friendly products (ready-to-cook bags of whole mussels and a wide range of processed products) have successfully brought mussels into the multiple retail stores.

Oysters

Ostrea edulis, the European flat oyster, is found the entire length of the Atlantic shoreline as well as in the Mediterranean, while two "cupped" oysters are also present. These are the Portuguese cupped oyster (Crassostrea angulata) (also called the "Japanese oyster" in

The density and proximity of individual production areas contribute to the rapid spread of such outbreaks. Increasing attention has been brought to the effects of marine pollution on oyster and other marine culture activities by the effects of successive oil spills from wrecked ships.

Production and price instability during the 1980s affected the potential for expansion of this sector. In addition, through occupation of the European coastal zone, there has been increasing competition with other coastal activities, most notably tourism. The sector is characterized by being composed mainly of small, family-owned businesses of limited financial capacity.

Marketing is done through cooperative and associated groups, and the professional capacity for these aspects has been raised by such actions. Adapting handling and packing stations to legislated

Europe) and the Pacific cupped oyster (C. gigas), which comes from the Pacific Ocean. Production has risen slowly from 145 000 mt (US$336 million) to 160 000 mt (US$280 million), demonstrating an apparent price drop of 24 percent, from US$2.3 to US$1.75.

European oyster-growing techniques have developed in order to supply the market for fresh oysters, delivered in the shell. Cultivation is usually a three-year process that starts with the collection of small oysters on a support from which they can be easily removed after six to eight months. During the second year of culture, oysters are spread out in the intertidal range, either directly on the ground (bottom culture), or in bags on trestles, or suspended (Mediterranean shores).

Top quality oysters may undergo the process of “affinage”, where feeding on blue algae (Navicula sp.) gives a green tinge to the oyster, which is duly called a “fine de clair” or a “special”. European oyster culture is dominated by France, which had over 93 percent of production in 1997, and is concentrated between Caen and Arcachon on the Atlantic coast. This area provides over 80 000 mt of Crassostrea annually. The other European countries have limited production capacity, with Ireland, Spain, the United Kingdom and the sanitary and hygiene requirements has been difficult, due to the burden of investment, but this has now been applied generally throughout the sector. The future outlook is cautious, where production appears to have been consolidated with regular price drops, circumstances that indicate a concentration of production and increased sensitivity to market changes and/or external influences, such as marine pollution.

Clams

The aquaculture of clams has shown considerable development and change in Europe, where production increased from around 14 000 mt in 1988, to 55 000 mt in 1997 after peaking at 76 000 mt in 1995. The most notable change has been due to the introduction of the Japanese carpet shell into Italy, which now sustains a wild fishery representing 95 percent of national production. Where Portugal had been the major producer of clams (57 percent) in 1988, by 1997 it has been displaced by Italy, which had attained 73 percent of European production.

This is explained mainly due to the replacement of the European species, the grooved carpet shell, (Ruditapes decussatus) with the Japanese carpet shell or Manila clam (R. philippinarium) for reasons of improved resistance and higher growth. In addition, European hatcheries are capable of

Netherlands providing the remaining contribution.

Oyster farmers have long been susceptible to parasitic and viral disease outbreaks, and production collapsed in Italy at the end of the 1980s.

reproducing the Manila clam, improving seed supplies. The Regional Government of Galicia (Spain) banned the use of Manila clam seed for semi-extensive use on beaches, and several authorities are actively promoting the use of the native clam.

The values for clams in Spain and Portugal are considerably higher, grooved and pullet (Tapes pulastra) carpet shells being reported at levels higher than US$8/kg, while the Italian Manila clam values are closer to US$2.5/kg. Prospects appear good for this sector, due to steady and increasing demand, combined with good prices. The availability of appropriate sites and acceptance of the use of the Manila clam appear as the main limiting factors.

Scallops

The cultivation of scallops has been of limited success in Europe. The great (Pecten maximus) and queen scallop (Chlamys opercularis) of the northern Atlantic have lent themselves to small-scale

Restocking/enhancement

Salmonids: Juvenile Atlantic salmon, brook trout, brown trout and rainbow trout are produced by hatcheries Europe-wide for enhancing native stocks or for restocking purposes, destined for sport or recreational fisheries.

"Coarse" fish: This refers to nonsalmonid species that offer sporting value and includes bream, carp, perch, pike, roach, rudd and tench.

Other: The ragworm (Nereis virens) is highly regarded as bait for seafish angling. Pilot projects have given promising results.

The estimated contribution of nonfood aquaculture is under 1 ongrowing in lantern nets hung from mussel-type long lines. The process remains based on capture of wild spat. Contamination by ASP (amnesic shellfish poisoning) toxins has been reported and may continue to cause problems to further expansion. Production is limited to Spain, France, Ireland and United Kingdom, with European production being around 450 mt in 1997.

Crustaceans

While crustaceans are popular with the consumers, European aquaculture has yet to be able to supply requirements. European populations of wild crayfish were virtually wiped out by the crayfish plague, and the signal crayfish (Astacus leniusculus) and the red swamp crayfish (Procambarus clarkii) were introduced as candidate species for aquaculture. At present, aquaculture of these species has contributed very little.

Many crustaceans are popular with the European consumer, but efforts for aquaculture and stock enhancement have given little fruit to date. Strong supply circumstances in Asia and Latin America make it difficult to envisage large-scale, commercial production that is technically feasible and profitable.

Nonfood aquaculture species

percent in both volume and value and, although growth will occur, this proportion is not expected to change significantly in the medium term.

Comparison of production trends within the region

The European aquaculture industry is an emergent, diverse and productive contributor to the region’s food production sector and has grown significantly over the last two decades. Much of this growth has been stimulated by extensive scientific and technological developments that have made different production activities technically and economically viable.

Between 1988 and 1997, the broad pattern of aquaculture development has been:

- high growth in Northern Europe,
- medium growth in Western Europe,
- low growth in Southern Europe, and
- decline in Central-Eastern Europe.

The development of production (quantities and values) for these geographically defined areas is given in Table 3. Value development has generally not followed production volumes, indicating price reductions in Northern, Western and

Aquarium and pond fish

Europe is a substantial importer of live exotic fish species, both freshwater and marine, many of which are of tropical origin. Ornamental carps (e.g. koi) and other freshwater species are being reared, and the possibility of developing this activity further appears promising, particularly for domestic purposes. Little is known of the position for marine ornamental species.

Central/Eastern Europe. Southern European production has diminished for some species and increased for others, resulting in a “value” contribution that has improved. Central/Eastern European aquaculture entered into a period of decline at the end of the 1980s, which appears to have stabilized at the end of the period examined.

In general, Northern Europe’s aquaculture growth has been largely underpinned by increases in salmon and large trout (>1 kg) cage farming. Western European growth has been supported by salmon, trout (portion-size) and molluscs, all of which have reduced in value during the time-period. Southern Europe has shown strong growth in marine fish farming and moderate growth in freshwater fish production (trout), while mollusc culture has fluctuated.

The decline of aquaculture in

As far as the disposable income of the populations is concerned, the demand for fish in Western Europe will not change much under the predicted economic growth (2.5 percent per year), while in Central-Eastern Europe the future fish consumption will be directly associated with the predicted gradual increase in disposable incomes.

The total per capita apparent fish consumption in 1997 was about 22 kg/yr in the EC countries and 6-9 kg/yr in the Central and Eastern European countries (Laureti, 1999). Increased fish consumption is expected, especially in Central-Eastern Europe, where per capita

Central/Eastern European is linked to being predominantly freshwater carp production. Pond-based fish production has decreased dramatically after the political and economic changes in Central and Eastern Europe.

In spite of the significant differences between the aquaculture sector in different regions in Europe, markets are the major issue, in which consumer demands, international competitiveness, health, environment and product quality are the determining factors of success.

Apart from this geographic distinction of aquaculture, within Europe one cannot ignore the political and economic distinction of the European Community (EC). The grouping of the 15 EC Member States shows that it provides 71 percent of European production volumes and 65 percent of the value (Table 3).

Population growth, demand and consumption

In general, the total demand for any commodity would be expected to grow in proportion to the growth of population, since the latter determines the overall size of the market. Significantly, the growth rate of the population in Europe is less than predicted. fish consumption is now very low.

The demand for fish products is influenced by consumer awareness (e.g. health and sanitary issues), disposable income (e.g. consumer choice of fish/crustaceans/molluscs vs. competitive food products) and availability (e.g. choice/availability within retail stores). It is believed that there will be a decline in demand for high-priced aquatic products, although such demand may shift to lower priced fish products. The future demand for fish will basically be determined by the number of consumers, their eating habits and disposable incomes, as well as by the price of fish products. Many of the changes that will occur in the level and structure of fish consumption will reflect more complex demographic and attitudinal variables. Ageing populations, changing gender roles, smaller household sizes, dietary concerns, food safety issues and ethical concerns are influential factors that exist throughout Europe. While future fish consumption will benefit from these trends, quantifying their effects on demand and consumption is difficult. Positive effects are expected due to an increased interest in healthy eating, but negative effects could be anticipated in respect of food safety concerns.

Recently, Western Europe has also seen the effects of two major incidents concerning food safety.

(FAOSTAT, 2000).

Recent projections have shown a slight increase of population in Western Europe (0.3 percent per annum), and a decrease in Central-Eastern Europe (0.1 percent per annum).

Table 3. Trends of aquaculture production quantities and values in the four main European subregions, including their APRs for 1988-1997 (quantity [1 000 MT] and value ['000 000 US$]) (FAO, 2000).

Region		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	APR
Northern	Quantity	150	183	236	251	227	261	304	359	410	448	13%
	Value	772	804	1 147	1 038	1 005	978	1 158	1 323	1 297	1 311	6%
Western	Quantity	439	477	504	462	484	516	552	549	611	617	4%
	Value	884	991	1 023	1 032	1 158	1 159	1 321	1 266	1 195	1 348	5%
Southern	Quantity	422	372	373	405	377	339	404	498	497	517	2%
	Value	649	735	797	859	864	724	823	979	965	987	5%
Central/	Quantity	128	127	109	103	101	79	81	79	74	73	-6%
Eastern	Value	284	274	239	227	229	178	183	172	155	154	-7%

The first of these was the occurrence of bovine spongiform encephalitis (BSE) or "mad cow disease". The effects of this disease have been wide-ranging and severe, the most recent action being a six-month ban on the use of animal meals as feed ingredients for food-producing animals. The second incident was the discovery of accidental dioxin contamination of feeds used in the Belgian poultry industry in 1999. These incidents

Generally speaking, aquaculture has yet to play a major role in European economies, although some notable exceptions exist. Salmon represents the second-most important export commodity of Norway, and aquaculture is an important contributor in specific areas within countries (e.g. oysters in the Oleron area of France, salmon in the highlands and islands of Scotland, seabass/seabream in Greek islands).

have raised the profile of the food supply sector, and very close examination of ingredients and practices has ensued, both in the public and private sectors. Without doubt, the public image of the food production sector has been damaged and consumer confidence impaired.

The long-term effects of the legislative controls and reviews are difficult to assess, but it is clear that European agriculture and aquaculture will be controlled more closely, either through legislative action or through nongovernmental governance techniques. These will be necessary, not only for the legislator, but also for the confidence of the consumer.

Additional measures that may influence fish consumption include the application of quotas on fisheries activities, notably for the EC Member States, positions that could reduce national supplies.

Aquaculture contribution to rural development and poverty alleviation

Aquaculture has a positive role in rural development, both in coastal and inland situations. In inland circumstances, agriculture and forestry have been the main elements of such rural development programmes throughout Europe. Increased integration between

Capacity of european aquaculture for development

Available natural and human resources provide a good basis for the further development of European aquaculture. Concern as to the scarcity of water is important in some inland areas of Europe, which will lead to tough competition among various water users. From the production point of view, environmental issues, notably those concerning effluents from intensive fish farms, will also determine the future development of this sector.

During the development of intensive land-based systems, the efficient use of water is a primary criterion that is applicable not only to tank use, but also to pond-based fish farming. A considerable proportion of fishponds, especially in Central and Eastern Europe, will be used for the semi-intensive production of traditional species (e.g. carps) for the local markets, using agricultural by-products and cheap protein resources for feed inputs. In general, more emphasis should be given to the development of aquaculture technologies integrated with agriculture, industry, water management, recreation etc., encouraging the multiple use of water resources. There will also be an increasing trend for such aquaculture and agriculture could be a good means to improve rural life through multiple use of resources. Although the main element of aquaculture will remain food production, the importance of various services to be provided in recreation, rural tourism, nature conservation and water management will increase in the future, and this will provide employment and business opportunities for the rural populations.

The contribution of marine aquaculture to employment and reduced rural migration has been noted in a number of countries, for example, Norway, United Kingdom/Scotland, and Greece, particularly in several rural areas where few alternative economic activities have been able to provide stable, longterm jobs.

diversification in pond aquaculture, directed towards intensification, waste recycling and integrated resource use.

In coastal areas, water quality problems have also become critical factors in aquaculture development. One can forecast the increased use and application of technological developments for the expansion of coastal aquaculture, primarily for minimizing the different environmental impacts of the activity (e.g. offshore and submersible cages, improved feeds and feeding technologies, controlled waste disposal etc.).

The development of intensive aquaculture production (predominantly in cage and tank systems) is likely to follow the development pattern of other agricultural food production sectors, being applied to all subsectors of aquaculture (i.e. increased process intensity, wider use of advanced technologies and equipment, high-quality products, high level of processing etc.).

Further application of water treatment and recycling systems for the production of higher value species is expected in the future. Nonetheless, the environmental benefits of this need to be balanced with the economic requirements (i.e. higher investment and operating costs) of using such systems.

Cage aquaculture is and will remain an important production technology for marine species, and there will be a strong trend toward the wider use of offshore cages. Increasing competition with tourism facilities throughout Europe provides an opportunity, supplying the consumer, and a challenge, integration of a production activity with the demands of tourism (e.g. pristine views).

There is a considerable scope for much greater integration among the various users of the aquatic resources, a philosophy that is

- improve its public perception,
- be more proactive, and
- be transparent and accountable at the same time.

Efficient use of primary resources

Aquaculture has good possibilities to be recognized as an efficient user of primary resources, applying modern methods, equipment and good management practices in intensive monoculture production systems.

Extensive or semi-intensive polyculture fishpond systems are also efficient users of primary resources, since within these systems fish production is based on naturally available nutrient resources. The combination of intensive monoculture and extensive polyculture systems, as well as the integration of aquaculture with other agricultural production activities could also increase the effectiveness of the use of primary resources.

Increased use of available resources (land, water)

Many of the best and most obvious sites for aquaculture production in Europe contain aquaculture projects, meaning that there is high competition for the remaining suitable areas. Furthermore, it is a time-consuming and lengthy reflected in policies for Integrated River Basin Management and Integrated Coastal Zone Management (ICZM). However, the elaboration of complex, integrated technologies requires the strengthening of research and development in this field, together with the corresponding adjustment of the institutional system. The key elements for the future technical success of aquaculture are the improvement of the existing technologies and good aquaculture management practices.

The following key challenges and issues must be resolved for successful aquaculture development in the future.

Recognition of aquaculture as a preferred user of resources

The operation of some intensive aquaculture systems has led to the sector being regarded as a major polluter of the aquatic environment in some developed countries in Europe. There is adequate scientific proof for aquaculture to defend its position but, in order to be a user of aquatic resources with equal rights to others, it needs to:

process to obtain approvals for the use of new sites. Therefore, the main trend in the future will be to increase production and improve the efficiency of water (e.g. recycling, water treatment) and feed use in all areas of aquaculture, probably accompanied by the wider application of offshore cages in marine aquaculture.

Diversification

"Sales and marketing" is a phrase that summarizes the major constraint for European aquaculture development. The entire sector has faced increased market competition, falling/stable prices and rising production costs, as well as market restructuring throughout Europe. The geographic dispersion of production and the concentration of markets (i.e. the multiple retail stores) have combined to impose a more professional and coherent approach for the sale of aquaculture products.

In order to meet present and future market requirements, identified solutions include species/product diversification, added-value processing, quality assurance schemes, branding and generic marketing.

Restructuring within the profession has also become a reality, where increased buy-outs and mergers within the corporate sector have resulted. Nonetheless, more than 93 percent (by number) of aquaculture enterprises are small, family businesses (Fédération Européenne de Salmoniculture, 1990).

Increasingly, grouped sales (through cooperatives or other structures) are being used in order to adapt to market requirements and to obtain economies of scale. In the future, one should anticipate further consolidation of sales and marketing within specific producer organizations in order to respond to the changing market requirements.

Intensification of production

Intensification of production is a key technical issue in European aquaculture. Where appropriate conditions are available, intensification will continue to be an important option for the producer, provided that the productivity of existing systems will increase, and that good financial and economic performance is pursued.

The principle of polyculture will need to be reconsidered; for example, species that feed at a lower level in the food chain could be used for water quality control, improving the conditions for the intensive production of species that require formulated feeds.

Increasing technical efficiency

There are three main systems whose increased development and application are foreseen:

- water efficient and environmentally friendly recycling systems for the production of higher value species, especially in areas where geothermal water resources are available;
- offshore deployment of marine cage aquaculture facilities; and
- increased mechanization for increased productivity within pond fish farming.

Research priorities should include the following areas:

- fish disease (e.g. vaccination, systems management approach),
- genetics (e.g. genetic

However, a large part of the considerable areas of fishponds in Central and Eastern Europe will remain to be used for the semi-intensive production of traditional species such as carps. Integration of aquaculture with agriculture and the use of polyculture technologies would increase productivity.

Recently, concern on welfare issues concerning farm animals have been extended to fish, and this topic will need to be correctly addressed by the aquaculture production sector.

Increased culture-based fisheries

There is significant potential for the development of culture-based fisheries. In Europe, recreational fisheries and tourism have increasing importance within the uses of water bodies such as lakes, reservoirs and rivers, and aquaculture has the potential to be an important service-provider to these purposes. Besides providing species of commercial importance, the supply of indigenous species and endangered native species for stock enhancement can be envisaged as viable activities.

Increase in integrated aquaculture

There is a great scope for integration of pond aquaculture with agriculture, water management and

engineering),

- feeding (e.g. fish meal substitution, environmental protection),
- product quality, and
- marketing.

Getting more people involved in aquaculture

A recent study (MacAlister Elliott and Partners Ltd., 1999) projected an 18 percent increase in direct aquaculture employment for the EC countries by 2005, which will result in further increases in the up- and downstream industries. Similar trends would be expected in other non-EC countries where aquaculture plays a role within the national economy. Although no similar data are available from Central and Eastern European countries, recent trends indicate that significant increase is expected in the number of new entrants as a result of the restructuring and privatization of the aquaculture sector.

Community involvement

There has been good progress in developing community involvement in the preparation of aquaculture strategies, plans and regulations in Western Europe, particularly within the EC countries. There is a need, however, for the further improvement of community involvement, particularly in respect of natural resource management natural parks; however, clear priorities should be set up in the use of a particular area. Wastewater fishponds might play an important role in the future for the recycling of organic wastes.

issues.

Such actions are to prevent or resolve conflicts, on resource use, through the involvement of all of the stakeholders in a given area.

Producer associations or organizations play a very useful role in order to assist the extension of actions across all sectoral participants. While the principle of subsidiarity has been widely recognized and is applied increasingly in Western Europe, it is neither well understood nor well applied in Central and Eastern European countries. The reasons for this are not only the reluctance of the authorities and official bodies to involve the communities within their decision-making process, but also the passivity of those communities, which is based on past experiences in the centrally planned economy. The enlargement of the EC, and the efforts made to improve democracy

Aquaculture will no longer be looked at in isolation; its interactions with other factors and activities of importance and the manner in which concerns can be answered will clearly affect the success of the technology to be used.

Institutional issues

Substantial differences in legislation (between countries) and administration (within countries) are key problems for successful aquaculture development. Special regard should also be given to small and medium size enterprises (SMEs), on the one hand, and to the Central-Eastern European Region on the other. Free-trade policies exist within the EC and are being promoted in an increasing number of non-EC countries. Centralized regulations to ensure the equitable allocation and

and stability in the accession countries, will improve this situation.

Key issues and constraints

Technological issues

The key issues of aquaculture development in Europe are defined by the two main categories of production (Tacon, 1997). These are, on the one hand, the intensive production of higher value species (salmonids, marine finfish and molluscs) in Northern, Western and Southern Europe and, on the other hand, the semi-intensive and extensive production of lower value freshwater finfish (mainly cyprinids) in Central and Eastern Europe.

With regard to intensive production, the main sectoral issues include the risks of over-production and market saturation, the dependence on fishmeal and oils for formulated feeds, decreasing mollusc production in Southern Europe, and increasing competition with other users for the available water resources. For extensive and semi-intensive production, notably that of Central and Eastern Europe, the main issues are related to the drastic changes resulting from the political-economic transition. These include the collapse of the state subsidies to the sector, high sustainable management of resources might be desirable, in order to establish the “level playing field” that is required within a free-trade scenario.

The role of public consensus, consultation and participation in the decision-making process will increase for all stakeholders. The development of the institutional capacity to adapt to these circumstances will be important for achieving these goals.

The development of institutional capacity in Central and Eastern Europe still requires considerable effort to be made at national and international levels, with special regard to fish inspection systems, technical training facilities, advisory service training and fisheries information systems.

Socio-economic issues

The principal issues of concern come from the very structure of European aquaculture, which is highly diverse and composed of:

- traditional artisanal and family shellfish farms,
- small-/medium-/large-size pond farms,
- medium-size trout and brackishwater farms,
- intensive land-based and marine farms, and
- multinational marine fish

inflation and interest rates and the consequent lack of capital, the loss of traditional markets and competition for water resources (Tacon, 1997).

farms.

The small, family-owned farms occupy, without doubt, a disadvantageous situation at present, where the changes in policies, legal and regulatory frameworks, and market structures; the increasing competition for resources; the increasing competition in the market;

and the increasing complexity of the business environment make it extremely difficult to find optimal management options, especially within the capacity and structure of the small enterprises.

Social tensions and economic difficulties in Central-Eastern European countries have been created during the transition period into the market-driven economy. Decreased economic growth rates, collapsed state subsidies, high inflation rates and decreased disposable incomes of the populations have created serious social tensions in most of these countries.

Europe, especially the EC, has been a traditional target market for aquaculture products from many exporting countries, where tropical shrimp, salmon, eels, seabass and seabream number amongst the most important products (Lem and Shehadeh, 1997).

The shift away from auctions to multiple retail stores as the first point of sale (as well as being the final one) has also imposed new “rules” within many European markets, especially since competition within the retail division is also very strong. The replacement of the fishmonger by the supermarket’s fish counter has also transformed the way in which the

Environmental issues

There are increasingly stringent environmental regulations and tough competition for resources. Sustainable development is the overriding strategic issue in European aquaculture, and will continue to be so in the foreseeable future. Legislation within the EC now encompasses most of the activities and resources used by aquaculture, a situation that is often seen as a high hurdle that is restricting development opportunities.

Governments need to create an "enabling" environment through appropriate policies and legal frameworks. The application of the principles of the FAO Code of Conduct for Responsible Fisheries should be encouraged and the development and implementation of better management practices is seen as a priority.

Financial and economic issues

Although aquaculture is clearly a market-led business in developed European countries, support measures by governments and international organizations should be available to assist sustainable aquaculture development. This could be achieved directly (e.g. structural funding through the Financial Instrument for Fisheries Guidance of the EC) or indirectly, consumer buys fish and seafood products. Consequently, for the producer, the multiple retail stores have become the most important route of access to the consumer. This circumstance has also meant a reduction in the number of buyers, while aquaculture expansion has increased the number of sellers. This concentration of buying power has weakened the market position of the producer/seller.

Supplies from European fisheries are increasingly subject to stock management restrictions, and the fisheries sector also has to respond to the issues of sustainability and biodiversity. The availability of products from European fisheries is likely to diminish and be accompanied by rising prices. Aquaculture products would be expected to occupy a larger portion of the food market, since the sector is capable of supplying a wide range of species and product forms. While import realities (such as the trade of salmon and shrimps) would not be expected to change significantly in the future, the availability of a large internal market and the scope for species/product substitution (fisheries or imports) will be the main stimuli for aquaculture development in Europe.

Development and research

Scientific research and technological development stimulated through research support. Special funds should continue to be provided for Central-Eastern and South-Eastern European countries (e.g. the PHARE7, ISPA8 and SAPARD9 facilities).

Market and trade issues

Responding successfully to market and trade issues is the key for a stable and reliable European aquaculture sector. Market constraints are due to the increasing market competition, falling/stable prices and rising costs, and a significant restructuring of the market throughout Europe (Stirling Aquaculture Ltd., 1996a,b).

significantly the growth of European aquaculture. A broad and well-developed aquaculture research capacity, possessing effective resources and concentrated skills, exists in much of Europe. However, serious constraints have developed in Central and Eastern Europe, primarily through inadequate core funding and weakened infrastructure.

An increasing trend has been the incorporation of private funding from aquaculture operators for specific research and development projects; indeed this is increasingly imperative for the maintenance and development of support facilities within the research sector. The lack of equipment, inadequate core funding and poor international contacts have been cited as restricting factors for the Central

The network extends throughout Europe, including EC and non-EC countries, and has become an efficient tool for improved communication and contact establishment, and has included the organization of specialized workshops between scientists and operators.

The EC research programme also supported a project that has looked and Eastern European research sector. A number of EC-financed projects have facilitated both intra-European and international collaboration and networking.

The EC's Fifth Framework Programme10 (1998-2002) provides support for research and technological development, within which sustainable fisheries and aquaculture are among the key actions identified. Priority areas for aquaculture research include:

- interactions between the environment, fisheries and aquaculture;
- scientific basis for fisheries management; and
- improvement of aquatic production.

Research centres and university departments that are involved in aquaculture research possess many years of involvement and collaboration with the aquaculture production sector; producers who are involved directly in research also use external specialists. Increasing recognition has been given to market-led or demand-led applied research, requiring closer contact between researchers and operators, which has been recognized as a key element of the Fifth Framework Programme. This also promotes transnational collaboration and network establishment that builds closer at the "Monitoring and Regulation of Marine Aquaculture" or "Maraqua". This project has involved the creation of a partnership where 25 organizations from 16 countries are involved, bringing together scientists, producers, regulators and voluntary organizations in an effort to coordinate and provide means for the efficient exchange and review of information. While the project does not involve new research, it instead concentrates on the review of existing information and issues and hopes to develop guidelines for the monitoring and regulation of marine aquaculture in Europe.

