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AQUACULTURE ASIA

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Remembering TVR "Ramu" Pillay

Freshwater fish biodiversity

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Editor
Simon Wilkinson
simon.wilkinson@enaca.org

Editorial Consultant
Pedro Bueno

NACA
An intergovernmental organization that promotes rural development through sustainable aquaculture. NACA seeks to improve rural income, increase food production and foreign exchange earnings and to diversify farm production. The ultimate beneficiaries of NACA activities are farmers and rural communities.

Contact
The Editor, Aquaculture Asia
PO Box 1040
Kasetsart Post Office
Bangkok 10903, Thailand
Tel +66-2 561 1728
Fax +66-2 561 1727
Email
simon.wilkinson@enaca.org
Website http://www.enaca.org

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Lessons in organizational action from a natural force

The Dec 26 Indian Ocean tsunami, while causing a lot of misery, may also have turned up better ways of looking at and approaching development work in coastal communities that might yet lead to improvements in the state of fisheries and brighter long-term prospects for fishers and fish farmers. CONSRN partners (BOBP-IGO, FAO Regional Office in Asia, NACA, SEAFDEC and the WorldFish Centre) are working with governments, NGOs and community organizations to assure that there is no disconnect between international actions and local aspirations. Having worked with governments, community organizations, and members of the civil society, as well as victims of the disaster - in assessing the needs and planning for rehabilitation - we have learned a few lessons to guide us through the long and difficult recovery and reconstruction period:

1. We have been part of many village-level, national and regional activities that leave no doubt that community organizations, NGOs and governments - while they may not all have the tools and may not know everything - know exactly what they want. This happily makes it less complicated for technical organizations such as CONSRN partners to organize and mobilize technical and donor assistance without complicating our own task by too much debate and philosophising. Listening, rather than talking to governments, civil society and victims may also avoid the pitfall of patronizing them with a well-intentioned assistance they do not need or that may exacerbate pre-tsunami problems such as overcapacity.
2. It has been amazing to see the peoples' resilience. Without waiting for external aid – the fishers, fishfarmers and housewives have begun to rebuild their homes, boats and fish cages, revive their paralysed economic and organisational systems, and try to get back to normal life. This adds more proof to history's accounts of how beleaguered peoples can rise above extreme penury with hope, inner strength and resourcefulness rather than with a lot of aid. The simple lesson here is to approach rehabilitation with a good dose of humility. In practical terms, it should be aimed at helping communities help themselves.
3. Working with those who are familiar with the local terrain gives one a better understanding of what it takes to do proper work. "Terrain" is the minds and circumstances of the people. The technical expertise from organizations would be better applied using a map of the terrain drawn by the grassroots workers rather than us going in to draw new strange looking maps. In practical terms, the application of international technical assistance would be better directed if strategies were developed for specific areas and with the communities.
4. The twin side of destruction is not reconstruction. It is salvation. It is not wrong to spend a lot of money and effort to rebuild what has been destroyed; but it is not right to do so without sparing thoughts and efforts for the more difficult battle of enabling communities to save themselves not only from more violence from a capricious nature but from the more insidious agents of despoliation, abetted sometimes by legal oversight, and sometimes by the wrong policy.

Pedro Bueno.

AQUACULTURE ASIA

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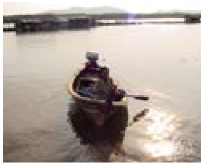

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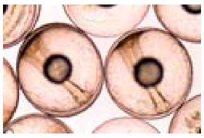

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Notes from the Publisher

Remembering TVR "Ramu" Pillay (1921-2005)

A passion for his work and a fine taste in wine.

In India they call them stalwarts, people like Ramu Pillay. It is shorthand for an otherwise lengthy list of descriptions like tall stature, strength of character and far vision, and a long list of achievements. He would have been described a stalwart had he only worked in India. He would have been recognized as the father of modern aquaculture had he chosen to apply his energy, passion and wisdom only within Asia where 90 percent of the world's farmed fish is now produced. But still 30 years before the previous millennium ended, when the best available record of global aquaculture production was 3.5 million tons, he saw that the world needed to farm more fish, farm it scientifically, and farm it cleanly. That was vision. How he sought to turn much of it into reality is the story of how modern aquaculture evolved.

Ramu blazed an outstanding career in fisheries and aquaculture research long before he moved into the sphere of international aquaculture development. He authored more than a hundred research papers many of them seminal and continue to be cited by researchers the world over. Beyond doing research, he felt a greater need in its systematic and practical application. While in FAO, where he served with remarkable distinction, he set several milestones for aquaculture. The first was the 1966 regional conference on warm water aquaculture that was probably the forerunner to the 1976 Kyoto Conference on Aquaculture. Besides organizing and technically backstopping innumerable national and regional projects on aquaculture development he also had a hand in initiating the collection of reliable statistics on aquaculture production.

With the growth of capture fisheries levelling off in the early 70s, despite improvements in fishing gear and fish finding technologies (a worrying combination even then), Ramu Pillay saw an urgent need for a concerted effort to accelerate the development of aquaculture to meet the increasing demand for fish and fishery products. However, fish farming was in the main a traditional practice, at best an art, and generally regarded as a poor cousin to capture fisheries. It did not even figure in most governments' economic development plans, and where it did, there were not enough support especially in terms of scientific and technological resources. Aquaculture was so diverse that the proposed mechanism to deal with its research and development needs, which was to set up an international research centre, was seen as inadequate. Ramu Pillay saw in this situation the opportunity to focus global attention on the new sector and design a novel arrangement to address its diversity, lift it from obscurity in national and regional plans, and move it from a traditional practice to a science-based food production sector.

That broad vision of a global organizational arrangement crystallized into the Kyoto Strategy for Aquaculture Development. The core of the strategy was technical cooperation among developing countries. It was a strategy that aligned with FAO's mandate and UNDP's advocacy.

The Kyoto Strategy was the product of a series of regional meetings and a global conference that FAO carried out with UNDP support. Ramu Pillay was charged with the planning, oversight and running of the African, Asian and Latin American regional workshops (held in Accra, Bangkok and Caracas during 1975) and the Kyoto Conference in May 1976. The Strategy conceived of a global network of regional aquaculture centres established in Africa (ARAC), Asia (NACA), Latin America (CERLA) and a regional programme in the Mediterranean (MEDRAP). Each regional centre and programme essentially comprised national institutions of excellence, or a network of such institutions for applied research and technology development, training and exchange of information. A fifth centre, the Fish Culture Research Institute in Hungary, or HAKI, by then strengthened through previous UNDP/FAO assistance, was later identified to provide these regional centres with support in key disciplines including pond design and engineering. HAKI's becoming a part of the global network owes much to Ramu Pillay's foresight. Hungary was one of the first European countries assisted by FAO for aquaculture development. Once rich in fisheries resources, a century of tampering with its rivers and wetlands led to its near total reliance on farming for fish supply. Ramu Pillay foresaw a similar global process in Hungary's transition, during the 1970s, from capture to culture fisheries. HAKI pioneered the transfer of highly productive

In 1988, as a member of a NACA team that visited the Wuxi integrated fish farms and Yellow Sea mariculture.

1991, Relaxing after the NACA Governing Council meeting with then DDG of Thai Fisheries, Mrs Bung-orn Saisithi.

Asian fish farming practices to Europe. With guidance from Ramu and its scientific advisory board, it grew into an international research, development and training centre that served well, through the global network, the needs of developed but especially developing countries.

To coordinate and develop this global network, UNDP supported the establishment in FAO of the project, Aquaculture Development and Coordination Programme (ADCP) and put Ramu Pillay in charge. As Programme Leader, he proceeded to translate the Kyoto Strategy into a global action programme. He recruited and welded a multidisciplinary team of scientists and mustered their expertise to develop regional system-oriented programmes of research, training and information that were carried out by the regional aquaculture centres. The centres were identified through consultations with governments and strengthened, with investments from governments, UNDP and other donors to become top calibre institutions of research and development. The regional programmes were developed for implementation with full participation of national teams of scientists, technologists, farmers and government planners, assisted by the ADCP Team. This infused the global programme elements of national and regional priorities relevant to local problems and needs. This and TCDC became the operating guidelines of the regional networks, probably exemplified best by the Asia-Pacific network, NACA, which established itself as an inter-governmental organization in January 1990. Two of five is a fair record but Ramu Pillay might have done more to improve on it had he not retired in 1985. Nonetheless, the efforts put into developing their programmes and staff enabled the others to develop into centres of excellence and continue rendering useful research and development services to their regions.

Retirement from FAO did not mean retirement from aquaculture. Ramu Pillay became Director of the Svanoy Foundation for Aquaculture Development, Norway, from which he channelled private sector contributions for aquaculture development in developing countries. When this phase ended as well he resumed writing books. Besides the earlier publications (Planning of Aquaculture Development and Advances in Aquaculture) his other books are: Aquaculture Principles and Practices, 1990; Aquaculture and the Environment, 1992; and Aquaculture Development: Progress and Prospects, 1994. These have become standard texts for students and practitioners and been translated into several languages. Most retirees would have kept to writing. Ramu Pillay stayed active in aquaculture. He lectured, advised the Government of India, wrote and gave numerous keynote papers at technical conferences. His contributions to world aquaculture development were recognized much earlier, in 1976, when he was awarded an honorary life membership by the World Aquaculture Society.

He maintained a close relationship with NACA and was appointed honorary adviser by its Governing Council in 1995, helping to guide it to become the model that a number of recent network development efforts have found worthy to emulate (such as the recently founded Network of Aquaculture Centres in Central and Eastern Europe, or NACEE, and the one being developed in the Americas, the putative NACtA).

At that late stage in his career, he sparked the second of his two most important contributions to world aquaculture: The Conference on Aquaculture in the Third Millennium in Bangkok in 2000, designed as the sequel to Kyoto. He worked with NACA to write the Conference prospectus and develop its agenda, and then headed a multi-agency committee to steer it to completion. The chairman of the Bangkok Conference summed up Ramu's role in it by acknowledging that he "provided the spark, vision and encouragement" for all participants to join the Conference. He was thus the architect of the Kyoto Declaration on Aquaculture and the prime mover of events that led to the Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000, two of the most important milestones in the development of world aquaculture. Guided by the Bangkok Declaration, NACA included in its programme of work for the first five years of the new millennium what Ramu Pillay had envisaged in 1976: inter-regional cooperation in accelerating and expanding aquaculture development. This has made inter-regional cooperation an important part of the organization's programme, and has found concrete examples in many of NACA's joint projects with institutions and countries in other regions including the South Pacific, the Americas, Africa and Europe, some in direct partnership, others in consortia with international organizations. The latest of these is sadly born of a catastrophe, but he would have been proud to see that the regional and international organizations, to which he had given his touch and legacy in various forms and degrees, rapidly formed a consortium to collectively respond to the restoration and development needs

"From Kyoto to Bangkok" at the Conference on Aquaculture in the Third Millennium, February 2000.

of the communities devastated by the Indian Ocean tsunami.

Ramu Pillay made aquaculture his raison d'etre, his life. But his influence on its development had not been like the spawning of a sudden wave of interest and action. It was, as with his life, a deliberate, systematic and progressive process, more like stemming from a headwaters of vision, given momentum by perseverance and doggedness, gaining volume and gathering substance from the confluence of numerous tributaries of interests and objectives as they flow along, and eventually branching out into several streams and rivulets of purposes, each carving its course and nourishing the developmental landscape as it flows on to the sea. The active career of Ramu Pillay in fisheries and aquaculture research and development may be recorded in finite terms as 58 years, from 1947 to 2005. But the river flows on.

His passing is a great loss to his family. The aquaculture community share their grief and wish them comfort in their bereavement. He worked until his time came up, having just finished the second revision of his book "Aquaculture Principles and Practices." It was as if he did not want the world aquaculture community to feel the loss of his going away.

Stalwarts are never lost to the world; they live on in their legacy. Ramu, we thank you for the legacy.

Friends of TVR "Ramu" Pillay, 9 February 2005.

Freshwater prawn culture in China and its market prospects

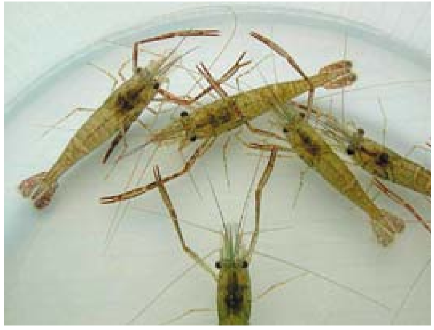
Miao Weimin

Freshwater Fisheries Research Centre, CAFS, No. 9 East Shanshui Road, Wuxi, 214081 China.

Development and present status

Freshwater prawns are among the animals most recently introduced to aquaculture production in freshwater environments in China, despite the traditional preference of the people to the product in many areas of the country. Real commercial culture of freshwater prawns did not start until the 1990s although its experimental culture was reported as early as late 1970s. However, freshwater prawn culture has achieved very fast development since the early 1990s. Such development is attributed to several factors; the traditional preference of Chinese to shrimp and prawn; the rapid decline in the production of marine shrimp culture caused by disease problems in the early 1990s; and increasing demand for high quality products resulting from the improving living standard of the Chinese people as a result of economic development.

The rapid increase in production of cultured freshwater prawn is the result of expansion in the area, improved culture techniques and diversification of cultured species. There is no national statistical data available on the total culture area of freshwater prawn at the moment. However, freshwater prawn culture has expanded very quickly across the country. For instance, *Macrobrachium rosenbergii* was cultured in only 12 provinces of China in 1993 and there was just one province with production more than 1,000 tons. By 2002, culture of *M. rosenbergii* had expanded to 25 provinces and autonomous regions in China. There were eight provinces with the production over 1,000 tons in 2001. In some areas, freshwater prawn culture is now an important component of freshwater aquaculture. For example, the total culture area of *Macrobrachium nipponensis*, one most important species of cultured freshwater prawn in China, reached more than 133,000 ha in Jiangsu province, the most important region for freshwater prawn culture in China in 2001 (Ge Xianping, 2002). It accounted for 22.51% of the total inland aquaculture area of 592,413 ha (Chinese Fisheries Statistic Year Book 2001) of the province in the same year.



Macrobrachium nipponensis.

Macrobrachium rosenbergii.

Penaeus vannamei.

The fast expansion of culture area and improvement in culture technique has resulted in rapid growth in production. Currently, there is no aggregated national statistical data for freshwater prawn species available in China. Production of *M. rosenbergii* during 1993 to 2001 (Figure 1) is a very good example. China is now the largest producer of cultured *M. rosenbergii* in the world, representing 69% of global cultured *M. rosenbergii* output in

Figure 1. Cultured production of *M. rosenbergii* in China 1993-2001.

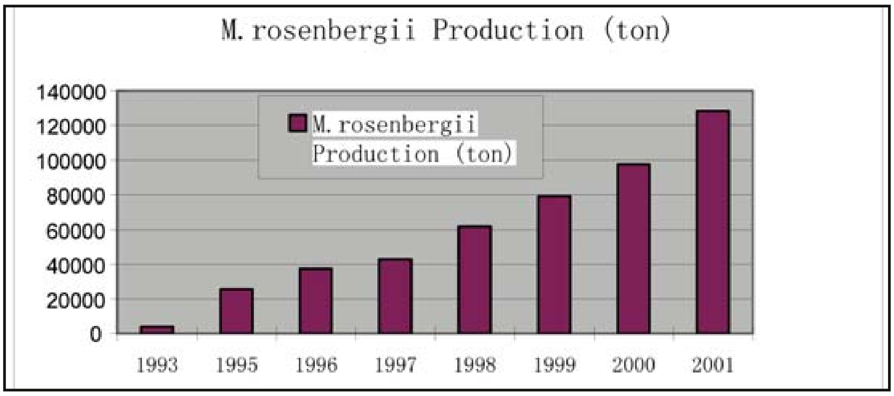
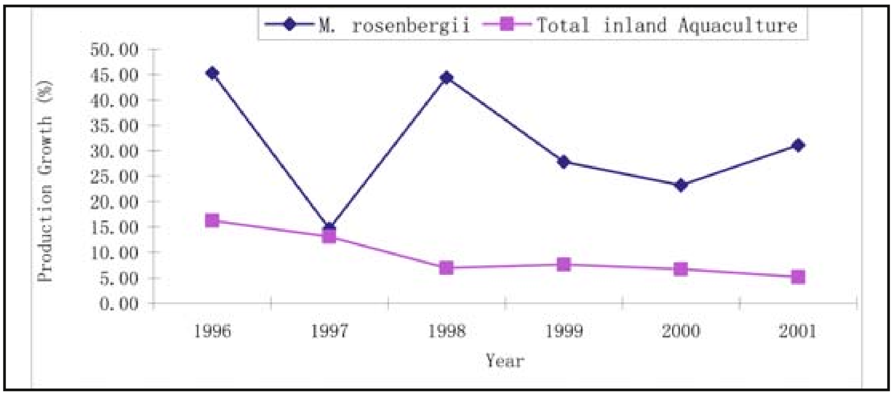


Figure 2. Production growth of cultured *M. rosenbergii* and whole inland aquaculture in China during 1996-2001.



2001. During 1995-2001, an average annual production growth of 31.19% was attained in *M. rosenbergii* culture. In comparison, the average annual production growth was only 9.27% for the whole freshwater aquaculture sector during the same period (Figure 2).

Production of another cultured freshwater prawn species; *M. nipponensis* was estimated to be around 120,000 tons in China 2001, close to the capture production of the species. In 2001, the total production of cultured freshwater prawn was estimated to be over 250,000 metric tons in China, not including the production of *Penaeus vannamei* cultured in freshwater environment. Aquaculture is now the major source of freshwater prawn in China.

Species and culture methods

Cultured Species

Although, freshwater prawn culture attained a very high growth rate in China during the past decade, only two species of real freshwater prawn, *M. rosenbergii* and *M. nipponensis* are currently cultured on a large scale.

M. rosenbergii is an exotic species in China. The species was cultured in a very limited area in the Southern China with very small production for more than a decade after it was first introduced in 1976. The fast development of culture of the species started only since the early 1990s. Now, it is one of two major freshwater prawns cultured in China.

Another real freshwater prawn species widely cultured in China now is *M. nipponensis*, an indigenous species that can naturally reproduce in all kinds of freshwater bodies. Therefore, traditional production of the species was mainly from wild fisheries. Although the earliest culture practice of the prawn was reported in the 1970s, commercial production started at more or less the same time as *M. rosenbergii*. Currently, cultured production of this prawn accounts for about 50% of total production of the prawn in China.

Penaeus vannamei is actually a marine shrimp species originally from South American countries along the South Pacific Ocean. It was first introduced to China for culture in seawater. It was then very recently introduced for culture in freshwater in China. Due to its fast growth rate, longer breeding and growth period (compared with *M. rosenbergii*), the culture of this shrimp in freshwater has expanded very quickly in the last few years and it has become another important freshwater cultured prawn/shrimp species in China. In 2001, production of *Penaeus vannamei* from freshwater pond reached 40,000 tons in Guangdong province, the most important area for freshwater culture of shrimp in China, with the area under culture reaching 8,000 ha. In 2000 the production and culture area were respectively 4,000 tons and 1,000 ha only. Presently, production of *Penaeus vannamei* cultured in freshwater has exceeded the production of *Macrobrachium rosenbergii* in China. It now contributes significantly to shrimp exports.

Culture Methods

Currently, earthen ponds are the basic culture method commonly adopted for all species of prawn / shrimp cultured in freshwater in China. The practice for different species may differ according to the biological characteristics of each species. For stocking, both brood prawn or post larvae of *M. nipponensis* can be stocked in growout ponds. For *M. rosenbergii* and *Penaeus vannamei*, post larvae can only be stocked for growout after acclimatization in freshwater. A single crop used to be the dominant practice for the culture of all species before. Aiming to raise the unit production, prolong marketing season and eventually raise the economic efficiency, multi-crop (2-4 crops/year) and rotating culture of *M. rosenbergii* and *M. nipponensis* has become increasingly popular in southern China. Such a change has effectively raised the unit production from originally 1.5-3.0 ton/ha to presently around 5-6 ton/ha (*M. rosenbergii* and *P. vannamei*). The improvement in the unit production is very important to maintain the minimum benefit in compensating for the reduced market price.

