# RESEARCH NEEDS TO SUSTAIN ASIA-PACIFIC AQUACULTURE TO YEAR 2025 AND BEYOND

4th to 7th June 2007, Thailand

**Funded by the International Development Research Cooperation, Canada (IDRC)**

# *CONCEPT NOTES*

The "Concept Notes" and a note on a success story from research, presented here represent a few of the major topics that we believe should receive attention but is not considered to be exhaustive, however. Hopefully these provide the base line for discussions and the format of the presentations that are expected from the participants. There will also likely to be some overlap in the contents, which perhaps is unavoidable to a certain extent.

The literature cited in the notes is available for reference, if needed, and all other presentations are also expected to be backed up with relevant citations. Obviously, there will be some overlap between some of the concept papers; this is perhaps unavoidable.

The "Concept Notes" included in this document are:

# Background Information on Aquaculture Production Needs

*Thuy T.T. Nguyen, C.V. Mohan, Michael Phillips, Sena S De Silva*

## *Preamble*

The information provided hereto is expected to help us proceed through the workshop in identifying major issues and determining the appropriate research needs- in essence the backdrop to our ensuing discussions. In this document we have attempted to trace the trends in population growth over the years, the current status of wild fisheries, the gap between demand and supply, and the predictions thereof in meeting the future needs. In order to keep the information succinct we have, where appropriate provided graphical information and kept the text to a minimum.

## *Trends in population growth*

### Historical aspects

The following information is based on two sources[1, 2]. The present population of 6.7 billion is expected to reach 9.2 billion by 2050. The recognized trends are as follows:

- Earth's population grew ten fold from 600 x 106 in 1700 to 6.3 x109 to in 2003.
- It took from the beginning of time until about 1927 to put the first $2 \times 10^9$ on the planet
    - Less than 50 years to add the next $2 \times 10^9$ (by 1974)
    - Just 25 years add the next $2 \times 10^9$ (by 1974)
- Asia has the world's highest population, currently estimated at 3.68 x 109, and expected to reach 4.78 x 109 by the year 2025
- More than half of the current annual increases occur in six countries, viz. India, China, Pakistan, Bangladesh, Nigeria and the USA

[1] United Nations Population Programme: http://esa.un.org/unpp/).
[2] Cohen, J.E. 2003. Human population: the next half century. Science, 302, pp, 1172-1175.

## Impacts/ implications of population increases

These are too numerous to enumerate. Suffice is to say the implications will impact on nutrition- food supplies, health, prosperity, demand on natural resources- biological and physical, security, prosperity- living standards, environmental integrity and so on. Contrary to perceived negative implications, increased population might also provide additional human resources to undertake agriculture related livelihood approaches.

## *Food fish demands/ needs*

The demand for fish is growing through out the world; these increases are driven by perhaps two factors:

- In the developed world primarily due to proven health benefits of fish as a food source, and,
- In the developing world, to a small extent for the above reason but mostly it provides an affordable source of animal protein to poorer sectors of the community

Increased availability, improved distribution systems and comparative price advantage over other animal protein sources - red meats - has meant that more people have access to fish at affordable prices.

## *Consumption rates (Asia-Pacific)*

### Predicted needs

Table 1: World population increases and future fish demand

| | Population ('000)* | | % increase | Supply (2001) per capita (kg)** | Supply current (t) *** | 2020 fish demand**** |
|---|---|---|---|---|---|---|
| | 2020 | | | | | |
| Africa | 905936 | 1228276 | 35.6 | 7.8 | 7,066,301 | 9,580,553 |
| Asia (excluding China) | 2589571 | 3129852 | 20.9 | 14.1 | 36,512,951 | 44,130,913 |
| Europe | 728389 | 714959 | -1.8 | 19.8 | 14,422,102 | 14,156,188 |
| Latin America & the Caribbean | 561346 | 666955 | 18.8 | 8.8 | 4,939,845 | 5,869,204 |
| North America | 330608 | 375000 | 13.4 | 17.3 | 5,719,518 | 6,487,500 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Oceania | 33056 | 38909 | 17.7 | 23 | 760,288 | 894,907 |
| China | 1315844 | 1423939 | 8.2 | 25.6 | 33,685,606 | 36,452,838 |
| World | 6464750 | 7577889 | 17.2 | 16.3 | 105,375,425 | 123,519,591 |