Major issues and constraints common to all regions

Sustainability

All natural resources are finite, and the demands on aquatic resources from differing production and service sectors are increasing. Water scarcity and growing difficulties of access are factors that lead to competition between the different users, including fisheries and aquaculture, and have become critical issues throughout Europe. The mechanisms and methods for assessing the impacts of various activities on aquatic resources are reasonably well established, but overcoming the complex problems of interactions remains to be solved. The Water Framework Directive of the EC addresses the core problems links between science and industry. The development of efficient networks within all of the different subsectors of European aquaculture is, without doubt, one of the major challenges in the short term.

Two projects oriented towards assisting aquaculture are the "Aquaflow" and "Maraqua" projects, both of which are EC-financed. "Aquaflow" was initiated to provide a wide and rapid information flow on the progress of EC-sponsored aquaculture research and development projects. It is composed of a pan-European network of scientists and aquaculture associations who diffuse one-page project summary papers directly to individual producers and scientists, in the national language of the country concerned.

of water management, including the obligations of users and managers, for these purposes.

The key issue is the promotion of the sustainable use of water resources, at an optimal level of exploitation and acceptable to all users. Appropriate strategies for sustainable water resources management should also include social, economic and recreational considerations, as well as biodiversity and natural habitat issues of the wider environment.

Institutional and policy development

A broad and well-developed institutional capacity exists for aquaculture support in many Western European countries, but this is weak in Central and Eastern Europe.

Considerable national and international efforts are needed to improve this situation. While there is a trend towards reducing direct government intervention in development, centralized regulations and laws are still required to be able to ensure both the appropriate allocation and sustainable use of resources. The critical features of aquaculture as a natural resource-based sector have been recognized within the EC, and it is likely that aquaculture will occupy a more important part within future policies. However, there is still a need to strengthen aquaculture policy in those countries where aquaculturists do not have user rights that are equal to other activities using the same resources.

Improved transnational collaboration and networking between the different players in the sector is needed for bringing together scientists, producers, regulators and policy makers in order to facilitate the efficient exchange and review of information throughout the entire sector.

Technology development

In recent years, scientific support for aquaculture has focused mainly on technical aspects of production, with less emphasis on environmental and social linkages. However, technological

Competition with cheap imported products is also a constraint for further development of the European aquaculture sector.

The geographic dispersion of the smaller enterprises makes coherent and effective marketing actions difficult. In addition, the possibilities for pan-European promotion of aquaculture products have yet to be realised. The expansion of Mediterranean fish farming has encountered market limitations through focusing on a few major markets, accompanied by limited efforts in "new" (northern European) markets. This can be compared to the expenditure made by the Norwegian aquaculture sector in promoting salmon throughout Europe.

These limitations, particularly when compared to more traditional agriculture sectors (e.g. poultry, pork), are beginning to be recognized and more cooperative efforts for marketing efforts will ensue. This will probably be accompanied by the creation of more producer organizations that are capable of assuming the marketing and promotional aspects that are needed for market development.

Issues and constraints specific to the regions

The marine area from France to

developments for sustainable operation are within the overriding strategic issue for aquaculture and will continue to be so in the foreseeable future.

This strategy includes technical, economic, legal, social and physical components and should ensure fair access to resources and mechanisms for conflict resolution. Since technological development has become a complex issue involving many aspects of the prevailing social, economic and environmental conditions, the key element of the future competitiveness of aquaculture is not just technical improvement, but also the successful adaptation to the challenges mentioned above.

Market development

In spite of the substantial differences seen for aquaculture production in the different regions of Europe, marketing problems are and remain a major constraint for immediate aquaculture development. In Central and Eastern Europe, the absorption capacity of local markets has shrunk due to decreased consumer purchasing power, and most of their aquaculture products have little export potential.

northern Norway offers excellent conditions for mariculture. In 1997, the share of this “northern European region” was about 52 percent of all European aquaculture production (mainly through the production of Atlantic salmon, large trout and shellfish).

The evolution of salmonid farming has been impressive since the early 1980s, and further expansion of the European salmon industry is expected in spite of the increasing potential competition with non-European producers, (e.g. Chile, Canada). Shellfish production, however, has shown little to no increase, and overall development has been slow in spite of resource availability.

The size and influence of the aquaculture industry has been small compared to that of other livestock agriculture (e.g. poultry, pork and cattle). The main constraints to the expansion of coastal aquaculture in this region are certainly environmental concerns that, in many cases, are based on insufficient knowledge. The economic potential and accompanying social benefits of aquaculture have probably not yet been fully recognized, a situation that may prevent the equitable access for mariculture to the natural resources.

Aquaculture production increased almost exponentially in the "Mediterranean region" during the past 15 years, its expansion being due to technological developments, institutional support and important investments in production inputs and, especially, facilities (mainly marine cages). Market development has been slower than the rate of expansion, which has caused significant price drops (34 percent in the past three years).
Nonetheless, continued growth is expected with the introduction of productivity, managerial and organizational improvements.
Market constraints relating to poor information services, uncontrolled trade and quality problems need to be eliminated and be accompanied by improved promotional and support services.

The inland areas of Europe have decreasing importance in quantities of aquaculture production compared to the coastal areas, as indicated in Table 4.

Some special measures of assistance, either related to existing structural policies or EC accession (conditions relative to accession treaties) may help specific cases.

Approaches and strategies for overcoming the constraints and addressing opportunities

Institutional and policy development

In spite of the trend towards reduced government intervention in development, there is a greater need for centralized regulations and coordinated efforts to ensure the equitable allocation and sustainable management of resources; thus the role of public consensus and participation in decision-making will increase.
Integrated river basin and coastal area [including landscape] management have become targets of primary importance, requiring

The contributions of freshwater aquaculture have declined, both for quantities and value, since freshwater production has stagnated at around 340 000 mt annual production. Furthermore, this hides the fact that increased EC production has been the counterfoil for reductions in non-EC European countries.

Inland aquaculture plays an important role in rural areas, where freshwater fish farming is an important source of fresh food and provides employment. The main constraint for the development of inland aquaculture is the competition for limited and vulnerable freshwater resources and obtaining permissions for access.

Freshwater aquaculture is of special importance in Central and Eastern European countries, but is likely to be bound by considerable structural an economical problems during their transition to market economies.

multisectoral integration with the involvement of the government agencies and stakeholders concerned.

The development of institutional capacity still requires considerable national and international efforts in Central and Eastern Europe, with special regard to the establishment of fish inspection systems (quality and health control), technical training facilities, business management training, advisory service training and fisheries information systems.

Sectoral consultation between the institutions responsible for aquaculture and the production sector needs improvement in several European countries. National aquaculture associations may need to be reinforced in order to respond to the different problems that are encountered. Within Europe, the Federation of European Aquaculture Producers (FEAP) unites the national aquaculture associations and is one of the interlocutors nominated to the EC Commission’s Advisory Committee on Fisheries and Aquaculture.

Table 4. Comparison of relative contributions of quantities and value of aquaculture production from major culture environments in 1988 and 1997 (FAO, 2000).

Culture environments	Data	1988	1997
Brackishwater culture	Production	6.3%	7.0%
	Value	6.4%	5.4%
Freshwater culture	Production	29.0%	20.4%
	Value	38.4%	26.4%
Mariculture	Production	64.7%	72.6%
	Value	55.2%	68.2%

This committee allows consultation and debate on many of the issues raised in this review, enabling improved communication and understanding between the stakeholders and the legislator.

Technology development

Key issues are to increase system productivity, and improve product quality and the competitiveness of the sector without deterioration of the environment. Technology development should focus primarily on offshore mariculture, wastewater treatment techniques, substitute materials for fishmeal and fish oils, polyculture and management assistance tools.

The role of science and technology

As a result, there is a relatively active inter-regional exchange of information and collaboration between aquaculture institutions and organizations, which helps the European aquaculture community to combine efforts to increase sectoral efficiency.

The enlargement of the EU to Central and Eastern Europe gives a historic opportunity for Europe to unite peacefully. Supplementing the existing PHARE, two new instruments are being introduced in favour of the accession countries:
a framework for assistance to agriculture and rural development (SAPARD), and
a new programme to support regional policy development (ISPA).

is vital and must be recognized as an essential enabling service. Research needs to be promoted in a broad and interlinked manner, being guided by strategic considerations.

Market development

The improvement of information flow is a basic precondition for overcoming market constraints. Market transparency and a clearer understanding of market mechanisms, regulatory factors and competitive trends would be of particular benefit to the small enterprises. The FEAP will continue to be a very important link among industry representatives, policy makers and scientists.

Species and product diversification should be important elements of future market expansion strategies; further research is needed on technology developments for improving productivity, promising species, disease protection and processing technology.

The improvement of the public perception of aquaculture products must also be of strategic concern. Besides generic promotion, niche and brand marketing actions, the environmental and dietary attributes that are associated with aquaculture and its products are likely to be influential in determining acceptability and

Although aquaculture and fisheries are not specifically mentioned within the objectives of these new instruments, they can be integrated into both programmes through related activities.

The Fifth Framework Programme of the EU has also given good opportunities to facilitate inter-regional collaboration between the different players of the aquaculture industry. Additional EC-funded specific programmes, such as TEMPUS11, INCO-COPERNICUS12, PECO-COPERNICUS, and the Science for Peace Programme of the North Atlantic Treaty Organisation (NATO-SFP), have also improved intra-regional collaboration and networking between research institutions and universities.

In order to support the development of aquaculture and fish processing in Central and Eastern Europe, the EASTFISH project was established, which is funded by the Danish government and executed by the FAO. Different international organizations and institutions (European Commission, FAO, the European Inland Fishery Advisory Commission (EIFAC), the General Fisheries Council for the Mediterranean (GFCM), FEAP and the European Aquaculture Society (EAS)] provide data and information on aquaculture. The increased involvement of professionals from Central and Eastern European market expansion in the future.

Opportunities for inter-regional cooperation

EC organizations play a significant role in the development of inter-regional cooperation, not only within the EC but also on a pan-European level, through different international fora and specific actions.

countries in the work of these organizations would significantly improve broader international cooperation.

An increasingly important role of producer associations is to provide information to farmers, with special regard to legislation, sectoral problems and market and price information. The FEAP has established an efficient forum for exchange of information among its 28 national associations from 21 European countries.

FEAP also acts as a common forum for these associations to discuss and develop common policies on a wider basis. Projects that aim to improve flow through networking are playing an increasingly important role in bringing together scientists, producers, regulators and NGOs, where the examples of "Aquaflow" and "Maraqua" have already been described. Further linking and networking for specific and broad issues can only contribute positively to European aquaculture development.

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[6] The review covers the following subregions/countries: Northern Europe - Denmark, Faeroe Islands, Finland, Iceland, Norway and Sweden; Western Europe - Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, Switzerland and United Kingdom; Southern Europe - Albania, Croatia, Greece, Italy, Macedonia, Malta, Portugal, Slovenia, Spain, and Yugoslavia; Central and Eastern Europe - Bulgaria, Czech Republic, Hungary,

Poland, Romania, and Slovakia. Countries marked in bold are members of the European Community (EC).

7 PHARE (Poland and Hungary: Action for the Restructuring of the Economy) is one of the EU's financial instruments in support of the EU's enlargement. 0riginally targeted at two countries, it has been extended to 14 countries in Eastern and Southern Europe.

8 ISPA (Instrument for Structural Policies for Pre-Accession) is intended to assist the candidate countries in the preparation for accession to the EU.

9 SAPARD (Special Accession Programme for Agriculture and Rural Development) is intended to assist pre-accession countries in their agricultural sectors and rural areas, targeting specifically the areas of environment and transport.

10 The Framework Programmes are the policy guidelines for research, technology and development.

11 The TEMPUS programme is the trans-European cooperation EC-supported scheme for higher education.

12 The INCO-COPERNICUS programme promotes scientific and technological cooperation with the countries of Central Europe and the New Independent States.

Aquaculture Development Trends in the Countries of the Former USSR Area

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ABSTRACT: There has been a dramatic decline in the aquaculture production of the former USSR countries, from a peak of about 420 000 mt in 1990 to 109 000 mt (-26 percent) in 1997. The share of aquaculture to total fisheries production has been decreasing, in contrast to the general global trend. However, some recovery in aquaculture production was observed in 1996 in Russia and Uzbekistan. This resulted in a 5 percent increase for the entire region. This is an indication that the sector is over the shock caused by the break-up of the Union of Soviet Socialist Republics (USSR) and could gradually increase, depending on the changes in the economic environment. Nonetheless, recovery is seen to take a long time. Research and development has suffered from substantial cutback in funds and the deterioration of research infrastructure. The rather lengthy economic recession and instability in the region have significantly affected aquaculture development, particularly as access to credit is hampered by unsettled property rights and lack of experience with the aquaculture sector among financial institutions.

The two main directions of aquaculture development in the region would be the revitalization of the existing, formerly prosperous inland aquaculture sector, consisting mainly of pond fishfarm complexes, and the further development of culture-based fisheries. The share of coastal and marine culture may also increase from the present 8 percent of volume, but freshwater aquaculture will remain dominant with the region’s tremendous freshwater resources. Integration with other sectors should be considered as much as possible in developing the region’s aquaculture.

One bright spot is that the professional and personal linkages that survived between the Russian Federation and the new independent states after the disintegration of the USSR provide a good basis for future regional collaboration. The establishment of producers’ associations is a recent positive development towards improving the exchange of

information among enterprises within the region. The establishment of databases, including directories of institutions and enterprises, is of great importance in view of the new and complex situation in the region. Twinning of institutions would provide an excellent basis for longterm collaboration. Although the Russian Federation and most countries in the region have joined major international treaties and participate in various international organizations, many countries are not adequately represented in international organizations. This situation could be improved to benefit individual countries and the region, as well as the organizations.

KEY WORDS: Former USSR, Aquaculture, Fish Farming, Development, Aquatic Production.

Introduction

The countries of the former Union of Soviet Socialist Republics (USSR) area, which cover parts of the European and Asian continents, comprises of 15 countries[6]. The area extends from the Baltic Sea, in the west, to the Pacific Ocean, in the east, and from the Arctic Ocean, in the north, to the Black Sea and the Caspian Sea, in the south. The total population of the countries of the former USSR area was about 293 million in 1996, which represents 5 percent of the world population. About 32 percent of the total population of this region is rural, compared with the global figure of 54 percent, varying from 24 percent in the Russian Federation to 54 percent in Central Asia. About 17 percent of the active population is engaged in agriculture, compared to 47 percent globally, varying from 12 percent in the Russian Federation to 30 percent in Central Asia. This reflects the importance of agriculture in Central Asia, while industry is largely predominant in the northern areas of the region. The Recent information indicates that the negative trend has halted and even been reversed, resulting in an increase (FAO, 2000a).

According to Laureti (1999), the average annual fish consumption (including both freshwater and marine species and products) in the countries of the former USSR area was 13.25 kg/caput[7] in 1997. While there is very wide variation in the different countries of the region, ranging from 0.1 kg/caput in Tajikistan to 18.8 kg/caput in Estonia, the mean figure is still below the world average (16.1 kg/caput). The main countries for fish consumption are Estonia, Lithuania, Russia and Latvia, which together show an average of about 23.2 kg/caput, while the average fish consumption in the other 11 countries of the former USSR area is only 3.1 kg/caput. The consumption of freshwater species is particularly low, with 2.0 kg/caput as the annual average consumption for the countries of the former USSR area. The main freshwater fish-consuming countries are Russia (3.1 kg/caput), Estonia (2.7 kg/caput), and average population density is 13 inhabitants/km2, compared with 43 inhabitants/km2 globally, varying from 9 inhabitants/km2 in the Russian Federation to 90 inhabitants/km2 in the Caucasus. The population growth between 1995 and 1996 was less than 0.06 percent, compared to the world average of 1.4 percent. While in the 1980s the annual demographic growth rate was still positive, many countries of this region have shown a negative rate since independence in 1991. The main reason attributed to this has been the difficult economic situation that has prevailed since independence, leading to lower birth rates and population migration.

It is within this context of dramatic social and economic change within a large region, that the development and contribution of aquaculture in the countries of the former USSR area is made.

Analysis of production, demand and consumption trends

Statistical data indicate a significant and unfortunate decrease in fish consumption in the countries of the former USSR area during recent years. Annual fish consumption was at its highest level, 30 kg/caput, in the mid-1980s, but has shown a gradual decrease since that time. Average fish consumption was 33 percent lower during the period 1991-1995 than for 1986-1990, compared to a reduction of 8 percent for meat.

Kazakhstan and Turkmenistan each with (2.1 kg/caput). The average freshwater fish consumption in the other countries is only 0.65 kg/caput.

The slight increase in fish consumption appears likely to continue in the short term, and it is assumed that current fish consumption is actually higher than the figures available in statistics. This is because a certain amount of fish is consumed directly by small-scale producers or sold locally and does not necessarily appear in the statistics.

It is considered that, given the availability of aquatic resources in many countries of the former USSR area and the traditional levels of fish production and consumption, both fish production and consumption will increase. This would be achieved in parallel with the consolidation of the economic situation in the region. It is expected that low- and medium-value species and products would be the initial targets, but there is scope for increasing consumption of quality or premium fish products in the longer term.

Aquaculture as a source of food and contribution of aquaculture for human nutrition

Fish has always been a major source of animal protein in the countries of the former USSR area, and the majority of the supply originates in marine capture fisheries, an activity that has also decreased dramatically in recent years.

Table 1. Aquaculture production of the former USSR area, 1988 – 1997 (FAO, 2000a).

Country	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Armenia	4 598	4 604	5 057	2 637	2 565	2 250	1 570	1 120	650	670
Azerbaijan	1 656	1 621	1 216	2 176	1 690	1 201	1 038	516	419	364
Belarus	16 152	17 817	16 638	14 750	8 415	7 018	6 934	5 463	6 038	4 322
Estonia	401	1 232	936	1 337	693	330	417	315	272	260
Georgia	1 273	630	607	2 660	1 045	580	228	157	101	61
Kazakhstan	7 034	9 050	9 450	13 382	3 379	2 928	1 161	1 948	1 682	1 921
Kyrgyzstan	1 108	1 135	982	974	642	223	163	179	161	150
Latvia	2 926	6 288	2 235	2 685	641	339	560	525	380	345
Lithuania	3 752	4 580	4 666	4 792	3 899	2 907	1 874	1 714	1 537	1 516
Moldova Republic of	7 146	6 756	7 141	5 124	2 935	2 275	1 212	1 401	1 067	1 202
Russian Federation	151 377	176 600	259 735	120 877	104 999	92 866	77 956	68 578	53 309	59 766
Tajikistan	3 227	3 267	3 603	3 689	1 874	2 462	980	284	93	71
Turkmenistan	2 380	2 464	2 410	2 248	1 950	2 163	2 125	1 669	307	605
Ukraine	96 182	94 891	81 639	54 648	66 904	66 117	43 686	35 368	32 709	30 000
Uzbekistan	20 471	21 001	21 962	24 316	18 751	19 043	14 559	10 197	5 006	7 490
Grand Total	**319 683**	**351 936**	**418 277**	**256 295**	**220 382**	**202 702**	**154 463**	**129 434**	**103 731**	**108 743**

Seven countries of the former USSR area (Armenia, Azerbaijan, Georgia, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) have been classified as low-income food-deficit countries (LIFDCs) (FAO, 2000b).

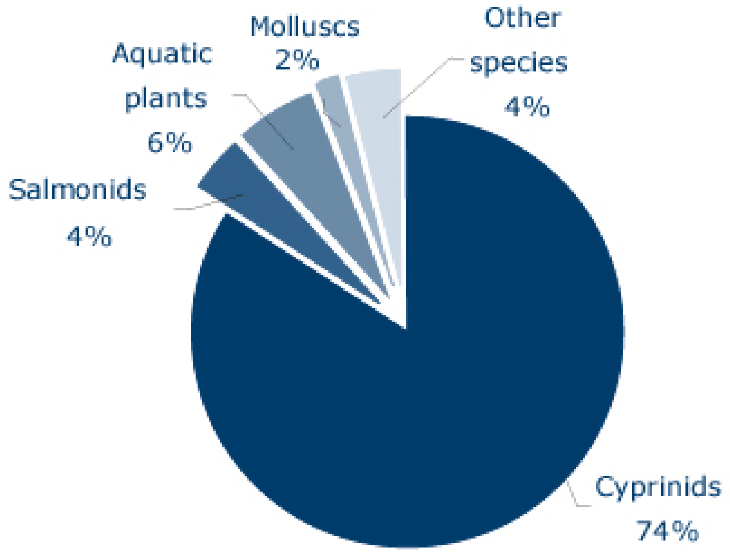
There has been a dramatic decrease in fish production in these countries, especially in Georgia, where production dropped from 2 600 mt in 1991 to practically zero by 1997. It is not only a coincidence that the fish production per caput in five of these countries (Azerbaijan, Georgia, Kyrgyzstan, Tajikistan and Turkmenistan) is the lowest in the region, the average being less than 40 gm/caput. Although the ratio of the rural population is the highest in the LIFDCs (around 50 percent as an average), large rural areas also exist in other countries (Moldova, Ukraine, Belarus and Russia).

Significant freshwater and marine aquatic resources that are available for fish production have not been exploited or have remained greatly underused. The development of aquaculture could play an important role in the improvement of nutrition and rural life in the countries of the former USSR area.

Analysis of regional production statistics

Aquaculture provided 108 743 mt in 1997, worth US$274 million, which represents a regional contribution of 0.3 percent (volume) and 0.6 percent (value) to global aquaculture. This level is well below the peak production of 420 000 mt seen in 1990, at a time when the region’s

Figure 1. Major species composition of aquaculture production in the countries of the former USSR area in 1997 (FAO, 2000a).

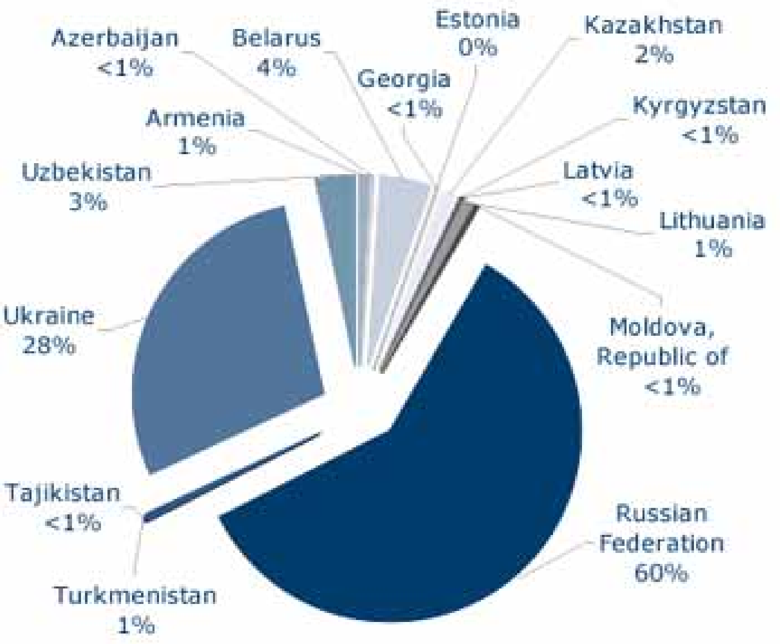


contribution was 2.6 percent (total quantity) and 3.2 percent (value). There was a dramatic decrease in aquaculture production in this region after the collapse of the former USSR and the consequent break-up of the state structure (Table 1). This led to a crash in aquaculture where harvests dropped by 74 percent in seven years. The regional APRs [Annual Percent Rate of Growth], since 1990, are -18 percent (volume) and -15 percent (value) (FAO, 2000a).

About 92 percent of the production in 1997 originated from freshwater activities, where cyprinids are the major species group (84 percent of quantity) (Fig. 1). The two dominant countries are the Russian Federation and Ukraine, with shares of 55 percent and 28 percent, respectively, of regional aquaculture production (Fig. 2) (FAO, 2000a).

The extreme situation seen at present should not be considered as an appropriate basis for insightful quantitative analysis, given that production appears at almost zero levels for some countries. There are uncertainties as to the accuracy of data, and production may well be higher than reported, but it is evident that aquaculture production has dropped considerably.

Figure 2. Aquaculture production by countries of the former USSR area in 1997. (FAO, 2000a).



If, for the sake of comparison, one looks at the figures for specific aquaculture production per caput, within the European Community (EC), a figure of 3 kg/caput is obtained, while it is 0.4 in the countries of the former USSR area. Another major distinction is that about 75 percent of EC production is mariculture compared to 8 percent in the countries of the former USSR area. For freshwater aquaculture, the value is 0.73 kg/caput in the EC and 0.34 in the countries of the former USSR area. These parallels may indicate potential for development, both for marine aquaculture (although climatic conditions may be less favourable) and freshwater aquaculture, given the immense freshwater resources that are available in the countries of the former USSR area.

As with aquaculture, capture fisheries production also decreased after 1990, but this decrease was not so dramatic and was measured at -17 percent between 1992 and 1997.

The region has shown the direct opposite of the aquaculture trends seen generally elsewhere in the world, decreasing in importance and providing a lower share of the total aquaculture production. It is suggested that the potential for aquaculture development, both in marine and freshwater conditions, remains largely untapped and that despite the abundance of natural resources, the current stagnant position will slowly improve in line with general economic consolidation.

Comparison of regional production trends

The 15 countries of the former USSR area can be grouped in five subregions, based primarily on geographic conditions and on hydroclimatic homogeneity, although the Russian Federation is, due to its size, subject to a wide variation of geographic and hydroclimatic conditions. The subregions referred to are:

- The Russian Federation;
- The Baltic States: Estonia, Latvia and Lithuania;

The total annual renewable freshwater resources (ARFR) of the countries of the former USSR area is about 5 306 km3, while it is only 1 395 km3 in the EC. If specific freshwater aquaculture production is recalculated on the basis of the ARFR, for 1997 it equates to 21 mt/ km3 in the countries of the former USSR area and 195 mt/km3 in the EC, almost a ten-fold difference. Such information indicates the potential for freshwater aquaculture development in the region, even assuming that considerable freshwater resources are contained in the permafrost. However, aquaculture production represents some 2 percent of the region’s capture fisheries harvest, which is well below the share of global aquaculture in the world’s total fisheries production with about 30 percent.