Culture in rice paddy is another method commonly adopted in the culture of *M. rosenbergii* and *M. nip-*

ponensis. Usually only one crop of prawn is produced a year. With a much-reduced stocking rate (*M. rosenbergii* and *M. nipponensis*), 300-450 kg/ha of prawn can be produced through supplementary feeding and good management in addition to the normal rice production. This is a very effective approach to improve the economic return of traditional rice cultivation. It also has very sound environmental effect due to much reduced pesticides and other chemicals.

Apart from above mentioned two culture methods, cage culture and indoor running water culture are also practiced for *M. rosenbergii* and *M. nipponensis* in some areas of the country. However, they are far less popular than pond culture and rice-paddy culture. Their contribution to the total cultured prawn production is very limited.

Market prospects

Prospect

Development of culture of freshwater prawn and other high valued aquatic animals is one of the priority options for local government in many parts of the country to replace the cultivation of some traditional crops with very low economic efficiency and has been proven to be very effective in past years.

Although freshwater prawn culture is now facing some problems and constraints, the industry is very likely to expand further in the future. This prediction is based on the two major factors. First, the potential new market for freshwater prawn is huge. Domestically, freshwater prawns are very much preferred aquatic products for Chinese consumers, not only because of high nutritional value and great taste, but also due to convenience in preparation. Presently, freshwater prawn production is estimated to be around 400,000 tons (including the wild catch), which account for less 1% of the total fisheries production in China. Per capita availability of freshwater prawn products is less than 0.3 kg. With the improving living standard, there will be a very large room for the domestic demand to increase. China has already entered WTO. Aquaculture products are considered most competitive products that have potential to enter international market. Freshwater cultured prawn is more likely to take a share in the international market compared to finfish. In 2002, China exported 108,000 tons of cultured shrimp. This increased by 66% compared with the previous year. Production of cultured prawn/shrimp from freshwater, especially *Penaeus vannamei* comprised significant portion of the export.

On the other hand, Chinese traditional agriculture is facing strong challenges from the global market since China entered the WTO. Mainly limited by small-scale operations, the products of many traditional farmed crops struggle to compete in the international market. To confront such a challenge, the Chinese government is deepening the structural reform to traditional agriculture. One of the government's strategies is to develop the aquaculture industry. Meanwhile, structural adjustment is also underway within the aquaculture sector for long-term sustainability and sound economic benefit. Priority is being given to the culture of those species have good market potential and high economic return rather than ordinary species such as carps whose market is close to saturated. Development of freshwater prawn culture is in line with such rural development policy.

Current problems

Falling price and declining economic return

Rapid development of freshwater prawn culture has been stimulated by the increasing market demand and high economic return from production. *M. rosenbergii* used to fetch a market price of US$ 6.0/kg very easily several years ago. The market price of *M. nipponensis* could reach US$ 15.0/kg or even higher during the Chinese New Year period. However, the rapid growth in production resulting from the expansion of prawn culture has already had significant impacts on the market price and economic returns of the culture industry.

The market price of *M. rosenbergii* has currently dropped to only around US$ 2.5-3.0/kg during the major harvesting season, almost half of previous levels. The economic benefits of prawn culture have declined significantly although the price of the seed has also fallen. This has mainly been compensated for through the increase in unit production. *M. nipponensis* used to maintain a fairly stable market price. However, great market pressure has arisen due to the fast growth of production in 2001, resulting in significant declines in the price of the prawn. *Penaeus vannamei* has faced a similar situation. The market price for the shrimp was fluctuating around US$ 2.5-4/kg during most of the harvesting season. The farm gate price of *Penaeus vannamei* dropped as low as US$ 1.5/kg at one point in 2002, a historical low in Guangdong province.

The marketing problems can be largely attributed to several factors. With *M. rosenbergii* and *Penaeus vannamei* problems are mainly related to the production and marketing pattern. Due to the requirement for high temperature and the season of seed production, the marketing period for these products is fairly short. As the production increases, it naturally causes the market price to decline. Disordered competition among the prawn/shrimp farmer is another important factor causing unbelievably low market price of cultured prawn/shrimp in peak harvesting season.

For *M. nipponensis*, the market pressure and reduced economic efficiency of culture are mainly due to two factors. One is the very fast growth in the production without much expansion of the market. The other factor is the reduced market size of the prawn, which significantly affects the selling price.

The drastic drop in price has caused significant decline in the economic return of freshwater prawn/shrimp culture in China during the last few years. Compared with the general high economic return several years ago, the profitability of freshwater prawn/shrimp culture is highly dependant on the management and production level. The profit from the culture is usually around US$ 2,000/ha in China. Some farmers may even lose capital due to inexperience, poor management and low production.

Uneven distribution of production

For all the species, uneven distribution of production is another factor that causes downward pressure on market price. For example, *M. rosenbergii* production from Guangdong, Jiangsu, Shanghai, Anhui and Zhejiang provinces accounted for 91.55% (117,494 tons out 128,338 tons) in 2001. Chinese consumers prefer live prawn, which usually fetches a much high price than the dead ones. Transportation of large quantities of live freshwater prawn over long distance is relatively more difficult. This results in great pressure on the local and nearby markets during peak harvesting season in these areas. Another factor is that processing technology for freshwater prawn is far behind the production in China.

Increasing pressure in the international market

Despite the significant growth of cultured shrimp export in recent years, export of cultured shrimp is now facing market barriers from the major importing countries. The issue of chloromycetin residue significantly struck the export of China's export of cultured shrimp to Europe in 2001-2002. Recently the "anti-dumping" action of the United States against most Asian shrimp exporting countries (including China) is likely adversely impact the shrimp exports of China. It is very likely that shrimp importing countries will undertake similar actions more frequently to protect their own shrimp culture industries in the future.

Strategies for future development

It is vitally important to effectively tackle the existing problems and implement an appropriate development strategy for future sustainable development and sound economic benefit of the freshwater prawn/shrimp culture industry in China. The following are among the priority strategies and measures.

Appropriate development strategy

Appropriate development strategies should be developed and implemented with regard to the present status of freshwater prawn culture in different parts of the country. Different development targets and priorities should be set for different areas. For instance, in the provinces where freshwater prawn culture has already developed to certain level development targets and priorities should be the improvement of product quality to increase their competitiveness in the international market. These provinces are mostly areas with relatively easy access to foreign markets.

In areas where freshwater prawn culture is still at an early stage priority should be given to expansion of the industry and increasing the production. The target should be to develop the local market and contribute to the economic development and income of rural people.

Establishment of quality seed production system

Quality of prawn seed is now a very important factor affecting the production and economic efficiency of culture. It also has significant implications for long-term development of the industry. It is extremely important to establish an effective system for production and distribution of high quality prawn seed. Scientific research work needs to be carried out on the genetic improvement of cultured prawn species. Prawn breeding techniques should also be developed for the purpose to maintain the genetic quality of species at production level.

In order to maintain the quality of prawn seed in production, a certification system needs to be developed and implemented for prawn hatcheries. Health certification and inspection mechanisms also need to be established for the trans-boundary movement of prawn brood stock and seed within and beyond the country. This will also benefit the export of cultured shrimp/prawn in the future.

Improvement of culture technique

Freshwater prawn culture is a relatively new aquaculture practice in China. There have been very limited studies on the culture technology of different prawn species in different environments. Present practice is mainly based on the farmer trials and the experience of other countries. There is a lot room for the improvement in feed and feeding, stocking and culture management.

These kinds of improvement are particularly important to delivering sound economic benefits given the current much-reduced market price of the products. Another important goal is how to ensure the high quality of the products throughout the whole culture and marketing process. Ecological culture that minimizes use of various chemicals and drugs needs to be studied to ensure safe products that are accepted in the international market.

Improvement in marketing and processing

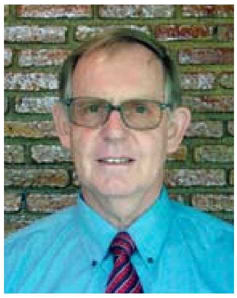
The long-term sustainability of the freshwater prawn culture industry will ultimately be determined by the economic performance of the industry. To maintain a reasonable economic benefit it is vitally important to the further the development of the industry. Development of effective marketing strategies and modification of culture systems to allow longer harvesting and marketing periods is particularly important to relieve market pressure that may result from further expansion of the industry. New culture practices such as multi-crop production and rotating culture have been proven to be effective in this aspect, but they need further refinement.

Processing technology for freshwater aquatic products has long been lagging behind the development of culture. This is due to both consumers' habit and limited efforts on technology development. However, appropriate processing technology can reduce the marketing pressure in the peak harvesting and improve the acceptability to the international market. Therefore, there is a real need to invest money and human resource to develop suitable processing technology for freshwater prawn as well as other cultured animals.

Peter Edwards writes on

Rural Aquaculture

Demise of wastewater-fed duckweed-based aquaculture in Bangladesh



Peter Edwards is a consultant, part time Editor and Asian Regional Coordinator for CABI's Aquaculture Compendium, and Emeritus Professor at the Asian Institute of Technology where he founded the aquaculture program. He has nearly 30 years experience in aquaculture in the Asian region. Email: pedwards@inet.ac.th.

Serpentine duckweed pond on the Agriculture Training Institute (ATI) campus, Khulna. Bamboo reduces the impact of wind which otherwise blows duckweed to the pond margin.

A duckweed feeding square in a fish pond at the Shobujbagh duckweed plant, Khulna.

In this column I continue with recent developments in, or perhaps 'demise of' is a more appropriate way to phrase it, wastewater-fed aquaculture. In my column in the last issue (October-December 2004, Vol. IX, No. 4), observations on the constraints facing wastewater-fed aquaculture in Hanoi were presented. This column outlines wastewater treatment and reuse involving duckweed and fish in Bangladesh.

Cultivation of duckweed using various organic fertilizers is traditional Chinese practice to produce small-size green fodder for grass carp fingerlings still unable to consume coarse grass. However, there has been a tremendous amount of research over the last three decades on various aspects of duckweeds, including their cultivation in wastewater and subsequent use to feed herbivorous fish. Duckweeds have many positive characteristics:

- Crude protein production up to 10 times greater than that of soybean, the most productive terrestrial protein crop.
- A high crude protein content of 25-45% on a dry matter basis.
- A dry matter productivity of 10-40 tonnes dry matter / ha / year.
- Ability to grow in shallow water and shade.
- Readily harvested by pole and net.

Unfortunately there are constraints:

- Growth adversely affected by both low and high temperature and high light intensity.
- Occasional insect infestation.
- Rapid decomposition following harvest.
- Economically difficult to dry, especially during rain which prevents solar drying.

The NGO PRISM in Bangladesh has carried out a R & D programme with duckweed-based, wastewater treatment and reuse through fish culture over the past 15 years. Two systems have been developed: A system fed with conventional wastewater or sewage for peri-urban areas; and a village level sanitation system with latrines connected to small derelict ponds to treat nightsoil and cultivate duckweed.

The first duckweed conventional wastewater treatment system, which still operates, was built in 1989 at Mirzapur, Tangail district. A 0.2 ha anaerobic pond precedes the 0.7 ha duckweed covered pond which was constructed as a 500 m long serpentine channel with a hydraulic retention time of about 20 days. About 1,000 m3 sewage / day are treated to such a high degree that the effluent could be used for unrestricted irrigation of vegetables according to WHO standards for wastewater reuse. Duckweed harvested daily is fed to fish in three adjacent fish ponds of 0.2 ha each. About 10-15 tonnes of mainly carps are produced each year although probably only half the yield is based on duckweed as rice bran and oil cake are fed to fish also. The net return according to Mohammed Ikramullah, Chairman of PRISM, is 5-10% annually, including land lease and 5 year facility depreciation. PRISM has demonstrated that it is possible for a duckweed-based wastewater treatment system incorporating fish culture to not only achieve cost recovery but to derive a net profit.

Despite having demonstrated the economic feasibility of low-cost, duckweed-based wastewater treatment and reuse, Mr. Ikramullah expressed major reservations about further dissemination of the technology in Bangladesh. The local government in Khulna, the third largest city in Bangladesh, provided 0.6 ha of land for a duckweed-based system at Sonagandha. The community-based project involving active participation of an adjacent slum community was funded by UNCDF but was destroyed only 3 years later to build a stadium for female athletes.

UNDP under the Sustainable Environmental Management Programme (SEMP) provided funds to build four duckweed pilot plants in Khulna but sufficient land could be found to build only two plants. Plants built on leased land on the campus of the Agriculture Training Institute in 2000 and at Shobujbagh on private land bought by PRISM in 2003 are also currently in operation. However, it is unlikely that land will become available to build additional duckweed-based plants either in Khulna, where there are 37 large sewage outlets in the city, or elsewhere in Bangladesh.

The UNCDF funded project Rural Enterprises with Fishermen provided credit to construct 1,500 rural duckweed-based units in villages. As there was no conventional wastewater in rural villages, latrines were constructed around derelict or unused ponds. The latrines consisted of a moulded concrete slab connected to a pipe that conveyed nightsoil directly to the duckweed pond but inside a retaining basket made of woven bamboo slats. Harvested duckweed was fed to fish in nearby ponds. Mr. Ikramullah informed me that fewer than 20% still grow duckweed although most continue to culture fish but with other inputs. Polyculture of carps has taken off since the rural sanitation project was implemented and farmers concentrate on more profitable fish culture without duckweed-based nightsoil treatment.

According to Mr. Ikramullah, the single biggest constraint to the sustainability of duckweed-based wastewater treatment and reuse is the availability of land for what is essentially a land-intensive system. The PRISM concept for duckweed was based on use of marginal and unutilized, fallow land. Earlier studies had reported that there were 250,000 ha of low-lying land in Bangladesh which could be used for natural collection, treatment and reuse of wastewater. However, the opportunity cost of land has gone up rapidly in Bangladesh, the most densely populated country in the world, excluding city-states.

In reality there is no shortage of land as plenty is held, especially by five bodies: Municipalities, Post and Telegraph, Railways, Roads and Highways, and Water and Power Development Board. As the opportunity cost of karst (government) land has risen so much, there is pressure for other uses, legal and illegal. Land speculation is the biggest business in Bangladesh. Although land availability is the biggest issue, other major constraints are complex and include multiple ownership of land, availability of working capital, and the rapid rate of infrastructure development, which often results in water bodies being filled in. Duckweed wastewater treatment is not attractive enough to gain full government support.

With so many constraining factors, it is difficult to end on a positive note. Perhaps duckweed wastewater treatment could become an integral part of green belts required to make the peri-urban areas of rapidly expanding cities socially as well as environmentally sustainable?

Harvesting duckweed with a scoop net on the ATI campus, Khulna.

Harvested duckweed being transported to an adjacent fish pond on the ATI campus, Khulna.

Freshwater finfish biodiversity – an Asian perspective I: Current status

Thuy T.T. Nguyen[1], Sena S De Silva[2*]

1. Network of Aquaculture Centres in Asia-Pacific, PO Box 1040, Kasetsart Post Office, Bangkok 10903, Thailand; 2. School of Ecology & Environment, Deakin University, PO Box 423, Deakin University, Warrnambool, Victoria, Australia 3280.

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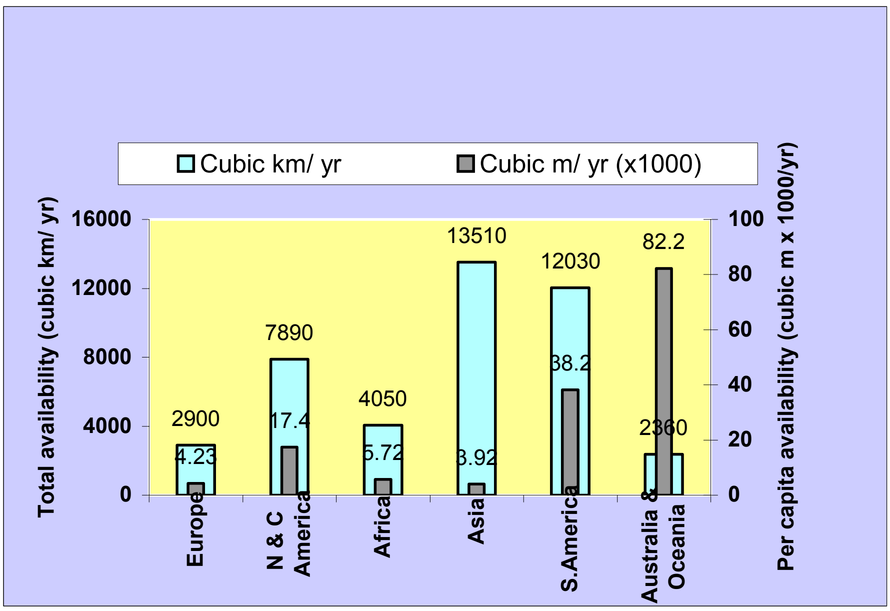
The overwhelming acceptance of the Brundtland Report, "Our Common Future' in 1987 (UNEP 1987) by the world community, freshened the general thinking on biodiversity and conservation initiatives and related issues and these became an integral part of all development. Subsequent follow-up global consultations lead to the establishment of the Convention on Biological Diversity (CBD) in 1994 (CBD 1994), which currently provides leadership with regards to global biodiversity issues and initiatives.

Biodiversity is variously defined. In essence, biodiversity refers to the abundance and the variety within and among flora and fauna, as well as the ecosystems and ecological processes to which they belong, and is usually considered at ecosystem, species and genetic levels (Kottelat and Whitten 1996). Biodiversity initiatives, by and large, have tended to be more focussed on terrestrial ecosystems, particularly in the past. Until recently, and when aquatic systems were targeted the emphasis generally was more on coral reefs and wetlands, but only marginally on freshwater *per se*. While less than 0.01% of the world's water resources occur as surface waters these are home to a very high level of biodiversity, supported through a number of freshwater ecosystems: Rivers, lacustrine waters, marshes, and seasonal or ephemeral wetlands. Almost 25% of global vertebrate diversity is accounted for by fish and a significant proportion of it is concentrated in this meagre 0.01% of earth's freshwaters. However, most emphasis on fish biodiversity issues have tended to be on marine species, perhaps because of the importance of the marine sector in food fish production and the consequent fishing pressures on the marine stocks. Most freshwater fisheries, particularly those in the Asian region, are artisanal, and fishing pressures *per se* are not thought to be a major culprit affecting biodiversity, except in very rare instances, but other developments taking place in watersheds are (Coates et al. 2003).

Global fish consumption and production have witnessed marked changes since the early 1970s; there has been a shift towards increased consumption of fish in the developing world, which also dominates production with around 70% of global output (Delgado et al. 2003). Inland fish accounts for about 20-25% of the animal protein intake, particularly in rural populations in the developing world (Delgado et al. 2003). Consequently, there is an increasing emphasis on the development of inland fisheries as a significant contributor in narrowing the growing gap between supply and demand for fish food (Welcomme and Bartley 1998; De Silva 2003). However, if these trends are to be sustained it is imperative that there needs to be a concerted attempt to maintain biodiversity and have appropriate conservation measures in place for maintaining environmental integrity and fish stocks.

There have been only a few studies on finfish biodiversity on a broad, regional basis in respect of Asia (Kottelat and Whitten 1996). In an era where there is likely to be an upsurge in inland fishery activities, including aquaculture, in most developing nations in Asia, and the fact that freshwater fishes are purported to be the most threatened group of animal food source for humans (Bruton 1995), it is opportune to evaluate the present status of finfish biodiversity in the region. Here, emphasis is laid on East, South and Southeast Asia in view of the greater inland water resources and finfish diversity compared to North, West and Central Asia (IUCN classification).