Source: UN; **Source: FAO; ***2005 population x 2001 per capita supply; ****2020 population x 2001 per capita supply

Table 2: Role of aquaculture in fulfilling the needs of food fish supplies

| Forecasts | By the forecast date | | Calculated quantities required from aquaculture by the forecast date | |
|---|---|---|---|---|
| | Global caput consumption | Food fish demand | Growing fisheries (0.7%) | Stagnating fisheries |
| Delgado et al., (2003) (IFPRI ) 2020 | | | | |
| Baseline | 17.1 | 130 | 53.6 (1.8%) | 68.6 (3.5%) |
| Lowest | 14.2 | 108 | 41.2 (0.4%) | 48.6 (1.4%) |
| Highest | 19.0 | 145 | 69.5 (3.2%) | 83.6 (4.6%) |
| Wijkström (2003) | | | | |
| 2010 | 17.8 | 121.1 | 51.1 (3.4%) | 59.7 (5.3%) |
| 2050 | 30.4 | 270.9 | 177.9 (3.2%) | 209.5 (3.6%) |
| Ye (1999) | 15.6 | 126.5 | 45.5 (0.6%) | 65.1 (2.0%) |
| 2030 | 22.5 | 183.0 | 102.0 (3.5%) | 121.6 (4.2%) |

(the above two Tables are modified after Siriwardena, P.P.G.S, Stirling University)

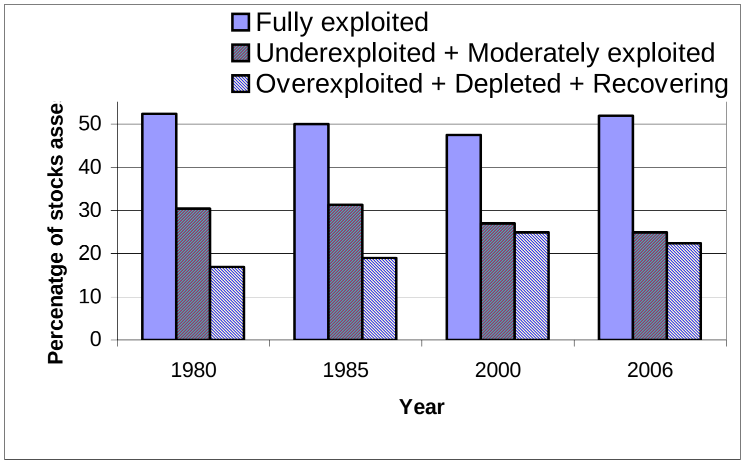
## *Fish food supplies*

### Capture fisheries stocks

The figure depicts (data from FAO 2007) the dire straits the capture fishery stocks are in currently; the growth of the sector is minimal - if any - and very unlikely to improve significantly. There is, however, some indication that the contribution from inland fisheries could improve (currently estimated to yield 10 x $10^6$ t; 80 % in Asia)[3] through well managed stock enhancement measures and culture-based fisheries development (a form of aquaculture)[4].

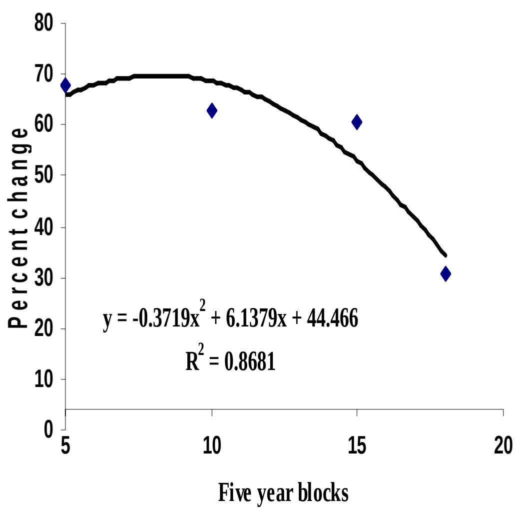
3 FAO, 2007. The state of world fisheries and aquaculture (SOFIA), 162 pp

4 De Silva, S. S., 2003. Culture-based fisheries: an underutilized opportunity in aquaculture. ***Aquaculture* 221**, 221-243.