- Eastern Europe: Belarus, Moldova and Ukraine
- The Caucasus: Armenia, Azerbaijan and Georgia; and
- Central Asia: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

In 1997, the division of aquaculture production within the subregions was the following: Russian Federation (54.4 percent), Eastern European States (32.5 percent), Central-Asian States (9.4 percent), Caucasian States (1.0 percent) and Baltic States (1.9 percent).

The subregional share of aquaculture production shows a close connection to the populations, which are 50.5 percent, 22.5 percent, 2.6 percent, 5.6 percent and 18.8 percent, respectively. This connection is more pronounced than that between aquaculture production and renewable water resources. The tendency towards a dramatic decline of aquaculture production between 1990 and 1997 has been very similar in all subregions, but was highest in Russia and Central Asia (-77 percent) and lowest in the Caucasian States (-65 percent), although production in Georgia dropped to virtually zero.

Some recovery has been seen since 1996, notably in Russia, and the general position is that the downward trend has halted. This seems to indicate that the aquaculture sector is recovering from the shock, but will remain dependent on improvements in the economic environment. Obtaining a full recovery of the aquaculture industry to reach the levels of production seen in the 1980s will probably take a long time.

Population growth, demand and consumption

The total population of the countries of the former USSR area was 291.7 million in 1998 (FAOSTAT, 2000), with 50.5 percent of the population in the Russian Federation, 22.5 percent in the Eastern European States, 18.8 percent in the Central Asian States, 5.6 percent in the Caucasian States and 2.6 percent in the Baltic States. The forecasts for population growth in this region appear to reflect the global projections. Although the population increase for the whole region is expected to be around 1 percent (295 million by 2020), there are significant differences between subregions. The biggest increase can be expected in the Central Asian States, where an increase of 28 percent is anticipated, the population reaching 70.2 million by 2020. Increases of 10 percent are forecast for the Caucasian States, while a decrease of -14 percent is expected for the Baltic States. According to United Nations (UN) projections, population decreases are also forecast for the Russian Federation (-5 percent) and the Eastern European States (-4 percent).

The share of marine species and related products is 85 percent of the total fish consumption in the countries of the former USSR area. The vast majority is This increase was well above the world average of 1.8 percent during the same period. Significant developments were made in aquaculture production during this period, and the sector enjoyed government support, directly through subsidies and indirectly through research and development efforts.

In fact, fish consumption started to decline from 1987, reaching the low of 13.3 kg/caput in 1997, lower than the 1961 average. Indications are that fish consumption will increase in the future, but the new and complex regional context makes accurate prediction risky. If fish consumption were to increase at an annual rate of 4 percent until 2020, then 25.5 kg/caput would be reached (still lower than 1986). Where the current percentage of aquaculture within consumption is currently 10-15 percent, this share ought to increase, and one could project 20 percent or more, thus contributing around 5 kg/caput by 2020. Based on a total population of 295.4 million in the region, the demand for aquaculture products could be 1.5 million mt. The aquaculture yield of the region (around 110 000 mt) in 1997 is less than 10 percent of the estimated demand for aquaculture products in 2020.

This simplified calculation does not account for anticipated regional differences arising from changes in population, consumer preferences and disposable income. For example, there will be a higher rate of population increase in Central Asia, where fish consumption is lower than average. Nonetheless, these arguments indicate both potential and a need for significant aquaculture development.

Aquaculture contribution to

derived from capture fisheries, noting that marine aquaculture represents only 8 percent of total regional aquaculture. Fish consumption is the highest in the Baltic and Russian subregions, as described in previous sections. There are countries where freshwater fish consumption (2.1 kg/caput) exceeds that of marine fish (e.g. Azerbaijan, Turkmenistan and Kazakhstan are all under 1 kg/caput), indicating that freshwater aquaculture could play an important role in satisfying demands of future populations.

The peak figure in the countries of the former USSR area for the consumption of fish and related products was attained in 1986 with some 30 kg/caput, rising from the 1961 figure of 14 kg/caput, giving an APR of 3 percent.

rural development and poverty alleviation

The political and economic changes in the region resulted in a dramatic drop not only in agriculture and aquaculture production, but also in the supply of fisheries products. The supply of frozen marine products from Russia decreased considerably due to the introduction of new borders, prices, regulations etc. Some countries like Azerbaijan, Georgia and Turkmenistan practically lost their entire fishing fleet or their access to coastal waters. After 1990, food security became a major problem in most countries of the Caucasian and Central Asian subregions. Seven of these countries have been classified as LIFDCs: Armenia, Azerbaijan and Georgia in the Caucasian subregion; and Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in the Central Asian subregion, with a combined population of 54 million people.

In 1997, the annual per caput gross domestic product (GDP) in these countries was below US$1 500, being only US$111 in Kyrgyzstan and US$240 in Tajikistan. Although many of these countries are now experiencing growth in GDP, and humanitarian aid contributes to alleviating the food supply problems, the fight against poverty will remain an important issue in this region in the future.

Aquaculture does not play a significant

Aquaculture can be considered as a method of poverty alleviation in some LIFDCs, as discussed before, and can also be integrated into rural development programmes. This would be particularly applicable in the countries where aquaculture (especially pond-based fish production) has a long tradition. Modern aquaculture systems (intensive cage culture and water recycling systems) could also be applied in certain coastal and inland areas, where appropriate infrastructure and inputs are available. The main obstacles to aquaculture role in the economy of these countries, but the contribution of aquaculture to poverty alleviation should receive more attention in the future, paying particular regard to use of the water resources available, especially in Uzbekistan and Georgia. Uzbekistan is the third largest aquaculture producer, after Russia and Ukraine, and an increase of production from the present 7 490 mt up to about 20 000 mt would be an important contribution to the improvement of food supplies, as well as providing employment.

Aquaculture virtually disappeared in Georgia, a country of five million inhabitants, even though it possesses the sixth highest (63.3 km3) renewable water resources within the region. This could be a good basis for future aquaculture development. Aquaculture could also be taken into account as a method for poverty alleviation in the two other Caucasian countries, Armenia and Azerbaijan. However, there is limited scope for aquaculture development in Kyrgyzstan and Tajikistan, where aquatic resources are scarce.

In some subregions, the changes in the political system were accompanied by the ruin of large collective agriculture farms, causing high local unemployment and reducing the local availability of animal protein resources. At the same time, the fish farms, which were previously integrated into the collective farms, served in many cases as the basis for the successful launch of aquaculture enterprises which, in turn, contribute to the re-establishment of protein supply.

Role of aquaculture from a development context

Aquaculture has an important role in development are, however, the lack of local financial resources and the loss of confidence among potential foreign investors.

The European Community (EC) is the largest donor to the New Independent States (NIS), which excludes the Baltic States, in this region. EC funds have been provided mainly through the Technical Assistance to the Commonwealth of Independent States (TACIS) programme, which assured about Euro 3.8 billion between 1991 and 1998 to the region, including Mongolia. About 50 percent of TACIS support has been allocated for nuclear safety, the environment, restructuring state enterprises, private-sector development, public administration reform, social services and education. Agriculture and food components represent about 9 percent of the total support, but the share of aquaculture within this has been minimal.

The other main donors to the region are the United States Agency for International Development (USAID), World Bank (WB), European Bank for Reconstruction and Development (EBRD), International Monetary Fund (IMF) and Japan, with similar patterns of fund allocation. Development assistance programmes in aquaculture have targeted principally the rehabilitation of sturgeon stocks in the Caspian region.

Potential for aquaculture development

The aquaculture sector was relatively strong and well organized in the former USSR. Production development was supported by effective, diversified and well-integrated research and development activities. An advanced certain subregions and localities, but its general weight in the overall economy is relatively low when compared to other agricultural sectors.

regulatory framework was also in place. In spite of fragmentation (due to the disintegration of the former USSR) and lowered efficiency (caused by serious financial constraints), valuable human resources, knowledge and experience are still available.

The region possesses impressive aquatic resources, both in coastal areas and inland, which could be fruitfully exploited for aquaculture production without deterioration of the environment. Technological enhancement of the aquaculture sector could be supported effectively by a well-developed industrial structure that is undergoing reorganization and seeking new tasks and customers for the future.

The regulatory framework is undergoing substantial change, a process that will probably continue for some time, but such progress as has been achieved is providing a constructive base for the management of aquaculture development. It appears that the region's aquaculture sector possesses the basic capacity for providing a significant increase in production through the application of effective and sustainable technologies. This capacity needs to be matched more precisely with market requirements. Nonetheless, the degree of success in development that could be attained is intrinsically linked to the overall economic development of the countries of the former USSR. The support measures provided through an

Efficient use of primary resources

There are outstanding possibilities for aquaculture to be an efficient user of primary resources, through the revitalization and modernization of the operating sector. Pond aquaculture has a long tradition in the countries of the former USSR, an activity that has been always based on the utilization of primary resources. There is great potential for furthering pond aquaculture in the region, based on the prevailing conditions and wide market acceptance of the species that feed low on the food chain. The application of appropriate polyculture technologies could not only assure that the primary resources are utilized efficiently, but also that fish ponds could play an important role in the recycling of organic wastes.

Culture-based fisheries can provide a most efficient utilization of primary resources and can be practised in water areas that are unsuitable for conventional aquaculture. However, the efficiency of primary resource use will depend on numerous factors that include the pollution of watersheds and the stability of legislation related to the assurance of adequate regulatory framework should assist development.

Aquaculture generally had a good public perception in the past. It may, therefore, be expected that the traditionally positive and welcoming approach towards aquaculture from both public and institutional environments would continue. However, further efforts will be necessary to maintain positive and affirmative public acceptance. If, however, competition for resource use develops, conflicts could develop around the need for additional infrastructure and support necessary for the exploitation of the resources.

Culture-based fisheries represent a significant share of current regional aquaculture activities. Related issues of management of natural populations should be of particular interest to the aquaculturists. Aquaculture has never been considered to be a tangible source of pollution in the region, and attention should be paid to the image of the sector, avoiding antagonistic situations that could constrain development. Given that regional aquaculture producers may not be powerful enough to form an effective producer association for treating sectoral issues, international collaboration takes on special significance.

land rights.

Expansion and the availability of water and land resources

The Russian Federation, Kazakhstan, Ukraine and Belarus all have water resources that would enable aquaculture expansion, since the combined quantities of available freshwater represent 93 percent of regional availability. Such expansion would not necessarily mean the construction of new ponds or other facilities, but also the reconditioning of existing systems and the further development of culture-based fisheries.

The area of reservoirs and lakes used for this activity could be significantly increased by improved stocking and integrated resource management, which could be supplemented by commercial lake management and recreational fisheries. Recreational fisheries are already playing a significant role, notably in the Russian Federation, Ukraine, Belarus, Moldova and the Baltic States. It can be expected that its significance will increase with economic stability. Consequently, one can predict that use of resources will increase.

Diversification

The traditionally homogeneous patterns of production (semi-intensive pond culture) and species composition (dominance by common carp) should be diversified in the future for the purposes of sustainability and market requirements. Presently, the main goal of most farms is to increase production volume and revenue, while accounting for the market needs and buying power of the local population.

The producers that are close to urban areas will increasingly compete with high-quality imported products. Aquaculture production should move towards diversification towards higher value and/or better appreciated species such as salmon, trout, whitefish and sturgeon. Only a limited number of cultivated species can be seen in published data of commercial aquaculture production, but numerous other species of fish, molluscs and crustaceans (both fresh water and marine) are grown in small-scale farms within the countries of the former USSR area. Considerable applied research has been conducted to develop farming technologies for indigenous and nonindigenous species. This situation may provide some potential for the introduction of different underused species into regional aquaculture, although great care must be applied, particularly with introductions and transfers of nonindigenous species from other regions or between catchment areas within the region, to ensure that no irreversible adverse impacts on local and regional aquatic biodiversity occur. Nonetheless, additional research would be needed to develop, update and adapt the farming systems within the current operating environment.

Improved water and husbandry management, combined with the use of improved feeds, can make a significant contribution to raising productivity, remembering that climatic conditions will affect the efficiency of many productivity-raising components.

Increased culture-based fisheries

Culture-based fisheries has a long tradition in the region, which is a good basis for future development, especially in view of the presence of numerous reservoirs. An important area for culture-based fisheries is the Caspian region, where several international projects assist the rehabilitation of sturgeon stocks and several sturgeon hatcheries have been installed or modernized.

Salmon production in the Russian Far East, through culture-based fisheries and marine ranching, can also be considered as an example of sustainable stock management. Rises in juvenile production could be expected to be as high as 5-7 percent per annum. Developments could include the transformation of small existing salmon research stations into full-scale hatcheries/nurseries, as has been done at number of sites at Sakhalin.

In the southern area of the Russian Pacific coast, efforts could continue to increase the production of seaweed, molluscs (e.g. scallops) and a number of other candidate species. In the Baltic States and North Russia, the restocking of salmon stocks should continue, and commercial salmon farming could influence future developments.

Countries around the Black Sea possess tangible perspectives for considerable developments for mussel culture and the

Intensification: increased productivity

Intensification is seen as a very important option for successful aquaculture development in the region, its extent varying with local circumstances. The introduction of modern fish feeds, greatly underused in the past, provides significant potential for improving productivity. The stocking levels in most farms are very low, mainly due to the poor availability and high costs of feeds and other input materials. Renovation of the local feed industry, improving ingredient quality and processing technology (with particular reference to the production of high-quality fishmeal) would play a critical role. Additionally, the productivity could be increased through the use of stock lines having improved performance.

lagoon ranching of mullets. In North Russia and Estonia, as well as in the mountainous regions of other countries, the lake ranching of several species of whitefish could be continued.

In the Russian Federation, Ukraine, Belarus and Moldova and, on a smaller scale in the Caucasian and Asian States, the further expansion of culture-based fisheries can be foreseen in large water bodies. The capacity of inland culture-based fisheries in the Russian Federation, excluding the higher value species (salmon, whitefish and sturgeon), was estimated to be at least 1 million mt. However, increased stocking for culture-based fisheries in inland waters should be supported by the development of a small-tonnage fishing fleet and the wide introduction of specialized fishing gear.

The increasing importance of recreational fisheries in urban and tourist areas should create additional demand for stock management and supply activities.

Integrated aquaculture

There are both longterm traditions and theoretical scope for the integration of pond aquaculture with other sectors. The advantages of integration have been recognized and technologies are known, having been applied for many years. There are about 1 million ha of water bodies in the Russian Federation being used conventionally by agriculture (e.g.

Getting more people involved in aquaculture

Significant changes have occurred, and are still happening, in the employment patterns in the countries of the former USSR area. While it is difficult to predict the numeric possibilities of employment, the potential for the expansion of many of the sectoral components is clear. Consequently, employment will increase in line with sectoral development. On the other hand, new aquaculture entrepreneurs could face problems created by unsettled property and tenure rights; a factor that may inhibit the rapid for irrigation). At the present, only 10 percent of these waters is used for integrated aquaculture, and this share could be significantly increased. The integration of aquaculture with rice production and irrigation is very common in the Asian States; unfortunately, pollution appears to be a restricting factor for increasing this type of production scheme, at least in the short term.

Successful actions for integration appear to be problematic, and integrated resource management policies, effective farmer associations and an appropriate institutional and legal framework need to be developed and implemented if satisfactory conditions are to be provided for this aspect of development.

Increasing technical efficiency

This is a key element for future aquaculture development in the region. The network of qualified research and development institutes, combined with a highly developed industry that is currently restructuring, creates a good basis for increasing technical efficiency. The aquaculture sector has demonstrated a sizeable capacity to adapt to new technologies. However, given the evident economic difficulties, long production cycles, substantial investment costs and prolonged pay-back periods on investments, it should be considered that state-supported aquaculture development programmes are inevitable if the technical efficiency of the sector is to be increased.

development of identified opportunities. In addition, newcomers to the sector will probably face problems relating to the availability and quality of special education, essential for the technical work in aquaculture. The EASTFISH project is addressing some of these problems, but further comprehensive international activities that target such requirements are needed.

Community involvement

A positive public attitude to fish farming exists in the region, but community involvement or interest in aquaculture concerns will depend on numerous other issues associated with the current transition. Associations of aquafarmers should devote special attention to the widening of their public relations and community participation, building up an “attractive” image of aquaculture. Attentive consideration to these tasks would be expected from the policy makers as well.

Key issues and constraints for aquaculture development

Technological issues

Valuable human resources are readily available for assisting the required technological developments, but the main questions are how to mobilize these resources and how to provide the necessary technical and financial conditions for success. Pondfish production technologies will continue to dominate freshwater aquaculture, but the gradual development of culture-based fisheries, sea ranching and marine aquaculture is expected within the next decades. Cage culture (both fresh water and marine) could be predicted to become more popular because of increased productivity and higher flexibility in farm management and business planning.

In the Eastern European subregion, pondfish culture will probably remain the major activity, a situation similar to that in the Russian Federation. There is also some scope to increase marine aquaculture in Ukraine, which has 2 766 km of shoreline on the Black Sea. In 1997, only 1 mt of marine aquaculture was reported, a negligible figure compared to the 352 000 mt sea catch.

In the coming period, it is unlikely that industrial aquaculture will have a significant share in overall production quantities, but its output could be substantial, particularly in climatically suitable areas.

Institutional issues

While substantial change is occurring in the regional institutional systems of the countries of the former USSR area, it has to be recognized that it will be a long time before the transformation is complete and efficient operation attained. Intra-regional national differences can be considerable, not only in respect of traditions and past advances of their institutions, but also in the state of progress of current economic transition. External assistance targeting institutional reform should continue and even be intensified, while considering thoroughly

There is a need for humanitarian aid in these countries, but low-input aquaculture could also contribute to the improvement of rural life. Even if scope at present is limited for aquaculture development, returning fish production (mostly low-value fish for rural populations) to former levels would make a significant contribution to the food supply of the population of this poor subregion.

In the Russian Federation, the traditionally significant role of capture fisheries could, in some areas, influence the development of commercial aquaculture. At the same time, the specificity of aquaculture is that activities related to restocking and rehabilitation of aquatic resources are very significant, and such patterns would be expected to continue. Since aquaculture is of long tradition in the region, its development would contribute to maintaining rural populations, helping to improve the quality of life and preserving cultural values.

In the Baltic States, the limited aquaculture production focuses on common carp and trout. Economic reforms have been progressing well in this region, and economic assistance is also directed toward these countries from the local and regional specificities and socio-political factors. Participants in such programmes of cooperation and assistance must be adequately qualified and motivated, but will only be effective if the content is given due recognition by governments, policy makers and legislators.

Socio-economic issues

The socio-economic changes are transitional, reflecting the move from a centralized, planned economy to one that is market-led and oriented. The problems experienced in aquaculture are the direct consequence of this transition. Socio-economic aspects should get a high priority in the planning of aquaculture development, while their objectives would differ within the countries of the former USSR area. Poverty alleviation should be the first priority for aquaculture in the LIFDCs. Elsewhere, aquaculture could supply good business opportunities, in addition to the activities of crop integration and stock enhancement.

The Caucasus nations and four of the five countries of the Central Asian subregion are classified as LIFDCs and face serious difficulties.

Scandinavia. This has given rise to a better entrepreneurial environment in these states, which may have positive effect on future aquaculture development. The move from large-scale, centrally managed aquaculture to small-scale independent production units would be in line with the philosophy of transition, and the resulting increase in numbers of small-scale producers would cause change in some social patterns.

Environmental issues

The region did not give enough consideration to the environment in the past, and significant environmental degradation has occurred through pollution from heavy industry, and chemical and forestry-related activities. While agriculture has been a source of pollution, aquaculture has not been implicated at all.

Sustainable development has become an overriding strategic issue in the region, especially in the Russian Federation, Belarus, Ukraine and the Baltic States. Rapid expansion of commercial aquaculture could sometimes face some obstruction by environmental groups. On the other hand, environmental disorders, such as aquatic pollution by other sectors, could hamper aquaculture development, especially activities related to culture-based fisheries.

Recreational fisheries and stock enhancement activities would be expected to contribute both substantially and directly to improved environmental management. In many cases, the rehabilitation of transboundary watersheds, which may be necessary for aquaculture development, could be achieved through international cooperation.

Throughout the region, the national governments need to create an "enabling" environment for development, requiring the urgent reestablishment of the appropriate intergovernmental agreements. The application of the principles held within the FAO Code of Conduct for Responsible Fisheries (CCRF) is to be encouraged

Financial and economic issues

The prolonged economic recession in the region has affected aquaculture development significantly and, for a number of countries, political stability can be regarded as a precondition for further development.

Within the region, the availability of financial resources is quite high and, as in many emergent economies, a significant amount of venture capital is present. Major obstacles for obtaining financial inputs are:

- the question of unsettled property rights;
- the need for longterm credits; and
- the lack of experience in the aquaculture sector in working with financial institutions, and vice versa.

In the Russian Federation, Ukraine and the Baltic States, aquaculture entrepreneurs have to compete with the

Marketing and trade issues

The domestic markets of the region are huge and represent excellent potential for aquaculture, not only for fresh but also for frozen, canned and processed products. The estimated demand is considerably higher than the current supplies available from aquaculture. Consumer preferences vary widely with the region, reflecting national or local preferences. While carp and herbivorous species are popular practically everywhere, sturgeon and salmon can also be sold easily in most of the countries. Eels find buyers mainly in the northwest, and whitefish has markets in the northern area of the region.

Aquaculture products will face competition from frozen seafood, traditionally popular in most parts of the region, and work should be done to improve distribution and retail networks in order to provide fresh/chilled products to a wider consumer audience. The provision of fresher products, having a wider range of processing or preparation, will bring the sector closer to the consumer, but would also provide significant opportunities for building and operating specialized aquaculture units near urban or recreational areas, assuring restaurant and consumer supplies with the appropriate products (including live fish, crustaceans, and mariculture products).

Research and development issues

The region needs new, demand-led multi-disciplinary research programmes that focus on specific issues related to the planned technology requirements but with special regard to environmental and socio-economic aspects.

fishing industry for investment capital and loans. In addition, aquaculture insurance is practically unavailable. State support for aquaculture includes tax benefits, state loans and credits. However, the tax concessions appear to benefit the traders rather than the producers, and the state loans seem to emerge as the preferred option. The international credit lines, which are administered through national banks, do not appear to have had much impact on aquaculture development. Increasing the role of producer associations and providing the professional links, where appropriate, should be encouraged and expanded within such programmes. Improving the financial and economic education of aquaculture entrepreneurs at all operational levels is necessary and should be encouraged through international training programmes.

Both research infrastructure and funding have deteriorated, and international support is needed for cooperation and the revitalization of the region's scientific resources. In order to ensure that national and international support for research and development is properly targeted, well-focused identification of priorities and selection of approaches and procedures for distribution of resources should be employed.

Discussion

The disintegration of the former USSR caused a decline in aquaculture production, with a similar pattern in all the countries, despite considerable variations in their national economies.

This indicates that the root causes of the process were general problems of the transition from a centrally planned to a market economy, which are indeed problems that are not related specifically to the aquaculture sector. This also leads to the conclusion that the solutions required for aquaculture development cannot be found within the sector itself, the more so as aquaculture is a relatively insignificant and weak part of the national economies in the countries of Eastern Europe and the former USSR area.

The transition period has proven to be a

While it is doubtful that freshwater aquaculture will regain the levels attained before transition, there is a need for coordinated efforts from all players in regional aquaculture in order to be competitive with other resource users and to meet the new challenges. Integrated resource use management should be considered, as much as possible, during the future development of aquaculture in the region.

The multifaceted nature of aquaculture and the potential multipurpose use of facilities offer unique opportunities for the creation of viable businesses, not only painful and prolonged process. Despite improved macro-economic stability since 1996, the investment climate has not improved, and other social conditions have deteriorated. These include aspects of local and national security, social security, education and poverty. Market reforms and private-sector growth have been disparate, resulting in large income differences in many countries.

Financial crises continue to affect the region, unemployment is high, poverty is increasing and food is expensive. These and other problems such as inefficiencies in the production, processing, marketing, transportation, banking and legal systems will take years to address successfully. Nonetheless, many countries are now showing growth in GDP, albeit at levels that are less than half of those experienced prior to transition.

The region possesses valuable natural and human assets that represent significant resources for aquaculture development, including experience, technology and research capacity, factors that can be further strengthened and combined to respond to the immense market potential of the region.

Approaches and strategies for aquaculture development

The two main directions for aquaculture development in the majority of the countries of the former USSR area could be:
the revitalization and development of the existing inland aquaculture sector, mainly pond-based fishfarm complexes; and
the development of culture-based fisheries.

The share of coastal and marine through fish production, but also by providing services for other sectors (e.g. juveniles and stocks for recreational fisheries, sport fisheries and angling ponds etc.). Pond aquaculture, however, will remain the major producer for species that feed low in the food chain, a particularly important aspect in rural areas. Scientists and aquaculturists in the region could play a leading role in promoting such diversification and developments, focusing on the development of "new" fishpond technologies, where waste recycling, appropriate polyculture and "organic production" would be the major elements. Within the restructuring of the aquaculture sector, any strategy for development must include the resolution and stabilization of land ownership rights and the improvement of the infrastructure for marketing and distribution.

Opportunities for inter-regional and international cooperation

Inter-regional cooperation has become one of the key issues for the countries of the former USSR area, where former links were broken or became inefficient after the disintegration of the USSR. The structural and financial problems have hindered the re-establishment or creation of prosperous collaboration. The participation of professionals or scientists in international aquaculture organizations and networks is very weak, and few are able to participate in international conferences, primarily for financial reasons.

Cooperation and development go hand in hand, and it should be of interest, both to the aquaculture sector in the countries of the former USSR area and to the international aquaculture community, aquaculture may increase through new developments, but freshwater aquaculture will probably remain dominant, especially when considering the immense freshwater resources.

that such collaboration be intensified. The improvement of cooperation between transition countries in order to exchange information and learn from each other's experiences should also be high on the agenda.

Although there have been some sporadic efforts, very limited support has been given to this idea, much less than in other regions of the world.

These countries have only very limited resources to advance collaborative efforts for aquaculture development, and the few, limited local initiatives have had very little effect. Professional and personal

Although the majority of the countries of the former USSR area are signatories to the main international treaties and participate actively in the work of international organizations, most countries in the region are inadequately represented in the international aquaculture organizations, such as the World Aquaculture Society (WAS), the European Aquaculture Society (EAS) and the European Inland Fisheries Advisory Commission (EIFAC). Improvement of this situation would be of equal benefit to the countries and the organizations concerned. Better use could be made of the EASTFISH project, a project managed by the Food and Agriculture Organization of the United Nations (FAO), one of whose goals is the stimulation of aquaculture trade within the region.