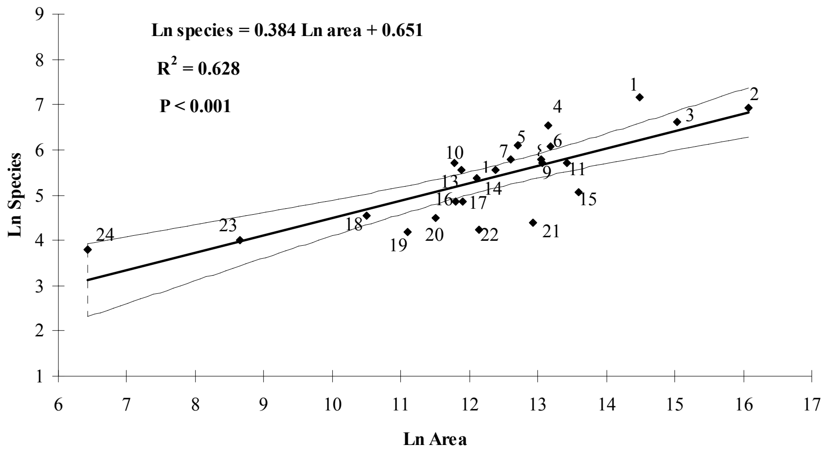
Figure 1. Average total and per-capita water availability in different continents (based on data from Shiklomanov, 1998).



Asian inland water resources

The earth is estimated to have only 35,029,000 km^3 of freshwater, representing 2.5% of all water resources and of which only 23.5% is habitable, the rest being ice caps and glaciers (Shiklomanov 1993; Smith 1998). Asia has the most inland water resources amongst all continents (Shiklomanov 1993, 1998), even though the amount available on a per capita basis is relatively low (Figure 1). Asia has a number of very large river systems, such as the Brahamputra, Ganges, Irrawaddy, Indus, Kapuas, Mekong, Pearl, Yangtze, Yellow and Red, amongst others, most of them flowing through a number of nations. The bulk of these rivers flow through the tropical and the sub-tropical regions, enhancing the potential diversity of the fish fauna (Oberdorff et al. 1995). Adding to main river habitats are the flood plains, interconnected streams, rapids and headwaters which all provide unique features that add to potential diversity.

Figure 2. The regression on ln land area (km²) on ln species in Asian nations/ regions provided in the database of Kottelat and Whitten (1996). The numbers refer to the corresponding number in table 1 and the broken line represents the 95% confidence limits.



There is a paucity of natural lakes in Asia compared to most other continents, these being mostly found in the active volcanic regions of South East Asia, such as in Indonesia and the Philippines (Fernando, 1980). On the other hand, the lacustrine water habitats created through reservoir construction, primarily in the second half of the last century in Asia is the highest amongst all continents, but these tend to have a much lower diversity than the original stretch of the dammed river/ stream, and will be dealt with in a later article. Suffice is to state that river impoundment / dam construction is rather a controversial issue with serious political and socio-economic repercussions and of global concern (McCully, 1995; Roy, 1999).

Apart from the above major finfish habitats others of importance are black water streams, marshes and swamps, and caves and aquifers. The fish fauna of some of these habitats has been little studied until recently, and their importance from a biodiversity point of view is just beginning to be unravelled. For example, the peat swamps of peninsular Malaysia are reported to contain 10% of all the fish species of the peninsular (Ng 1994).

Table 1. The land area (km²), number of finfish species recorded and the ratio of the number of finfish to land area x 1000 in selected nations/ regions of Asia.

Country	Area (km^2)	Species no.	(Species/Area)10^3
Indonesia	1,944,000	1,300	0.7
China	9.560,948	1,010	0.1
India	3,387,593	750	0.2
Thailand	513,517	690	1.3
Vietnam	329,566	450	1.4
Borneo	535,830	440	0.8
Philippines	299,404	330	1.1
Papua New Guinea	462,000	329	0.2
Sumatra	475,300	300	0.6
Malay peninsular	131,235	300	2.3
Myanmar	676,581	300	0.4
Laos	236,798	262	1.1
Bangladesh	144,054	260	1.8
Cambodia	181,035	215	1.2
Pakistan	803,941	159	0.9
Java	132,570	130	1.0
Nepal	147,181	129	0.9
Taiwan	36,179	95	2.6
Sri Lanka	65,610	90	1.4
Korean peninsular	99,143	90	0.7
Irian Jaya	414,800	80	0.2
Sulawesi	186,140	70	0.4
Brunei	5,765	55	9.9
Singapore	618	45	72.9
Data from Kottelat and Whitten, 1996; Mongolia has been omitted.			

Asian fish fauna

The number of recognised finfish species in the world is estimated to be around 25,000 (updated to 28,100; http://www.redlist.org/info/tables/table1.html) and of these about 10,000 are found in freshwater, and another 160 species require freshwater, at one stage or another, to complete their life cycle (Nelson 1976). However, these numbers are not static, as new species are often recorded from the region, and as the taxonomy of some others is sorted out.

According to Kottelat and Whitten (1996) East, South and Southeast Asian nations have a cumulative total of a freshwater finfish fauna of 7,447 species, with Indonesia having the largest number of 1,300. It is also important to note that the fish fauna in most nations, except perhaps Singapore and Sri Lanka, two relatively small island nations, is not fully documented. Table 1 gives the species richness and the land area and the ratio of these parameters in selected nations/regions in Asia. It is evident that Singapore ranks highest in this regard with a ratio of 72.9. The ln of finfish (freshwater) species number to land area ratio was significantly correlated to the ln of the land area, the relationship (figure 2) being:

ln (species ratio) = ln 0.384 (land area in km^2) + 0.651 (R2 = 0.628; P< 0.001).

In general, ecologists and biogeographers have long recognized that species richness increases with area, but at a decreasing rate (Connor and McCoy, 1979; Rosenzweig, 1995; Ovadia, 2003). The species-area relationship, as seen in respect of finfish species in Asia, is non-linear, and the implications in managing biodiversity "hotspots" (Myers, 1988, 1990) have been discussed by Ovadia (2003).

In Asia by and large, as elsewhere in the world, the major diversities in the fish fauna occur in the large river systems and their associated floodplains (Welcomme 2000; CBD 2003; Coates et al. 2003). The fish fauna in East, South and Southeast Asia is dominated by cyprinids (about 1,000 species), followed by loaches (about 400 species) of the families Balitoridae and Cobitiidae, gobies of the family Gobiidae (300 species), catfishes (about 100 species) of the family Bagridae and members of the Osphronemidae family (85 species). Most of the fish species diversity occurs in the tropical area (Kottelat and Whitten 1996). Lundberg et al. (2000) noted that in Asia the diversity at the family level (121 families) was considerably higher than in African and Latin American inland waters, where only 50 and 55 families, respectively have been recorded.

Of the Asian rivers the Mekong is the richest in fish fauna with 37 families and 450 recorded species, but currently it is estimated that the number of finfish species in the Mekong could actually be as high as 1,200 (CBD 2003; Coates et al. 2003). The finfish faunal diversity of 21 major river basins in East, and South and Southeast Asian nations (table 2) indicates that species diversity is not necessarily related to familial diversity. The Irrawaddy basin has the highest known familial diversity with 34 families but has only 79 species, as opposed to the Mekong basin, which is poorer in familial diversity but very rich in species diversity. Bhat (2003) documented the diversity and composition of freshwater fishes in river systems in the Central Western Ghats, India, and found that there was 25% endemicity amongst a species richness of 92. In general, there is a paucity of studies of finfish biodiversity in Asian rivers. Dudgeon (1992) attempted to point out that Asian river ecosystems are endangered, and the main reasons he listed were all related to human activity, but over fishing was not one of these. He compared the degradation of Asian rivers to those of the north-temperate regions, but stressed that the biological understanding on Asian rivers was insufficient to halt or limit further degradation.

When the major river systems in the region were considered as a separate entity, the ln species richness index (number of species to basin area ratio*1000) was significantly correlated to the ln basin area for the major river systems (Figure 3), the relationship being:

ln (species richness index) = - 0.789 ln (area) + 9.368 (R^2= 0.748; P< 0.001)

The above relationship however, differs from that derived by Welcomme (2000) for African rivers, where the relationship was based on data transformed into $\log_{10}$. Based on the above regression relationship the species richness index was estimated for each of the river systems (Table 2) and it is evident that the rank order changes dramatically compared to the estimates of that of the World Conservation Monitoring Centre. This analysis demonstrates that fish species richness is not necessarily correlated to river basin size, and indeed in the region, rivers with small basins such as the Cauvery (India/Nepal), Kapuas (Indonesia) and Chao Phraya (Thailand), have high indices of 1.62, 1.53 and 1.32, respectively.

Status of finfish biodiversity

According to the IUCN Red List (2003) of all life forms 21,067 species are threatened (includes critically endangered, endangered and vulnerable) globally, and of these 2,640 (12.5%) are finfish species (Table 3). In Asia as a whole, 6,106 organisms are threatened of which 688 are finfish species, and in

Figure 3. The regression of number of ln of species to basin area ratio.1000 to ln of basin area for major river basins (table 2) in East, and South and Southeast Asia.

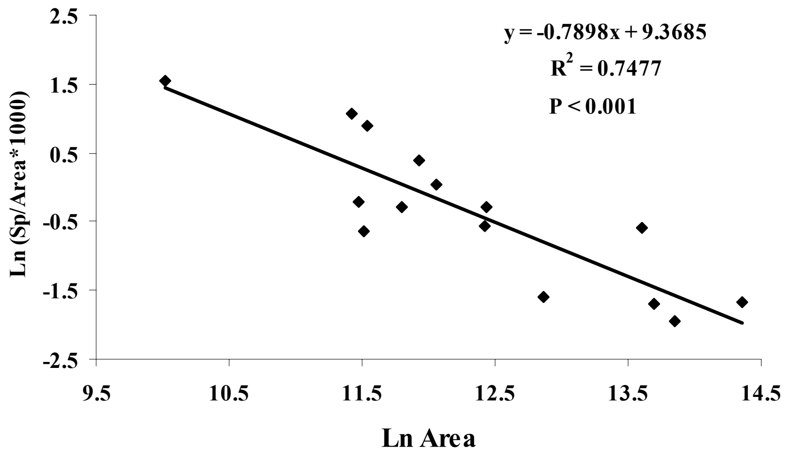
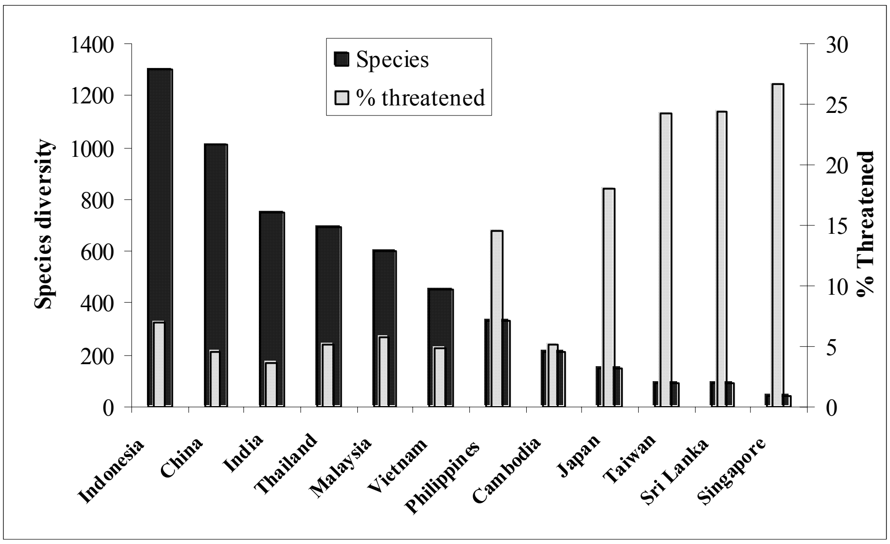


Table 2. The fish faunal characteristics of major river basins that are located in East, South and Southeast Asia. The countries of location of the respective basins are given in parentheses. Species richness @ is calculated in relation to basin area based on a regression derived for river basins world wide, and @@ is based on the regression relationship of the basins given in the table. Data, except @@, from Conservation Monitoring Centre (http://www.unep-wcmc. Orginformation_services/public); @@ based on the regression in Figure 4.

River basin	Basin area (km^2)	No. of finfish:		Species richness	
		Families	Species	@	@@
Yantze (Ch)	1,711,156	23	320	1.10	0.140
Ganges-Brahamputra (Ban, Bhu, In, Nep)	1,684,918	32	na	na	0.209
Indus (Afg, Ch, In, Pak)	1,031,425	24	147	0.44	0.236
HwangHo (Ch)	880,881	21	160	0.56	0.254
Mekong (Cam, Ch, La, Myan, Tha,Vn)	804,381	37	450 (1200)*	1.62	0.452
Irrawaddy (Ch, In, Myan)	387,631	34	79	0.06	0.634
Godavari (In)	320,937	28	na	na	0.640
LiaoHo (Ch)	274,124	17	na	na	0.857
Krishna (In)	252,443	29	187	1.02	0.947
Salween (Ch, Myan, Tha)	249,481	34	143	0.76	1.047
SongHong- Red River (Ch, Lao, Vn)	172,462	24	180	1.08	1.288
ChaoPhraya (Tha)	151,868	36	222	1.32	1.315
Mahanadi (In)	149,500	26	na	na	1.360
Fly (Indo, Png)	133,687	13	101	0.56	1.415
Kapuas (Indo.)	102,874	32	250	1.53	4.273
Sepik (Indo, Png)	100,243	10	53	-0.02	0.140
Narmada (In)	96,062	26	77	0.37	0.209
Cauvery (In, Nep)	91,375	27	265	1.62	0.236
Ma (La, Vn)	36,550	25	na	na	0.254
Ca (La, Vn)	22,975	26	na	na	0.452
Pearl (Ch)	22,537	21	106	1.04	0.634

Afg- Afganistan; Ban- Bangladesh; Bhu- Bhutan; Cam- Cambodia; Ch- China;In- India; Indo- Indonesia; La- Laos; Myn- Myanmar; Nep- Nepal; Pak- Pakistan; Png- Papua New Guinea: Tha- Thailand; Vn- Vietnam
* Coates et al. (2003).; but not used in the regression in Figure 4.

Figure 4. The number of threatened finfish species (of ten or more) in each of the in nations in East, South and Southeast Asia, and the number threatened expressed as a percentage of the total finfish fauna of that nation/ territory (data extracted from http://www.redlist. org.info/ tables/table5).



territories when considered in relation to the respective total finfish fauna is tantamount to nearly 25% of the finfish fauna of Singapore, Sri Lanka and Taiwan, all three relatively small island states (Figure 4). On the other hand, in Indonesia 91 finfish species is under threat and accounts for 17.1% of the total finfish species under threat in the region but elsewhere it is less than 10% (Figure 5).

In East, and South and South East Asia 66 species of freshwater fin-fish are critically endangered and/or endangered, that is about 1.3% of all freshwater finfish species in the region (Table 3). The endangered species belong to 16 families, of which Family Cyprinidae accounts for 32 species or nearly 50% of all endangered species (Table 4). Of the 66 critically endan-gered and/or endangered species more than half (34 species) fall into the

Figure 5. The number of threatened finfish (ten or more) species in nations in East, South and Southeast Asia, and the number threatened expressed as a percentage of the total for the region (data extracted from http://www.redlist.org.info/ tables/table5).

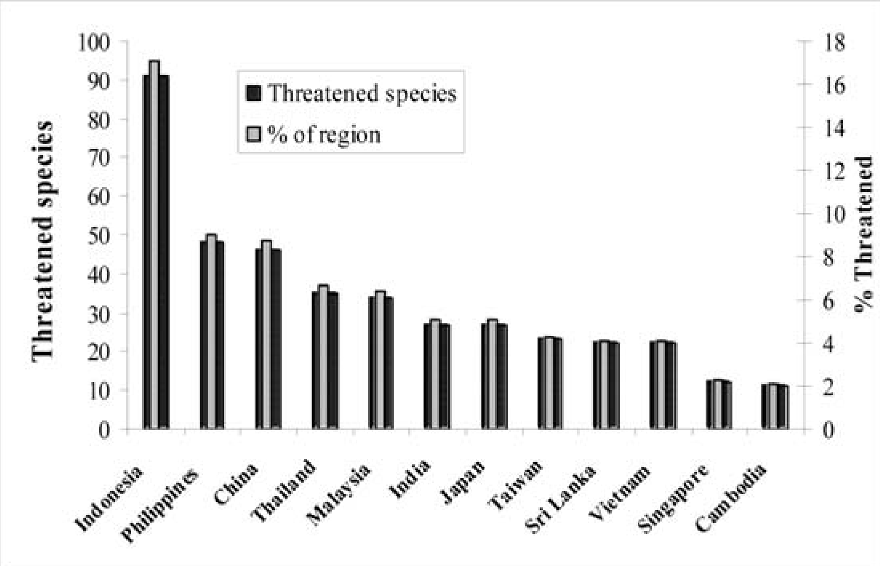


Table 3. Numbers of threatened species of all forms and finfish species in the different geographic regions. The geographic regions are those used in the IUCN Red List and the data are extracted from the Red List (2003; http://www.redlist.org/info/tables /table5.html).

Region	Number of threatened species	
	All organisms	Finfish
North Africa	201	58
Sub-Saharan Africa	4076	465
Antarctic	26	2
East Asia	873	119
North Asia	237	38
South & South East Asia	4102	343
West & Central Asia	894	188
Europe	1676	366
Mesoamerica	1410	203
Caribbean Islands	1201	294
North America	1165	181
South America	3362	149
Oceania	1844	234
Total	21067	2640

former category. Habitat wise (Table 4) it is relatively disconcerting that 14 endemic species, all cyprinids, in Lake Lanao, Mindanao, Philippines are critically endangered, followed by five species from five families (Amblycipitidae, Bagridae, Balitoridae, Cyprinidae, Siluridae) in Dian Chi Lake in China.

It is also important to point out that different nations may have prepare their own list of endangered species, taking in to consideration depletion of populations of certain species which on the other hand remain almost intact elsewhere. A case in point for example is India. In India, Conservation Assessment and Management Plan has identified 327 freshwater fishes in India to be threatened, of which 45, 91, 81 and 66 to be critically endangered, endangered, vulnerable and low risk near threatened, respectively (Haniffa et al., 2004), which is obviously significantly different to that of the IUCN list. However, in the present article, to retain uniformity, we have adhered to the IUCN records, and in a manner this also helps to minimises confusion.

This article will be followed-up by one on factors affecting biodiversity of finfish in the Asian region in a forthcoming issue of this magazine.

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Table 4. Critically endangered (CR) and endangered (EN) finfish species, and the English common names, belonging to different families in East and South and Southeast Asia. The known habitats (anadr.- anadromous; br- brackish water; ma- marine; fw- freshwater) together with the distribution of each species is given. Where available the specific location of occurrence is given. The table is based on data obtained from the IUCN Red List of Threatened species (http://www.redlist.org/search.php?freetext).

Family / Species	Common Name(s)	Distribution	Habitat	Status
Acipenseridae				
Acipenser dabryanus	Dabry's sturgeon	Korea and Yangtze Basin, China	andr; fw	CR
	Yantze sturgeon			
A. mikadoi	Sakhalin sturgeon	Japan and Korea	andr; fw; br; ma	EN
A. chrenckii	Amur sturgeon	Endemic to the Amur basin, China	fw; br	EN
A. sinensis	Chinese sturgeon	China, Japan and Korea	andr; fw; br; ma	EN
Huso dauricus	Kaluga	Amur basin, China	fw; br	EN
Adrianichthyidae				
Adrianichthys kruyti	Duck-billed buntingi	Indonesia	fw	CR
Oryzias orthognathus	Buntingi	Indonesia	fw	EN
	Sharp-jawed buntingi			
Xenopoecilus oophorus	Egg-carrying buntingi	Indonesia	fw	EN
X. poptae	Popta's buntingi	Indonesia	fw	CR
X. sarasinorum		Indonesia	fw	EN
Amblycipitidae				
Liobagrus nigricauda		Dian Chi Lake, China	fw	EN
Bagridae				
Pseudobagrus medianalis		Dian Chi Lake, China	fw	EN
Balitoridae				
Yunnanilus nigromaculatus		Dian Chi Lake, China	fw	EN
Belontiidae				
Betta livida		Peninsular Malaysia	fw	EN
B. miniopinna		Indonesia	fw	CR
B. persephone		Malaysia	fw	CR
B. spilotogena		Indonesia	fw	CR
Parosphromenus harveyi		Peninsula Malaysia	fw	EN
Clupeidae				
Tenualosa thibaudeaui		Mekong River Basin	fw	EN
Cobitidae				
Lepidocephalichthys jonklaasi	Spotted loach	Sri Lanka	fw	EN
Botia sidthimunki		Chao Phraya and Mekong basins	fw	CR
Cyprinidae				
Acheilognathus elongatus		Dian Chi Lake, China	fw	EN
Anabarilius polylepis		China.	fw	EN
Balantiocheilos melanopterus	Silver shark	Thailand, Malay Peninsula, Indonesia	fw	EN
Cephalakompsus pachycheilus		Endemic to Lake Lanao, Philippines	fw	CR

Table 4 continued.