## *Aquaculture*

The sector has been mooted as the fastest growing food production sector, globally, over the last few decades, growing at an average rate of 8.0 % /year- a very familiar and a commonly heard “mantra”. Aquaculture currently contributes over 40% to all food fish consumed. The contribution to total supply of aquatic products is expected to increase. Some salient points of Asian aquaculture are:




- Asian-Pacific aquaculture contributes over 85% to global production. This dominance is expected to continue.
- Most aquaculture is small scale; clustered holdings
- Still freshwater finfish is the largest cultured commodity group
- Mariculture is growing rapidly

- The number of species cultured is increasing5
- Increasing intensification
- Continued diversification of species
- Continued diversification of culture systems
- Increasing influence of markets, trade and consumption (food safety)
- Enhanced regulation and better governance to sustain aquaculture
- Increased competition for natural resources, such as freshwater, fish meal and others
- Increasingly integrated aquaculture business structures

## *Growth in aquaculture*

There is evidence to show that, although the absolute production is increasing, the rate of growth is on the decline (see Figure and also the reference Subasinghe, 2006[5]).

The above mathematical trend is to be expected as production volumes increase (recent population growth follows the same trend). The key question is whether this decline points towards a growing gap between supply and demand- if so, there is a problem, and this is where research comes in; helping to proactive in solving the said problem.

**How do we sustain what is current and or can we overcome the trend of decreasing growth rate in aquaculture (do we need to?)? If so how? What are the main issues that we need to address?**

***Some issues for brain storming:***

1. Production systems

- farming of species feeding low on the food chain
- exploiting the natural productivity of aquatic systems (farming the seas, enhanced fisheries)
- less dependence on fish meal based feeds and improving resource use efficiency
- integrated systems

[5] For example, in Asia and the Pacific region 204 species belonging to 86 families are cultured, as opposed to 336 and 245, respectively, globally (Subasinghe, R., 2006. State of world aquaculture: 2006. ***FAO Fisheries Technical Paper* 500**, 134 pp.)

- domestication as opposed to wild seed as source of stocking material
- promoting culture of native species
- encouraging responsible introductions

2. Servicing the sector

- Organizing small scale farmers and preparing them to meet the future challenges facing aquaculture

3. Economic development and poverty

- value addition for aquaculture products (please note that this one may not be relevant to production needs, but is more related to economic development through aquaculture – i.e. more value to the producer, or producing country. This is an important issue for development and poverty reduction, rather than production *per se*).
- role of the sector in economic development and poverty reduction
- market and globalization trends and future competitiveness of small-scale aquaculture farmers

4. Global trade and markets

- equivalence in food safety standards for aquaculture products meant for domestic consumption and export
- national and international standard setting for aquaculture
- implications of international trade and globalization of services, production systems and markets
- future competitiveness of small-scale aquaculture farmers in global markets

5. National and international policy

- effective policies for inland culture based capture fisheries and mariculture in open waters
- role of national and international policy environment for sustainable aquaculture, and role of research in creating the right policies for aquaculture

# Climate Changes & Aquaculture Research

*Sena S De Silva and Michael Phillips*

*« It is among those nations that claim to be the most civilized, those that profess to be guided by a knowledge of laws of nature, those that most glory in the advance of science, that we find the greatest apathy, the greatest recklessness, in continually rendering impure this all- important necessity of life…. Alfred Russel Wallace, Man's Place in the Universe, 1903*>>

## *Preamble*

It is not a question of when and if climate change- more floods (in 1960 approximately $7x10^6$ were affected but today the figure is $150x10^6$, annually), more hurricanes, irregular monsoons etc. etc., global warming and sea level rise will occur but to what degree these changes will take place in the coming decades? The reasons underlying these changes are well understood and basically have been driven as a result of industrialization that has brought about changes through excess emission of carbon dioxide, methane etc. into the troposphere and the stratosphere (Fig. 1): for example the atmospheric methane level has increased from 715 ppb in the pre-industrial revolution level to 1775 ppb at present. The average temperature on our planet has been increasing steadily, being accelerated since the dawn of the industrial revolution (Figure 2).