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links have remained between the Russian Federation and the new independent states, even after the disintegration of the USSR. These provide a good base for realising regional collaboration in the future.

A recent, positive development has been the establishment of several producers' associations, in particular the Association of Inland Aquaculture Enterprises8, for improvement of the information exchange between aquaculture enterprises. Also, the organization of regional and international aquaculture conferences has become more regular in Russia, Ukraine and Belarus, and one would hope that other countries of the former USSR area could also be involved, particularly in topics of high regional priority.

The establishment of consolidated databases and directories is also of great importance within this context of cooperation in the new and complex situation in this region. The first steps in this direction were taken within the framework of several international projects, and national fishery databases are under development in the Russian Federation, Belarus and the Baltic States.

The twinning of institutions should be encouraged and promoted, both within the region and elsewhere, and would provide an excellent basis for longterm collaboration. As an example, the “International Council for Research and Development Co-operation in Water Bioresources Research and Aquaculture” was created by several aquaculture enterprises, regulatory bodies and research institutions from Ukraine, Russian Federation, Poland, Belarus and Moldova. Amongst its activities, the council holds annual meetings that are devoted to the problems of developing inland fisheries and aquaculture during the transition period.

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[7] All fish consumption figures provided are annual and in kg/caput unless otherwise indicated.

[8] Rybkhozassociation

A Global Perspective of Aquaculture in the New Millennium

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ABSTRACT: In modern times, not many primary industries have consistently recorded high yearly growth over a period of two decades. Aquaculture has sustained a global growth, continues to grow, and is expected to increasingly fill the shortfall in aquatic food products resulting from static or declining capture fisheries and population increase well into the year 2025. Its further growth and development will have to occur under a different socio-economic milieu in the new millennium. The basic paradigm changes will be from an increased production at almost any cost, to a sustainable increase in production with minimal environmental perturbations. Despite such paradigm changes, aquaculture will increasingly contribute to food security, poverty alleviation and social equity.

The contribution of aquaculture to world food supply of aquatic products has been increasing over the past 10 years, in comparison to capture fisheries, growing from 15 to 28 percent of total production between 1988 and 1997. As the bulk of aquaculture is rural and subsistence, it plays a major role as a provider of direct and indirect employment to the rural poor and, thereby, to poverty alleviation. In many developing countries, aquaculture provides opportunities for diversification on agriculture farms and productive use to otherwise idle land during certain seasons. The main cause for the upsurge in the sector has been the transformation of aquaculture from an "art" form to a "science". This brought many advantages, ranging from less dependence on wild stock to the development of techniques that optimized yields, such as polyculture, or enabled the achievement of high yields with low inputs. Two major developments also enabled the sector to maintain growth momentum, appropriate institutional frameworks and concerted research and development. Regions or continents have many commonalities. These include the predominance of finfish among the cultivated species, and the predominance of species that feed lower in the food chain, although shrimp, which does not naturally feed high in the trophic level but is mostly reared on artificial feed, has become a significant culture commodity. Notable differences, however, include the fact that all regions, except Africa and the countries of the former USSR, have recorded a significant increase in per capita production between 1984 and 1997. While Asia continues to dominate world aquaculture in overall tonnage, as well as in every major commodity, South America has registered a very high (72.8 percent) average annual growth between 1984 and 1997.

The global and regional trends over the last 20 years in the sector from a number of perspectives, such as production trends, contribution of aquaculture to aquatic food consumption etc., are evaluated. Based on these different trends and in the light of changing socio-economic conditions globally, and in particular, in developing nations, the potential changes in the sector in the new millennium are highlighted. Finally, projections are made for the next 20 years, where opportunities, constraints and strategies for achieving the targets are presented and discussed.

KEY WORDS: Aquaculture, Production, Aquatic Food Consumption, Global, Continents, Commodities

Introduction

In modern times, there have not been many primary industries in the world that have recorded consistent annual growth over a period of two decades or so. Aquaculture is one of these; a sector that has not only achieved regular annual growth on a global basis, but is also continuing its expansion. Aquaculture is anticipated to account increasingly for the shortfall in aquatic food supply that would result from the population increase projected until 2025 (Hempel, 1993; Williams, 1996; Sverdrup-Jensen, 1997) and the levelling off, if not the dwindling, of the returns from wild fisheries (Botsford et al., 1997; Ye, 1999). Aquaculture is often seen as an important primary production sector from the food security, poverty alleviation, socio-economic and industrial view points, but the further growth and development of this sector in the new millennium will be forced to occur within a different socio-economic milieu. The "core paradigms" of the sector will have to be different from those of the previous 20 years and, therefore, the strategies have to be equally different and innovative.

In the new millennium, it is expected that the basic paradigm change will be from that of increasing production at almost any cost, as seen in the past, to that of

The past 20 years

Aquatic products as a food source

Civilisations have almost always developed in association with rivers or other suitable water resources. It is to be expected, therefore, that the hunting instincts of Homo sapiens were used effectively to harness the fish resources of such waters from time immemorial, as often demonstrated in ancient inscriptions. Nonetheless, the most effective exploitation of fish resources globally has occurred in the period following the Second World War (Botsford et al., 1997), when fish became an increasingly important component of our daily animal protein intake and calorie supply.

Although aquaculture originated at least two millennia ago, it was only since the latter part of the 20th Century that it began to make a significant contribution to overall human food supplies, and it is now seen as an important sector for the supply of animal protein. With the increasing awareness of the positive effects of fish consumption on health and well being, the importance of aquaculture in the food sector is destined to grow further. Equally, the sector will also continue to contribute to income generation and livelihoods of significant portions of the global population, mostly the rural poor.

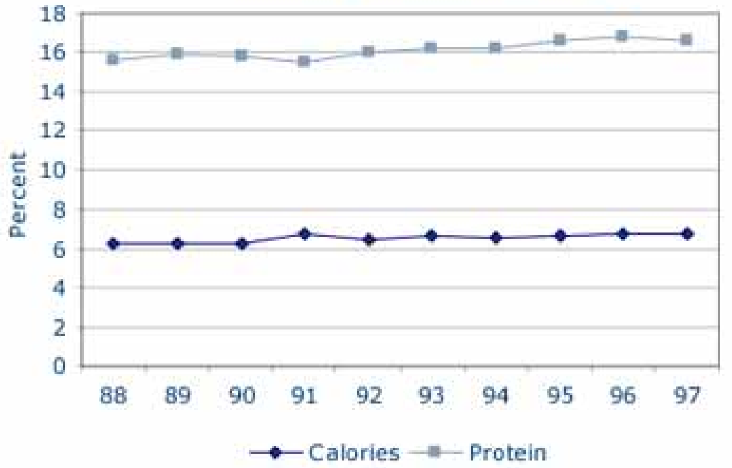
The contribution of aquatic food products to attaining a sustainable increase in production with minimal environmental perturbation. In spite of such paradigm changes, there is little doubt that aquaculture will increase its contribution to food security, poverty alleviation and social equity. The key challenge, however, is to ensure that aquaculture development in the new millennium will continue to contribute to food supply whilst making a more effective contribution to improvement in rural livelihoods, carrying an increased emphasis on equitable development.

This paper attempts to provide a global synthesis of the aquaculture sector's development and performance over the last 20 years, addressing the important issues encountered during this period, particularly over last five to seven years as the vision for sustained growth has been applied to the sector. In addition, plausible changes that may be imposed on the sector are highlighted, these being the foreseen results of modifications in the socio-economic milieu, particularly in densely populated developing countries, some of which also happen to be epicentres of aquaculture activities.

Finally, and most importantly, projections are made for the next 20 years, where opportunities, constraints and strategies for achieving the targets are presented and discussed.

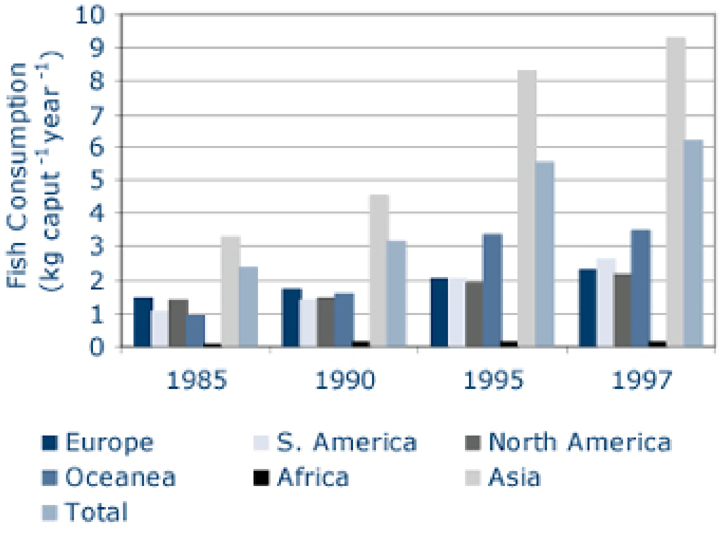
the per caput calorie and animal protein supplies is shown in Figure 1.

Figure 1. The changes in percent contribution of aquatic food supplies to per caput calorie and animal protein intake



While it is clear that the figure for calorie supply has remained almost unchanged over the last 20 years or so, the contribution to animal protein supply has shown a gradual increase, currently being 16.6 percent. This gradual increase in importance of aquatic food is a reflection of the increase in world fishery production. The per caput fish consumption in 1996 was 15.8 kg/yr, and consumption has grown at an annual rate of 4.7 percent between 1990 and 1995 (Ye, 1999), noting that consumption rates differ significantly amongst continents (Fig. 2). Furthermore, there are also large differences of per caput consumption of fish in different regions/countries within a continent. This is best exemplified in the case of Europe, which has an average per caput consumption of around 16.5 kg/yr, but where the European Community (EC) countries consume around 22 kg/yr as opposed to the 6-9 kg/yr reported for the Central and Eastern European countries (Varadi et al., present volume).

Figure 2. The changes in the per *caput* fish consumption in the different continents (from Ye, 1999)



The most significant change in fish consumption patterns, over the years, has also been seen in Europe, when it dropped from the top position to fourth in the ranking order, which currently is led by North America with 21.6 kg/yr. One must also note that fish consumption in low-income food–deficit countries (LIFDCs) was only 12.7 kg/yr compared to 19.5 kg/yr in the rest of the world. Overall, Ye (1999) concluded that fish has become more and more important in peoples' diets, and that, from a food security point of view, fish was important mostly to LIFDCs[2].

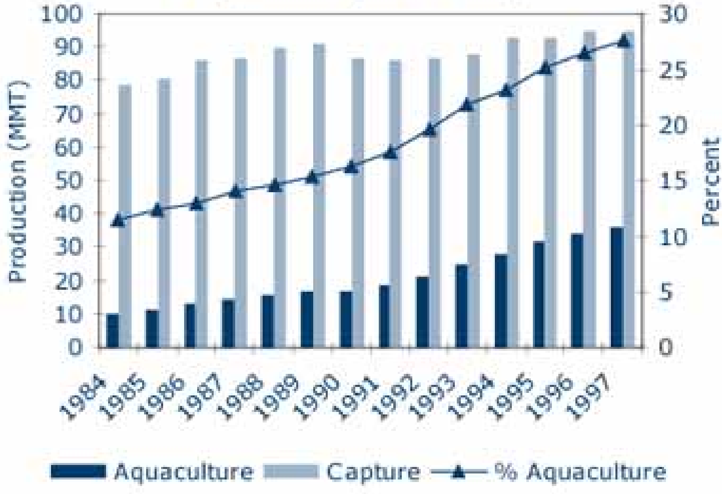
Food security is considered to exist when all people, at all times, have physical and economic access to sufficient, safe and nutritious food, allowing them to meet their dietary needs and food preferences for an active and healthy life. Apart from the fact that, in most instances, aquatic food costs less than other animal protein supplies, aquaculture also enables employment and income generation, which in turn helps to alleviate poverty, establish food security and assist rural livelihoods in general.

Contribution of aquaculture to the aquatic food supply

Prior to 1980, the aquaculture sector was small and mechanisms did not exist for providing distinct data, either for production or contribution. As the sector grew and developed, combined with the simultaneous reduction in the growth of global capture fisheries, the provision of separate statistics for the sector became imperative. World aquaculture in 1997 provided 36 million mt, or 28.8 million mt if one excludes aquatic plants (FAO, 2000)[3], as opposed to 87.1 million mt from the capture fisheries in 1996 (FAO, 1999).

On the other hand, and perhaps more importantly, the contribution of

Figure 3. The contributions of capture fisheries and aquaculture to the total aquatic food supply and the percentage contribution of aquaculture (1988 – 1997)



aquaculture to the global aquatic food supplies has increased steadily during the last 15 years by comparison to the capture fisheries (Fig. 3). Between 1984 and 1997, its share in the total supply has grown from 12 to 28 percent, tantamount to the position that nearly every third kg being consumed is cultured. These shifts within the two sectors reflect the changes in availability of aquatic food products from the capture fishery as opposed to those from aquaculture.

Accordingly, the per caput availability from aquaculture increased from 2.3 to 6.4 kg/yr over the period 1984 to 1997, a development that enabled the aquatic food supply to be maintained around 16 kg/yr, in spite of the stagnation of the returns from the capture fishery and the increasing population size.

This clearly indicates the increasing global importance of aquaculture as a valuable food resource for the growing population, particularly in developing countries with very high population densities, a position that will become apparent later.

Review of production

It is relevant to consider the main reasons for the impressive rise of the sector over the last 20 years. One of the underlying causes can be summarized by the transformation of aquaculture from an "art" to a "science", not only in the approach, but also in the application. A

Both these aspects must continue to be nurtured, extended in scope and strengthened, if the growth of the sector is to be maintained and stabilized in the new millennium. The current (1997) aquaculture production of 36 031 129 mt (FAO, 2000) is made up of finfish, aquatic plants, molluscs, crustaceans and miscellaneous commodities (including other invertebrate and a few vertebrate species). The main trends seen for global aquaculture production since 1988 are shown in Figure 4. From 1988 to 1997, which is the period under review in this and accompanying papers, the total increase has been 132 percent, with an APR [Annual Percent Rate of growth] of 9.8 percent.

major advance has been the reduction of the sector's dependence on seed caught from the wild, and this for the great majority of species cultured.

Currently, the life cycles of almost all major cultured species, except perhaps in the case of anguillid fish, have been closed, on a technical basis. On the other hand, for some species, such as the penaeid shrimps, while the life cycle has been closed technically, it is not necessarily practised commercially; i.e. this sector, in some countries, depends on wild-caught broodstock, as well as wild-caught postlarvae (Primavera, 1998). Similarly, techniques have been developed and extended to optimize yields from different culture practices. In this regard, a major stride forward encompasses the technical developments and the effective popularization of polyculture practices, when high yields were made possible with relatively low-cost inputs.

The list of technical advances that have been made in the last two decades is indeed exhaustive, and it is futile to try to summarize them all in this paper. However, it is the author's view that two other significant developments have enabled the sector to retain its momentum - the establishment of appropriate institutional frameworks, national and regional, and the initiation of a concerted R & D strategy.

Figure 4. The main trends in aquaculture production (quantity and value) from 1988 – 1997

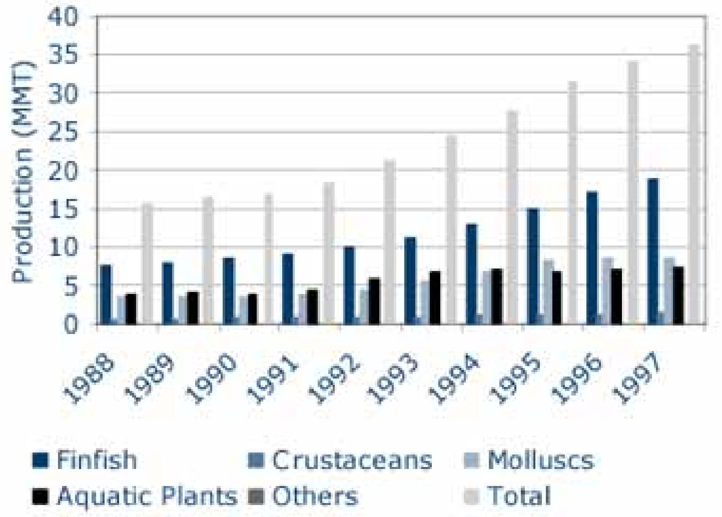
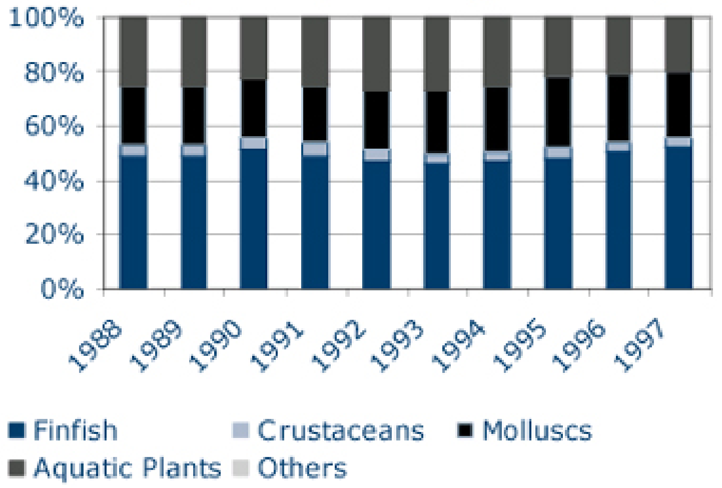


Figure 5. The changes in percent contribution of the major commodities to total aquaculture production (1988 – 1997)



It is evident that finfish represents the bulk of the aquaculture production (by volume), contributing about 50 percent of the total, a position that has remained almost unchanged throughout this time (Fig. 5). In 1997, finfish (52 percent) was followed by molluscs (24 percent), seaweeds (20 percent) and crustaceans (4 percent). The main change to be seen, however, has been with regard to the culture of aquatic plants, whose contribution has decreased from about 25 percent to 21 percent. Mollusc production has slightly increased its contribution and, after a period of rapid growth in the second half of the 1980s, the crustacean contribution stabilized at around 4 percent.

Important changes have been seen with regard to the species cultured (Table 1). In 1988, the ten species that were produced in highest quantity included five finfish, three aquatic plants and two molluscs4, where the top four species each exceeded 1 million mt. By 1997, five finfish, three mollusc and two aquatic plant species made up the top ten. Of these, the production exceeded 1 million mt in eight taxa (Table 1). One of the important facts that emerges from the species listing is that in spite of the major strides made in terms of technology, adding value, marketing etc., all of the species (or species groups) listed are ones that feed lower in the food chain. Indeed, the list does not include a single species whose culture is dependent on the provision of an artificial feed. This statement does not, however, preclude the fact that commercial feeds are used, to varying degrees, for some of the species cited.

A key question is whether this "league table" will change markedly in the new millennium. Although some changes will occur, it is unlikely that carnivorous species, or species which are high on the trophic ladder, will enter into the table. Exceptions could be Atlantic salmon and tiger shrimp, both of whose production is almost exclusively based on artificial feeds.

In spite of these generalized observations made for the sector, there is a marked disparity in aquaculture production between the different continents (Fig. 6), regions and countries. The reasons for these differences are manifold, and a detailed analysis at this level is beyond the scope of this paper, but is treated in the individual regional reviews.

Nonetheless, it has to be conceded that the initial upsurge in certain regions was, in all probability, linked to the cultural background, which in turn reflects a consumer preference for aquatic food products and a tradition of some form of fish culture.

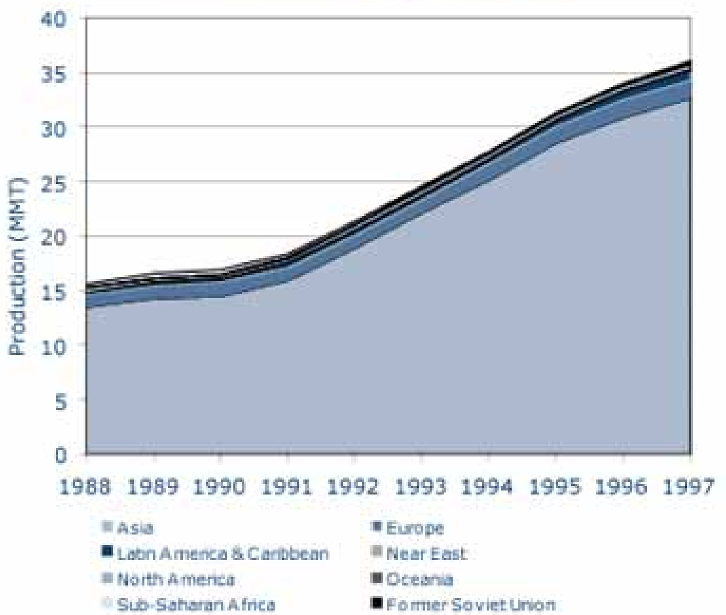
One of the most important facts of the sector is that in all continents, except Africa, there has been a significant increase in the production per caput over the period 1984 to 1997. The increase in production per caput in Europe was, however, comparatively smaller. It is within this context that the leading role of Asia in the global aquaculture sector has to be considered.

On the other hand, the sector has also witnessed the development of large-scale, industrial aquaculture during the last two decades, which is not so interlinked with the traditions mentioned previously, but may be due to the consumer preferences in the developed countries. The development of aquaculture for salmonids and shrimps in South America, salmonids in northern Europe, marine finfish in the Mediterranean Region and channel catfish in the United States are examples of this from throughout the world.

Table 1. The ten species that were produced in the highest quantity in 1988 and 1997, the amount produced is given in metric tones.

Species	1988		1997
Japanese kelp	2 072 383	Japanese kelp	4 401 931
Silver carp	1 587 691	Silver carp	3 227 617
Pacific cupped oyster	1 217 663	Pacific cupped oyster	2 974 460
Common carp	1 093 754	Grass carp(=White amur)	2 711 131
Bighead carp	725 603	Common carp	2 229 826
Laver (Nori)	670 816	Bighead carp	1 552 461
Grass carp(=White amur)	609 858	Japanese carpet shell	1 275 104
Wakame	492 196	Yesso scallop	1 256 799
Blue mussel	415 846	Crucian carp	862 554
Milkfish	345 829	Laver (Nori)	861 231

Figure 6. Aquaculture production in the different continents/regions, 1988 - 1997



Perhaps, in the new millennium, developments of this nature will continue to strengthen the sector, and this aspect will be considered in detail later.

Asia continues to dominate global aquaculture production, not only from the point of view of the total contribution (91 percent of reported yields), but also within the major commodity groups. A significant global change has been the increased

Another major change seen has been the dramatically reduced production in the countries of the former USSR are, the only region where diminished activity has been seen, dropping from 320 000 mt to 109 000 mt, represented by a negative APR of –11.3 percent. The trends in production within each region are dealt with in detail in further reviews within this volume.

It is, however, important to underline the significance of Asia in global aquaculture production. In 1988, Asia contributed 86 percent to global aquaculture production but had increased its position to 91 percent by 1997. Furthermore, within Asia and indeed globally, China5 remains the leading aquaculture producer; China's contribution6 to Asian and global production in 1997 was 74 and 67 percent, respectively, demonstrating that it has retained and improved its lead position since 1988, when these figures were 55 and 47 percent, production in Latin America, moving from 179 000 mt in 1988 to 783 500 mt in 1997, representing an APR of 17.8 percent for the period. Aquaculture production in Oceania and sub-Saharan Africa also increased, with APRs of 11.2 and 10.2 percent, respectively but, if measured in absolute terms, these increases represented only 68 000 mt or 23 500 mt, respectively.

respectively.

In 1988, eight Asian countries/territories were among the top ten aquaculture producers, with China leading with a production of 7 million mt (Table 2). By 1997, the top ten was entirely composed of Asian nations, with China leading and providing 24 million mt. This means that its production had increased by 340 percent over the ten-year period. The Democratic People's Republic of Korea, Japan and Taiwan Province of China recorded reductions, while all the other Asian nations increased their production in this period, 13 of them recording at least a doubling in production. Also, by 1997, Thailand and Vietnam had emerged as major aquaculture nations.

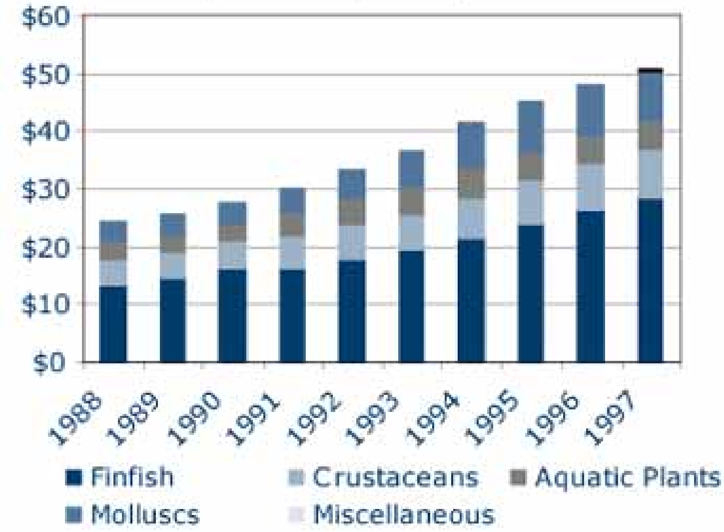
Table 2. The top ten aquaculture producing countries in 1988 and 1997. The amount produced is given in metric tones.