Chela caeruleostigmata		Mekong and Chao Phraya basins	fw	CR
Cyprinus micristius		Dian Chi Lake, China	fw	EN
Danio pathirana	Barred danio	Nilwala River basin, Sri Lanka	fw	CR
Hampala lopezi		Born, Indo-China, Siam, Philippines	fw	CR
Labeo fisheri	Green labeo, Mountain labeo	Sri Lanka	fw	EN
	Mountain labeo			
Labeo lankae		India and Sri Lanka	fw	CR
Mandibularca resinus	Bagangan	Endemic to Lake Lanao, Philippines	fw	CR
Onychostoma alticorpus		Taiwan	fw	EN
Ospatulus palaemophagus		Endemic to Lake Lanao, Philippines	fw	EN
O. truncatus	Bitungu	Endemic to Lake Lanao, Philippines	fw	CR
Probarbus jullieni	Julien's golden carp	Chao Phraya and Meklong basins	fw; br	EN
	Seven-striped barb			
Puntius amarus	Pait	Endemic to Lake Lanao, Philippines	fw	CR
P. asoka	Asoka barb	Sri Lanka	fw	EN
P. bandula		Sri Lanka.	fw	CR
P. baoulan	Baolan	Endemic to Lake Lanao, Philippines	fw	CR
P. clemensi	Bagangan	Endemic to Lake Lanao, Philippines	fw	CR
P. disa	Disa	Endemic to Lake Lanao, Philippines	fw	CR
P.lavifuscus	Katapa-tapa	Endemic to Lake Lanao, Philippines	fw	CR
P. herrei		Endemic to Lake Lanao, Philippines	fw	CR
P. katalo	Katalo	Endemic to Lake Lanao, Philippines	fw	CR
P. lanaoensis	Kandar	Endemic to Lake Lanao, Philippines	fw	CR
P. manalak	Manalak	Endemic to Lake Lanao, Philippines	fw	CR
P. martenstyni		Sri Lanka	fw	EN
P. tras	Tras	Endemic to Lake Lanao, Philippines	fw	CR
Rasbora wilpita		Sri Lanka.	fw	EN
Schizothorax lepidothorax		China	fw	EN
Spratellicypris palata	Palata	Endemic to Lake Lanao, Philippines	fw	CR
Tor yunnanensis		China	fw	EN
Gobiidae				
Pandaka pygmaea	Dwarf pigmy goby	Indonesia, Philippines and Singapore.	fw; br; ma	CR
Weberogobius amadi	Poso bungu	Indonesia	fw	CR
Melanotaeniidae				
Chilatherina sentaniensis	Sentani rainbowfish	Lake Sentani, Indonesia.	fw	CR
Melanotaenia boesemani	Boeseman's rainbowfish	Indonesia.	fw	EN
Osteoglossidae				
Scleropages formosus	Asian arowana	Indonesia, Malaysia, Thailand,	fw	EN
	Asian bonytongue	Cambodia and Viet Nam		
	Golden arowana			
	Golden dragonfish			
Pangasiidae				
Pangasianodon gigas	Mekong giant catfish	Endemic to the Mekong basin	fw	
Polyodontidae				
Psephurus gladius	Chinese paddlefish	Endemic to the Yangtze River basin, China	fw	CR
Salmonidae				
Oncorhynchus formosanus		Taiwan	fw	CR
O. ishikawai	Satsukimasu salmon	Japan	fw	EN
Salvelinus japonicus	Kirikuchi char	Japan	fw	EN
Siluridae				
Encheloclarias curtisoma		Peninsular Malaysia	fw	CR
E. kelioides		Peninsular Malaysia, Indonesia	fw	CR
Silurus mento		Endemic to Dian Chi Lake, China	fw	EN

The STREAM Column

We've been debating what a STREAM column in Aquaculture Asia should do. It's been quite impassioned actually (which is almost certainly a good thing!). That's partly because as a learning and communications initiative, since November 2001, we have many existing communications *vehicles*. There is the STREAM Journal sharing six short pieces each quarter, from farmers, fishers, fisheries officers, specialists from many fields and building links, one to another; our website with its News and Events feature and Media Monitoring Service, and the ever-growing Virtual Library. There are country pages and documents about *ways of working*: developing country strategies, planning processes, ways to monitor and evaluate those expected changes (the ones in Logic Frameworks) and the unanticipated changes, told by real people in *significant change stories*.

A regional network reaching out to people

From early pilots in Vietnam and Cambodia, STREAM Communications Hubs are currently operated from 11 countries across Asia-Pacific, managers are fluent in English and local languages, with a background in fisheries, aquaculture or other natural resource management and an understanding contemporary development issues. They are good communicators, and in regular face-to-face and internet contact. They are part of a system linking government and non-government colleagues embedded through Partnership Agreements into ministries, provincial offices, cities and towns and reaching out to diverse networks of people, self-help groups and their federations, supporting them to provide ever better services.

What began as a general desire to share messages about processes, technologies, lives and opportunities amongst farming and fishing communities and those who work with them, is having to evolve into a system of *sharing meaning*, currently in 14 languages, about complex concepts like sustainable development and livelihoods approaches and some of their basic components like foraging from paddies and small water bodies, gleaning from shores and reefs, fishing and managing small-scale aquaculture, finding opportunities and hope.

Communications and learning shared over gulfs of distance, culture, language, social and natural systems and environments are brave yet lofty aspirations. They ask us to confront complex situations in people's lives and hint at even more lofty goals like the democratization of knowledge. They immediately raise practical challenges about the structure and functioning of institutions to understand and support people, especially people with least voice and power. Scariest of all, they tempt us to muddy our hands with problems and processes that give rise to policy development.

Many readers of Aquaculture Asia grapple with the basics and the bigger pictures. If this column provokes debate and thinking about lofty and the local goals then we can cease debating about what this column should do.

STREAM Website
www.streaminitiative.org

STREAM Regional Office
c/o NACA
Department of Fisheries Complex
Kasetsart University Campus, Phaholyothin Rd
Bangkhen, Bangkok 10903 Thailand
Phone: 662 561 1728/29
Fax: 662 561 1727
Email: stream@enaca.org

E-mails and other tales…

Working together

Dear HQ Rome,
Today I had a talk with STREAM Vietnam and I think we are completely on the same line concerning the fisheries network for Vietnam and even better, they have done already a great part of the job to establish it. Please find attached the proposal of STREAM Vietnam for a national fisheries network of June 2004 and give your comments on it. They and I will try to launch the internet site as soon as possible after consulting some other big parties such as OneFish, UNDP, FMIS and NACA.

We are on the right way now!

Regards,
Fisheries Specialist
Food and Agriculture Organization
of the United Nations, Hanoi.

E-mails and other tales…

Legal use of documents

Dear STREAM Initiative,
At your webpage (www.streaminitiative.org) we found interesting and valuable documents relevant to our ongoing work. Unfortunately, I couldn't find any statement about their legal use.

We are a Cooperation Programme between the German Technical Cooperation Agency (GTZ) and the Mekong River Commission working in the field of watershed management within a regional policy framework.

We kindly request permission to download and store the documents provided on your webpage within our internal system and to post them further at MekongInfo.

Information Management
MRC-GTZ Cooperation Programme

Thank you for your enquiry and your positive feedback on our website and your interest in our work. The legal position is as follows: All our publications are Copyright ©The STREAM Initiative, publication year. Reproduction for educational or other non-commercial purposes is authorized without prior permission from the copyright holder, provided the source is fully acknowledged. Reproduction for sale or other commercial purposes is prohibited without prior permission from the copyright holder. Therefore you are welcome to reproduce our publications on the above basis. We try to log downloads and distribution of our publications and your help in doing this would be appreciated. We might also consider linking the two webpages. We could put a link from our Virtual Library to your site and visa versa. Let me know if you are interested to do this.

E-mails and other tales…

Dear STREAM Initiative,

As always I do appreciate your courtesy and service. I have found your publications resourceful and informing. Please keep the noble work up.

Sincerely,
Paul Namisi

More tools for sharing meaning and where to get them: Livelihoods CD

Dear STREAM Initiative,
I am interested to acquire the CD, *A Process and Practice for Understanding the Livelihoods of Fishers and Farmers.* How can I get it? Thanks a lot for any kind of information.

Yours,
Université Montpellier II
France.

Dear Montpellier,

Thank you for your message. If you email us your postal address, we will send you a copy of the CD in which you are interested. We invite you to visit our website and library (www.streaminitiative.org).

STREAM E-Bulletin

Dear Colleague

Welcome to the STREAM E-Bulletin, outlining activities and outputs of the STREAM Initiative, which is distributed to a range of stakeholders concerned with aquatic resources management. We invite you to view the E-Bulletin at http://www.streaminitiative.org/Subscribe.html.

Her farm is destroyed, how can we help?

By S.Y. Sim.

The tsunami caused severe damages in six provinces in southern Thailand. Many lives were lost. For many of those who survived life goes on – but in an extremely difficult situation.

Khun Chew Oi Charuanhatakid is a 65 year old lady who was born and lives in Krabi. She has been farming marine fish for more than 20 years. Originally, she invested 600,000 baht from her savings to start up a marine fish farm with twenty floating cages. She gradually built her farm up and before the tsunami she was running 48 cages of around 3 x 3 x 3 metres, located near Krabi Fishing Port.

After the tsunami: The tangled wreckage of Khun Chew Oi's cages is visible to the right of the damaged farmhouse, now run aground.

Khun Chew Oi as I first met her: A happy fish farming lady in Krabi who liked to help small fishermen by buying their catches.

Khun Chew Oi used to employ casual workers to help with her farming activities such as grading fish, buying fish feed, cleaning and repairing nets and harvesting. She lived in a floating house built on the farm. She used to have two boats, each worth about 6,000 baht, one with an engine costing 10,000 baht. She also had a small generator, which cost around 13,000 baht.

She bought her marine fish fingerlings mainly from small-scale fishers who were fishing in the nearby areas. Although she could buy fingerlings from elsewhere she preferred to help out the small local fishers, because she knew that if she doesn't buy from them they cannot sell to other places, due to the difficulty in transporting small quantities of marine fish fingerlings. When I first met Khun Chew Oi prior to the tsunami, she said "if I don't buy from them, they will have no income and if they do not have money, they will do bad things". There were more than ten fishers she bought her fingerlings from.

Her farm was totally destroyed by the tsunami. She has nothing left - no fish, no cages. She cannot do other work because of her age and her lack of schooling. She does not have employable skills except for fish farming.

After the tsunami, a fisheries official visited her farm. He told us that she is now using her very last savings to try to put together a very small area to start her farm again. She was in tears, and in need of help.

Khun Chew Oi paddles back to her farm after sending off visitors.

Khun Chew Oi feeding her fish during a visit conducted under the NACA/ Deakin University survey visit in April 2004.

Women oyster vendors in Eastern Thailand

Brian Szuster and Mark Flaherty

Oyster vendor shucking oysters with her son.

Thailand's seafood industry is a major source of employment for households in many rural and peri-urban coastal communities. Although the wild fishery continues to account for the largest volume of seafood production in Thailand, and is the largest source of wage labor, aquaculture is playing an increasingly important role in the overall fisheries sector. Participation in aquaculture is, however, often characterized by a distinct gender division of labor (DFID, 2000; Chaisri, 1997). Men are usually responsible for husbandry while women predominate in post-harvest activities such as sorting, processing and marketing. Despite the high visibility of women in post-harvest activities, very little research has been undertaken to develop a better of understanding of the specific roles that women play in the aquaculture sector. While aquaculture is generally seen as playing an important role in poverty reduction, little is known about the income that women derive from aquaculture, factors that contributed to their participation in the industry, or issues that limit their involvement. Such information would be invaluable in developing training and extension programs that support women's aquaculture activities and thereby enhance household incomes (Felsing et. al., 2000). To date, however, relatively little emphasis has been placed on developing these programs in most Southeast Asian countries (Brugere et. al., 2001; Matics, 1997). The Thailand Aquaculture Management Project, which is a collaborative project involving faculty from the Department of Aquatic Sciences at Burapha University in Thailand and the Department of Geography at the University of Victoria in Canada, is currently designing a small pilot program to help address this gap.

This paper reports the results of a small study undertaken to collect baseline data on the involvement of women in oyster vending. The study site selected was Ang Sila, a small peri-urban community located approximately 100 kilometers southeast of Bangkok along the Bangpakong river estuary (Figure 1). This area is an important oyster growing area in eastern Thailand that is now farmed quite intensively. The research focuses on women oyster vendors who operate small roadside operations adjacent to the oyster grow-out sites. In addition to information about their oyster marketing activities, the women were surveyed regarding their knowledge of product handling and seafood safety issues. This information will be used to help develop a targeted extension program that would help women oyster vendors to improve their operations and enhance the safety of seafood products sold to domestic consumers in Thailand.

Oyster production and marketing in Thailand

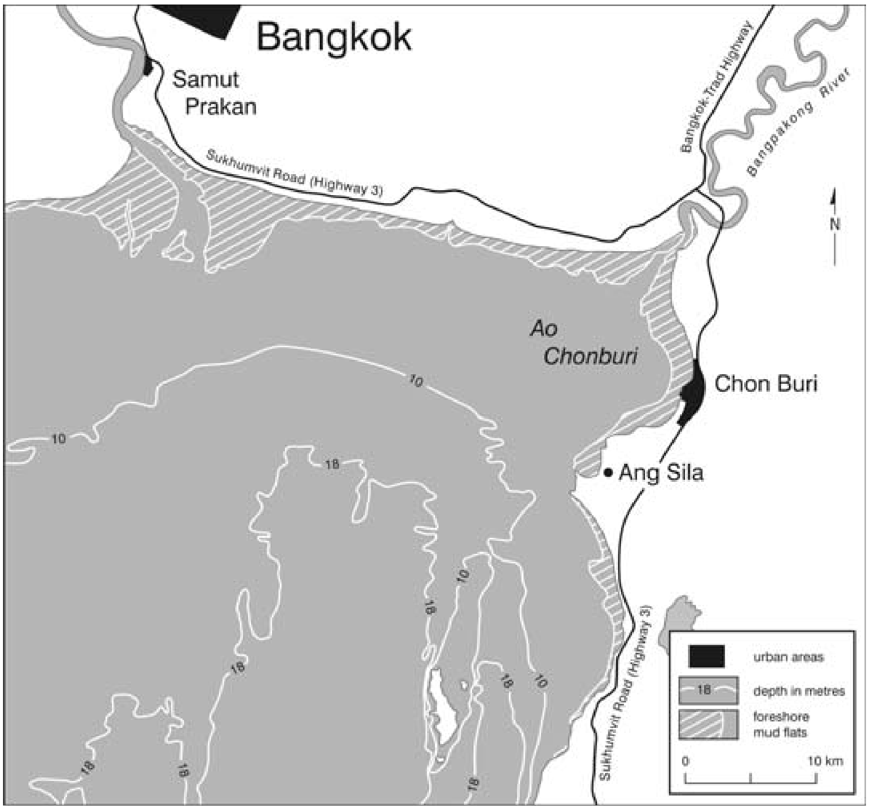
All oysters in Thailand are produced by aquaculture, and total harvests during the year 2001 were approximately 20,000 tonnes (Department of Fisheries, 2003). Although oysters represent only approximately 16% of Thailand's total farmed shellfish harvest by weight (green mussel and blood cockle harvests are much larger) the oyster crop was worth more than $20 million USD in 2001. Semi-traditional culture techniques are employed and typically involve the use of concrete posts or bamboo rafts to support oysters growing within suitable near-shore areas. Fresh shucked oysters are a very popular food item in Thailand that is commonly sold at roadside stands or in local markets. A small proportion of the oyster crop is frozen for sale in areas more distant from the coast or bottled and preserved in brine.

The sale of Thai oysters is largely limited to domestic markets as a result of stringent seafood safety regulations in major export markets such as Japan, Europe and the United States (Chalermwat et. al, 2003). Although Thailand's seafood processors have made significant improvements in product safety and sanitation in recent years, these advances have been largely restricted to large-scale commercial processing plants that supply international markets. A far larger number of small-scale operations supply seafood such as oysters to the Thai domestic market. Unfortunately, these small commercial enterprises regularly process and market oysters in conditions that have the potential to compromise public health. As noted previously, women dominate the small-scale marketing of farmed oysters in Thailand. Extending basic seafood sanitation techniques to this group could enhance the quality and safety of fresh oysters sold to domestic consumers, and potentially allow these women entrepreneurs to access more lucrative markets such as Bangkok.

Background of female oyster vendors

Twenty women oyster vendors in the Ang Sila district of Chonburi Province were interviewed during August of 2003. This group represents approximately 50% of the total number of female oyster vendors operating in the district at that time. The average age of the women was 46 years and 95% were married and had children. Education levels were modest (averaging Grade 5) with Grade 9 being the highest level of education attained by any of the women surveyed. All the women lived in the Ang Sila area and 40% had more than 10 years experience with oyster vending. The balance of the women in the sample had been selling oysters for an average of just over three years. A large percentage of the women (45%) decided to become oyster vendors because shellfish farming and/or market-

Figure 1: Location of the Study Site.



Oyster harvest, Ang Sila, Thailand.

Women oyster shuckers, Ang Sila, Thailand.

Above and below: Oyster vendor at her stand, Ang Sila, Thailand.

Preserved bottled oysters and other seafood products.

Oyster strings on bamboo racks, Ang Sila, Thailand.

ing was a traditional activity in their family. Other factors that led women to participate in oyster vending included good income levels and the nature of oyster vending as a flexible, local job. The part-time nature of oyster vending was particularly important to younger women with pre-school aged children. Most of the women (55%) focused on selling oysters at their own road-side stand, but other survey participants were also involved in shellfish farming or operating a second small food stall or gift shop.

Income and marketing information

Half of the women surveyed obtained their oysters from a local family farm that is often operated by their husband. This pattern matches the division of labor between men and women found elsewhere in Southeast Asia with respect to aquaculture activities (Chaisri, 1997; Spliethoff, 1987). It is notable, however, that 20% of these women directly participate in oyster farming in addition to managing a small roadside marketing outlet. In most of these situations a husband and wife team manages the family oyster farm, but a small number of women operate oyster farms independently with the assistance of hired male laborers to assist with physically demanding tasks. The average female vendor obtains approximately 200 kg. of oysters per week from local farms, and pays approximately 7 baht ($0.18 USD) per kilo for shell-on oysters sold in baskets or sacks. Substantial spoilage occurs in fresh oysters purchased from local farms, but the women can only determine the extent of this loss after shucking.

Most of the women shuck their own oysters, but many (75%) also employ part-time help for this task. Part-time shuckers are usually a family member or a local woman hired by the oyster vendor on a day-by-day basis. Part-time shuckers typically earn 20 baht ($0.50 US) per kilo of shucked oysters, and an experienced person can shuck up to 30 kg. per day. Their potential daily income of $15.00 US for shuckers should be placed in the context of Thailand's minimum wage, which is 146 baht ($3.65 US) per day in Chonburi province (TDRI, 2002). Most of the vendors would like to sell more product, but fresh oysters must be sold within 24 hours of being shucked and this limits the total daily amount of oysters a vendor can process each day. Unsold shucked oysters are typically bottled in fish sauce to avoid spoilage, and this is the only form of preservation practiced by most vendors. Bottled oysters are, however, much less popular than the fresh shucked oysters in Thailand. A typical vendor sells approximately 100 kg. of fresh oysters per week and two or three bottles of preserved oysters. The average retail price of a kilo of fresh shucked oysters was 100 baht ($2.50 USD) during the survey period, and a bottle of preserved oyster typically sold for $3 USD. Most customers are members of the general public who stop at a favorite roadside stand, but 25% of the vendors indicated that they also sell to local restaurants or food stands. The average vendor sold 30 kilos of fresh oysters per week and had a approximate weekly net income of 2000 baht ($50 USD).