There is agreement that our planet will heat by 1.1°C this century come what may, and business as usual will commit to a 3°C rise in temperature. Earth's average temperature is around 15°C, and whether we permit it to rise by a single degree or 3°C will decide the fate of thousands of species and most probably billions of people[6]. The Intergovernmental Panel on Climate Change (IPCC) has estimated that the oceans will rise 10 cm to 100 cm over this century; thermal expansion contributing 10 to 43 cm to the rise and melting glaciers would contribute 23 cm. The overall mitigating measures that are being put in place are major political decisions (e.g. Montreal Protocol- CFCs, HCFCs; Kyoto Protocol- $CO_2$) and are beyond the realm of our purview.

Admittedly, to date reported impacts from climate change have been relatively small. Over the past eight years drought and unusually hot summers for example have caused world grain yields to fall or stagnate (but the number of mouths to feed has grown by 600 million). Nevertheless some of the major changes related to global warming that have already occurred and or predicted to occur could impinge on aquaculture development, and are:

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[6] Flannery, T. 2005. The Weather Makers. Text publishing, Melbourne, Australia.

- Notably, the Indian Ocean is the most rapidly warming ocean on earth, affecting major changes in ocean and also on land e.g. Sahelian drought[7]; productivity changes and changes of current patterns
- Biological productivity of the north Atlantic is predicted to plummet 50%, and oceanic productivity world wide by over 20%[8]: major changes to fish meal availability?
- El-nino affects; reduction in fish catches; impact on global fish meal supplies
- Changes/declines in the krill (Euphausid spp.) populations- often mooted as a possible alternative replacement for fish meal in feeds for cultured stocks- in the Arctic and Antarctic waters and these being replaced by species of rather low nutritional value such as salps[9].
- Major changes in biodiversity, leading to extinction of significant number of species. To date the extinction of one species is clearly related to climatic change- the golden toad (Bufo periglenes) from Costa Rica[10].
- Predictions on overall loss of biodiversity are staggering; one of the most notable studies being that of Thomas et al.[11], when extrapolated indicates that at least one out of five living species on this planet is committed to extinction by the current levels of green house gases.
- Coral bleaching is a major cause of global warming and when continued will bring about major changes in biodiversity of coral flora and fauna, loss of most diverse habitats etc. etc.- Australia will be one of the major nations that will be affected and is being affected[12];

### *Food production and climate changes:*

The great majority of studies on impacts of climate changes have been done on potential loss of biodiversity- in relatively specialized habitats- coral reefs, Amazonian forest, alpine areas etc. and mainly on plants and terrestrial food crops[13], but less on fisheries and aquaculture related aspects per se; changes in yields, crop patterns, and the like. Nevertheless, there is increasing recognition of that climate change will have significant impacts on fisheries and aquaculture, and the livelihoods of people dependant on the sector.

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[7] Gianni, A., Saravanan,R., Chang, P. 2003. *Science* 302, pp. 1027-30.
[8] Schmittner, A. 2005. *Nature* 434, pp. 628-33.
[9] Atkinson, A. *et al*. 2004. *Nature*, 432, pp. 100-03.
[10] Crump,M. 1998. In Search of the Golden Frog. University of Chicago Press.
[11] Thomas, C.D. *et al.* 2004. *Nature* 427, pp.145-48.
[12] Australia has the highest per capita greenhouse emissions; 25% higher than the US; Australia's growth in emissions over the last decade has been faster than the other OECD countries (Hamilton,C., 2001. Running from the Storm: The Development of Climate Policy in Australia. UNSW Press, Sydney)
[13] FAO Climate Change. http://www.fao.org/clim/default.htm