Country	1988		1997
China	6 995 409	China	24 030 313
Japan	1 425 991	India	1 862 250
Korea Dem. People's Rep	1 090 000	Japan	1 339 861
Korea Republic of	898 649	Korea Republic of	1 040 230
India	893 330	Philippines	957 546
Philippines	599 464	Indonesia	777 547
Indonesia	499 597	Thailand	552 356
United States of America	357 614	Bangladesh	512 738
Taiwan Province of China	300 981	Viet Nam	509 000
Spain	271 356	Korea Dem. People's Rep	489 321

Value of production

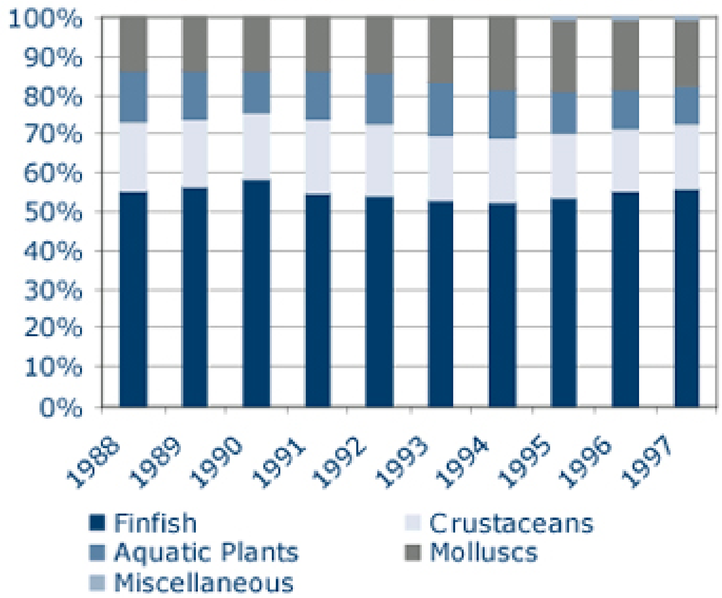
The value of the products of world aquaculture in 1997 was US$50.7 billion, an increase of US$26 billion, representing an APR of 8.5 percent over the period 1988-1997. These figures suggest that, at a global level, the total value of aquaculture produce has increased at a slower rate than that of production (APR 9.8 percent). The contribution of each of the major commodities to the total value of aquaculture produce is shown in Figure 7.

Figure 7. The contribution of each of the major commodities to the total value (billion US$) of a quaculture produce, 1988 - 1997



It is evident that finfish contribute the highest value (55.9 percent in 1997), ranging from 52-58 percent (Fig. 8), followed by molluscs (17.2 percent in 1997) and crustaceans (16.7 percent in 1997). The high market value of crustaceans, particularly shrimp, is reflected in the lower percent contribution to production (3.8 percent) compared to that of molluscs (23.8 percent) and aquatic plants (20 percent of production but only 9.6 percent of value) [also see Fig. 5].

Figure 8. The changes in percent contribution in the value of the major commodities to the total value of aquaculture produce 1988 – 1997



The distribution of the value of produce amongst the regions (Fig. 9) reflects the nature of production in these areas (also see Fig. 6). It is however, important to note that the values obtained for a majority of finfish, crustacean and mollusc species, notably those whose production exceeded 40 000 mt in 1997, have declined over the years (Tables 3 to 6). Twenty-three of the 40 species (or groups, i.e. freshwater fishes nei) show a negative APR for value/kg during the ten-year period 1988-1997.

For example, the unit value7 of Atlantic salmon has decreased by US$2.87, while even more spectacular drops have been seen for Japanese eel (-US$6.23), gilthead seabream (-US$6.30) and coho salmon (-US$3.02). This general trend has interpretations that vary on the basis of the commodity and the market within which it is sold. The likely principal reasons for price reductions are competition between producers in the marketplace and decreased production costs due to improved efficiencies in farming systems. The improved efficiencies of different farming systems were achieved through technological advances, improved farm management and realisation of economies of scales that provide for adequate returns on investment in spite of lower sales prices.

Figure 9. The changes in the value of aquaculture produce of different continents and regions 1988 - 1997 (billion US$)

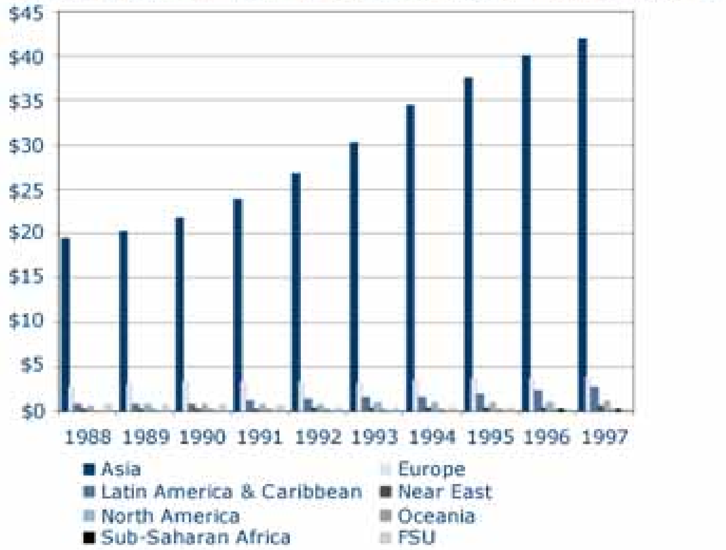


Table 3. Finfish and crustacean species whose production exceeded 40 000 mt in 1997, showing changes in production and value (1997 vs 1988), factors of change and the change in value/kg.

Species	Production 1988	Production 1997	Factor of Change Production	Factor of Change Value	Value (US$)/Kg 1988	Value (US$)/Kg 1997
Gilthead seabream	1 785	41 691	23.4	12.4	13.39	7.10
Japanese eel	91 737	222 623	2.4	1.0	10.81	4.59
Coho salmon	25 780	84 794	3.3	1.8	6.83	3.81
Freshwater crustaceans nei[1]	28 427	44 845	1.6	1.0	7.64	4.63
Atlantic salmon	112 377	646 513	5.8	3.1	6.18	3.31
Silver seabream	45 241	81 426	1.8	1.3	10.37	7.60
Whiteleg shrimp	76 450	168 967	2.2	1.6	7.70	5.42
Chinese river crab	0	100 692			7.50	6.01
Climbing perch	37 291	61 313	1.6	0.7	2.20	1.00
Torpedo-shaped catfishes nei	42 563	126 196	3.0	1.9	2.14	1.37
Common carp	1 093 754	2 229 826	2.0	1.4	1.73	1.21
Rainbow trout	248 010	427 338	1.7	1.5	3.57	3.16
Grass carp	609 858	2 711 131	4.4	3.1	1.34	0.92
Crucian carp	121 803	862 554	7.1	5.0	1.30	0.91
Fleshy prawn	199 520	104 456	0.5	0.5	7.50	7.12
Catfish, hybrid	12 551	52 680	4.2	3.1	1.11	0.83
Marine fishes nei	37 597	280 659	7.5	6.0	1.28	1.03
Channel catfish	164 183	238 234	1.5	1.3	1.77	1.56
Silver carp	1 587 691	3 227 617	2.0	1.8	1.08	0.93
Bighead carp	725 603	1 552 461	2.1	1.9	1.05	0.92
White amur bream	194 900	434 896	2.2	2.1	1.27	1.20
Nile tilapia	129 214	741 015	5.7	5.5	1.24	1.18
Black carp	117 100	138 638	1.2	1.2	1.75	1.70
Mrigal carp	142 099	515 556	3.6	3.7	0.90	0.92
Freshwater fishes nei	551 496	1 431 621	2.6	2.6	1.14	1.16
Thai silver barb	16 673	48 047	2.9	3.0	0.95	0.97
Mud carp	78 165	150 084	1.9	2.0	1.02	1.05
Catla	207 875	577 756	2.8	3.0	0.90	0.96
Mozambique tilapia	37 058	51 507	1.4	1.5	1.96	2.16
Milkfish	345 829	367 429	1.1	1.4	1.40	1.80
Banana prawn	35 470	54 849	1.5	1.7	3.60	4.02
Giant tiger shrimp	199 898	531 198	2.7	2.9	6.63	7.17

Mud carp	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Catla	207 875	577 756	2.8	3.0	0.90	0.96
Mozambique tilapia	37 058	51 507	1.4	1.5	1.96	2.16
Milkfish	345 829	367 429	1.1	1.4	1.40	1.80
Banana prawn	35 470	54 849	1.5	1.7	3.60	4.02
Giant tiger shrimp	199 898	531 198	2.7	2.9	6.63	7.17
Giant river prawn	19 981	109 051	5.5	6.4	5.88	6.87
Tilapias nei	128 518	130 341	1.0	2.0	1.09	2.11
Metapenaeus shrimps nei	19 938	41 455	2.1	2.9	2.61	3.63
Roho labeo	217 193	692 966	3.2	7.3	0.94	2.14
Penaeus shrimps nei	26 927	74 353	2.8	3.6	4.67	6.07
Japanese amberjack	167 186	138 536	0.8	1.1	6.22	8.62
Marine crabs nei	8	58 769	7 346.1	21 040.1	1.75	5.01

[1]nei = not elsewhere included.

Table 4. Major ISCAAP[1] groups whose production exceeded 30 000 mt in 1997, showing changes in production and value (1997 vs 1988) and factors of change.

Group	Production		Factor of Change		Value (US$)/Kg	
	1988	1997	Production	Value	1988	1997
River eels	98 109	232 908	2.4	1.1	10.64	4.76
Redfishes, basses, congers	54 915	178 901	3.3	2.4	10.67	8.01
Salmon, trouts & smelts	436 390	1 225 112	2.8	2.1	4.61	3.42
Flounders, halibuts & soles	3 278	38 203	11.7	10.8	15.25	14.16
Miscellaneous marine fish	37 606	280 954	7.5	6.0	1.28	1.03
Shrimps & prawns	576 453	1 000 565	1.7	1.7	6.68	6.44
Carps, barbels & other cyprinids	5 194 827	13 230 197	2.5	2.1	1.27	1.07
Tilapias & other cichlids	309 109	938 497	3.0	3.3	1.24	1.36
Miscellaneous freshwater fish	867 690	2 085 001			1.35	1.55
Miscellaneous diadromous fish	350 166	388 313	1.1	1.5	1.42	1.93
Sea-spiders & crabs	3 574	70 948	19.9	24.0	3.94	4.76
Freshwater crustaceans	81 617	279 796	3.4	4.1	4.82	5.76
Jacks, mullets, sauries	193 711	183 983	0.9	1.2	5.77	7.24

[1] International Standard Statistical Classification of Aquatic Animals and Plants

Table 5. Molluscs, aquatic plants and miscellaneous groups whose production exceeded 40 000 mt in 1997, showing changes in production and value (1997 vs 1988), factors of change in value/kg.

Species	Production 1988	Production 1997	Factor of Change Production	Factor of Change Value	Value (US$)/Kg 1988	Value (US$)/Kg 1997
Northern quahog(=Hard clam)	23 113	43 753	1.9	1.3	1.91	1.29
Laver (Nori)	670 816	861 231	1.3	1.0	2.05	1.55
Yesso scallop	303 984	1 256 799	4.1	3.3	1.72	1.36
Japanese carpet shell	189 653	1 275 104	6.7	6.1	1.44	1.31
Gracilaria seaweeds	32 380	136 531	4.2	3.2	0.53	0.40
Mediterranean mussel	95 531	130 768	1.4	1.2	0.78	0.68
Razor clams nei[1]	140 673	354 152	2.5	2.3	1.00	0.90
New Zealand mussel	24 598	65 500	2.7	2.0	0.39	0.30
Eucheuma cottonii	220 509	609 287	2.8	1.3	0.16	0.08
Pacific cupped oyster	1 217 663	2 974 460	2.4	2.3	1.13	1.07
Japanese kelp	2 072 383	4 401 931	2.1	2.0	0.70	0.65
Blue mussel	415 846	401 133	1.0	0.9	0.67	0.63
Marine molluscs nei	225 210	1 135 158	5.0	4.7	0.52	0.48
Wakame	492 196	535 357	1.1	1.0	0.35	0.32
Green mussel	62 299	59 360	1.0	0.8	0.17	0.14
Red seaweeds	85 000	115 000	1.4	2.7	0.05	0.10
Aquatic plants nei	196 304	472 015	2.4	2.9	0.60	0.73
Sea mussels nei	429 784	399 095	0.9	2.7	0.07	0.20
Blood cockle	107 025	199 019	1.9	2.3	0.83	1.03
Korean mussel	15 693	63 573	4.1	6.6	0.34	0.55
American cupped oyster	81 073	65 147	0.8	1.3	0.47	0.77
Brown seaweeds	28 871	41 060	1.4	2.1	0.74	1.09
Softshell turtle	71	47 066	662.9	902.0	3.56	4.84

[1]nei = not elsewhere included.

Table 6. Molluscs, aquatic plants, invertebrates and miscellaneous groups whose production exceeded 30 000 mt in 1997, showing changes in production and value (1997 vs 1988), and factors of change.

Group	Production 1988	Production 1997	Factor of Change Production	Factor of Change Value	Value/Kg 1988	Value/Kg 1997
Turtles	795	47 773	60.1	17.1	17.71	5.05
Red seaweeds	1 030 129	1 744 657	1.7	1.0	1.39	0.83
Scallops & pectens	305 444	1 269 063	4.2	3.3	1.74	1.39
Clams, cockles, arkshells	531 423	1 941 872	3.7	3.4	1.39	1.31
Oysters	1 331 402	3 082 260	2.3	2.2	1.12	1.07
Miscellaneous marine molluscs	225 210	1 135 158	5.0	4.7	0.52	0.48
Brown seaweeds	2 593 460	4 978 402	1.9	1.9	0.64	0.62
Mussels	1 047 589	1 136 050	1.1	1.2	0.39	0.44
Miscellaneous aquatic plants	196 304	472 015	2.4	2.9	0.60	0.73
Sea squirts	23 660	30 166	1.3	2.2	0.62	1.08

The combination of increased sales volumes with reduced prices has created the situation where previously high-valued species are now within the reach of a greater proportion of consumers.

With notable price crashes seen for some of the higher valued species, one might have expected a decline in their production, since economic viability is paramount for the growth of any sector. This has rarely been the case, since buy-outs or corporate restructuring, imposing improved operations and management, have been seen in many

Higher yields per unit area, lower feed costs and better health management are the key technical elements for successful production, while improved marketing and financial management are also integral components that are required for continued growth.

Major commodities

Aquaculture is a very diverse activity, involving the culture of invertebrates to reptiles, being done in all types of aquatic environments.

different parts of the sector.

Figure 10. The total cultured non-carnivorous and carnivorous finfish production and the percent contribution of non-carnivorous fish to the total in selected years

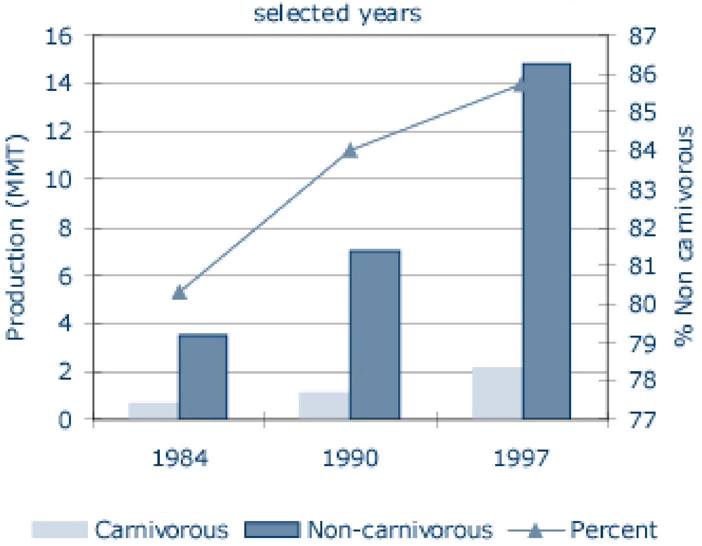
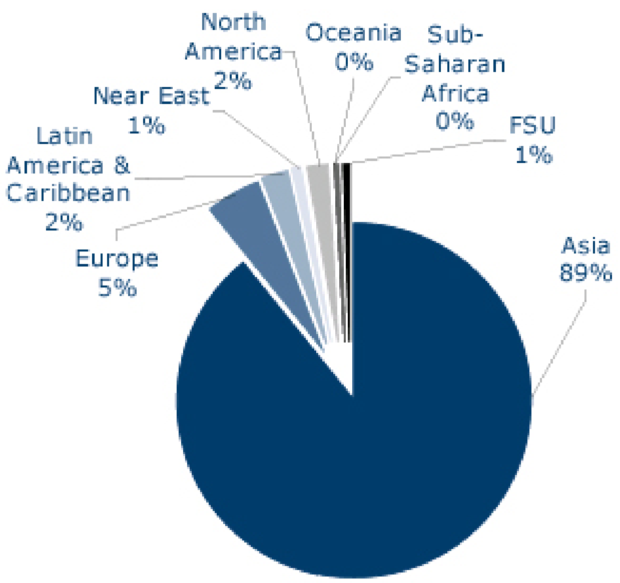


Figure 11. Percent contribution to cultured finfish production by different continents.



Obviously, this diversity has its pros and cons. On the positive side is the fact that the sector's diversity allows it not only to adjust to varying consumer demands, but also to respond to the changing aspirations of society. On the negative side, one can identify the efforts that are required in research, development and marketing, which have to be dedicated to each potential commodity to render their potential technically and economically viable.

Finfish

As indicated earlier, finfish is the major commodity that is cultured globally, where over 125 species are contributors, in all environments (fresh, brackish and marine waters) and temperatures (warm, temperate and cold). The number of species whose production exceeds 100 000 mt /yr is less than 20, of which 11 are cyprinids. The great bulk of finfish culture is constituted by freshwater species, followed by diadromous and marine species. Cyprinids and diadromous fish dominate freshwater culture, followed by carps and salmonids, in warm and cold climates, respectively. The global value of the produce of each category reflects the amounts produced.

The changes seen for the production of carnivorous and noncarnivorous finfish production in selected years are shown in Figure 10, from which it is evident that the contribution of the latter to cultured finfish production increased continuously, always remaining in excess of 80 percent.

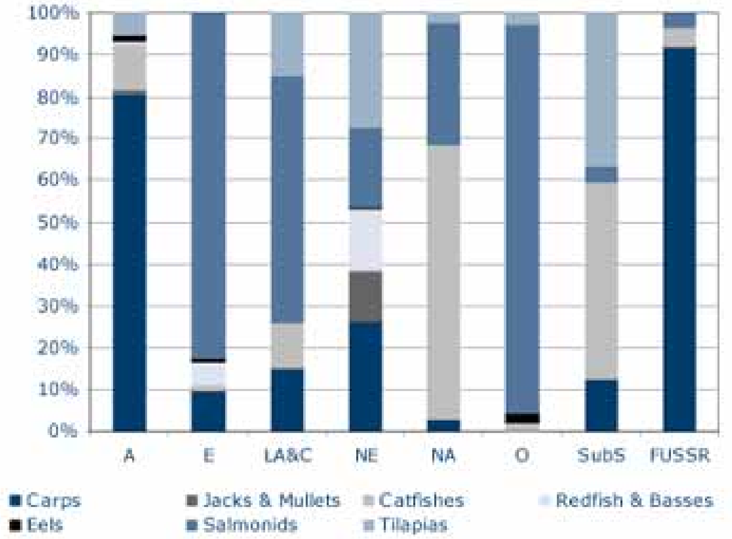


Figure 12. The distribution of major finfish groups cultured in different regions (based on 1997 data). (A=Asia, E=Europe, LA&C=Latin America, NE=Near East, NA=North America, O=Oceania, SubS=Sub-Saharan Africa, FUSSR=Former USSR)

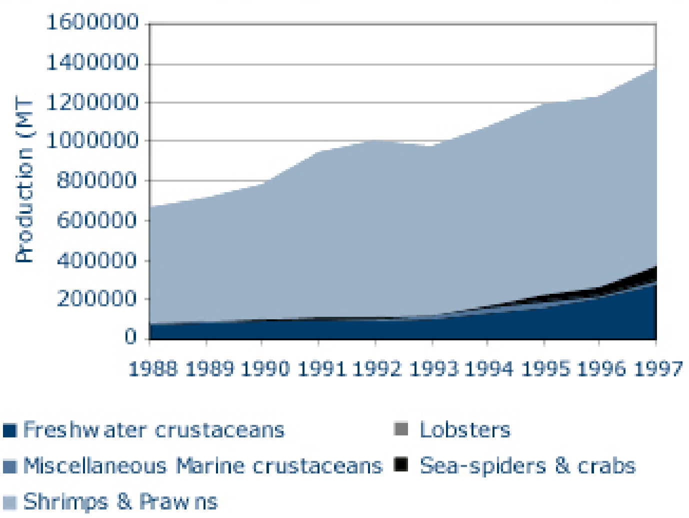
In essence, although some minor changes have occurred in respect of individual species, the gross picture has remained almost intact over the years. The conclusion of this analysis is that the great bulk of finfish culture does not have to depend on the provision of formulated feeds.

Asia leads the world in finfish culture, producing nearly 90 percent of that produced globally in 1997 (Fig. 11). The dominance of Asia in finfish culture is further exemplified when one considers the proportion of each of the seven major groups of teleost fish cultured in each continent (Fig. 12). From this analysis, it is evident that, with the exception of salmonid species, Asia leads in the culture of all the other groups.

Upon deeper analysis of the information provided in Figures 11 and 12, notably on a regional basis, it becomes apparent that the culture of carnivorous finfish is a developed-country activity, while noncarnivorous finfish culture is essentially an activity made in developing countries.

In all continents and regions, with the exceptions of Africa and the countries of the former USSR area8, the per caput availability of cultured finfish has increased steadily, the largest increases occurring in Asia and North America, during the last decade in particular for the latter. This general trend is encouraging, in that finfish culture is appearing to keep ahead of population growth and, as such, will be able to maintain its importance from the point of view of food security.

Figure 13. The growth of the cultured crustacean production and the contribution of the major groups, (shrimp, freshwater prawns, crabs and miscellaneous species).



Crustaceans

Compared to that reported for finfish production, the annual yield of cultured crustaceans is relatively small, currently measuring about 1.4 million mt. This is a sector that continued to grow, consistently and substantially, although few fluctuations observed during the process (Fig. 13). A concurrent growth of crab culture, mainly a fattening process, has occurred, particularly in Asia, which has assisted the overall growth of crustacean aquaculture. All cultured crustaceans are relatively high valued, and the value of the different products is almost identical (Fig. 14) to the production.

As evident from Figures 12 and 13, marine shrimp culture almost completely dominates crustacean culture, representing 96 percent that is done in brackish water and 73 percent of all crustacean aquaculture (1997). The relative contribution of the various shrimp species to global cultured shrimp production is shown in Figure 15, which shows that the tiger prawn, Penaeus monodon, contributes in excess of 50 percent to the total followed by the whiteleg shrimp, P. vannamei (18 percent), and the oriental or fleshy prawn, P. chinensis (10 percent).

Shrimp culture is essentially confined to Asia and South America (Fig. 16) and, interestingly, the production share of the latter has continued to increase steadily throughout the decade, rising from around 15 percent to nearly 20 percent of global production in 1997. It is envisaged that Africa may become an important player in this sector in the future.

Figure 14. The total value of cultured crustacean produce and the contribution of the major groups cultured.

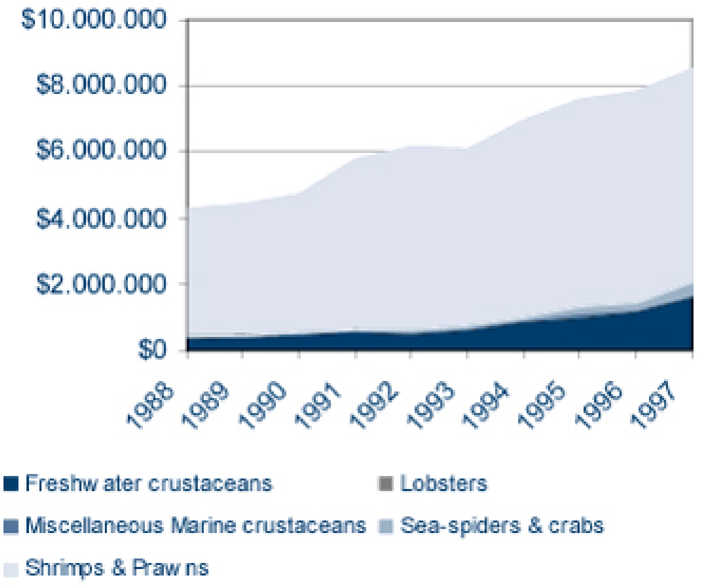


Figure 15. The relative contribution of different shrimp species to the global cultured shrimp production in 1997.

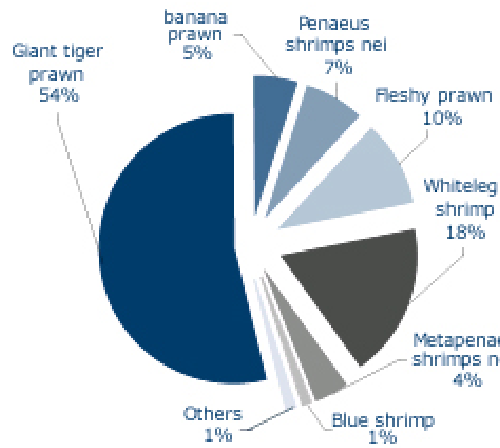


Figure 16. The contribution of the different continents to cultured shrimp production, 1988 to1997.

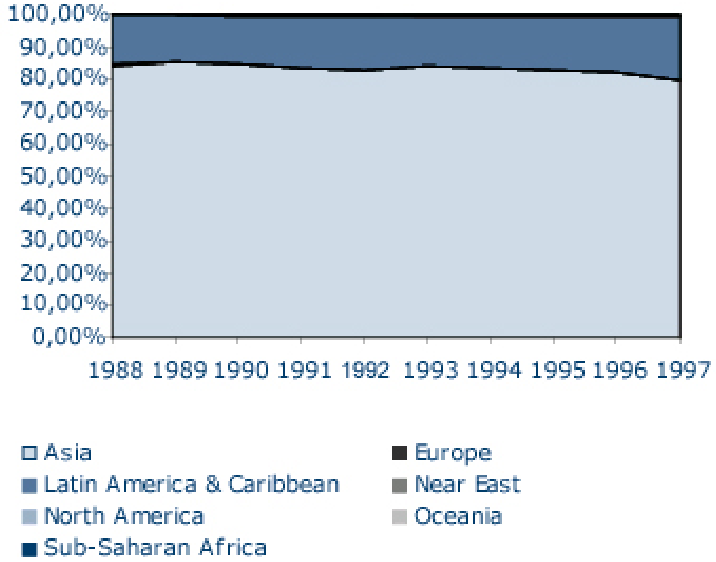
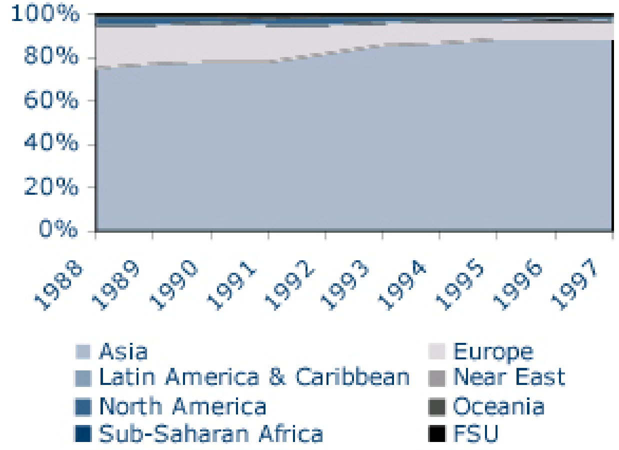


Figure 18. The contribution of the different continents to cultured mollusc production, 1984 to1997.