Seafood safety issues

Oyster consumption can potentially produce a number of health concerns related to the presence of pathogenic bacteria, viruses, shellfish biotoxins or chemical contaminates (U.S. FDA, 2001). Fortunately most of the phytoplankton blooms in the Gulf of Thailand are not toxic, but pathogenic bacteria such as Vibrio do exist in oyster growing regions contaminated by sewage (Chalermwat et.al., 2003). Outbreaks of viruses such as Hepatitis A can also occur as a result of consuming of uncooked contaminated shellfish. Chemicals in the form of pesticides, herbicide or heavy metals are potentially present in coastal waters, and these can produce illness if contaminated shellfish are consumed by over a longer period of time.

The control of pathogenic bacteria is particularly important in Thailand because fresh, uncooked oysters are the preferred product form for most domestic consumers. Given this concern, the women oyster vendors of Ang Sila were surveyed for their level of knowledge related to seafood sanitation and potential health concerns related to their oyster processing activities. In general, sanitary conditions at the stalls were poor and fresh oysters were commonly processed in conditions favorable for pathogen growth. Temperature

Oyster farming in the upper Gulf of Thailand, Ang Sila area.

control is the key factor controlling the degree of pathogen growth in fresh oysters. However, none of the roadside vendors had access to refrigeration. Ice is used to prevent spoilage of shucked oysters, but this form of temperature control is both limited and variable in its ability to limit bacterial pathogen growth. Fresh and shucked oysters were regularly exposed to temperature abuse as daytime temperatures typically rise above 35 degrees C at the roadside stands. The female vendors we interviewed had a limited understanding of seafood safety issues with only 10% of the sample having any formal training in this area. This training consisted of a one-day government-sponsored course in basic food hygiene techniques developed to improve sanitary conditions in restaurants and other food outlets. Nevertheless, it is encouraging that most of the vendors (80%) acknowledged their lack of knowledge in this area and indicated that they would like to have more information about seafood safety and food hygiene techniques.

Discussion and conclusions

Oyster vending is a flexible, local form of employment that provides a valuable source of income for women with modest levels of education in rural and peri-urban coastal communities of Thailand. Women dominate the processing and marketing of oysters in Thailand, but their training needs have been largely ignored by government agencies that provide aquaculture extension services (DIDF, 2000). There are several reasons for this situation. Shellfish aquaculture was not part of the export-oriented boom in seafood production that swept Thailand during the past fifteen years. Most extension services that developed during this time focused on large commercial plants involved in the processing of farmed crops such as shrimp. Oyster production is almost completely restricted to small domestic markets in Thailand and is considered a relatively insignificant generator of revenue. Part-time seafood processing and marketing activities conducted by women also continue to be viewed as less socially significant than full-time farming activities undertaken by men (Brugere et. al., 2001). This situation is changing slowly through the action of groups such as the Thai National Women in Fisheries (TWIF) that provide both organizational and operational support to women involved in aquaculture. The Thai Department of Fisheries has agreed to act as a focal point for the TWIF, but much more government attention is needed in this area.

Female oyster vendors are keenly aware of the limitations associated with their reliance on fresh-shucked oyster sales. Many of the women in the survey group expressed a desire to learn value-added processing and preservation techniques. A lack of suitable small-scale technologies represents a major existing constraint for most female oyster vendors. A focused training program would clearly benefit women oyster vendors by providing them with the skills required to process and preserve larger quantities of oysters on a daily basis. A lack of training and extension opportunities has not only limited the growth of oyster sales in Thailand, but it has also denied Thai consumers the health benefits of seafood sanitation procedures that are enjoyed by consumers in Europe, Japan and the USA. Fresh oysters are susceptible to contamination from a variety of sources, but many of these hazards can be controlled through appropriate seafood sanitation techniques. The extension of training programs that focus on women are clearly appropriate given the dominance of women in the processing and marketing of oysters in Thailand, and technical support of this type could play an important role in improving the safety of a seafood that is highly valued by Thai consumers.

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Authors

Dr. Brian Szuster is an Assistant Professor in the Department of Geography at the University of Hawai'i at Manoa (445 Social Sciences Building, 2424 Maile Way, Honolulu, HI, USA 96822)

Dr. Mark Flaherty is a Professor in the Department of Geography at the University of Victoria (PO Box 3050 STN CSC, Victoria, BC, V8W 3P5, Canada)

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Asia-Pacific Marine Finfish Aquaculture Network

Magazine

SKRETTING

NACA

January-March 2005

Feed and feeding practices at farm level for marine finfish aquaculture in Asia-Pacific: 25

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Grouper grow-out feeds research at Maros Research Institute for Coastal Aquaculture, South Sulawesi, Indonesia: 42

Feed and feeding practices at farm level for marine finfish aquaculture in Asia-Pacific

Sih Yang Sim and Kevin Williams

There are many marine finfish species cultured in the Asia-Pacific region and many of these still rely on trash fish as the sole food source for nursery and grow-out stages. Although there are some commercially produced formulated feeds, Asia farmers, particularly small scale operators, prefer the traditional methods of feeding trash fish to carnivorous species such as snapper, Asian seabass (barramundi) and groupers because of its availability and the farmer's view that pelleted feeds are more expensive. In contrast, Australian fish farmers exclusively use pelleted dry feeds for almost all farmed fish, including barramundi, groupers, snappers and Atlantic salmon. Southern blue fin tuna is the only marine finfish species in Australia where fresh fish (usually pilchards) is fed but even this industry is slowly changing to feeding pelleted dry feeds as better tuna formulations are developed.

Farm worker feeding pelleted feed at a Penang seabass farm.

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Contact
Asia-Pacific Marine Finfish Aquaculture Network
PO Box 1040
Kasetsart Post Office
Bangkok 10903, Thailand
Tel +66-2 561 1728 (ext 120)
Fax +66-2 561 1727
Email grouper@enaca.org
Website http://www.enaca.org/marinefish

Editors
Sih Yang Sim
Asia-Pacific Marine Finfish Aquaculture Network
c/o NACA
sim@enaca.org

Dr Michael J. Phillips
Environmental Specialist & Manager of R&D, NACA
Michael.Phillips@enaca.org

Simon Wilkinson
Communications Manager
simon.wilkinson@enaca.org

Dr Mike Rimmer
Principal Fisheries Biologist (Mariculture & Stock Enhancement)
DPIF, Northern Fisheries Centre
PO Box 5396
Cairns QLD 4870
Australia
Mike.Rimmer@dpi.gov.au

Feeding pelleted feed to threadfin at a marine fish farm in Johor.

Malaysia

Marine finfish farmers in Malaysia use a limited commercial formulated feed. Most carnivorous species are cultured on trash fish although several carnivorous and omnivorous species (eg. *Lates calcarifer* Asian seabass, *Eleuthonema tetradectylum* fourfingers threadfin and *Trachinotus blochii* pompano) use generic Asian seabass feed as the main feed source, supplemented with trash fish. Snapper and grouper species are mostly fed with trash fish. This is often of poor quality and consists of a mixture of unwanted fish species, usually very small in size.

However, other marine finfish species such as milkfish are fed with industrial bakery rejects or low-grade wheat flours. The growth rate of these fish is very slow, requiring a total of 18 months for 1 cm fry to reach a marketable size of around 300-500 grams.

Indonesia

The farming practice in Indonesia is a mixture of feeding pelleted dry feed produced by commercial feed companies, or trash fish. Although commercial feed for grouper is available in Indonesia, the price is still high, about US$1/kg. By comparison, the cost of trash fish is about US$ 0.35-0.59 per kg, depend on species and season. However, since trash fish contains a lot of water, around 70% or more, whereas pelleted dry feed contains only about 10% water, the pelleted feed is less expensive than trash fish when the comparison is made on the basis of the amount of nutrients each provides. Cost is only one factor to consider as some fish do not readily take to pelleted feed unless they have been weaned onto it from an early age.

Most humpback groupers (*Cromileptes altivelis*) are fed on pelleted

Farm worker feeding formulated feed to pompano fingerlings at a floating cage farm in Johor.

Farm worker cleaning fresh sardine, headed, gutted and de-boned for feeding to groupers.

Trash fish cut into different sizes to suit various sizes of groupers in different cages.

dry feeds while other grouper species (*Epinephelus* spp and *Plectropomus* spp.) are mostly fed on trash fish.

Normally, commercial feed is broadcast into the cages and the fish fed to apparent satiety based on the judgment of the workers. Trash fish is usually chopped into pieces according to the size of groupers. Some farmers will remove the head and gut before feeding to the grouper, while others who are running on a larger scale simply cut the whole fish into chunk-size pieces, gut included.

The species of trash fish used varies from place to place and the time of the year. Most of the trash fish used in Indonesia is of good quality.

Thailand

Formulated pelleted dry feed is used for most seabass farming in Thailand. However, for other carnivorous species such as grouper, snapper and trevally most farmers still prefer to use trash fish. The quality of trash fish is generally quite good, with a price of around US$ 0.20-0.28 per kg depending on season and species. Currently, there is no commercial feed available locally for snapper or groupers.

Hong Kong and China

In Hong Kong most cultured marine finfish species are carnivorous with species including seabreams, snappers, amberjack, cobia and pompano. Most farms are still feeding trash fish but some farms use dry pellets, with a few using moist pellets for grow-out practices.

Several species of marine finfish farmed in the southern part of China are fed mostly on trash fish, particularly for aggressive feeders such as amberjack and cobia. Fresh trash fish cost around US$ 0.20-0.25 per kg. Other species such as tiger grouper (*Epinephelus fuscoguttatus*), tongue soles (*Cynoglossus* spp.) and flounders (*Pseudorhombus* spp.) are mostly fed with farm made moist feed, with local trash fish as the main ingredient and mixed with fishmeal. When the supply of trash fish is scarce, particularly during closed fishery season, formulated dry feed is used as a supplement. Dry feed costs around US$0.85/kg.

Farmer feeding trash fish to groupers in Southern Thailand.

Trash fish and fishmeal mixed to form a "block" of moist feed for nursery of five centimeter grouper fingerlings.

Milkfish feeding on industrial bakery rejects.

Typical polar cages used for Atlantic salmon culture in Tasmania.

Vietnam

Vietnam farms a wide range of marine carnivorous finfish species including snappers, seabreams, groupers and cobia. Most of the feeding is based on trash fish particularly in farming areas at Cat Ba Island and Halong Bay. The trash fish cost around US$ 0.19-0.45/kg. Most of the trash fish are freshly caught by small-scale fishers and delivered to the farms by boat daily.

Australia

The main marine species cultured in Australia are southern bluefin tuna (*Thunnus maccoyii*), Atlantic salmon (*Salmo salar*), Asian seabass/barramundi (*Lates calcarifer*) and yellowtail king fish (*Seriola lalandi*). There is also some production of snapper (*Pagrus auratus*), groupers (*E. coioides*), mulloway (*Argyrosomus hololepidotus*) and black bream (*Acanthopagrus butcheri*). All marine finfish farming in Australia uses extruded pelleted dry feed except for southern bluefin tuna where a transition is occurring from feeding fresh pilchards to extruded pellets. Depending on the species, these feeds are produced as slow-sinking pellets (for most seacage farms) or as a floating pellet. Floating pellets are used for aggressive feeders such as yellowtail king fish and especially for barramundi cultured in freshwater impoundments where the turbidity of the water encourages the fish to feed at the surface. Atlantic salmon, southern bluefin tuna and yellowtail king fish are cultured in large polar cages of 80 m diameter or bigger while barramundi are cultured in rectangular or polar cages of varying sizes. Smaller and typically rectangular cages (lengths of 4 to 6 m) are used for fish cultured in freshwater impoundments while larger rectangular or polar cages (lengths or diameters of 20+ m) are used for fish in seawater. Atlantic salmon and barramundi feeds are formulated specifically for these species while these or slight variants of them are used for the other species. Barramundi feeds typically contain 45-50% crude protein and 13 to 18% lipid and cost from US$1.10 to 1.20 per kg. Atlantic salmon feeds are 40-42% crude protein and 28-30% lipid, costing from US$1.30 to 1.45/kg.

Feeding commercial slow sinking feed to groupers in Lampung.

Farm workers are feeding trash fish to cobia in Cat Ba Island.

Sea cages used at Marine Harvest's Tiwi Island (near Darwin) barramundi farm, which produces about 1,500 tonnes of fish per year. Problems with crocodile and shark predation has been overcome using stainless steel mesh.

ACIAR grouper grow-out feeds program and related CSIRO research

Kevin C. Williams[1], David M. Smith[1], Ian H. Williams[2], Simon J. Irvin[1] and Margaret Barclay[1]

[1] CSIRO Marine Laboratory, PO Box 120, Cleveland, Qld. 4163, Australia, Email: kevin.williams@csiro.au
[2] Animal Biology, Faculty of Natural and Agricultural Sciences, University of Western Australia, 35 Stirling Highway, WA, 6009, Australia.

Groupers are highly prized fish in the live reef fish markets of Hong Kong and other Asian cities where prices (US$/kg) range from 8-11/kg for gold spot grouper (*Epinephelus coioides*), $15-20 for tiger grouper (*E. fuscoguttatus*), $30-40 for coral trout (*Plectropomus* spp) and red grouper (*E. akaara*) and $80-95 for mouse grouper (*Cromileptes altivelis*). The recent development of technology for large-scale hatchery production of grouper fry in Indonesia and the Philippines, largely as a result of research carried out in the collaborative ACIAR grouper project, is producing a plentiful supply of grouper fingerlings for aquaculture on-growing. At the time that the ACIAR grouper project began in 1999, information on the nutritional requirements of groupers for grow-out from fry to market was almost non-existent. To address this need, the ACIAR grouper project collaborators in Australia, Indonesia, the Philippines and Vietnam embarked on grow-out feeds research with the primary aim of developing cost-effective pelleted grouper grow-out feeds. Our approach was to:

1. Define the requirements of groupers for the key nutrients that determine the rate at which fish grow.
2. Determine the nutritive value of locally available marine and terrestrial feed ingredients; and

3. Examine the extent to which high cost marine protein feed ingredients could be replaced using cheaper and more renewable terrestrial protein feed ingredients.

The ultimate goal is to develop pelleted grouper feeds as a more sustainable, lower-polluting and cost-effective alternative to the feeding of fresh fishery bycatch. If achieved, this would provide a more sustainable and profitable way of culturing groupers and at the same time reduce competition between man and aquaculture for a dwindling supply of fishery catch and lessen aquaculture's impact on the surrounding environment.

This article details the project research carried out by CSIRO and summarizes other grow-out feeds research in the ACIAR grouper project. Other articles in this series describe in more detail the project work that was carried out in Indonesia and Vietnam.

Flow-through constant temperature seawater experimental array consisting of 48 x 100 L insulated tanks at CSIRO used for grouper nutrition research.

ACIAR Grouper Project grow-out feeds team

The research was a collaborative effort between four laboratories that were formal participants in the ACIAR Grouper project and a fifth institution, which became affiliated with the project through a complementary Australian AusAID CARD project. The collaborating institutions and team leaders were: Dr Kevin Williams, CSIRO Marine Research, Cleveland, Australia; Dr N. Adiasmara Giri, Research Institute for Mariculture, Gondol, Bali, Indonesia; Ms Asda Laining, Research Institute for Coastal Aquaculture, Maros, South Sulawesi, Indonesia; Dr Oseni Millamena, South East Asian Fisheries Development Centre, Tigbuaan, Ilioli, the Philippines; and Dr Nguyen Dinh Mao, University of Fisheries, Nha Trang, Vietnam.

CSIRO studies on protein and lipid utilization in mouse groupers *C. altivelis*

A series of growth assay and digestibility studies were carried out under controlled laboratory conditions (filtered flow-through seawater at 29ºC and 12:12 photoperiod) to determine the optimum dietary protein and lipid specification for mouse grouper fingerlings. Additional metabolic studies were undertaken to see if feeding lipids comprised mostly of medium chain fatty acids (12-14 carbon chain length) would stimulate the fish to better use lipid as an energy source and so spare or reduce the amount of protein needed in the diet. Key findings of the research are outlined below.

Optimal dietary protein and lipid content

An 8-week comparative slaughter growth assay and digestibility study involving 10 pelleted dry feeds and 4 replicate tanks of fish per treatment (10 g start weight) was carried out to determine the optimal dietary crude protein (CP) and lipid specifications for juvenile mouse grouper. Fish growth rate, food conversion ratio, nutrient retention and protein digestibility of the diet improved linearly as the amount of CP in the diet was increased from 38 to 59%. However, increasing the amount of lipid in the diet from 14 to 22% reduced energy digestibility but growth rate of the fish was unaffected. Fish fed the higher lipid diets were much fatter (Table 1).

As the digestible protein (as N) content of the diet increased, the amount of digestible N required per kg fish weight gain increased: linearly for the 14% lipid diets, and curvilinearly for the 22% lipid diets (Figure 1). This shows feeding the higher lipid diet did bring about some sparing of protein for energy.

A second comparative slaughter growth assay and digestibility experiment employing the same culture conditions as for the first experiment was carried out to see if supplying lipid at moderate (15% added oil) or high (30% added oil) concentrations in the diet and in the form of either long-chain fatty acids (LCFA, as olive oil) or medium-chain fatty acids (MCFA, as coconut oil) affected the way the fish used the lipid as an energy source. Five diets, a low-lipid (6%), high-protein (76% CP) control diet and four 'lipid' diets that made up a 2 x 2 factorial of the two types and two concentrations of lipid, were fed to six replicate tanks of fish (300 fish in total; 14 g average initial weight) for 8 weeks. The formulation of the 'lipid' diets was identical to the control except that the required amount of lipid was included at the expense of defatted fishmeal with a concomitant lowering of the dietary CP from 76 (control diet) to 64 and 53% for the 15 and 30% lipid treatments, respectively.

Increasing the amount of lipid in the control diet by adding 15% of olive oil (LCFA) at the expense of fishmeal resulted in a 14 to 20% improvement in growth rate and food conversion, a doubling of the body fat content of the fish (from 15 to 29% DM) and the retention of dietary protein was increased by 28% (from 25 to 32%). Higher addition of olive oil (30%) reduced voluntary food intake by 40%, and consequently depressed growth rate by 32% while protein retention and body fat content were unchanged. Adding coconut oil (MCFA) instead of olive oil depressed food intake by 59%, with a similar reduction in growth rate and no increase in protein retention. The amount of dietary lipid retained as body fat in the fish relative to that oxidized for energy decreased with increasing dietary lipid and was less for MCFA than for LCFA lipids (Fig. 2).

Metabolism of fatty acids

The 'lipid' diets fed in the aforementioned Experiment 2 were used in this study except that radioactively-labeled fatty acids were incorporated to allow the metabolism of these fatty acids to be traced. As a marker for MCFA, ^{14}C-octanoic acid (an 8 carbon chain fatty acid) was used while ^{14}C-oleic acid (an 18 carbon chain fatty acid) and ^{14}C-palmitic acid (a 16 carbon chain fatty acid) were used as markers of LCFA. Diets with these labeled fatty acids were fed to fish in metabolic chambers (7-9 replicates per treatment) and the amount and rate of lipid oxidation quantitatively determined by measurement of the ^{14}C label present in the fish, in the expired CO_2 and in the dissolved and particulate organic matter in the water of the metabolic chamber.

The lipid in the MCFA diets, irrespective of whether present at 15 or 30% of the diet, was oxidized far more rapidly than the LCFA lipid, with far more of the ^{14}C label appearing in the respired CO_2 and less remaining in the fish (Table 2). The amount of lipid in the diet appeared to have no effect on the amount of lipid oxidized. Moreover, respiration rates increased dramatically when fish were fed the MCFA compared to the LCFA diets, indicating a physiological response of the fish to remove CO_2 produced as a result of lipid oxidation (Figure 2).