### *Climate change and aquaculture:*

The potential scenarios developed by the IPCC forecast - with indications of "confidence" levels – for fisheries in general indicate the following effects[14]:

- Globally, saltwater fisheries production is hypothesized to be about the same, or significantly higher, if resource management deficiencies are corrected. Also, globally, freshwater fisheries and aquaculture at mid-to-higher latitudes could benefit from climate change: **Medium Confidence**
- Local shifts in production centres and mixes of species in marine and fresh waters are expected as ecosystems are displaced geographically and changed internally: **High Confidence**
- Positive effects such as longer growing seasons, lower natural winter mortality and faster growth rates in higher latitudes may be offset by negative factors such as a changing climate that alters established reproductive patterns, migration routes, and ecosystem relationships: **High Confidence**
- Changes in abundance are likely to be more pronounced near major ecosystem boundaries. The rate of climate change may prove a major determinant of the abundance and distribution of new populations. Rapid change due to physical forcing will usually favor production of smaller, low-priced, opportunistic species that discharge large numbers of eggs over long periods: **High Confidence**
- There are no compelling data to suggest a confluence of climate-change impacts that would affect global production in either direction. Marine stocks that reproduce in freshwater (e.g. salmon) or require reduced estuarine salinity will be affected by changes in temperatures and the amount and timing of precipitation and on species tolerances: **High Confidence**
- Where ecosystem dominances are changing, economic values can be expected to fall until long-term stability (i.e. at about present amounts of variability) is reached: **Medium Confidence**
- Subsistence and other small-scale fishers who lack mobility and alternatives, and are often the most dependent on specific fisheries, will suffer disproportionately from changes: **Medium Confidence**
- Because natural variability is so greatly relative to global change, and the time horizon on capital replacement (e.g. ships and plants) is so short,

14 The UN Ocean Atlas. Fisheries and global climate change from http://www.oceansatlas.org

impacts on fisheries can be easily overstated, and there will likely be relatively small economic and food supply consequences so long as no major fish stocks collapse: **Medium Confidence**

The predictions to date suggest that sensitivity to global change will vary between fisheries. The most affected will be fisheries in small rivers and lakes, in regions with larger temperature and precipitation change and on anadromous species. They will be followed by fisheries within Exclusive Economic Zones, particularly where rigid access-regulations reduce the mobility of fishers and their capacity to adjust to fluctuations in stock distribution and abundance; fisheries in large rivers and lakes; fisheries in estuaries, particularly where there are species without migration or spawn dispersal; and in the high seas. For example, how would the changes in monsoonal rain patterns, already reported for India[15], impact inland fishery resources, and in turn on aquaculture activities?

Whilst predictions vary widely, there is little doubt that significant changes in fisheries will occur, and some fisheries changes will likely have significant implications for aquaculture.

## *Known direct impacts to date:*

The climate, directly and indirectly, obviously plays a critical role in aquaculture, determining the species that can be cultured, biological processes of cultured species, occurrence of pests and diseases and the availability of key natural resources such as water.

To our knowledge to date there has been only one reported impact from human-induced climatic change on aquaculture, directly. This relates to the smog cloud generated over SE Asia during the 2002 El-Nino, cutting sunlight off by 10% and heat the lower atmosphere and the ocean, that some authors attributed to dinoflagellate blooms that impacted aquaculture in coastal areas, purportedly from Indonesia to S.Korea, purported to be causing millions of $ worth of damage to aquaculture[16].

## *Potential impacts*

The impacts on aquaculture from climate change, as in the fisheries sector, will likely be both positive and negative arising from direct impacts, and indirect impacts, on natural resources required for aquaculture; the major ones being

[15] Goswami BN, VnnugopalV et al. 2006. Increasing trend of extreme rain events in a warming environment. ***Science*** 314, pp. 1442-1445.
[16] Swing, T.G. 2003. What Future for the Oceans? Foreign Affairs September-October, pp. 139-52.

water, land, seed and feed (biodiversity) and energy. As fisheries are a major source of inputs for aquaculture – feed and seed in particular –changes in fisheries caused by global climate change will also flow through into aquaculture systems, particularly in suitability of different areas for aquaculture species, and the availability and prices of resources such as fish protein for fish feed.