Molluscs

Fifty-eight species of molluscs are cultured globally, and the total production is about 8.6 million mt. However, the production exceeded 50,000 mt (in 1997) for ten species only (two oysters, five mussels, two clams and cockles and one scallop species). The relative contribution of each of the groups to total production is shown in Figure 17. As with the previous two commodities, Asia also leads global mollusc culture (Figure 18), its contribution growing steadily from about 76 percent in 1988 to nearly 90 percent in 1997, giving an APR of 12.6 percent. This has been achieved through a superior growth rate to the other important regional producer, Europe, whose expansion has been much slower, measured by an APR of 1.1 percent for the period.

Aquatic plants

Annual aquatic plant production currently exceeds 7 million mt and is confined to three marine seaweed taxa, the brown (Phaeophyceae - four species), red (Rhodophyceae - nine species) and green (Chlorophyceae - three species) seaweeds. The relative contribution of each of these groups to total production and the value of the produce, from 1984 to 1997, is given in Figures 19 and 20, respectively, where it can be seen that the value of green seaweeds is slightly higher than that of the other two groups. Aquatic plant culture is almost totally confined to Asia, with recent culture activity expanding for Gracilaria in Chile, but elsewhere it is only of a very small scale (sub-Saharan Africa, Europe and Oceania).

Figure 17. The growth of the cultured mollusc production and the contribution made to the total by the major groups

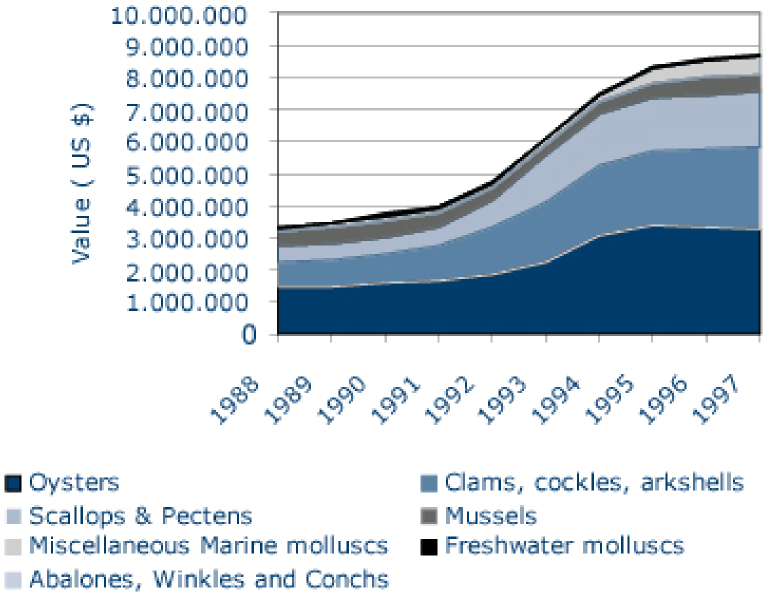


Figure 19. The growth of the cultured aquatic plant production and the contribution made to the total by the major groups.

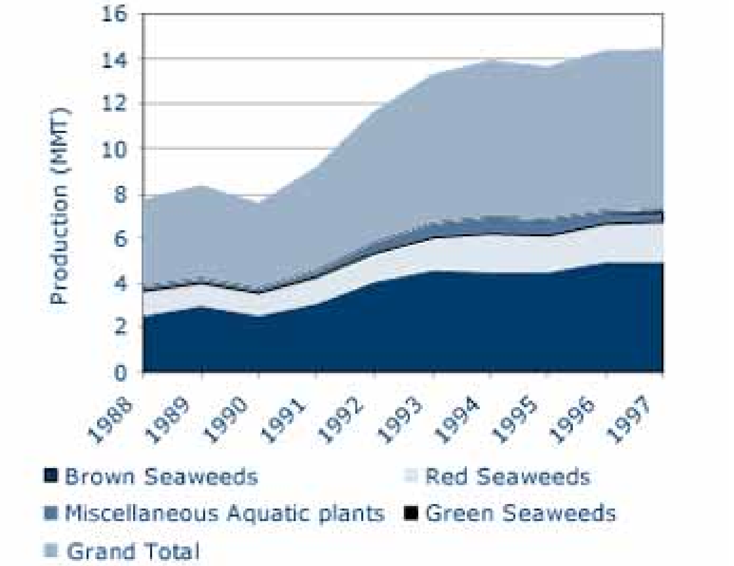
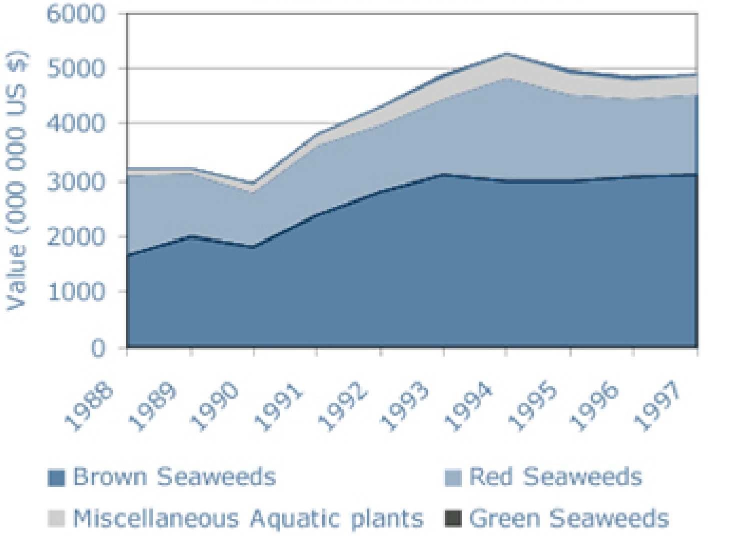


Figure 20. The total value of cultured aquatic plants and the contribution made to the total by the major groups cultured.



Growth trends

As stated before, global aquaculture production has shown a steady increase from 1988 to 1997, measured as a 132 percent increase with an APR of 9.8 percent. Some

The results of this analysis (in metric tonnes per annum) for global aquaculture production, together with that of the major commodity groups, in respect of value of produce and in terms of percent change, for the same time periods in all cases, are shown in Figures 21 and 22. The results show that the annual rates of change in the totals for both production and the value of produce increased steadily until about 1990, after which the increases, although positive, have tended to be smaller than in the previous years.

It is not realistic to expect continued and increasing growth, or as seen in some instances, bordering on exponential growth, within global aquaculture and, least of all, in a primary production sector. However, aquaculture has experienced this scenario of increasing growth for less than a decade. Furthermore, a concern for aquaculture in the new millennium comes from the observation that the continent that contributed most of continents and regions have witnessed an even greater rate of growth. Nonetheless, the measured annual growth rates in a sector or its subsectors tend to mask important variations and intermediate trends and thus can often be misleading. De Silva (1999), in projecting fishmeal demands for the future, was the first to deviate from using the measure of mean annual growth, and quantified aquaculture growth within different stanzas. This procedure is extended further here, when the moving average growth (MAG)9 per annum was considered over the period 1984 to 1997.

the development is currently experiencing a decline in rates of growth. This recent trend indicates, therefore, that the sector cannot be complacent if it is to pursue and attain continued, long-term growth in the new millennium. On the other hand, sectoral growth has kept pace with increasing populations in all regions except Africa and the countries of the former USSR are. Even though this is a remarkable achievement for the sector, it is not a matter for complacency, particularly since aquaculture accounts for only about 30 percent of the aquatic food supply. In the new millennium, therefore, it is important that growth keeps pace with demand. All growth, however, needs to be achieved with minimal environmental perturbations.

Figure 21. The moving average in increase in total, fish and shellfish and aquatic plant global production from 1988 to 1997. Note that the first point on the moving average is the mean for the increase in production between 1988 and 1997, and the second is for between 1989 and 1997 and so on.

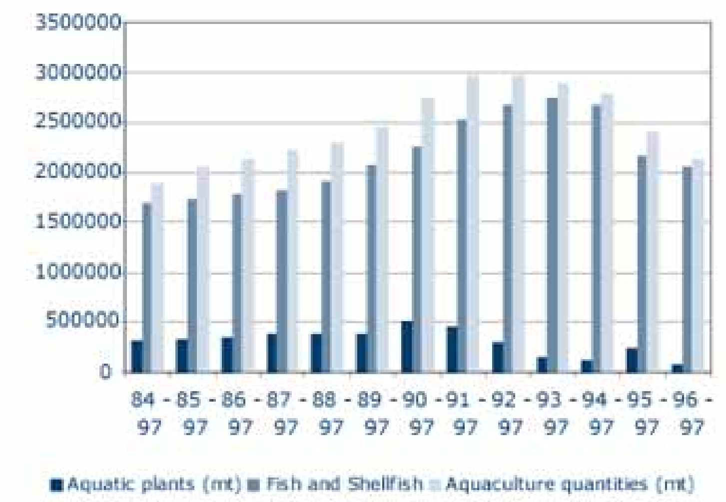
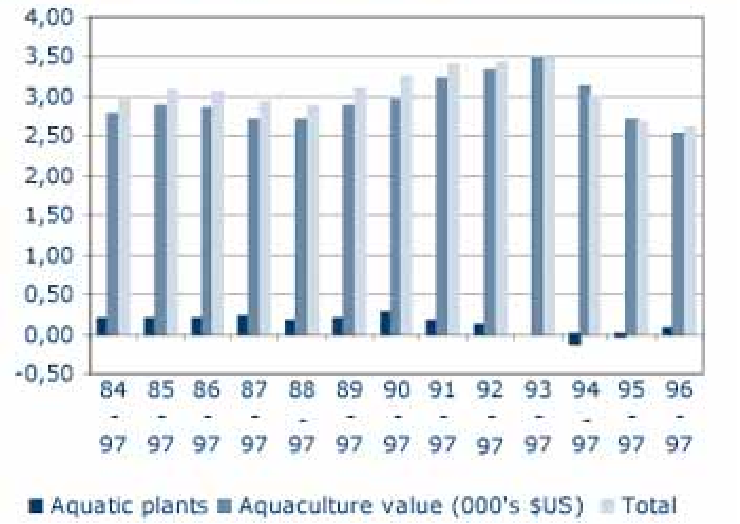


Figure 22. The moving average in the value of total cultured produce, and fish and shellfish and aquatic plant produce globally 1988 to 1997. (see Figure 21 for explanation).



Other benefits

The great bulk of aquaculture is both rural and subsistence-based, where the activity plays a major role as a significant provider of employment, in particular to the rural poor, and thereby in poverty alleviation. More often than not, this important contribution of aquaculture to the socio-economic well being of rural communities is seldom taken into account, being rarely quantified or appreciated by the many lobby groups who do not believe that aquaculture should be promoted.

In China, for example, the total number of labourers in full-time employment in rural aquaculture increased from 1 530 083 in 1989 to 3 292 557 in 1997. It was estimated that 1 688 million and 93 000 persons were employed in India, in rural inland and brackishwater aquaculture, respectively (Sinha, 1999). Aquaculture also provides seasonal employment, such as in the collection of shrimp fry, for example. In leaving aside the environmental debate on this activity, it is estimated nonetheless to provide part-time employment to 1-1.2 million and 50 000 fry collectors in Bangladesh and India (West Bengal), respectively (Primavera, 1998). Similarly, in Thailand, only 1 312 persons were employed full-time in coastal aquaculture in 1987, while it currently employs around 70 000. The estimate for total employment in the aquaculture sector in Thailand is about 313 000, of which some 77 percent are engaged in inland aquaculture. The shrimp farming industry is estimated to provide direct employment to 584 000 globally (excluding China and Bangladesh), and to about 2 020 000, including indirect employment in the industry (Singh, 1999).

Such benefits are not restricted to developing countries. The growth of the salmon industry in rural areas of Scotland has not only created significant employment opportunities (estimated at around 10 000 direct and indirect jobs], but it has also

Generally speaking, in most countries, the income levels of aquaculture employees are also thought to be higher than those in the fishery sector and other primary-sector industries. For example, in China, the mean income per labourer in fishing and aquaculture has increased steadily over the years, but the average income of a fish farmer was almost always twice that of a fisherman. Comparisons on income generation from integrated rural activities are available for a number of cases. In Vietnam, within the integrated VAC systems (vegetable-fish-livestock plots or gardens), the income from aquaculture activities was higher than that from either animal husbandry or gardening. Also, in such systems, the income generated was related to the location of the activities, the lowest being in suburban regions.

Sinha (1999) conducted a comparable analysis on fish-crop-livestock-forestry integrated systems in India. He found that percentage return on fish exceeded 350 percent in all cases and that, in most instances, the net income, percentage return and cost-return ratio were best for fish, with plantation/forestry performing better only occasionally. A direct comparison of the per caput income of agriculture and aquaculture households in four provinces in China (Song, 1999) showed that the latter was higher, the difference also being dependent on the province, where the average income of aquaculture households (in 1997) was 5 324 Yuan, a figure 2.1 times that of agriculture households.

From the foregoing, it is evident that rural aquaculture plays a very important role in providing employment and in poverty alleviation of rural communities. Obviously, its contribution in this regard will also indirectly influence social equity.

The above synthesis on employment in the sector referred to direct employment only, but the sector also creates a considerable contributed much to rural areas that have little other opportunities for development (McCunn, 1992). The potential for continuous, rather than seasonal employment, has meant that the decline of the rural population in Scotland has, for the first time in this century, stopped, leading to a slight increase in the population of some communities. The role of aquaculture can be therefore be important in contributing to and maintaining rural communities.

proportion of indirect employment, particularly in industrial aquaculture. It has been estimated that in Australia, for example, three indirect jobs are created for each direct employment in the sector (Anon., 1999). In the European Community (EC), it was recently estimated that there were 40 000 full-time equivalent employees (FTE) in production, with 4 500 FTE upstream (supply sectors) and 12 000 FTE downstream (mainly processing), representing jobs that would not exist without aquaculture. These calculations did not include the jobs maintained or created by commercial or individual spending in the areas of the farms (Macallister Elliott and Partners, 1999).

The aquaculture sector, particularly in some developing countries, has also provided opportunities for additional food production through seasonal land use on plots that would have otherwise remained idle. A case in point in this regard is the traditional rotation in rice-shrimp farming in the Mekong Delta (Vietnam). During the dry season, because of high salinity, shrimp is farmed, whereas in the wet season, rice is grown, thereby enabling effective utilization of cultivable land throughout the year (Binh and Lin, 1995).

Diversity and goals of aquaculture

The aquaculture sector is probably the most diverse of all animal food production sectors. This diversity is the result of a number of factors, the foremost of which are:

- the number of species and/or species groups cultured, which is nearly 200,

The new millennium

It is to be expected that the new millennium will pose new challenges to most global primary industries, and the aquaculture sector will not be an exception. Some of the new challenges that the sector will confront will be consequent to perceptions that have been generated, many rather erroneously, in recent years. These perceptions are linked indirectly to the increasing global call to minimize environmental perturbations and the need to strive towards sustainable development, taken in the broadest context, of all primary production sectors. Some have suggested that the sector's future will not depend on its economic viability per se, but that its longterm sustainability will only be ensured by environmental viability (Kutty, 1997). The equation however, is neither that simple nor that straight forward. Other influential factors, primarily social, political and even global marketing issues, also need to be brought into the

although only about 25 of these account collectively for over 90 percent of the production;
- the range of aquatic environments (freshwater, brackish and marine) and temperatures (cold, temperate and warm) in which culture practices are conducted;
- the wide range of "containment" systems used (ponds, raceways, cages, pens etc.); and
- the differing degree of the "intensity" applied, where "intensity" is defined within the context of extensive, semi-intensive and intensive practices (Tacon, 1987; Tacon et al., 1995). These definitions are, in turn, based primarily on the degree of external nutrition supplied to the cultured stock.

Increasingly, the division between rural, subsistence aquaculture and industrial aquaculture is coming to the forefront. In the former, the species cultured are generally those that feed low in the food chain, using a low-level of primary inputs and where the culture activity may not necessarily be the main source of income of the household, but one of a diverse range of economic activities on a small-scale agriculture farm.

At the other end of the spectrum is industrial aquaculture, which tends to culture species of higher value, and generally involves more intensive practices that use a high level of primary resources, such as water, feed, energy etc. It is needless to say that issues regarding the "ecological cost" of industrial aquaculture have been raised and the sustainability of such practices questioned (Folke & Kautsky, 1992; Naylor et al., 1998).

equation.

In the past, the primary goal of the sector was to increase production and profitability, either through the application of technology, the use of more resources or an increase in the area under culture. Environmental issues were only of limited concern; likewise the social aspects have also been given limited attention. While most of the environmental and social issues were recognized, there has been limited emphasis on the development of suitable strategies to deal with these. Indeed, during the early years of sectoral growth, it was often argued that aquaculture was environmentally friendly by virtue of the fact that only marginal lands were used for aquaculture development.

We are now aware that this is a gross misnomer. Aquaculture uses primary resources, has to compete with other prospective users and is not always environmentally friendly; indeed, the degree of "environmental friendliness" depends on various factors, such as the farming system, the location, and how a particular aquaculture practice conducts its activities, among others. The aquaculture sector in the new millennium will develop, thrive and be sustained only if it can ensure environmental integrity. The sector will need to take a different emphasis, that of longterm environmental, social and economic sustainability, and adapt its goals to these requirements.

Public perceptions

The public's perception of a sector influence both policy formulation and development, both directly and indirectly, of that sector. A proper, pragmatic policy structure is essential to all development, and particularly for primary production sectors. In recent years, the public's perception of aquaculture has all but tarnished the sector and, in some nations, public outcry has resulted finally in major policy changes (Murthy, 1997). In the new millennium, the sector will have to attempt to clean this tainted image and endeavour to correct the public view on aquaculture. The message in this regard should be that aquaculture is essential to meet human demand for aquatic products and will continue developing as a sector that minimally perturbs the environment; that it can be a gross environmental cleaner, a prudent user of primary resources, and a producer of healthy and nutritious food of high consumer acceptability.

It is also important to highlight the contributions of the sector to humanity, in general. First and foremost, it is a sector that is predominantly rural, which, in most instances, tends to benefit the poorer sectors of the community. Aquaculture is a gross contributor to providing food security, gainful employment and poverty alleviation. These are issues that are rarely focussed on during public debate on aquaculture and, in the new millennium, when competition for primary resources is likely to intensify, it is important that these are brought to light.

Interest groups generate and influence the public's views and perception of a sector, more often than not. In the aquaculture sector, it is unfortunate that, in recent years, exaggerating the harmful environmental impacts of certain forms of aquaculture, in particular shrimp and Environmental problems existed, but these were not insurmountable. However, as in this case, by laying emphasis on the environmental issues, sympathy can be gained across the board, from all sectors, and the case is strengthened.

More importantly, it is appropriate to hypothesise what could have been the outcome if the same wasteland were to be used for shrimp culture (in India), but through the application of small-scale farming activity, being executed as a strategy to alleviate poverty and provide employment to the rural poor.

Aquaculture may have been more successful and, in all probability, may have resulted in less environmental problems in some countries if social objectives – such as poverty alleviation and rural development – were given a more central focus in aquaculture development strategies. For the new millennium, there is a lesson to be learnt from the above-mentioned experience, and governments need to be alert in choosing the appropriate strategies for development, minimizing the tinkering of the social fabric.

Environmental aspects

The main environmental issues in aquaculture development relate to the replacement of natural and man-made habitat by aquaculture farms, the use of natural resources in farm inputs (particularly feed) and the release of materials (such as nutrients, organic matter and even pathogens) as effluent.

Effluent quality

The most direct local influence of intensive aquaculture on the environment is often through the effects of effluent discharge. The culture of most aquatic organisms that salmon culture, has generated negative perceptions of the sector as a whole. It is also not uncommon, often in developing nations, that lobby groups with vested interests use environmental issues to mask underlying social and political issues. Of course, quantification of the latter is difficult.

For example, it is often suggested that the core of the "shrimp" issue in India was not an environmental concern but a social one. This was an issue which was created, in all probability, by promotion of the "wrong" strategy, the promotion of shrimp culture in "wasteland" through the mobilization of big businesses. This strategy was not acceptable to the community at large, which felt that rural communities were being alienated from their land and traditional farming practices.

depend on an external feed input results in the deterioration of the quality of effluent water, primarily resulting from uneaten food, faecal discharge and nitrogenous metabolism. It is estimated that in salmonid cage culture, for example, only 25 percent of the food nitrogen results in production (Hakanson, 1986). There have been marked improvements in feed utilization in salmonid culture, brought about by the use of high-energy feeds in recent years, where a protein retention of 42 percent has been achieved (Hillestad & Johnsen, 1994). In the case of organisms such as shrimp, which are not recognized to be efficient feeders, the wastage is even greater. There has been good recent progress in improving such efficiency, but the sector will increasingly need to address this issue in the new millennium.

Some major calamities have been seen within the aquaculture sector in different nations, mostly in respect of shrimp culture ventures. Viral disease outbreaks augmented by transboundary pathogen transfers and poor management practices caused significant losses. The spread and intensification of shrimp farming is also thought, in some regions, to have brought about land subsidence (such as in Taiwan Province of China through excessive use of ground water) and the salination of freshwater resources in others.

As a result of such negative incidents, the complete withdrawal of culture activities from large pond acreage has occurred in some coastal areas, and questions as to whether shrimp culture is environmentally sustainable have been raised. Comparable

Apart from such erroneous notions, rarely substantiated by quantitative information, lobby groups have rarely appreciated the progress made through the development of "high energy" diets, which have been directly responsible for significant reductions in the amounts of nitrogen and phosphorous in salmonid culture effluent.

It is needless to say that this trend will have to be increasingly pursued with regard to the intensive culture of finfish and crustaceans in the ensuing decades and, indeed, may be considered to be a priority area for sectoral research and development in the new millennium. Pursuance of this goal also has the direct benefit of a decrease in the usage of fishmeal as a protein source in feeds, a resource that is predicted not only to become increasingly issues have surfaced elsewhere in aquaculture. For example, stocks of southern bluefin tuna (Thunnus maccoyii), worth millions of dollars, were lost in cages located off the coast of south Australia, an event thought to have been caused by the upwelling of bottom sediments and anoxic water due to unusual weather conditions. However, these conditions were all attributed to farm effluents and wastes and, hence poor management practices and poor site selection. This incident resulted in the introduction of even more stringent environmental requirements and, of course, restrictions were imposed on the number of potential aquaculture permits to be granted.

Achieving sustainable development of the sector requires that water quality be protected. In many cases, multiple other users also affect water quality, and aquaculture is often a minor contributor to such deterioration as is observed. The sector needs to seek a fairer application of water quality laws, whilst continuously working towards an improved quality of water that is discharged by itself. Similarly, efficient and effective water use will also be an issue that needs to be duly addressed.

More often than not, environmental deterioration has been erroneously attributed to the sector, particularly in respect of excessive discharge of nitrogen and phosphorous in aquaculture effluent. However, when compared to traditional agriculture and municipal waste, the discharge of nitrogen and phosphorous from the sector is minuscule.

costly but whose supply may also become increasingly unreliable (Wijkstrom & New, 1989; Tacon, 1996; De Silva, 1999).

Mangrove destruction

The aquaculture sector, more particularly the shrimp industry, has often been blamed as the main cause for mangrove destruction. In the eyes of experienced aquaculturists and planners, however, the "mangrove" issue is, to all intents and purposes, closed. Nonetheless, as new regions take to shrimp and coastal aquaculture, this subject is likely to resurface again and again. In this context, it is relevant that the purported association between aquaculture and mangrove destruction be assessed by applying the available scientific information, using quantitative information, where possible.

The sector, particularly in the early stages of the expansion of the shrimp industry, was responsible for some degree of destruction. However, it is certainly not the main cause for the dwindling of the world's mangrove acreage. As accurate, quantitative data are being made available, the general belief that shrimp farming was almost solely responsible for mangrove destruction is being increasingly and successfully challenged.

In the case of Thailand, for example, it has been shown that shrimp farming was responsible for the destruction of 17.5 percent or some 65 000 ha of mangroves between 1979 and 1986, as opposed to 35.9 percent (134 000 ha) for other uses (Menasveta, 1997).

Since 1986, the destruction of mangroves in Thailand, the current leader in world shrimp production (227 560 mt in 1997), has decreased significantly and, of the destruction that has occurred, almost none is attributable to shrimp farming. However, the figures available from a few other nations are less encouraging (Primavera, 1998).

It is important that the application of new and effective Codes of Practice is embraced by the sector, throughout the world, enabling the demonstration of responsibility and sustainability demanded by the public. It should go without saying that the sector itself is obliged to communicate such actions to the public.

As pointed out by Phillips and Barg (1999), the positive contributions made to employment and income diversification outweigh the negative aspects associated with shrimp farming, an additional and urgent message for the public. It is unlikely that the shrimp farming industry will continue to make the costly mistakes, economical and environmental, seen in the early stages of the industry. The survival and sustainability of the industry will be determined primarily by the modus operandi of the operating practices, which will, by necessity, have to be environmentally acceptable (Beveridge et al., 1997).

In a nutshell, the new millennium will, in all probability, encounter a shrimp culture industry that possesses different ethics and motives, where the primary goal will not be confined to profitability.

Other environmental issues, such as the responsible use of chemicals, relations between aquaculture development and biodiversity and conflicts with other sectors, for example, tourist development in some coastal areas, will also have to be addressed with a more concerted effort in the new millennium.

A most relevant and revealing topic, which provides evidence in this regard, is rice-fish culture, an old traditional practice that is being revived and will, in all probability, spread to regions other than Asia in the new millennium.