Conclusions

- Diets for fingerling mouse grouper should contain not less than 41% digestible protein (about 55% CP) on an as fed (~92-93% DM content) basis.
- Increasing the lipid content of the diet above about 15% did not promote greater fish growth but rather led to increased body fat deposition and a reduction in food intake. There was some evidence of protein sparing by dietary lipid.
- Replacement of LCFA lipids (such as fish or long-chain vegetable oils) with MCFA lipids (such as coconut oil) did increase the rate of fat oxidation but had a detrimental effect on food intake, and consequently also on growth rate.

Laboratory Technician Leigh Whitlock Laboratory carrying out lipid analyses at CSIRO's Cleveland laboratory.

Other grow-out feeds research in the ACIAR Grouper Project

Digestibility of feed ingredients

The apparent digestibility of a comprehensive range of ingredients available in the Philippines and Indonesia was determined for gold spot grouper (*E. coioides*) and mouse grouper (*C. altivelis*), respectively. CP in both marine and terrestrial animal meals was well digested (above 76%) by both grouper species with the exception of oven-dried blood meal, which was poorly digested (55%). The protein digestibility of plant products was more variable (from 43 to 100%) with high fibre meals such as rice bran and lucaena (ipil-ipil) meal being poorly digested. The DM digestibility of the meals was adversely affected by the amounts of ash and fibre they contained. A collation of the DM and CP apparent digestibility values of the tested ingredients is presented in Table 3.

Nutrient requirements of juvenile groupers

Growth rate and survival of sea-caged mouse groupers were improved when diets were supplemented with up to 150 mg/kg of vitamin C as the heat-stable form of L-ascorbyl-2-monophosphate-Na-Ca. This benefit of vitamin C supplementation was most apparent following heavy flood rains, which caused a marked deterioration in the turbidity and dissolved oxygen content of the water around the cages. The dietary requirement for the essential omega-3 highly unsaturated fatty acids (n-3 HUFA) was examined for mouse and tiger grouper. Increasing the supplementation rate up to 1-1.5% of the diet resulted in improved fish growth rates and better survival. In studies examining the capacity of mouse grouper to utilize different types of carbohydrate as energy sources, best results were achieved using glucose while starch and sucrose were the least effective.

These nutrient requirement studies indicate that juvenile groupers require diets that are high in digestible CP (around 45-50%), moderately low in lipid (around 10%) and contain not less than 1.0% and preferably 1.5% of n-3 HUFA. Addition of at least 100 mg of a heat stable form of vitamin C per kg of diet is recommended and this should be increased to 150 mg/kg if stressful culture conditions are likely to occur.

Table 1. Apparent digestibility (AD) of crude protein (CP) and energy (E) of diets and specific growth rate (SGR), dry matter (DM) food conversion ratio (FCR), DM body fat (BF) and retention of digestible N (RDN) and digestible E (RDE) of juvenile mouse grouper.

Response	CP (%)					Lipid (%)	
	38	43	49	54	59	14	22
ADCP (%)	46.8[C]	55.3[BC]	58.5[A]	69.7[A]	74.0[A]	59.8	61.9
ADE (%)	59.9[A]	58.4[B]	51.3[C]	61.3[B]	68.1[A]	62.2[X]	57.5[Y]
SGR (%/d)	1.12[C]	1.11[C]	1.26[B]	1.42[A]	1.52[A]	1.31	1.26
FCR (g:g)	1.58[C]	1.49[C]	1.24[B]	1.08[A]	1.00[A]	1.28	1.27
BF (%)	23.5	23.2	23.7	23.1	23.5	21.7[X]	25.1[Y]
RDN (%)	58.6[A]	48.8[B]	50.3[B]	42.3[C]	38.8[C]	48.9	46.7
RDE (%)	35.0[C]	38.6[C]	52.3[A]	47.5[B]	44.2[B]	40.7[Y]	46.3[X]

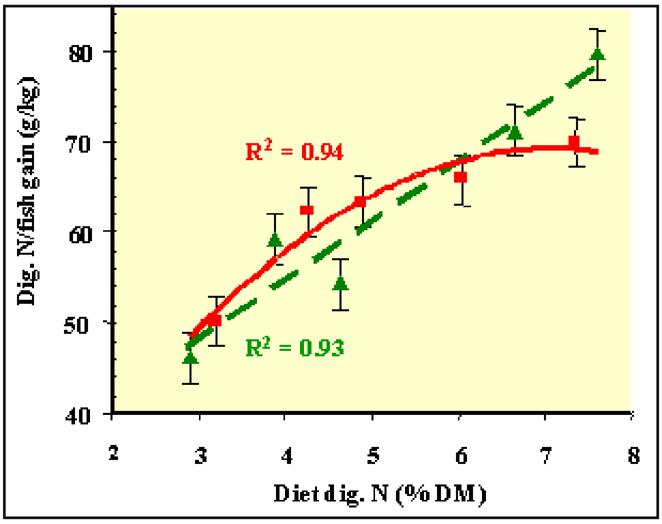
[A,B,C; X,Y] Within comparisons, means without a common letter differ ($P < 0.05$).

Table 2: Percentage distribution of radioactivity following ingestion of ^{14}C-labeled diets containing varying inclusion rates of either coconut oil (MCFA) or olive oil (LCFA).

Diet label	Distribution of radioactivity (%)			
	Fish	Respired CO_2	DOM	POM
15% LCFA	70[B]	15[B]	11[B]	3.9[B]
30% LCFA	67[B]	11[B]	11[B]	11.5[C]
15% MCFA	23[A]	51[A]	26[A]	0.6[A]
30% MCFA	17[A]	49[A]	34[A]	0.6[A]

A,B,C Means in the same column with different letters differ (P <0.05).
DOM = Dissolved organic matter in metabolic chamber water.
POM = Particulate organic matter (faeces and in some cases, regurgitated feed) in metabolic chamber water.

Figure. 1: Relationship between the digestible N content of the diet and the amount of digestible N required per kg weight gain of fish fed diets containing either 14 (▲) or 22 (■) % lipid.



Fishmeal replacement studies

In studies examining the ability of terrestrial protein meals to substitute for fishmeal in formulated feeds for juvenile gold spot grouper, a 4:1 combination of meat meal and ring-dried blood meal, respectively was able to replace up to 80% of fishmeal protein in the diet without adverse effects on growth, feed conversion or survival of the fish. Other terrestrial protein meals such as cowpea, corn gluten, lucaena (ipil-ipil) meal and soybean meal were less successful as fishmeal replacements. With mouse grouper, growth rate and feed conversion deteriorated markedly when shrimp head meal was used at inclusion rates above 10% as a replacement for fishmeal protein.

In laboratory and field cage studies, a practical low-cost pelleted dry diet was formulated on a digestible nutrient basis to meet the requirements of juve-

Figure. 2: The amount of consumed dietary lipid retained as body fat or oxidized by fish fed either a low lipid (6%) control (Con) diet or diets with 15 or 30% added olive oil (LCFA) and 15 or 30% added coconut oil (MCFA).

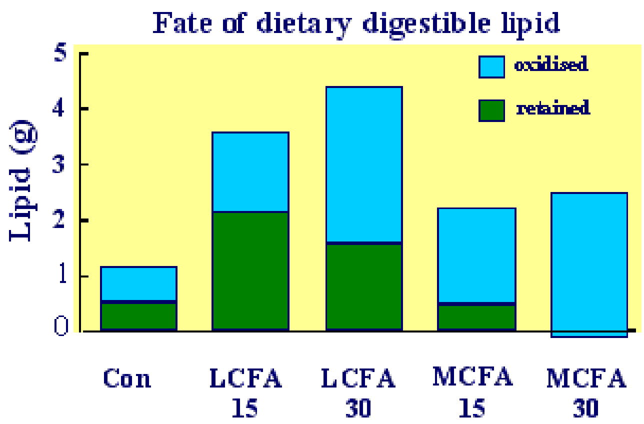


Figure 3: Respiration rate of fish following ingestion of diets containing coconut oil (MCFA) or olive oil (LCFA) added at 15 or 30% of the diet.

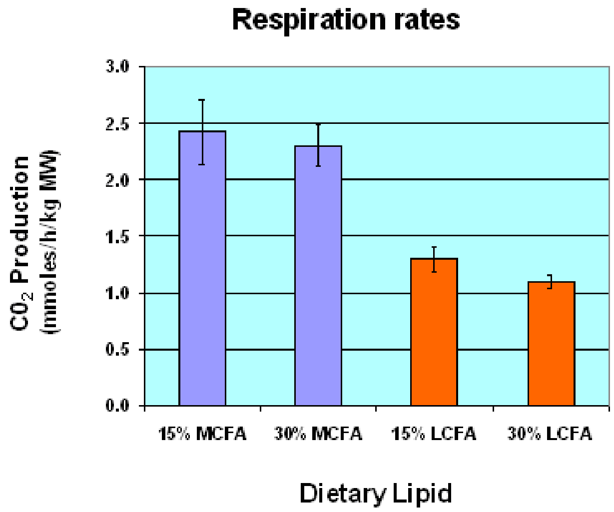


Table 3. The dry matter (DM) and crude protein (CP) apparent digestibility (AD) of selected feed ingredients determined for gold spot grouper in the Philippines and for mouse grouper in Indonesia

Feed ingredient	Gold spot grouper		Mouse grouper	
	DMAD[1]	CPAD[1]	DMAD[1]	CPAD[1]
Marine product				
Fishmeal (Chilean 65% CP)	84 ±3.1	98 ± 0.7		
Fishmeal (mixed 45% CP)	59 ±1.2	82 ± 2.0	59 ± 1.2	82 ± 2.0
Fishmeal (sardine 65% CP)			87 ± 2.5	93 ± 1.4
Fishmeal (tuna 50% CP)	75 ± 3.6	76 ± 1.9		
Fishmeal (white 69% CP)	89 ± 1.7	99 ± 0.3		
Shrimp meal (Acetes 72% CP)	76 ± 4.0	95 ± 0.7		
Shrimp head meal (50% CP)			59 ± 3.3	78 ± 1.3
Squid meal (71% CP)	99 ± 1.0	94 ± 0.2		
Terrestrial animal product				
Blood meal (Australian ring 84% CP)				
Blood meal (oven dried 84% CP)			48 ± 0.9	55 ± 1.4
Blood meal (formic 87% CP)			68 ± 1.6	88 ± 0.6
Blood meal (propionic 84% CP)			62 ± 2.6	84 ± 0.7
Meat meal (Australian 44% CP)	61 ± 0.8	99 ± 1.3		
Meat meal (Philippine 45% CP)	78 ± 0.1	84 ± 1.7		
Meat solubles (73% CP)	99 ± 0.5	98 ± 0.1		
Poultry feather meal (67% CP)	74 ± 3.1	82 ± 2.6		
Plant product				
Corn germ meal (8% CP)	85 ± 2.8	83 ± 4.7		
Corn gluten meal (56% CP)	94 ± 2.0	99 ± 0.7		
Cowpea meal (white 24% CP)	74 ± 3.1	94 ± 1.2		
Lucaena (ipil-ipil) meal (19% CP)	56 ± 0.1	79 ± 2.6		
Lupin albus meal (26% CP)	54 ± 1.2	98 ± 3.7		
Palm oil cake meal (11% CP)			45 ± 2.4	81 ± 1.3
Rice bran meal (11-14% CP)	69 ± 7.0	43 ± 5.4	22 ± 1.5	60 ± 1.4
Soybean concentrate (54% CP)	76 ± 4.9	86 ± 0.4		
Soybean meal (full-fat 41% CP)			55 ± 2.7	67 ± 1.3
Soybean meal (solvent 51% CP)	76 ± 1.7	96 ± 0.1		
Wheat flour (9% CP)	73 ± 0.9	83 ± 1.3		
[1] Mean ± SD.				

nile gold spot grouper and compared with feeding either a commercial pellet diet or fresh fishery bycatch. In both studies, fish fed the project formulation diet survived and grew as well as those fed the fresh bycatch. In the laboratory study, fish fed the commercial pellet diet grew significantly slower and converted feed less efficiently than those fed either the project diet or fresh bycatch. The analysis of the commercial pellet diet showed a sub-optimal specification. When the commercial mill adjusted the formulation to meet these specifications, fish fed that diet in the field study performed as well as those fed either the project diet or fresh bycatch.

Conclusions

The research carried out in the project has conclusively shown that juvenile groupers will readily accept pelleted dry diets. Diets formulated to meet the fish's requirements for digestible nutrients, and not containing excessive amounts of plant protein meals, will enable juvenile groupers to grow as well, if not better, than those fed fresh fishery bycatch. Further research is needed in the areas of essential fatty acid requirements of tiger groupers (*E. fuscoguttatus*) and to examine whether the nutritional requirements of groupers above 200-300 g are different to juveniles of 10-100 g size. Another area of potential research is to develop nursery feed formulations and to develop management practices for successful weaning of fry from live/fresh feeds to a pelleted dry feed.

Feed development and application for juvenile grouper

Ketut Suwirya and Nyoman Adiasmara Giri

Gondol Research Institute for Mariculture, P.O. Box 140 Singaraja 81101, Bali Indonesia. E-mail: gondol_dkp@singaraja.wasantara.net.id

Groupers are potentially important aquaculture species since they have a high economic value. Groupers, predominantly *Epinephelus spp*, have been cultured throughout Asia for many years with commercial production based on captured wild seed and the fish reared on trash fish. Recently, hatchery technology has been developed for seed production of some grouper species and this has stimulated interest in grow-out farming. However, the continued use of trash fish as a feed source for groupers should be discouraged because of the risk of disease transfer and the environmental problems associated with its use.

Feed is often the single largest cost item in fish culture. Although trash fish is presently the first choice of farmers for on-growing groupers, its availability can be limited and varies with season. Information on the nutrient requirements of groupers is still very limited and it is imperative that this is addressed if cost-effective and high performing artificial feeds are to be developed to replace the feeding of trash fish. Based on the limited available information on the nutrient requirements of groupers, some feed companies have produced feeds for nursery and grow-out. However, these have not been well accepted by grouper farmers because they are thought to be expensive and the fish do not accept it as well as trash fish. In order to develop a better artificial feed for juvenile groupers, a series of experiments have been conducted at Gondol to increase our knowledge about the dietary requirements of several grouper species.

Nutrient requirements of juvenile groupers

Dietary protein and lipid requirements

Tiger grouper (*Epinephelus fuscoguttatus*) and humpback or mouse grouper (*Cromileptes altivelis*) are carnivorous fish and thus naturally have a high requirement for dietary protein. Grow-out studies have examined the optimum dietary protein and lipid specifications for juvenile tiger and humpback groupers. A significant interaction between dietary protein and lipid has been observed for growth rate. Although fish productivity generally increases with increasing dietary protein, feeding with 9% lipid feed was found to be better than feeding either the 6 or 12% lipid feeds. Food conversion ratio (FCR) improved and more dietary lipid was retained as dietary protein increased; retention of dietary lipid also increased with increasing lipid content of the diet. There was a slight difference between tiger and humpback groupers in the optimal dietary protein specification: 47% for juvenile tiger grouper and 54% for humpback grouper. In another series of experiments, five levels (0.0, 3.0, 6.0, 9.0, and 12%) of dietary lipid were fed to juvenile tiger and humpback grouper. This confirmed the earlier results with the optimal dietary lipid found to be 12 and 9%, respectively for juvenile tiger and humpback grouper. Thus for juvenile tiger and humpback groupers, pelleted diets of about 90% dry matter (DM) should contain around 50% protein, 9-12% lipid, about 4.5 kcal gross energy/kg (18.8 MJ/kg) and a protein to energy ratio of 120 mg/kcal (27 g/MJ).

Essential fatty acid requirements

Omega 3 or n-3 highly unsaturated fatty acids (HUFA) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are essential dietary fatty acids for marine fish. Requirement for n-3 HUFA varies with the species and size of fish. Experiments have examined the n-3 HUFA requirement of juvenile humpback and tiger groupers. Juveniles of average starting body weight of 5 ± 0.7 g were reared for 9 weeks in 100 L tanks and supplied with flow through seawater. Fish were fed one of six feeds that provided n-3 HUFA levels of 0, 0.5, 1.0, 1.5, 2.0 or 2.5%. Based on growth rate and FCR, the optimal dietary n-3 HUFA specification was found to be 1.5 - 2.0% for humpback grouper and 1.75 –2.8% for tiger grouper.

Vitamin requirements

Similar to all other carnivorous marine fish, groupers require a dietary source of vitamin C (ascorbic acid). A lack of vitamin C in very young fish will result in skeletal deformities such as lordosis and scoliosis (curvature of the skeleton) and deformity or absence of the gill opercula; in older fish a deficiency is exhibited as slow growth, weak sickly fish, anemia and death in severe cases. Vitamin C is very important for maintaining a strong immune system and any deficiency will increase the fish's susceptibility to stress and disease. Pure ascorbic acid is very easily destroyed by mild heating and exposure to light. To overcome the low stability of ascorbic acid, other more stable types of vitamin C have been developed. Some products are simply ascorbic acid coated by glycerine or some other film which helps to reduce exposure of the ascorbic acid to light and so slow its destruction. However, these coated ascorbic acid products are still not very stable and are mostly destroyed during any type of hot pelleting process. Ascorbyl phosphate is a much more stable form of vitamin C, which has been shown in other fish species to be effective in meeting the fishes nutritional needs. To evaluate its effectiveness for groupers, juvenile humpback groupers of about 14 g starting weight were fed feeds containing 0, 15, 30, 60, 120 or 250 mg/kg of ascorbyl phosphate magnesium (APM) for 126 days. Based on the results of this experiment, it is recommended that pelleted grouper feeds should contain not less than 30 mg APM/kg for maximum fish growth and to ensure that the fish's immune system is fully functional.

Another experiment has been conducted to determine the requirement of vitamin B6 (pyridoxine). This is another important and essential vitamin for fish and in severe deficiency neurological disorders such as erratic and spiral swimming, shock reaction to stress or handling and death are seen. In a less severe deficiency, the signs are fairly non-specific such as poor appetite and slow growth rate of the fish. Fortunately, pyridoxine hydrochloride, which is the commonly available form of pyridoxine, is very stable to heat and light. To determine the pyridoxine requirement of groupers, six levels of pyridoxine (0, 20, 40, 60, 80 or 160 mg/kg) were fed to juvenile humpback groupers for 98 days. Using the increase in blood haemoglobin as an index of pyridoxine adequacy of the feed, the optimal specification for maximum blood haemoglobin was 60 mg/kg. This is much higher than the 15-20 mg/kg dietary specification recommended for many other marine fish. Since pyridoxine HCl is quite soluble and groupers are fairly slow feeders, this higher specification may be due to leaching of pyridoxine from the feed. In any event, it is recommended that grouper feeds have a dietary pyridoxine HCl specification of 40-60 mg/kg to maintain the healthy condition of fish.

Table 1. Formulation and macro nutrient composition of the Gondol practical feed formulation for juvenile groupers

Ingredient	Formulation (%)	Nutrient	Composition (% of diet)
Fishmeal (65% CP)	55	Crude protein	46-50
Soybean meal	10	Total lipid	9-13
Squid liver meal	14.5	Fiber	6-7
Mysid shrimp meal	6	Ash	18-25
Squid oil	6		
Trace mineral mix	2.5		
Vitamin mix	2.0		
CMC binder	4.0		
Total	100		

Table 2. Result of a 4-month feed comparison trial with humpback grouper in net cages

Productivity traits	Test diets		
	Gondol feed	Commercial feed	Trash Fish
Initial weight (g)	36.0	36.0	36.0
Final weight (g)	147.6	132.8	133.4
Survival rate (%)	98.7	98.0	95.1
FCR	1.39	1.54	5.82
Haematocrit (%)	37.3	38.2	24.2

Practical feed development for juvenile groupers

Fishmeal replacement

Fish meal is the main source of protein in conventional pelleted feeds for most fish species. Because capture fisheries production has not increased since the early 1990's and production of fishmeal has similarly not increased but aquaculture's demand has skyrocketed, it is not surprising that the price of fishmeal continues to increase at rates above inflation. In an attempt to offset the spiraling cost of fishmeal as an ingredient in pelleted fish feeds, there has been a lot of research worldwide to find cheaper protein alternatives. At Gondol, we have examined the extent to which soybean meal can be used to replace

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Present status in the development of culture technology for the silver pomfret *Pampus argenteus*

Sulaiman M. Almatar and Charles M. James

Kuwait Institute for Scientific Research, Aquaculture, Fisheries and Oceanography Department, P.O. Box 1638, Salmiya 2201, Kuwait

Silver pomfret about 35 days old after hatching.