In China, in addition to the approximate 250 kg/ha of fish produced, rice yields from this system were 7.8 percent higher, while the combined harvest gave a total product value that was 41 percent higher than for rice alone (Xuegui et al., 1995). Additional indirect benefits include the reduced use of fertilizer and pesticides (Lightfoot et al., 1990).

Other direct environmental benefits of aquaculture include sewage fish culture, which provides a mechanism for the "stripping" of water with a high nutrient content and the production of fish, which may or may not be used for human consumption, this being determined by cultural inhibitions (Edwards, 1999).

There is a growing trend in developing countries of exploring the possibilities of using aquaculture as a means to strip nutrients from food processing waste (e.g. dairy and processing industries). In this instance the fish, if not directly available for human consumption, might be used to produce other products, or as ingredients in animal feed. For example, in Australia, there is interest in the use of such fish by the pet food industry, another sector that is under pressure to reduce the amount of wild-caught fish used.

There are many other examples of sustainable aquaculture. As pointed out earlier, aquaculture enables the use of certain land resources throughout the year, which would not be possible otherwise, through a form of crop rotation. Polyculture, a relatively common form of rural aquaculture, can also be considered to be a sound and effective sustainable system for the use of environmental resources.

Environmental benefits of aquaculture

As demonstrated in the previous sections, the aquaculture sector has been the target of much criticism from environmental groups, whose content has been exaggerated or ill founded, more often than not. However, the sector needs not only to respond to and refute such criticisms with relevant data, but also needs to enhance its public image. This can be achieved through the use of concerted communication campaigns that focus on the positive, contributory aspects of aquaculture.

Aquaculture, apart from the traditional integration with rice and/or animal farming, is increasingly finding a place for integration with other agricultural systems. Such integration generates a beneficial synergy and contributes towards the sustainable use of primary resources. Good examples of this approach are the shrimp-mangrove-forestry farming systems (Johnston et al., 1999).

Nonetheless, even in the scientific literature, the negative aspects of aquaculture tend to be highlighted, focusing on the environmental effects of the intensive aquaculture of salmonid and shrimp species (e.g., Folke & Kautsky, 1992).

One commonly finds the extrapolation of energy needs and primary resource inputs from intensive farming being applied to the whole sector, a misleading approach, especially since the vast majority of aquaculture is rural, small scale and using semi-intensive to extensive practices.

The examples cited above are not only elements that could be used to enhance the image of aquaculture, they are also demonstrations of how aquaculture is used as a means to add value to other resources.

Socio-economic milieu

Major socio-economic changes have occurred during the last 20 years and, at a global level, these are possibly comparable to what was witnessed at the start of the industrial revolution. The development and the expansion of free-market economies have changed the socio-economic climate of nations, almost without exception.

Very little of these products are for export, the bulk satisfying the increasing demand for a new and different commodity by a growing middle class. Comparable changes are likely to occur with increasing frequency, and the aquaculture sector will have to make suitable adjustments to such demands. Evidently, if the sector's growth is to be sustained, the research and development arm of the sector has to be ahead and capable of providing the production side with the tools it needs.

In the same vein, the sector will also need to take into account that such changes in direction or in activity will have to be accommodated, to a great extent, within the context of the primary resources that are already available. These are principally the resources of land, water and feed materials and, as such, the prudent use of primary resources becomes an imperative.

Such developments can be catered to and

Indeed, some of the major impacts are still being felt a decade or so later, and certainly in the most populous nations that also happen to be “epicentres” of the aquaculture industry, such as China and India. One of the major socio-economic changes that has occurred, and will continue to do so, is the development of a substantial middle class, whose aspirations and demands are also developing. In the nations cited previously, the increasing development of an identifiable middle class will give a significantly high number, although it may be small in terms of population percentage.

As this sector of the population develops, it will demand new and/or improved food products, imposing on the aquaculture industry the need to cater to these requirements, for simple economic reasons. Already such changes are apparent in the sector in China, where the production of high-valued species, such as mandarin fish (Siniperca chuatsi) and the freshwater hairy crab (Erichoeir sinensis), reached production levels of 68 000 and 101 000 mt in 1997, respectively. These production levels were attained within a period of less than ten years. Equally, the production of the softshell turtle (Trionyx sinensis) is in a rapid growth phase, since its production has risen from some 70 mt in 1988 to about 45 000 mt in 1997.

the opportunities grasped, but only if research and development can establish and maintain the leads necessary to move forward. To elaborate the potential of new, and currently, “high-value” species, the question of appropriate funding is raised, as is the morality of using public funds for such activities. It is the generally accepted norm that public funds should be utilized for activities that give the highest return to the community at large. This is essentially tantamount to saying that public funds should be preferentially directed towards funding research that will accrue benefits to the largest sector of the population and, even more so, to the poorer sectors of the population. Implicit in such a stance is that the private sector be encouraged to invest research in the “higher valued” species. However, here it is assumed that poor sectors of the community do not engage in the culture of high-valued species. This is far from the truth. For example, hairy crab and mandarin fish culturists in China are mostly rural farmers. Similarly, developments of the private sector also result in a lot of “spill overs” to the poor, such as by providing direct and indirect employment opportunities, ancilliary small businesses/self-employment opportunities and the like. We are rapidly moving into an era in which it is becoming increasingly difficult to define and/or demarcate beneficiaries of research and development. The diversity of the aquaculture sector, especially with regard to the varying number of species cultured, the extent of the holdings etc. make it even harder to determine the beneficiaries of research, and hence, which should publicly funded.

What is generally known, however, is that private-sector investments in R & D in aquaculture, particularly in developing countries, are relatively low to nonexistent. This is a trend that needs to be changed if the sector is to be sustained in the long term, to the benefit of everybody.

Targets

It is a formidable task to make reasonable and acceptable production forecasts for global aquaculture and for many reasons, including:

- the diversity of the sector, notably the number of major species that are cultured in different systems and at different intensities;
- the changing demands for produce, factors that depend on changes in disposable income and, hence, influence the target markets; and
- the fast-changing nature of the rural sector, as the great bulk of aquaculture is a rural, small-scale activity.

In spite these limitations, an attempt is made here to project qualitative changes which might occur in the sector, and to set quantitative targets to be developed in the new millennium.

All aquaculture development will strive to be sustainable, to all intents and purposes. Sustainable development was defined initially, in the Bruntland Report, as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). A more explicit definition is that proposed by the International Union for the Conservation of Nature (IUCN) - "sustainable development improves peoples quality of life within the context of earth's carrying capacity" (Girardet, 1992). Sustainability, especially in respect of rural, integrated aquaculture, has been expressed

It is arguable whether such a change is needed and, indeed, if such a change would occur in the medium term. As indicated earlier, rural and industrial aquaculture developments will develop hand in hand, much as rural rice production co-exists with industrial rice production, or as small-holdings of cash crops (such as tea, rubber and coffee) co-exist with large industrial "estates" of these crops. In all probability, both rural and industrial aquaculture will continue to contribute to the growth of the sector as a whole. Needless to say, R&D aspects that are common to all forms of aquaculture need to be shared, with information exchange being facilitated. Good examples of shared R & D within rural and industrial aquaculture would be the adoption of a selectively bred strain of a cultured species and effective disease management strategies. The growth of both rural and industrial aquaculture is needed for the well being of the sector as a whole, and they are by no means mutually exclusive.

Qualitative changes

Aquaculture is characterized not only by its very diverse array of cultured products, but also by a wide range of management practices. At one extreme, these are the rural, subsistence-level, low-input practices that often tend to be household oriented. The system used would be depicted typically by the culture of one or two species in a relatively small, shallow pond. At the other end of the scale are those of large-scale industry, which are typically capital intensive, with high primary resource inputs, and market driven. Such industrial practices are represented, for example, by salmon culture in temperate regions and some forms of shrimp culture in the tropics.

Between the two extremes, there are many intermediate examples where it is increasingly difficult to use "industrial" as an appropriate adjective. This could perhaps be defined better by recognizing the point at schematically (AIT, 1994 cf Edwards, 1998), where it was considered in terms of three interrelated aspects.

Recently, it has been suggested that aquaculture is at a cross-roads, and that it will come of age in this millennium. But for this is to happen, the sector will require more responsible research and more integrated research and development approaches than seen at present (Sorgeloos, 1999). In this analysis, it is implicit that aquaculture will only come of age if the bulk of aquaculture changes from food security aquaculture to business/industrial aquaculture.

which, once a production entity exceeds the requirements of the operator, the majority of the produce is sold to third parties. This circumstance is "market-driven" aquaculture. The majority of salmon farming is now deemed to be industrial, while this is not considered to be the case for shrimp culture. The climatic conditions required for the different species mean that salmonid culture has been dominated by the wealthier, industrialized nations, while shrimp culture is spread across both rich and poor nations.

There is considerable inter-relationship between rural and industrial aquaculture and qualitative changes in the systems are expected in the first part of the next century. Indeed, the inter-relationship can be considered as a modified image of that depicting extensive, semi-intensive and intensive aquaculture practices (Tacon, 1987). It is anticipated that there will be a shift within the rural aquaculture sector towards a higher degree of intensification, a strategy driven by the need to make more effective and efficient use of natural resources.

In addition, the scope of industrial aquaculture will increase significantly. However, the intermediate practices, which are oriented towards the production of carps and other species low in the trophic chain, will probably continue to dominate and lead global production. This situation will ensure that the sector will retain its contribution and importance in respect of the existing and burgeoning global problems

While various forecasts have been made of the needs for fish and fishery product of the future, as well for aquaculture production, the most comprehensive of these is that of Ye (1999). This forecast is based on models for each global region (Africa and the Near East, Asia, Europe, Latin America, North America and Oceania), each of which was based on the historical data of individual nations for consumption patterns and gross domestic production (GDP). From this analysis, the world demand for fish and fishery products was forecast to be 183 million mt in 2030, which corresponds to an increase of 95 million mt over the 1995 fish consumption. More importantly, the increase in demand is only 110 percent when compared to the figure obtained over the last 35 years, which was 210 percent. In other words, the global demand of 183 million mt in 2030 will also represent an increase in per caput consumption from 15.6 kg to 22.5 kg (+44 percent), which is lower than that between the previous 35 years (1961-1995; 8.3 kg to 15.6 kg [+88 of poverty alleviation, food security and employment in rural areas.

In other words, the sector will continue to retain and honour its primary objectives and will also contribute substantially to the economy of major aquaculture nations.

Production targets

Predicting or setting production targets for the sector cannot be done without considering three factors:

- the predicted changes in the capture fishery sector,
- the per caput consumption trends of fish and fishery products, and
- the trends in population growth.

The most variable of these factors is the per caput consumption of fish and fishery products and the trends observed (Ye, 1999). However, unlike most commodities, it is believed that consumption of fishery products is predetermined (Bird, 1986) and that, for a perishable commodity such as fish, production is very nearly equal to domestic consumption (Fox, 1992). This implies that the volume of fish production is a variable which is determined independently of the price of fish, particularly in respect of capture fisheries. As the world becomes increasingly dependent on aquaculture for the supply of its fish and fishery products, the scenario described is bound to change, and market demand theories will increasingly come into play.

percent]).

In contrast to the prediction cited above are those forecasts for aquaculture production which have been based on the core premise that aquaculture will be required to meet the demands resulting from population growth but static capture fisheries. These forecasts are based generally on current per caput consumption rather than trends of consumption.

Challenges and opportunities

At a global level

Each and every forecast made for aquaculture in the new millennium provides a major challenge, while offering, at the same time, a host of opportunities, although these will differ, to a greater or lesser extent, between nations, regions and continents. There is a clear call for the development of suitable strategies, be they national, regional or inter-regional, where the sharing of information is commonly highlighted. To be concise, the global strategies may be two-fold:

- to increase aquaculture production significantly, so that it continues to have an impact on food security, employment generation and social equity; and
- for all development to be sustainable and environmentally sound.

In order to achieve these primary objectives without compromising any of the basic goals of aquaculture, there are common challenges cum strategies that the sector will have to face. The major ones10 are seen to be the following:

Technical challenges

The individual technical challenges, and the research and development needs of the sector, are treated under separate themes within this publication. Those that are likely to confront the sector are not insurmountable, provided that a coordinated effort is made and the required human resources are available. It is relevant, at this point, to highlight the main technical needs and advances that are needed by the sector so that it can meet the production targets, within a milieu of sustainability. Foremost amongst these are:

- genetic improvement of major aquatic species used in aquaculture;
- feed developments, encompassing both a decreasing dependence on fish meal as a major protein source in feeds and a lowering of nitrogen and phosphorous in effluent; and
- improvements in the health management of cultured organisms.

The above technical challenges were also previously identified as being crucial to the envisaged development of the sector (Sorgeloos, 1999).

The genetic improvement of cultured aquatic organisms has lagged behind considerably other food production sectors (i.e. plant crops and animal husbandry). Amongst the species reared, some improvement in performance has been achieved through genetic selection in only two fish groups, namely salmonids (Gjedrem, 1997), and tilapias [Nile tilapia] (Bensten et al., 1997). This appears as a poor record for a sector that is based on the culture of over 200 aquatic species, and of

Dietary developments, on the other hand, represent an area that has made significant progress, particularly in respect of improved effluent quality and reductions in fishmeal content. However, the sector will be able to realise the envisaged growth only if the reliance on fishmeal is reduced or, at least, if the increase in fishmeal requirements is not directly proportionate to the increases in aquaculture production. Since 1990, the amount of fish available for reduction to fishmeal has levelled off, between 22 and 25 million mt of wet fish (Grainger & Garcia, 1996), and most believe this situation is unlikely to change. The projections for the feed requirements of the aquaculture sector differ between authors (see De Silva, 1999), but an estimated median figure for the fishmeal requirement is about 1.5 million mt. Although much research and development is being done in respect of fishmeal substitution in diets, an additional problem is likely to be the supply of fish oil. While this aspect has received scant attention as yet, it will also provide a major challenge for researchers in the ensuing years.

Disease is recognized clearly to be one of the most significant constraints to aquaculture production and trade, affecting both economic and socio-economic development in many countries of the world. Within the shrimp culture sector, disease is currently considered to be the single most important limiting factor on production. Although environmental factors, such as poor water quality due to effluent and waste mismanagement, have been implicated in major disease outbreaks, the underlying cause(s) of epizootics are usually more complex and difficult to pinpoint. Experience in trying to control aquatic disease outbreaks demonstrates the importance of taking all components of the production system into account. This includes the need for broader “ecosystem management” approaches, actively preventing environmental deterioration, as well as the introduction of pathogens which most of the important species have a relatively short life cycle. Furthermore, when one considers that more than 75 percent of aquaculture production occurs in the tropics, the achievements for the genetic improvement of appropriate species and the concomitant sectoral impact are almost negligible. One could envisage, therefore, considerable scope for improved production performance through genetic improvement. In addition, issues concerning the use of transgenic organisms will be in the forefront, and researchers and developers will have to confront associated public perceptions before such technical advances can be fully transferred to the production sector.

through live introductions and transfers. This is otherwise known as the "systems management approach" (SMA) to aquatic animal health.

Controlling all aquatic diseases would require a level of understanding that we lack at present, not only in respect of the pathogens themselves but also for the host. For example, many important aquaculture species require accelerated investigation, at the molecular level, of both the host and its pathogens, in order to improve the efficacy of proposed therapies and other disease prevention measures. Such work must go hand-in-hand with a concerted effort to develop certified domesticated stocks.

Protocols for the safe transboundary movement of aquatic animals and animal products form a first line of defence against the inadvertent introduction or transfer of infectious pathogens or diseases. Countries which are particularly vulnerable in this respect are those that depend on imported broodstock and fry to sustain their aquaculture industries. Protocols must therefore be developed for the needs for sustainable culture within national, regional or international contexts. Detailed Codes of Practice have been developed by international organizations to address minimizing the risks associated with introduction and transfer of live aquatic organisms. These provide a good starting point for conceiving appropriate national fish health legislation and related international agreements.

However, to be maximally effective, such efforts must be accompanied by:

Similarly, an imperative for the new millennium is that such networking is extended further, and this theme could, in all probability, be the dominant issue in the short term. The core of this should be inter-regional cooperation and networking that focuses on facilitating the transfer and exchange of technology and information, education and training and the dissemination of relevant knowledge to all. Involvement in longterm research and development programmes is also seen as a key priority in cooperative programmes. It is heartening to see that some headway has been made recently in this regard when the Network of Aquaculture Centres in Asia-Pacific (NACA), an inter-governmental regional body in Asia, entered into a memorandum of understanding with the Peruvian government.

Governmental role

The role of government will undoubtedly be

- agreed lists of certifiable pathogens,
- the standardization of acceptable diagnostics techniques, and
- the presentation of health certificates of unambiguous meaning.

The establishment of intra- and inter-regional fish health information systems, linked to those of relevant regional and international agencies, would also be a significant support for regional aquatic animal health control efforts. The success of such programmes depends entirely on strong commitment by national governments, as well as that of the producer and the import/export sectors. Mutually acceptable approaches to health control benefit all of those concerned, where sectoral participation in the formulation of appropriate health control programmes reduces further the risk of noncompliance and the spread of disease.

Inter-regional cooperation

It is often conceded that the Asian dominance in global aquaculture is partly a result of effective cooperation amongst the nations of this region, especially in facilitating the transfer, adoption and extension of technology. A significant part of this is due to the institutional frameworks that were established over 20 years ago and have become increasingly effective, leading the nations through the path of sustainable development. Unfortunately, however, the equivalent structures in Africa and Latin America did not reach a position of self-reliance, and the time is now perhaps ripe for these institutions to be reconstituted and nurtured.

the most variable element in the aquaculture development equation. The suggested roles for government range from zero involvement to complete control of aquaculture development. In the early years of this millennium, national governments will have to make crucial decisions concerning the sector, particularly in regard to its role in extension services and active participation in regional and inter-regional institutions. Governments will also need to establish suitable policies to facilitate and augment aquaculture development and, most of all, remain alert to the establishment of fair legislation and not be subject to the dictates of various lobbyists. Governments need to accept that regulatory frameworks have to be fair whilst being responsible and responsive to identifiable problems and constraints.

The governmental role has to go beyond mere "policing" of the sector's activities and be developed, so that it encompasses working hand-in-hand with practitioners. To be more effective than in the past, government should make investments in partnerships, where appropriate and needed, in order to solve common problems. One of the best examples that can be given is the partnership made for the development, including investment, of seawater irrigation systems for shrimp culture in Thailand (Tookwinas & Yingcharoen, 1999). This specific example will enable, in all probability, this nation to maintain its dominance in the shrimp culture industry. Indeed, this example essentially encompasses the establishment of cultivated/culture areas, supplying the required infrastructure. It reflects a policy that requires serious consideration by other nations, at least by those which are seeking to expand their industrial aquaculture activities, which otherwise tend to happen in clusters.

Lee (1997) suggests that such demarcation of culture areas, accompanied by the provision of appropriate infrastructure, will avoid the over-exploitation of ground water, improve water quality management and provide a range of other benefits.

It is important, and indeed crucial, that governments give sufficient recognition to the sector. It is a fact that the sector has almost always played second fiddle to agriculture and fisheries, for instance. While recognizing that, in most countries, agriculture contributes more than aquaculture to the GDP, it is timely that governments recognize both the contribution and the development potential of the sector, providing the recognition it deserves in national planning and policy development.

Nonetheless, it has also to be conceded that the practitioners in the sector, particularly in the "epicentres" of activity, are not sufficiently organized into professional groups or other suitable organizations. The lack of suitable organizational elements corresponds directly to the lack of proper representation with government. In the new millennium, it is expected that, accompanied by appropriate governmental recognition of the sector, representative associations of the sector will take root, and work responsibly in conjunction with governments.

Other challenges and opportunities

Culture-based fisheries

As pointed out previously, the availability of resources (land and good quality water) for expansion of the area allocated to aquaculture is likely to be small. Consequently, the majority of the

The annual yield of culture-based fisheries in China is known to be around 740 kg/ha, totalling over 1 million mt, having experienced an estimated annual increase in production of 53 percent since 1979 (Song, 1999). More importantly, this development has been achieved through a long planning process, starting with the planning stages of reservoir impoundment (when fishery needs were taken into consideration) and augmented by a concerted management strategy in which stocking size, species ratio, harvesting time and methods have been well researched, developed and extended. Large areas of small-sized reservoirs are available throughout the tropics (Sugunan, 1997; De Silva, 1996), and numerous attempts have been made in the past to utilize such resources (De Silva, 1988). In South America, of the estimated 1 million ha of reservoir surface, only about 12 percent is used for fish production, and this not as effectively as it could be (Hernández-Rodríguez et al., this volume).

Culture-based fisheries are attractive to most environmental groups, as the activity entails little to no manipulation of the environment, except in cove culture (Lu, 1986). A good example of the effectiveness of culture-based fisheries in increasing fish production is China. In China, a well planned and executed stock and recapture strategy yields an average of 743 kg/ha/yr, which has resulted in the production of 11 605 075 mt in 1997 from culture-based fisheries (Song, 1999). Also, the improvements to culture-based fishery practices in China have resulted in 52.5 percent per annum growth of the fishery between 1979 to 1997 (Song, 1999).

Culture-based fisheries, however, will continue to use exotic species where production increases foreseen will have to be obtained through increased productivity. Many nations are now examining the possibilities of using inland lakes and reservoirs to improve and/or start culture-based fisheries11. Indeed, this subject is seen as a major means of enhancing fish production, and Welcomme (1996) estimated that this form of aquaculture is one of the fastest expanding sectors of fisheries. The aims will differ between nations and regions since, in the developed world, sport fishing will be the main result while, in developing countries, culture–based fisheries provide an easy access to a source of animal protein.

appropriate (e.g. where the exotic species already exists or where environmental impacts have been minimal). Exotic species have often proven to be the ones that give the most effective and profitable yields (De Silva, 1988; Quiros, 1994). In general, most successful stocking and enhancement programmes involve both introduced and native species (Born, 1999). This stance should not be misunderstood as being an advocacy for introducing exotic species; the introduction of new species is a practice that seems to be decreasing globally.

The responsible use of exotic species is advocated here and best achieved by following internationally accepted codes of practice and guidelines such as those of the International Council for the Exploration of the Sea (ICES) and the European Inland Fisheries Advisory Commission (EIFAC) (e.g. ICES, 1995).

Reservoirs can also provide a suitable means for the expansion of inland cage culture, which is also often seem as a means of alternative employment to displaced persons (Costa-Pierce and Soemarwoto, 1990), as well as for rural communities that live in the vicinity. In some instances, such developments have assumed industrial proportions, on a collective basis, and many nations view inland cage culture as a major option for development in the immediate future. Needless to say, cage culture development in such water bodies has to be managed very carefully, both from the environmental and social points of view.

It is relevant, at this time, to pose the question whether or not researchers need to be oriented towards a systems approach. In hindsight, one could argue that if a systems approach had been applied to the research sector, the losses due to the many epidemics during the last decade might have been minimized. In the new millennium, researchers with different expertise will have to work together and not in watertight compartments, and this target should be considered a priority.

In most nations, and indeed in some regions (e.g. Africa), one of the biggest impediments to successful aquaculture development is seen as being the lack or improper extension of technology. A classic example of this is the observation of Gregory (1999), on the understanding on stock maintenance of a rural fish farmer in Uganda. Extension is an essential ingredient for the sustenance of rural aquaculture and, in this regard, Asian know-how on rural aquaculture should be used to the best

One of the key limitations experienced in this activity is the availability of suitably sized fingerlings for the development and maintenance of rural aquaculture activities, primarily those based on pond culture. Such limitations cause the stocking of under-sized fingerlings, or even fry, which results in suboptimal yields. This important factor is not a result of inadequate hatchery technology, but is due mostly to having inadequate facilities for fry to fingerling rearing, and distribution of the live fish to the area of culture. It will be appropriate to explore the possibility of using reservoir resources for enhancing such nursery aquaculture activities.

Education, training and extension

The education and training needs of global aquaculture, as well as the extension requirements, will be different within the regions, following the degrees of sectoral development. For example, in Asia, training and education is fairly satisfactory at the farmer level, this being an ongoing activity facilitated by regional bodies such as NACA. In most regions, extension workers have a very strong commodity and/or discipline-oriented background. In view of the envisaged aim,that aquaculture should move rapidly towards sustainable development, a more holistic approach would need to be superimposed over the classic methodology. Regional institutions are likely to play an increasingly important role in providing guidance at the national level in this regard.

benefit of Africa, for example, through the vehicle of regional cooperation.

Certain regions are perhaps ready for the next step forward, which can only be achieved through technological advances and development. In Asia, on the other hand, a contrasting situation is to be seen. While there is already a large amount of knowledge available on small-scale/rural aquaculture, the dissemination of this knowledge to practitioners is, unfortunately, less effective than desired. On the other hand, Asia will also need to prepare for the next technological leap, which calls for a rationalization of its education programmes and the acquisition of critical mass of researchers, a subject which is discussed in detail in elsewhere in this volume.

The issues concerning education, training and extension are closely linked to capacity building and the development of human resources. This aspect requires to be accelerated within the aquaculture sector if it is to maintain its growth momentum in an environmentally sustainable milieu. In view of the rapid developments concerning communication using information technology, the sector will have to be increasingly innovative in the methods of the dissemination of knowledge.

Markets and marketing

Marketing issues are common to both rural and industrial aquaculture, but the manner of their handling may be different. These are issues that are common to the sector in both developed and developing countries.

Poor understanding and weak marketing are often seen as hindrances to aquaculture development in Europe (Varadi et al., present volume). Similarly, in Latin America, rural aquaculture has difficulty in making significant impetus due to lack of suitable markets for the produce (Hernández-Rodríguez et al., present volume).

It is not uncommon for sectoral analysts to refer to aquaculture products as being high- and low-valued commodities. In the past five to ten years, some notable changes have occurred within the national and international markets for aquaculture products, where the specific examples of Atlantic salmon, European seabass and tilapia can be cited. These changes are not only in respect of prices, but also the market destinations. The prices of Atlantic salmon and European seabass have diminished considerably (-53 percent in both cases), their target markets being those that displayed keen competition (with other fish or food products) but which were also restructuring (shifting towards the multiple retail store, away from the fishmonger, as the point of sale). While this has been attributed to being a result of "industrial" methods of production (New, 1999), this is perhaps a simplistic conclusion. As in many sectors, the aquaculture sector of the developed countries is no exception, the producer does not control the price; the sector has to adapt to market changes and demands, which are predominantly influenced by consumer preferences.

On the other hand, tilapia, once mooted as the "aquatic chicken" of the 1980s and the "poor man's fish" (Smith & Pullin, 1984), has established a position within the supermarkets in developed countries. The success of tilapia is, without doubt, linked to the provision of fillets at a reasonable price, giving consumer satisfaction. A parallel "success" story is that of the Nile perch fillet (Lates niloticus), a product that has

The case in point is the aquaculture development in the Mediterranean Region in the past decade, during which dramatic price reductions have been seen for both European seabass and gilthead seabream, 34 percent in the last three years alone (see the European review by Varadi et al., this volume). Different interpretations exist for this phenomenon, including the considerations of oversupply and inadequate marketing efforts. An interesting analysis, from within the sector itself (Federation of European Aquaculture Producers (FEAP), pers. comm.), is that there were too many suppliers, who are geographically dispersed, for relatively few buyers, who were concentrated in one major market, namely Italy. It was estimated recently, that six to seven points of purchase are responsible for over 75 percent of fish sales in France.

It has been suggested that aquafarmers are weak individual players within modern economic activities (Lee, 1997), where the author believes that governments need to provide a helping hand to organize producers within structures (e.g. cooperatives or associations), which in turn should assume the marketing and sale of the produce. Indeed, this is the position adopted within the European Community (EC), where producer organizations12 are being increasingly used as the entities for marketing and sales. It has been argued that dearth of cooperative marketing has resulted in unfavourable prices, making aquaculture less economical.

Conclusions

We are in a new millennium that promises to deliver breathtaking changes in our lives. Plausible developments that have been put forward range from humans stepping onto Mars to the near eradication of most diseases caused by genetic disorders. The human genome has been unravelled and our lives are likely to be dominated and established its place in the European market, without much advertising, on the basis of being an inexpensive, boneless fillet.

A common pattern has been the early focus on established markets followed by market diversification (i.e. targeting different markets or providing different products) when prices are too competitive or market saturation (for the product concerned) is identified. These circumstances impose on the supply sector the requirement to market their product, a situation in which few producers have real experience.

Where aquaculture production has increased, but is not associated with concurrent market development, market crashes can occur.

revolutionized by biotechnology developments as they were with the transistor, plastics and the microchip during the last 50 years of the previous millennium. In spite of these miracles of technology, a major issue that faces the globe remains poverty and the feeding of the hungry.

This does not appear to be an easy task when the trends of food production are taken into consideration. The world has experienced a decline in the rate of growth of agricultural production, dropping from an annual increase of about 3 percent in the 1960s, the period of the "green revolution", to 1.6 percent in the period 1986-1995.

The outlook until 2010 is an annual growth of 1.8 percent, a position that is only marginally better (FAO, 1999). When this prediction is combined with the growing concerns for improvements in health and human well being, and with no further increases to the aquatic food supply from capture fisheries, aquaculture may well have an increasing role to play in the next decade and beyond.

Aquaculture should become the mainstay in the supply of aquatic food supplies in the new millennium. This is not an unrealistic goal. However, this will be achieved only if further developments in aquaculture are environmentally sustainable at all levels. The primary aim of increasing aquaculture production should be pursued in conjunction with

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alleviating poverty and contributing to food security of the masses. Indeed, none of these aims are mutually exclusive, and all can be pursued in such a manner as to generate synergies that will help the cause further and allow aquaculture to respond to the hopes anticipated.

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[2] LIFDC's having an average per capita income less than US$1 505/annum in 1996.

[3] For the purpose of this review, all aquaculture production data were obtained from FAO FISHSTAT PLUS Version 2.3. http://www.fao.org/fi/statist/fisoft/fishplus.asp.

[4] Individual species do not include freshwater fishes nei (not elsewhere included) and sea mussels nei from the statistical data.

[5] In this volume China refers to Peoples Republic of China.

[6] Including China, Hong Kong SAR and Taiwan Province of China.

[7] Calculated from the total value divided by total production (FAO Statistics).

[8] See review for this region by Varadi et al. in this volume.

[9] MGA was calculated by determining the percentage rate of increase in production per annum, over a decreasing time scale; for example if the production was y1, y2 and y3 in years x1, x2 & x3, respectively, and the period x1 to x3 was ten years, then the ten-year average is y3-y1 ¸ x3-x1 (=10) and the moving average between years x2 and x3 will be y3-y2 ¸x3-x2 and so on.

[10] More specific issues, including those concerning food safety and trade, regulatory frameworks etc., are treated separately within this publication.

[11] see Regional Reviews, this volume.

[12] Producer organizations have to be officially recognized by national governments and the European Commission

Part V - Bangkok Declaration and Strategy

Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000

1. Preamble

The first international Conference on Aquaculture organised by the Food and Agriculture Organization of the United Nations (FAO) was held in Kyoto, Japan in 1976. The Conference adopted the "Kyoto Declaration on Aquaculture."

In February 2000, some 540 participants from 66 countries participated in the "Conference on Aquaculture in the Third Millennium" in Bangkok, Thailand. This Conference was organised by the Network of Aquaculture Centres in Asia-Pacific (NACA) and the FAO and hosted by the Government of Thailand.

Throughout 1999, NACA and the FAO facilitated the preparation of reviews on aquaculture developments in Africa, Asia, Europe, Latin America, North America, the countries of the former USSR, the Near East, and the Pacific Island nations and held

2. The declaration

We, the participants to the Conference on Aquaculture in the Third Millennium, Bangkok 2000, recognise that:

2.1 during the past three decades aquaculture has become the fastest growing food-producing sector and is an increasingly important contributor to national economic development, the global food supply and food security;

2.2. aquaculture consists of a broad spectrum of users, systems, practices and species, operating through a continuum ranging from backyard household ponds to large-scale industrial systems;

2.3 the per caput supply of food fish from capture fisheries is likely to decline with population increase;

2.4 a great proportion of aquaculture production comes from developing countries, where expert meetings to consider trends in aquaculture development. Thematic Reviews on various aspects of aquaculture were also conducted. Participants to the Bangkok Conference were informed of the findings and conclusions of these activities.

Against this background, the Conference participants discussed strategies for the development of aquaculture for the next two decades, in the light of the future economic, social and environmental issues and advances in aquaculture technologies.

Based on these deliberations, the participants to the Conference adopted the following Declaration.

aquaculture will continue to contribute to peoples' livelihoods, food security, poverty alleviation, income generation, employment and trade;

2.5 there has been a significant increase in commercial and industrial aquaculture, both in developed and developing countries, that has contributed to food supply, export income and trade;

2.6 globally, aquaculture is at varying stages of development and will require different strategies for growth;

2.7 the potential of aquaculture to contribute to food production has not yet been realised across all continents;

2.8 aquaculture complements other food production systems, and integrated aquaculture can add value to the current use of on-farm resources;

2.9 aquaculture can be an entry point for improving livelihoods, planning natural resource use and contributing to environmental enhancement;

2.10 responsible aquaculture practitioners are legitimate users of resources;

2.11 education and research will continue to make a significant contribution to the growth of aquaculture;

2.12 some poorly planned and managed aquaculture operations have resulted in negative impacts on ecosystems and communities;

2.13 aquaculture has also been negatively impacted by other unplanned activities;

2.14 the continued growth of aquaculture will occur through investment by the private and public sectors;

2.15 effective national institutional arrangements and capacity, policy, planning and regulatory frameworks in aquaculture and other relevant sectors are essential

2.20 aquaculture policies and regulations should promote practical and economically viable farming and management practices that are environmentally responsible and socially acceptable;

2.21 national aquaculture development processes should be transparent and should take place within the framework of relevant national policies, regional and international agreements, treaties and conventions;

2.22 in pursuing development, States, the private sector, and other legitimate stakeholders should co-operate to promote the responsible growth of aquaculture;

2.23 strengthened regional and inter-regional co-operation should increase the efficiency and effectiveness of aquaculture development efforts; and2.24 all parties formulating improved policies and implementing practices for aquaculture development should consider and where appropriate, build on the FAO Code of Conduct for Responsible Fisheries.

The following contains the major strategy elements based on the Conference session recommendations. The detailed recommen-dations from the sessions are given in the Conference Report.

to support aquaculture development;

2.16 improving co-operation amongst stakeholders at national, regional and inter-regional levels is pivotal for further development of aquaculture;

2.17 the potential of aquaculture to contribute to human development and social empowerment cannot be fully realised without consistent, responsible policies and goals that encourage sustainable development;

and declare that:

2.18 the aquaculture sector should continue to be developed towards its full potential, making a net contribution to global food availability, household food security, economic growth, trade and improved living standards;

2.19 the practice of aquaculture should be pursued as an integral component of development, contributing towards sustainable livelihoods for poor sectors of the community, promoting human development and enhancing social well-being;

3. Strategy for aquaculture development beyond 2000

States are encouraged to incorporate in their strategies for aquaculture development the key elements identified during this Conference.

The key elements are:

3.1 Investing in people through education and training

- Further investments in education and training are essential to build the knowledge, skills and attitude of all people involved in the sector. Human capacity development can be made more cost-effective and responsive to needs through:
- using participatory approaches to curriculum development;
- improving co-operation and networking between agencies and institutions;

- multidisciplinary and problem-based approaches to learning;
- use of modern training, education and communication tools, such as the Internet and distance learning, to promote regional and inter-regional co-operation and networking in the development of curricula, exchange of experiences and development of supporting knowledge bases and resource materials; and
- providing a balance of practical and theoretical approaches to train farmers and provide more skilful and innovative staff to industry.

3.2 Investting in research and development

There is a need to increase investment in aquaculture research, whilst making efficient use of research resources and building the capacity of research institutions to be more responsive to development requirements through such mechanisms as:

- collaborative multidisciplinary research;
- stakeholder participation in
- providing effective mechanisms for access to relevant and reliable information to all stakeholders; and
- making effective use of new technologies to improve information flows and management policies and practices within aquaculture.

The collection and dissemination of accurate and verifiable information on aquaculture may help to improve its public image and should be given attention.

3.4 Improving food security and alleviating poverty

Enhancing food security and alleviating poverty are major and complementary global priorities. Aquaculture has a special role in achieving these objectives because, firstly, fish is a highly nutritious food that forms an essential, if not indispensable, part of the diet of a large proportion of the people in developing countries. Secondly, while aquaculture contributes to the livelihoods of poor farming households, particularly in areas of Asia where it is a traditional farming practice, there is a huge,

research identification and implementation;
- improving linkages between research, extension and producers;
  collaborative funding arrangements between institutions and public and private sector organisations;
- efficient communication networks;
- regional and inter-regional co-operation; and
- a continued effort to build the skills of researchers involved in aquaculture development.

3.3 Improving information flow and communication

Efficient management of the sector requires improved information flows at the national, regional and inter-regional levels which will avoid duplication of effort and save costs, while encouraging consistency in areas such as education and training, policy-making, planning and the application of rules and procedures.

Improved information flows will increase institutional capacities for dealing with emerging issues and can be achieved by:

- establishing arrangements for sharing data and information;
- strengthening national capacity to determine data

unfulfilled potential in most countries, as aquaculture is a relatively recent and underdeveloped sector as compared to agriculture and animal husbandry. Aquaculture could improve food security, provide entry points and contribute to sustainable livelihoods for the poor through:

- promoting poor-people-centred development focus in aquaculture sector policies, wherever appropriate;
- promoting systems to farm low-value fish affordable to the poor, particularly small-scale household production in rural areas where it may be the only source of fish due to poor infrastructure;
- disseminating information about the nutritional advantages of fish to vulnerable groups of people such as pregnant and lactating women, and families with infants and pre-school children;
- greater use of holistic, participatory approaches to identify the poor and assess their needs; and to develop and extend aquaculture technologies appropriate to the resources and capabilities of poor households;
- recognising that the development of small-scale

requirements and data selection and management;

aquaculture requires initial public sector support, with more support needed and for longer periods for poorer target groups; and

- empowering poor stakeholders to actively participate in policy decision-making.

3.5 Improving environmental sustainability

There is a need to develop and adopt policies and practices that ensure environmental sustainability, including environmentally sound technologies and resource efficient farming systems, and integration of aquafarms into coastal area and inland watershed management plans. Improvements in environmental sustainability can be achieved through:

- development, adoption and application of environmental, economic and social sustainability assessment criteria and indicators of aquaculture development;
- integrating aquaculture with other rural development efforts to improve resource utilisation, such as integrated coastal area management and inland watershed management;
- awareness-raising in other rural development sectors of the potential of aquaculture to improve livelihoods;
- using participatory approaches to involve stakeholders in policy-making, planning, implementation and monitoring; and
- the documentation and wide dissemination of information on experiences and utilisation of good practices and benefits thereof.

- development of and support to implementation of improved management practices and codes of good practice for aquaculture sectors that are supported by enforceable regulations and policy;
- research and development of resource-efficient farming systems which make efficient use of water, land, seed and feed inputs; exploring the potential for commercial use of species feeding low in the food chain; and utilising enhancement techniques;
- development of strategies to integrate aquaculture into the coastal areas and inland watershed management plans and ensuring aquaculture developments are within local and regional carrying capacities;
- promotion of good practices for environmental management of aquaculture; and
- promotion of aquaculture, where appropriate, as a means of improving environmental quality and resource use.

3.6 Integrating aquaculture into rural develoment

With the goal of increasing the impact of aquaculture on rural

3.7 Investing in aquaculture development

Future investment in aquaculture should be made with long-term strategies in mind to ensure sustainability. Private sector investments make the biggest contribution to aquaculture development, but adequate public sector finance for capacity building, institutional development and infrastructure, is indispensable for society to reap the full benefits of a well managed and efficient aquaculture sector.
Sound investment strategies should include:

- providing initial financial encouragement and facilitating investments in aquaculture development;
- encouraging continued public investment in rural and small-scale aquaculture in developing countries, and in applied research and farmer access to knowledge and capital;
- encouraging private sector funding and investment in aquaculture development and infrastructure which will provide the benefits of aquaculture to rural communities;
- developing mechanisms (e.g., investment screens, credit linked to performance or

development and poverty alleviation, strategies are required to put people as the focal point for planning and development for such programmes and to integrate aquaculture into overall rural development programmes. In essence, this can be achieved through:

- integrating aquaculture planning within overall rural development planning, taking into account multi-sectoral developments and views, and multi-sectoral co-ordination which brings agencies together;

adoption of best management practices, performance bonds) which encourage the growth of environmentally and socially responsible aquaculture, including economic, educational and other incentives for responsible aquaculture;

- support to sponsorship of industry-driven codes of practice to promote responsible aquaculture;
- fostering a greater understanding within financial institutions and bilateral and multilateral assistance agencies regarding aquaculture development and its financial needs; and

- establishing credit schemes that support sustainable aquaculture, e.g., micro-credit programmes, particularly for small-scale development.

International development assistance is becoming increasingly directed towards poverty alleviation and needs to adhere to basic principles of social equity, including

- developing mechanisms and protocols for the timely collection and reporting of statistics;
- sharing information on policies and legislation, rules and procedures that encompass best practices in aquaculture;
- clarifying legal frameworks and policy objectives regarding access and user

gender equity, environmental sustainability, technical feasibility, economic viability and good governance. The level of risk is important when supporting initiatives to address poverty alleviation.

To make efficient use of international donor resources, a programme approach to multi-sectoral development should be applied under which donors can more effectively co-operate and collaborate with each other. Ultimately, this should occur within comprehensive planning and development frameworks. There is thus a need for donors to adopt more cohesive approaches and procedures.

3.8 Strengthening institutional support

One of the key issues for the growth of aquaculture will be the ability of countries and organisations to strengthen their institutional capacity to establish and implement policy and regulatory frameworks that are both transparent and enforceable. Incentives, especially economic incentives, deserve to be given more attention in the planning and management of aquaculture development.
Institutional capacity should be made more effective and

rights for farmers; and
- improving the capacity of institutions to develop and implement strategies targeting poor people.

3.9 Applying innovations in aquaculture

The technologies for sustainable aquaculture development should provide a varied and adaptable “tool box” from which people can select and design the system which most effectively meets their needs and best fits the opportunities and constraints of the local environment. The delivery of such techniques requires efficient communication networks, reliable data on the merits and drawbacks of the various approaches, and help with the decision making process through which people choose their production systems and species.

As we move into the next two decades, water and land for aquaculture will become critical issues. New opportunities for aquaculture development will also emerge through improvements in science and technology for aquaculture systems.

The potential areas for further consideration include:

- technologies for sustainable stock enhancement and strengthened through:

- developing a clear aquaculture policy, andidentification of a lead agency with adequate organisational stature to play a strong co-ordinating role;
- developing, through a participatory approach, comprehensive and enforceable laws, regulations and administrative procedures that encourage sustainable aquaculture and promote trade in aquaculture products;
- providing education and training, research and extension services to support the development of enforceable legislation, policy and regulatory frameworks, encompassing economic and other incentives to improve aquaculture management;
- targeting not only government ministries and public sector agencies dealing with administration, education, research and development, but also organisations and institutions representing the private sector, NGOs, consumers and other stakeholders;

ranching programmes, and open ocean aquaculture;

- increased use of aquatic plants and animals as nutrient stripping;
- increased emphasis on integrated systems to improve environmental performance; and
- emerging technologies (e.g., recirculating systems, offshore cage culture, integrated water use, artificial upwelling and ecosystem food web management).

3.10 Improving cultured-based fisheries and enhancements

Fisheries enhancements in inland and coastal waters include culture-based fisheries and habitat modifications in common pool aquatic resources, which require minimal food and energy inputs.

These practices therefore provide important opportunities for resource poor sections of the population to benefit from relevant aquaculture technologies and permit efficient use of under-utilised, new or degraded resources. Culture-based fisheries in particular have considerable potential for increasing fish supplies from both freshwater and marine fisheries and generating income in rural inland and coastal areas.

The full potential of enhancements and culture-based fisheries could be achieved by:

- creating conducive institutional arrangements to enable and sustain investment in common pool resources;
- providing appropriate research and development inputs;
- managing environmental and other external impacts; and
- promoting effective regional co-operation and information exchange.

3.11 Managing aquatic animal health

Disease is currently an important constraint to aquaculture growth which has impacted both socio-economic development and rural

and sensitive diagnostic methods, safe therapeutants, and effective disease control methodologies, and through studies into emerging diseases and pathogens;

- promoting a holistic systems approach to aquatic animal health management, emphasising preventative measures and maintaining a healthy culture environment; and
- developing alternate health management strategies such as the use of disease resistant, domesticated strains of aquatic animals to reduce impact of diseases.

Establishment of an effective international mechanism, such as an international task force which is outcome-oriented with focused strategies and milestones that are independent of vested interests, would be beneficial in reducing the losses due to diseases in aquaculture.

3.12 Improving nutrition in aquaculture

Nutrition and feeding strategies play a central and essential role in the sustainable development of the aquaculture sector. Feed livelihoods in some countries. Addressing aquatic animal health issues has, therefore, become an urgent requirement for sustaining growth of aquaculture, especially through pro-active programmes. Harmonising health protection approaches and measures and effective co-operation at national, regional and inter-regional levels are needed to maximise the effectiveness of limited resources.

This can be achieved through:

- developing, harmonising and enforcing appropriate and effective national, regional and inter-regional policies and regulatory frameworks on introduction and movement of live aquatic animals and products to reduce the risks of introduction, establishment and spread of aquatic animal pathogens and resulting impacts on aquatic biodiversity;
- capacity building at both the institutional and farmer levels through education and extension;
- developing and implementing effective national disease reporting systems, databases, and other mechanisms for collecting and analysing aquatic animal disease information;
- improving technology through

development will need to give increased emphasis on efficient use of resources and reduction of feed waste and nutrient discharge. Fishmeal reduction in diets will be important to reduce feed costs and avoid competition with other users.

These can be achieved through:

- increasing the understanding of dietary nutrient requirements of cultured species, including their application to practical culture conditions;
- developing species-specific broodstock diets that allow complete domestication and maximal reproductivity and larval quality;
- better understanding of larval nutritional requirements in order to develop suitable compound diets, which will further reduce the need for live food;
- improving the understanding of the aquaculture farming systems and the potential nutrient loads and losses to the environment, to maximise nutrient retention efficiency;
- improving the use of agricultural and fishery by-products and non-food grade feed materials, and basing feeding strategies, wherever possible, on the use of renewable feed ingredient

research to develop, standardise and validate accurate

sources;

- better understanding of nutrient bioavailability and interactions of commonly used feed ingredients;
- better understanding of the mechanisms of nutrient modulation of disease resistance as well as improved strategies to minimise toxicity of nutrients and other compounds of feed origin;
- promotion of "good aquaculture feed manufacturing practice" and "good on-farm feed management;" and
- ensuring that limitations in the selection and trade of raw materials for aquaculture feeds are based on sound, documented scientific facts.

3.13 Applying genetics to aquaculture

Genetics has an important role to play in increasing productivity and sustainability in aquaculture

3.14 Applying biotechnology

Biotechnology as a science has the potential to impact on all food production sectors. In the future the aquaculture sector will confront the issue of biotechnology through:

- developing and applying biotechnological innovations for advances in nutrition, genetics, health, and environmental management;
- addressing the potential implications for aquaculture of biotechnology, including GMOs and other products, in a precautionary, safe and practical way; and
- encouraging public awareness and providing information to consumers on the potential applications of biotechnology.

3.15 Improving food quality and safety

As consumer awareness increases,

through higher survival, increased turnover rate, better use of resources, reduced production costs and environmental protection. This will require resources, but the benefits in both the short and long term should justify these efforts.

There are many elements and practices of genetics that may be considered for aquaculture. Recognising that aquaculture has not benefited as much as terrestrial animal husbandry from the adoption of best practices such as selective breeding and stock improvement programmes, high priority should be given to the application of genetics in aquaculture. The interventions include:

- developing and utilising improved domestication and broodstock management practices and efficient breeding plans to improve production in aquatic animals;
- designing and promoting strategies for equitable dissemination of genetic techniques and genetically improved organisms;
- encouraging public awareness and providing information to consumers on the application of genetics;
- greater application of genetic technologies to the conservation of aquatic

aquaculture producers, suppliers and processors will need to improve the quality of products and enhance product safety and nutritional value. The incentives for this will be potentially higher prices, lower insurance rates and increased consumer demand.
This can be achieved through:

- improvements in diets, feeding regimes and harvesting strategies to enhance product quality and nutritional value of aquaculture products;
- promoting the application and adoption of international food safety standards, protocols and quality systems in line with international requirements such as the Codex Alimentarius;
- adopting international protocols for residue monitoring in aquaculture and fisheries products;
- appropriate and informative labelling of aquaculture feeds, including information on additives, growth promoters and other ingredients.
- collection, analysis and dissemination of relevant and scientifically sound information to allow producers and industry operators to make informed decisions and ensure consumer confidence in the food safety of

biodiversity; and
- addressing the potential implications for aquaculture, including environmental and human health implications, in a precautionary, safe and practical way.

aquaculture products;
- application of appropriate safety assessments based on risk analysis and the precautionary approach prior to market approval, including products from modern biotechnology; and
- increasing consumer confidence in aquaculture products by ensuring that industry takes responsibility for the production and distribution of safe products, utilising systems that allow traceability of product ingredients, including information on packaging, processing and production conditions.

3.16 Promoting market development and trade

A focus on market development and trade will increase demand, add value and increase returns for aquaculture products. This will require developing marketing and promotional strategies for aquaculture products and understanding consumer

Implementation

1.1 The Conference encourages States, the private sector and other concerned organisations to implement Strategies for Development of Aquaculture Beyond 2000.

1.2 The aquaculture sector has become considerably more diverse requirements and changing market demands.

These goals can be achieved through:

- reducing trade barriers for aquatic products;
- assisting producers, processors and manufacturers in identifying markets for aquaculture inputs, products and technology;
- providing data for, and investing in, information-technology based market-information systems that are easily accessed by producers and processors;
- researching changing consumption patterns, market segmentation trends and the emergence of new markets and products; and
- ensuring transparency in the chain of custody ("chain traceability") of aquatic products and encouraging the provision of relevant information to consumers through product labelling (e.g., nutritional values, environmental friendliness).

3.17 Supporting strong regional and inter-regional co-operation

Over the years, regional and inter-regional co-operation has brought considerable benefits to since the Kyoto Conference and has developed a broad range of stakeholders. This diversity provides considerable opportunity for productive co-operation.

1.3 The Conference recognises that the primary responsibilities for development and implementation of these strategies rest with States and their private sectors. The Conference recommends that States develop strategies through encouraging private sector development incorporating the key elements identified above.

1.4 The Conference further affirms that co-operative mechanisms among countries provide an excellent opportunity to co-ordinate and support the development of aquaculture, through sharing of experiences, technical support, and allocation of responsibilities for the varied research, education and information exchange. The fostering of co-operation among developing countries deserves special attention and support.

1.5 Furthermore, the Conference recommends that effective use of existing regional and inter-regional mechanisms be made, and that decision-makers seek to promote synergy and co-operation between existing organisations. Where effective regional inter-governmental organisations to aquaculture development through disse-mination of knowledge and expertise. In an era of globalisation, further strengthening of this co-operation at all levels will ensure increased benefits for sectoral development and sustainability.

This could be achieved through:

- supporting and strengthening existing regional organisations;
- improving inter-regional collaboration and networking between existing regional organisations to ensure synergy;
- encouraging the formation and development of regional organisations for aquaculture development in regions where they are lacking; and facilitating in-country support for the establishment and operation of these organisations.
- The Conference noted there are issues relevant to aquaculture development that require a strong global focus to be addressed and that this need might best be achieved by establishing a global intergovernmental forum within an appropriate existing international organisation, having sustainable aquaculture development as

promote co-operation in aquaculture development do not exist, such as in Africa and Latin America, building of such mechanisms, and sharing experiences with the existing regional networks, is recommended.

1.6 The Conference notes that there are considerable opportunities for enhanced regional and inter-regional co-operation among different partners including governments, non-governmental organisations, farmers organi-sations, regional and international organisations, development agencies, donors and lending agencies with a common interest in development through aquaculture.

1.7 In this regard, the Conference strongly recommends the development of an effective programme of regional and inter-regional co-operation to assist in implementation of the Strategies for Aquaculture Development Beyond 2000.

its primary focus, and with a mandate for discussion, decision and agreement on technical and policy matters.

The Declaration and Strategy was drafted by a Technical Drafting Committee (TDC), taking into account the recommendations of all conference sessions, and the views and suggestions expressed by the participants during and after the Conference.
The composition of the TDC is:

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