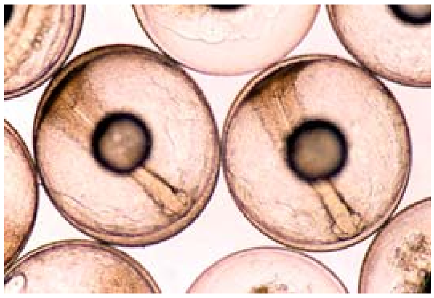
The silver pomfret *Pampus argenteus,* locally known in Kuwait as 'zobaidy', is a high priced food fish having worldwide market demand. It is also extensively distributed in different regions of the world from the East China Sea to Southeast Asia, Indian Ocean and in the Arabian Gulf. In recent years the silver pomfret capture fishery from the wild has been declining in Kuwait and in other regions due to over fishing. In spite of the decline in wild stock and increasing market price, there has been little research on developing technology for the hatchery and grow-out culture of this species until recent years. During June 1997, in a preliminary attempt to develop hatchery and larval rearing techniques, the Aquaculture Fisheries and Oceanography Department (AFOD) of the Kuwait Institute for Scientific Research (KISR) succeeded for the first time in the world in larval rearing and fry production of *Pampus argenteus* under hatchery culture conditions. This was achieved using eggs stripped from wild spawners caught by drifting gillnets, with 45 larvae successfully grown to juvenile stage. Pursuant to the success of 1997 larval rearing, a five-year research project was initiated in April 1998 to assess the technical feasibility of silver pomfret culture in Kuwait. Since then the project has successfully produced several thousand silver pomfret fingerlings for nursery and grow-out production and developed larval rearing techniques to grow-out fish to marketable size. Continued efforts are underway to develop domesticated broodstock for spawning under controlled culture conditions.

Hatchery performance

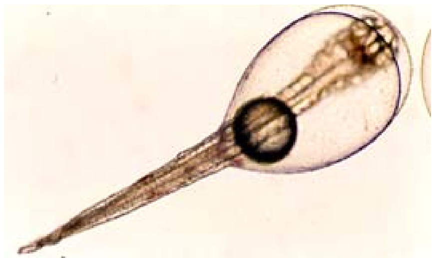
The present source of eggs for larval rearing is based on stripping wild caught spawners. Fully mature males and gravid females are found during June to September in the coastal waters of Kuwait at about a depth of 5-20 m. They are captured with drifting gillnets in the daytime during spring tides at new and full moon. During the spawning period, the surface seawater temperature ranges from 28-33 ºC and the water salinity ranges from 35-39 ‰. The peak spawning period is June-July when the water temperature ranges from 28-29ºC.

Fully ripe gravid females, with hydrated and free-flowing eggs, occur between 15:00-18:00 hours during ebb tides. In the gillnet catch, fully mature males outnumber the females at an average ratio of 5:1. Males also mature earlier with a much lower gonado-somatic index (GSI) than females. Fecundity and histological studies indicate that the broodstock is indeterminate showing that a female may spawn at least six batches of eggs from June to August with an average relative batch fecundity of 170.6 eggs/g of somatic weight. Total fecundity of a 500g female is about 350,000 eggs. An average of about 40,000-60,000 viable eggs can be collected from each ripe female, depending on the size and condition of the ovary. The percentage of viable eggs depends on the fishing season/month and accordingly the highest percentage of viable eggs are collected during June. The fertilized eggs are spherical, transparent and pelagic and about 1.1mm diameter in size. The egg hatching time is 15 hours at 29-30 ºC. The hatching rate depends on the

Stripping for egg collection from wild spawners.



Above: Fertilized eggs and embryo development of silver pomfret. Below: Newly hatched larvae.



egg collection time and conditions and normally it ranges from 28-50%. The newly hatched larvae have a large ellipsoid yolk and measure about 2.4 mm in total length.

Larval rearing

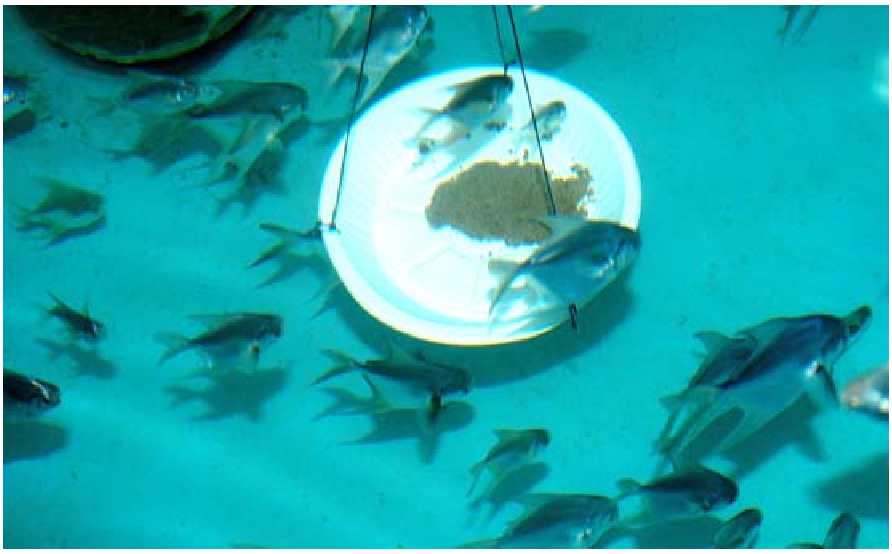
The optimal temperature for rearing larvae is 27-29 ºC and salinity 39-40‰. The newly hatched larvae are generally stocked at a density of 30-120 larvae per litre. However, stocking rates of 20-40 larvae per litre are conventionally used without any significant difference in larval survival at these stocking densities. Significantly higher survival rates at 12 days after hatching were observed for larvae fed on a combination of mixed species of micro-algae consisting of *Chlorella, Isochrysis* and *Nannochloropsis* at a cell density of 1 million cells per ml in the larval rearing waters along with nutritionally-enriched rotifers, compared to those reared using a single algal species. First larval feeding is with rotifers at a density of 5 rotifers per ml until 6 days after hatching, and then increased to 10-15 rotifers per ml since prey consumption by the larvae increases significantly at 8 days until they are weaned to newly hatched *Artemia* nauplii. Larval feeding on rotifers is significantly higher in cultures with mixed species of algae compared to those using a single algal species in the culture system. Furthermore, the essential ω3 HUFA were also significantly higher in rotifers treated with mixed species of algae along with commercial enrichment media 'Super Selco' and 'DHA Protein Selco'. Within a week of feeding on *Artemia* nauplii, the larvae could be weaned to a formulated paste feed. The larvae are also easily trained to accept the paste feed kept in trays suspended in the water column. Under experimental culture conditions the survival was up to 4.2% to juvenile stage. Mass larval rearing and fry production using 1m^3 and 4m^3 capacity round fiberglass tanks showed that better larval survival is achieved in larger tanks. One of the reasons for larval mortality in the hatchery is due to a behavior of the larvae in swallowing tiny air bubbles at the water surface. This is due to the innate feeding habit of silver pomfret, which consume small jellyfish and medusae. As tiny air bubbles may mimic jellyfish in appearance, the larvae consume them and tend to float, losing their balance in the water column. This phenomenon increases during the later part of the larval rearing period from day 25. Larval mortality due to air-bubble ingestion has been substantially reduced by introducing indirect aeration techniques instead of using air-diffusers directly in the larval tanks. Larval mortality due to cannibalism is low in the hatchery phase compared to other marine fish species. The lack of cannibalism and ready acceptance of forumulated feeds make the hatchery techniques developed thus far promising for commercial ventures. Further research studies to refine larval rearing are in progress, focussing on feed and tank management techniques to enhance fry production.

Grow-out culture

To date the grow-out culture of silver pomfret has been restricted to land-based culture systems using different capacity round circular tanks of up to 65 m^3 with flow-through seawater. Screening for a commercial feed suitable for use in the grow-out phase is still in progress. In the meantime, based on the results obtained from various experiments, a semi-moist feed is used. The feed is kept in a plastic bowl, which is suspended in the water column. In trials between 1998-2003, the average weight gain for fish of less than 50g was up to 0.34g per fish per day and 0.23 g per day in fish above 50g. Due to feed improvements made through feed additives in 2004, the growth rate for fish less than 50g in size has been increased to 0.62g per fish per day and in the above 50g size group it has been increased to around 1.32g per fish per day. During this period the specific growth rate (SGR) was up to 5.98% per day for fish in the below 50g size group and about 2.13% per day for fish above 50g. The growth rate declines during the winter period

About 45 days old after hatching.

in Kuwait from November to March when the water temperature drops to 13 ºC. Growth performance of this fish stocked at different densities of 60, 80, 100 and 120 fish/m^3 in a re-circulating tank culture system showed that better survival could be obtained at a stocking density of 60 fish/m^3. Growth performance of silver pomfret using earthen ponds and sea-cages is yet to be investigated.



Grow-out culture of silver pomfret.

Domesticated broodstock development

During the grow-out culture, fast growing selected fish were maintained in separate tanks for the development of domesticated broodstock. Histological studies have shown that silver pomfret are a gonochoristic species, in which the male and female sex exists in separate individuals. The studies also show that the processes of sexual differentiation for the male and female are completed at the ages of 115 and 135 days after hatching from the egg, respectively. Under tank culture conditions, fully grown broodstock size ranged from 124 to 823g. The fish selected for broodstock development were found to undergo gonad maturation in captivity as evidenced by the occurrence of fully ripe male producing milt at a size of 134g in body weight and 17cm in fork length (FL). The first occurrence of female maturation in the broodstock holding facility was with stage-2 gonad at the size of 222.5g in body weight and 19.5cm in FL. During July 2004 a 408g female with a stage-IV ovary was observed. However, the broodstock holding tank was infested with *Cryptocarion* and mass mortality of the fish occurred hampering further progress in spawning of the broodstock during 2004. Further investigations are in progress towards developing domesticated broodstock from hatchery produced individuals. Towards achieving spawning in the broodstock holding facility, efforts made to inject the fish with chorionic gonadotrophin (HCG) failed to yield any results. The potential spawners were also not tolerant to handling and injection stresses, particularly in the case of wild brooders. Techniques for the spontaneous natural spawning of the captive broodstock using improved tank management and feeds are yet to be developed.


Hatchery produced potential broodstock.

Future prospects

In general, developing commercial culture technologies for marine fish species takes many years of research and development. Compared to some of the economically important farmed tropical marine fish species, the research on silver pomfret has only been initiated relatively recently and should be considered at the initial stages of development, although substantial progress has been made towards commercial applications. Based on the results achieved so far, the silver pomfret *Pampus argenteus* seems to be an excellent candidate for aquaculture


A 408g cultured female with stage-IV ovary

Best practices for using trash fish in the culture of juvenile Malabar grouper, *Epinephelus malabaricus*

Le Anh Tuan

Faculty of Aquaculture, University of Fisheries, Nha Trang, Vietnam. Email: leanhtuan@dng.vnn.vn.

University of Fisheries' nutritional wet laboratory comprising 48 experimental tanks.

Malabar grouper *Epinephelus malabaricus* is a highly valued species in the live fish markets of Vietnam and throughout Asia. The recent development of hatchery production technology for Malabar grouper fry and its successful exploitation by a commercial hatchery in Vietnam has resulted in a promising supply of fry for aquaculture. Commercial culture of grouper in Vietnam relies almost entirely on the feeding of low-value fish and fishery by-product ('trash fish'). In Viet Nam, the species of trash fish most commonly fed are lizard fish (*Saurida* spp.), pony fish (*Leiognathus* spp.), cardinal fish (*Apogon* spp.), anchovy (*Stolephorus* spp.), pomfret (Psenes spp.) and spinefoot (*Siganus* spp.). Some farmers have a preference for using lizard fish and cardinal fish. Although grouper aquaculture production in Vietnam is increasing each year and was 3,000 metric tonnes in 2003, the size of the industry is still not large enough to get aquafeed companies involved. 'Trash fish' will continue to be used in Vietnam for some years as a major feed for groupers. It is a comparatively inexpensive source of feed that is available locally, although its availability and price does fluctuate during the year and it can be scarce and expensive during the winter typhoon season. However, poor husbandry and feeding practices can result in a lot of the trash fish being wasted and as a consequence, can cause serious downstream pollution problems. For these reasons, determining best practices for using trash fish is a high priority for the Vietnamese grouper industry. This paper describes an experiment comparing different types of trash fish and feeding rates for culturing juvenile Malabar grouper.

How the research was done

A 3 x 4 factorial design was used in an 8-week experiment to investigate the effects of feeding juvenile Malabar grouper of initial size 10 ±0.3 g either of three different types of trash fish – cardinal fish, lizard fish or a combination of equal amounts of cardinal fish and lizard fish – and four daily feeding rates – 5, 7, 9 or 11% of fish biomass. A total of 480 fish were stocked equally into 48 x 100 L polyethylene tanks (four tank replicates per treatment) under controlled laboratory conditions. Each tank was supplied with flow-through bio-filtered seawater (33 to 35 g L^{-1}) at an exchange rate of 500% day^{-1} and with supplementary aeration.

The feed processing laboratory.

By-catch was bought fresh from the Cu Lao Trung Fishing Port, Nha Trang city and immediately weighed into plastic bags and stored at -20ºC until required to be fed. The trash fish was thawed and chopped into pieces immediately prior to feeding with the daily allocation being fed in two equal amounts twice daily at 0730 and 1530 h. Uneaten food was collected, oven dried and its weight used to calculate actual food intake after correcting for leaching loss.

What was found

There were some very minor interactions between the type of trash fish fed and feeding rate but these were so inconsequential in comparison to the main treatments that they will be ignored in this article. However, productivity of the groupers were markedly affected by both trash fish type and feeding rate.

Effect of type of trash fish

Growth rate, expressed as average weekly gain (AWG) or as specific growth rate (SGR), as-fed and dry matter (DM) food conversion ratio (FCR) and fish survival were generally best when cardinal fish and lizard fish were fed as the combination while feeding cardinal fish by itself resulted in the worst productivity (Table 1).

Lizard fish has a higher lipid and lower ash (and thus, higher energy) content than cardinal fish (Table 2) and this most likely explains why the Malabar grouper grew better when fed the lizard fish. However, why a combination of the two trash fish types should result in better grouper productivity than either alone is not so easily explained. Clearly, the combination of trash fish was more preferred by groupers than either type alone since food intake was significantly higher for the combination. This perhaps explains the better growth of the groupers on the combination but it does not explain the significantly better DM FCR that was also observed for the combination. The improved FCR suggests that the combination provided an overall better nutritional profile for the groupers but in what respects is not known.

Effect of feeding rate

In line with the applied treatment, daily food intake increased incrementally with increasing feeding rate up to the 9% level with a non-significant increase thereafter for the 11% rate. As a consequence, fish weight gain showed a parallel response with significantly better grouper growth rates as the feeding rate was increased from 5 to 9% (Table 3). FCR was almost identical for the three lower feeding rates but worsened slightly when the feeding rate was increased to 11%. While this may be a genuine reduction in the efficiency with which the grouper used the food, it equally could have been due to incomplete collection of uneaten food since some feed refusal was common at this feeding rate.

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Table 1. Effect of trash fish type on the productivity responses of juvenile Malabar grouper.

Response trait	Type of trash fish fed			
	Cardinal	Lizard	Combined	± SEM
Weekly gain (g)	4.36^{C}	4.92^{B}	5.13^{A}	0.017
SGR (%/d)	2.61^{C}	2.78^{B}	2.85^{A}	0.013
Daily intake (g as-fed/d)	2.94^{C}	3.03^{B}	3.15^{A}	0.007
FCR (as-fed)	4.70^{B}	4.29^{A}	4.29^{A}	0.017
FCR (DM)	1.19^{C}	0.99^{A}	1.04^{B}	0.004
Survival (%)	93.1^{B}	95.6^{AB}	97.5^{A}	0.98

^{A,B,C} – Within each response trait, means without a common superscript letter are different (P < 0.05).

Table 2. Whole body chemical composition (± SD) of common trash fish species caught in the central coast region of Vietnam.

Analysis	Trash fish species			
	Cardinal	Lizard	Anchovy[1]	Spinefoot
	Fresh basis			
Moisture	74.7±0.99	74.8±0.44	75.7±0.42	74.6±0.42
Ash	5.3±0.14	3.7±0.08	3.1±0.04	6.5±0.08
Protein	16.2±0.07	17.3±0.65	14.9±0.30	13.1±0.74
Lipid	1.7±0.22	2.6±0.37	1.6±0.19	2.0±0.23
	Dry matter basis			
Ash	21.0±0.55	14.7±0.33	12.9±0.15	25.4±0.30
Protein	64.0±0.09	68.7±0.88	61.3±0.60	51.6±0.98
Lipid	6.7±0.65	10.3±0.75	6.6±0.38	7.9±0.46

[1] Long-jaw anchovy.

Table 3. Effect of feeding rate on the productivity responses of juvenile Malabar grouper.

Response trait	Feeding rate (% of biomass per day)				
	5	7	9	11	± SEM
Weekly gain (g)	3.06^{C}	4.44^{B}	5.87^{A}	5.84^{A}	0.020
SGR (%/d)	2.15^{C}	2.70^{B}	3.05^{A}	3.08^{A}	0.015
Daily intake (g as-fed/d)	1.90^{D}	2.76^{C}	3.65^{B}	3.85^{A}	0.008
FCR (as-fed)	4.36^{A}	4.36^{A}	4.36^{A}	4.63^{B}	0.020
FCR (DM)	1.06^{A}	1.06^{A}	1.05^{A}	1.12^{B}	0.005
Survival (%)	90.8^{C}	95.0^{B}	99.2^{A}	96.7^{AB}	1.13

^{A,B,C} – Within each response trait, means without a common superscript letter are different (P < 0.05).

Grouper grow-out feeds research at Maros Research Institute for Coastal Aquaculture, South Sulawesi, Indonesia

Usman[1], Rachmansyah[1], Asda Laining[1], Taufik Ahmad[2]

[1] Research Institute for Coastal Aquaculture, Jl. Makmur Dg. Sitakka, No. 129, Maros, Sulawesi Selatan, 90512, Indonesia. E-mail: syah@indosat.net.id; [2] Central Research Institute for Aquaculture, Jl. KS. Tubun VI, Slipi PO. Box 50, Jakarta Pusat, Indonesia.

In Sulawesi, the development of grouper aquaculture is hindered by dependence on the fluctuating and uncertain supply of perishable trash fish. While some commercially produced pelleted grouper feed is imported from Java and Thailand, it is expensive and fish that have previously been fed on trash fish do not readily adapt to dry pellets, resulting in slower fish growth. To address this problem, grouper feed research at Maros has focused on examining the potential of locally available meals as ingredients in farm-made feeds. This has entailed determining the apparent digestibility of locally available feed ingredients and examining their potential as partial replacements for imported fishmeal, and investigating the nutrient requirements of juvenile mouse (*Cromileptes altivelis*) and tiger (*Epinephelus fuscoguttatus*) groupers. While much of this past research has involved feeding acclimatized fish on laboratory-made dry pellets, our current research emphasis is to adapt these findings for the production of moist pelleted feeds that can be made on-farm using simple equipment. Moist pelleted feeds are well accepted by juvenile groupers and can be used as the only food source or alternatively as a way of training the fish to accept pelleted feeds without losing condition that otherwise frequently occurs when only dry feed pellets are fed.

Results of past research are outlined in this article and some information is given about producing farm-made moist pellets for feeding juvenile mouse and tiger groupers.

Apparent digestibility of Sulawesi feed ingredients

To date, the apparent digestibility of nine locally available feed ingredients have been determined for mouse

Dry ingredients and fish oil being weighed prior to being hand mixed together with the minced fish.

grouper. These feed ingredients are available throughout the year and in sufficient quantities to justify this research. Each of the feed ingredients was incorporated in a reference diet at an inclusion rate of typically 30% and its apparent dry matter, crude protein and energy digestibility determined by reference to the digestibility marker, chromic oxide. Although these studies were carried out using mouse groupers, it is expected that other grouper species would show similar results. The outcomes of the experiments are summarized in Table 1.

The data shows that protein contained in shrimp head, formic and propionic blood, sardine, mixed-fish and palm oil cake meal is well digested by mouse grouper. However, the low dry matter and energy apparent digestibility of palm oil cake meal and rice bran meal indicates that groupers do not use these meals very well. The comparatively poor digestibility of soybean meal, especially that of protein, was surprising and indicate that it may not be very suitable as a replacement for fishmeal in compounded feeds for groupers. Not unexpectedly, the oven-dried blood meal was not well digested but this could be markedly improved by organic acid fermentation.

Replacement of fishmeal

A 9-week growth experiment was carried out with mouse grouper to see if shrimp head meal could be used as a partial replacement for fishmeal. Fish were held in 1 x 1 m seacages and fed twice daily. Five diets were examined in which shrimp head meal at 10% inclusion increments from 0 to 40% were used to substitute for fishmeal on an isonitrogenous basis. Table 2 shows the results of this experiment.

Although survival rate was unaffected by the amount of shrimp head meal in the feed, most other response characteristics became worse with increasing inclusion of shrimp head meal. The reduced intake associated with increasing amounts of shrimp head meal is most likely a dual effect of the fish not liking this feed and the smaller size of the fish resulting from the lower biological value of feeds containing the shrimp head meal. The results suggest that shrimp head meal should not be used at inclusion rates above 10% as a substitute for fishmeal in grouper feeds. The high content of chitin in the shrimp head meal may explain the poor performance of the fish fed these feeds since the chitin would likely be poorly digested by the fish.

Preparation of moist feed pellets (noodles) using simple on-farm equipment. A kitchen meat mincer is used to mince the trash fish. The mixed dough is extruded through the meat mincer and the resultant noodles subsequently broken into suitable lengths for feeding to groupers.

What carbohydrate is best for groupers?

A 6-week growth and nutrient retention experiment was carried out to compare four different types of carbohydrate – dextrin, starch, sucrose and glucose – when each was included at a similar inclusion of 16%. The object of this study was to see if including carbohydrate in the feed formulation would provide the fish with an alternative source of energy instead of breaking down absorbed protein for this purpose. If carbohydrate can be digested and effectively metabolized it would enable the amount of protein in the feed to be reduced, lowering both the cost of the feed and reducing the excretion of nitrogen to the water. The results of the work are shown in Table 3.

As shown by the data in Table 3, glucose was the most effective type of carbohydrate, resulting in higher growth rates and higher retentions of protein and energy. Starch and dextrin were the next best while sucrose was the least effective type of carbohydrate.

Table 1. Dry matter, crude protein and gross energy apparent digestibility coefficients (%) of locally available feed ingredients in Sulawesi.

Ingredient	Dry matter	Crude protein	Gross energy
Shrimp head meal	59	78	64
Soybean meal (full-fat)	55	67	51
Palm oil cake meal	45	81	40
Dried blood meal[1]	48	55	ND
Formic blood meal[2]	68	88	ND
Propionic blood meal[3]	62	84	ND
Local sardine meal	87	93	85
Local mixed-fish meal	59	82	77
Rice bran meal	22	60	44

ND: Not determined as insufficient faecal sample for energy analysis.
[1] Whole cattle blood recovered from slaughterhouse and oven dried.
[2] Oven dried cattle blood following fermentation using formic acid.
[3] Oven dried cattle blood following fermentation using propionic acid.

Since glucose is not a standard feed ingredient and starch and sucrose were not very effective as alternative energy sources, it seems that carbohydrates will not have a useful role in grouper feeds for protein sparing.

Vitamin C requirements

Carnivorous fish such as groupers do not have the capacity to synthesize vitamin C and neither do they carry sufficient microorganisms in their digestive tract to provide a non-dietary supply of this vitamin. Vitamin C has many physiological functions, including maintenance of epithelial tissue functionality and maintaining the fish's immunity system. In larval fish, a deficiency of vitamin C leads to skeletal and other deformities while in older fish, a deficiency will cause slow growth, increased mortality and reduced resistance to disease. Ascorbic acid, which is the active chemical of vitamin C, is very easily destroyed by ultra violet light and heating. To overcome this problem, and especially where feed is pelleted by hot extrusion or steam press, more stable forms of Vitamin C have been developed. One such product is L-Ascorbyl-2-phosphate-sodium-calcium (APNaCa). An 8-week experiment was carried out with groupers held in seacages to test the efficacy of this product as a source of vitamin C. In the experiment, four incremental levels of APNaCa from 0 to 150 mg/kg were examined and compared with feed of the same formulation but in which a proprietary vitamin premix was used. The vitamin C in the proprietary premix was in an unstable form. The results of this study are shown in Table 4.

In the experiment, fish performance improved with increasing supplementation of APNaCa with the best growth seen at the highest amount of 150 mg/kg. Interestingly, most of the difference in growth of the fish occurred in the last few weeks of the experiment when severe flooding caused a marked deterioration in water quality. Compared to fish fed the low vitamin C feeds, those fed the higher APNaCa feeds were better able to handle the water quality stress with high survival rates and continued good growth. The fish fed the commercial vitamin premix containing non-stabilized ascorbic acid grew poorly, hardly better than those fed the zero APNaCa feed, and survival was low. Adding APNaCa at rates of 150 mg/kg feed is advised and especially if culture conditions may be stressful.

Moist feeds

Although the above studies were carried out using pelleted dry feeds, current research is examining moist pellets as a cost-effective way of providing feeds for groupers. Moist pelleted feeds have many advantages for the small-scale grouper farmer:

Table 2. Biological response of mouse grouper to feeds containing increasing amounts of shrimp head meal.

Variables	Shrimp head meal (%) in the diet				
	0	10	20	30	40
Weight gain (%)	101.5[a]	102.6[a]	76.8[b]	67.9[b]	27.8[c]
DGC (%/d)	1.17[a]	1.14[a]	0.85[b]	0.84[b]	0.51[c]
Feed conversion ratio	1.52[a]	1.55[a]	1.79[b]	1.78[b]	2.64[c]
Feed intake (g/week)	23.2[a]	23.0[a]	19.6[b]	19.0[b]	13.8[c]
Protein efficiency ratio (g:g)	1.35	1.36	1.34	1.19	0.89
App. digestibility coefficient (%)	85.2[a]	86.9[a]	81.3[b]	79.6[b]	81.9[b]
Survival rate (%)	100[a]	96.7[a]	95.0[a]	98.3[a]	96.7[a]

[a,b,c] Values in the same row with a similar superscript letter are not significantly different (P>0.05).
DGC – Daily growth coefficient (100 times the difference between start and end weights raised to the one third power and divided by the number of days on experiment).

Table 3. Biological response of mouse grouper fed diets containing different types of carbohydrate.

Variables	Source of carbohydrate			
	Glucose	Sucrose	Dextrin	Starch
Absolute growth rate (g/d)	0.40[c]	0.27[a]	0.34[b]	0.34[b]
Feed efficiency (%)	100.8[c]	78.6[a]	91.2[b]	90.1[b]
Protein retention (%)	35.0[c]	26.2[a]	33.1[c]	29.7[b]
Lipid retention (%)	67.8[b]	45.7[a]	53.9[a]	49.8[a]
Survival rate (%)	100[a]	100[a]	100[a]	100[a]
App. digestibility of NFE	96.6[a]	87.7[b]	82.8[b]	69.3[a]
App. digestibility of protein	94.4[b]	93.4[a]	94.6[b]	94.8[b]
App. digestibility of lipid	97.2[a]	96.2[a]	95.6[a]	95.3[a]

[a,b,c] Values in the same row followed by a similar superscript letter are not significantly different (P>0.05).

Table 4. Weight gain, daily growth rate, feed efficiency and survival rate of mouse grouper fed different levels of APNaCa.

Variable	Comm. premix (control)	APNACa level (mg/kg)			
		0	50	100	150
Weight gain (%)	120[a]	110[a]	170[b]	187[b]	254[c]
DGC (%/d)	1.40[a]	1.32[a]	1.78[b]	1.88[b]	2.26[c]
Feed efficiency (%)	33.5[a]	32.0[a]	49.8[b]	54.7[c]	69.9[d]
Survival rate (%)	72.5[a]	75[a]	85[b]	86.7[b]	95[c]

[a,b,c,d] Values in the same row followed by a similar superscript letter are not significantly different (P>0.05).
DGC – As for Table 3.

- They can be easily made on-farm with simple equipment (some form of meat grinder to mince and cold-extrude the mixed dough to form the noodle pellet).
- Reduced dependence on trash fish since only a quarter or less is required compared to using trash fish as the sole source of food.
- Enables locally-available ingredients to be used in the formulation.
- Enables effective vitamin enrichment (often deficient when trash fish only is fed).
- Reduces food wastage (and consequential pollution of the water) as moist pellets are eaten by the fish with minimal loss.
- Moist pellets can be used to train fish to accept dry pellets.

There are a couple of disadvantages. Moist feeds have to be prepared daily (unless refrigeration is available) and preparation can be time consuming and labor intensive. Additionally, some knowledge about what feed ingredients can be used is essential otherwise a nutritionally unsatisfactory feed might be produced. However for a small-scale farmer, the advantages far out weigh the disadvantages.

Examples of suitable moist pellet formulations for feeding juvenile groupers are shown in Table 5 and the ease with which they can be made on-farm using simple equipment is illustrated in.

Table 5. Examples of formulations and gross nutrient composition for producing moist pelleted feed for juvenile groupers

Ingredient	1	2	3	4
	Kg (as used)			
Trash fish	50	50	60	60
Fishmeal (65% CP)	13	12	10	11
Mussel/snail meat		7	0	0
Mysid meal	5	0	0	0
Soybean meal (solvent)		0	15	0
Groundnut meal[1]		0	0	15
Dry blood meal		10	0	0
Rice bran	16	15	9	0
Tapioca/cassava starch		0	0	9
Wheat gluten (80% CP)	10	0	0	0
Fish oil[2]	4	4	4	3
Additives[3]	2	2	2	2
Total	100	100	100	100
	Nutrient composition (% as fed)			
Moisture	42	47	50	50
Crude protein	29	26.5	24.5	24
Lipid	7.5	7.5	7.5	7
Ash	7.5	6.5	6.5	5.5

[1] Do not use unless known to be free of fungal mycotoxins such as aflatoxin.
[2] Can be deleted but inclusion will produce better fish growth.
[3] Use quality vitamin and trace mineral premixes.

Future research

Past work has focused on feed development for mouse grouper and particularly for juvenile fish of 20 to 150 g size. Our focus will now change to examine fish in the size range of 200 g to market size and with an increasing emphasis on tiger grouper since its faster growth lends itself better as an aquaculture species. Research will also continue to determine apparent digestibility of locally available feed ingredients and the further development of practical moist feed formulations using locally available ingredients.

Grouper grow-out feeds... continued from page 41...

Conclusions

This research has demonstrated that trash fish can be an excellent food source for culturing Malabar groupers with DM FCR's of less than 1.0 able to be achieved under experimental conditions. It has also demonstrated that the type (species) of trash fish used can significantly affect the productivity of the grouper. In this study, lizard fish was a better species to feed than cardinal fish although a combination of both gave the best overall result. These productivity response differences of the grouper are thought to be due to differences in the macro- and/or micro-nutrient composition of the trash fish being fed. The best rate to feed the trash fish was found to be 9% of the fish biomass with the total amount fed as two equal meals a day. Not only did this rate result in the best growth and FCR of the fish but survival was almost 10% higher than feeding at a 5% rate.

Future research

The above study was carried out under closely controlled laboratory conditions. It will be important to see if these findings can be validated under normal seacage farming conditions. Under such conditions, nutrient losses from the trash fish are likely to be greater (leading to poorer FCRs and growth rates) and the freshness of the trash fish at feeding is often far from satisfactory. The addition of a vitamin supplement and some simple form of binding the trash fish into a more stable food may overcome both of these problems.

Acknowledgement

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Feed development and application for juvenile grouper...
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fishmeal in grouper feeds. Unfortunately, using soybean meal in amounts exceeding 10% of the diet as a protein replacement for fishmeal caused growth rate and food conversion of the fish to worsen.

Practical feed formulation for juvenile groupers

A suitable practical feed formulation for juvenile groupers has been developed at Gondol (Table 1).

In a 4-month trial with humpback grouper held in a floating net cage, the effectiveness of the Gondol feed formulation has been compared against a commercial pelleted grouper feed and trash fish.Table 2 shows the results of this comparison. Growth rate and FCR were best for grouper fed the Gondol feed. In terms of growth rate and FCR, the commercial feed was as good as the vitamin-supplemented trash fish. Interestingly, the haematocrit value (proportion of red cells in the blood – an indirect measurement of haemoglobin content) of the grouper fed trash fish was quite low, suggesting either a vitamin deficiency (even though a vitamin supplement was mixed with the trash fish) or some other toxic or infectious agent present in the grouper.

Future research

Gondol will continue research to increase our knowledge about the nutrient requirements of groupers with tiger grouper being the main species to be used for these investigations. A priority area is to develop successful nursery feeds in order to quickly and easily wean fry from live feed (or trash fish) to pelleted dry feeds. This work will be coordinated with other grouper feeds research that will be carried out in the ACIAR Marine Finfish Technology Improvement project at Maros (Indonesia).

Collaborators

The following organizations and contacts are focal points for communication in the network:

Hong Kong
Dr Jim Chu, jim_cw_chu@afcd.gov.hk

India
Dr Mohan Joseph Modayil, mdcmfri@md2.vsnl.net.in

Indonesia
Dr Ketut Sugama, crifidir@indonet.id
Dr Muhammad Murdjani, lbapstbd@radnet.id

Iran
Dr Shapour Kakoolaki, bsh443@yahoo.com

Malaysia
Coastal marine fish culture
Mr Ali bin Awang, ppbuk@po.jaring.my

Fish quality
Mr Ismail Ishak & Mr Hamdan Jaafar
anasofiah@hotmail.com / hamdanj@yahoo.com

Low food chain species
Mr Hussin bin Mat Ali
pppil@po.jaring.my

Philippines
Ms Prescilla B. Regaspi, pregaspi@bfar.da.gov.ph
Ms Marygrace C. Quintero, mgquintero@bfar.da.gov.ph

Collaborating organisations

Queensland Government Department of Primary Industries and Fisheries

CSIRO

SEAFDEC

Department of Fisheries Malaysia

What's New in Aquaculture

Launch of VCDs on Fishery Technologies

The Fisheries College and Research Institute, a constituent Institute of Tamilnadu Veterinary and Animal Sciences University, India has released two new extension VCDs on Composite Fish Culture and Preparation of Fish Pickle – a Value added fishery product from low value fish. The VCD on Composite Fish Culture deals with aspects such culturable species, pond preparation, fertilizers and their applications, stocking, feeding and transportation of fish fingerlings, water quality management, harvesting and economics. The VCD on Preparation of Fish Pickle contains information on suitable species, ingredients, steps involved in the preparation of fish pickles, and economics. Both are 25 minutes in duration. The above VCDs are aimed at entrepreneurs interested in starting composite fish culture and in the commercial production of fish pickle using cost effective technology. The VCDs are US$20 and may also be obtained in the form of DVD for US$30, inclusive of postage and handling.*To order, contact: Dr.G.Sanjeeviraj, Professor & Head, Department of Fisheries Extension, Fisheries College and Research Institute, Tamilnadu Veterinary and Animal Sciences University, Thoothukudi - 628 008, India. Email: ttn_fishco@sancharnet.in or fax: 091-461-2340574.*

Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries

The proceedings of the symposium have been released in the form of a two-volume hardcover set of peer-reviewed papers. The symposium had three primary objectives: To provide a forum to review and synthesise the latest information on large rivers; to raise the political, public and scientific awareness of the importance of river systems, the living aquatic resources they support and the peoplethat depend on them; and to contribute to the better management, conservation and restoration of the living aquatic resources of large rivers.The symposium was organised in six sessions covering the status of rivers, value of river fisheries, fisheries ecology and conservation, management of river fisheries, statistics and information, and a synthesis. Contributed papers represented 96 rivers from 61 basins from all continents and climatic zones. Published by FAO and the Mekong River Commission.

MRC have a reputation for producing high-quality publications, and this is no exception. Excellent. Ed.

Aquaculture Calendar

For more events listings the NACA Events & Training page at

http://www.enaca.org/modules/extcal/

Annual Workshop and Conference of the Australian Society for Fish Biology, 11-15th July 2005 Darwin, Australia

The Australian Society for Fish Biology (ASFB) would like to invite scientists from across Asia to participate in its annual workshop and conference. Conveniently situating in Australia's northern city of Darwin, the event will be easily accessible for all. The theme for this year's workshop is 'Monitoring Fish Stocks and Aquatic Environments'. The conference is open to all aquatic research and management topics. Registrations and abstracts are now being accepted. Further information: Contact gmesser@thebestevents.com.au or visit http://www.territorylive.com/asfb2005/.

Marine and Freshwater Toxins Analysis, 11-14 April 2005, Baiona, Spain

The symposium will address new developments and validation efforts in the analysis of marine and freshwater toxins, and is held as a joint meeting with the AOAC Task Force on Marine and Freshwater Toxins.

Presentations will address special needs of the community from toxin monitoring to new concerns in the intentional contamination of food and water. The conference venue is the University of Vigo, in new on-site conference facilities. The University, home to the Department of Analytical and Food Chemistry, is located near Baiona and Vigo in the Galicia region of northwestern Spain. In addition to being the largest European producer of mussels, shellfish-rich Galicia is also a very beautiful and historic area. In addition to contributed posters and oral presentations, there will be several keynote presentations and opportunities to discuss state of the art detection methods. The symposium will also offer unique opportunities to presenters and attendees:

- To learn more about the Marine and Freshwater Toxins Task Force and how to contribute to this new and exciting effort to foster the development and validation of powerful and practical methods for toxin analysis, and greater availability of toxin standards.
- A forum to meet with international members of the seafood industry, their associations, and also regulatory agencies. These stakeholders, who are the ultimate users and/or benefactors of the analytical methodology, will also find that the symposium and Task Force can be used to express their needs.
- To observe or participate in the activities of focused subgroups in the areas of saxitoxins, diarrhetic toxins, yessotoxins, domoic acid, and others. Subgroups have proven to be the most effective means of developing methodology needs and validation strategies. Symposium presenters and attendees are welcome to attend.

For more information contact james.hungerford@fda.gov or visit: http://www.aoac.org/marine_toxins/task_force.htm.

World Aquaculture 2005, 9-13 May 2005, Bali, Indonesia

It's the biggest aquaculture conference on the planet and in 2005 it will be held in Bali, Indonesia. WAS 2005 will create a unique opportunity to meet farmers, scientists and government regulators from every corner of the globe. An international trade show will be held simulteously. For more information, including a downloadable conference brochure, abstract submission and registration details visit the WAS website, http://www.was.org.

6th Symposium on Diseases in Asian Aquaculture (DAA VI), 25-28 October 2005, Colombo, Sri Lanka

The theme of the sixth symposium is 'Aquatic Animal Health Facing New Challenges'. A workshop, a training course, an expert consultation and the 7th Triennial General Meeting (TGM-7) of FHS are being planned in conjunction with DAA VI. Details will be made available through a dedicated website to be launched in October. Five previous Symposia (Bali 1990, Phuket 1993, Bangkok 1996, Cebu 1999 and Brisbane 2002), each brought together more than 200 aquatic animal health scientists, students, government researchers and industry personnel from some 30 countries to discuss disease related problems affecting aquaculture production and to find solutions for them. Please visit the FHS website for more detailed information about the society and DAA. Expressions of interest to participate or request for inclusion in the mailing list may be sent to Dr. Melba B. Reantaso at Melba.Reantaso@fao.org using the subject: DAA VI. More information about DAA VI is available for download as an attachment from: http://www.enaca.org/PDF/DAA_VI_First_Announcement.pdf

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