Positive impacts might arise from changes in water temperatures leading to enhanced growth rates and changes in the distribution of species and extension of the range of warmer species; and opening up of new opportunities for brackish water aquaculture in flooded coastal deltas (such as the Mekong delta), where agriculture may become non-viable due to saltwater intrusion.

Negative impacts, which will probably outweigh the positive, and might include:

Increased vulnerability of sea-based aquaculture (e.g. cages) to severe weather, water quality changes (e.g. from plankton blooms) and possibly pollutants and other run off from land based sources caused by flooding.

- Increased vulnerability of near-shore land based coastal aquaculture to severe weather, erosion and storm surges, leading to structural damage, escapes and loss of livelihoods of aquaculture farmers. Some of the most sensitive areas will be the large coastal deltas of Asia, which contain many thousands of aquaculture farms and farmers, particularly the Mekong delta, Ganges and Brahmaputra/ Meghna system in India/ Bangladesh and southern China, already highly developed areas for aquaculture. The downstream delta ecosystems are also likely to some of the most sensitive because of upstream changes in water availability and discharge, leading to shifts in water quality and ecosystems in the delta areas.
- Impacts caused by changes in freshwater availability and drought patterns. Changes caused by shifting monsoons, which are predicted to be more variable, and patterns of water availability in inland areas is likely to have profound implications for aquaculture, as well as agriculture. Water availability for aquaculture is already become a serious constraint in several parts of Asia, including China, and climatic shifts caused by climate changes are likely to exacerbate the impacts.

Biodiversity changes in global fisheries, which in some scenarios are predicted to be highly significant, could impact through the limitations on fish meal supplies. Changes in El Nino, for example, a major factor in Peruvian fisheries (primary source for a very significant quantum of the raw material for the fish meal industry), have potential to cause major impacts on availability and pricing of fish meal in aquatic animal diets.

- Impacts caused by warmer water temperature will bring about changes in the distribution of cultured species, as well as likely changes in growth patterns and production. The range in which species can be cultured will also likely change, and particularly species currently farmed near the edge of their optimal range (e.g. Atlantic salmon in Tasmania) will likely be most significantly impacted. The other implication of water temperature changes has increased vulnerability to diseases and stress, resulting in increased economic losses.

## *Country and specific vulnerability*

The impacts of climate change will not affect aquaculture in all countries, or indeed all aquaculture farmers, in the same way[17].

Asia features highly in vulnerability assessments for aquaculture, with the large producing countries of Bangladesh, China, India, Cambodia, the Philippines and Vietnam being particularly vulnerable to climate change.

Vulnerability will also vary between aquaculture farmers, and other stakeholders along the aquaculture "value chain". The poorest producers will have least resources – financial capital, social or institutional support – to be least able to adapt to climate change, and will likely be the most vulnerable.

## *Potential impacts & research needs?*

The potential impacts on aquaculture reviewed above, and potential research needs can be considered from three fronts: all aquaculture, mariculture and freshwater aquaculture.

The most obvious research area is to conduct further studies on the potential impacts of global climate change on aquaculture, developing some of the general assessments into this paper into more quantitative assessments. Further work on adaptations to climate change is also required.

A GIS type approach, which has shown some promise in initial aquaculture vulnerability assessments, may prove further to be of further use at this early stage to overlay the predicted features and locations of climate change with major aquaculture areas and species.

[17] Neil Handisyde, Lindsay Ross, Marie-Caroline Badjeck & Eddie Allison **(xxx)** The Effects of Climate change on World Aquaculture: A global perspective. Report for DFID http://www.aquaculture.stir.ac.uk/GISAP/gis-group/climate.php

## All aquaculture

- Impact through the limitations on fish meal supplies and is dealt with in a separate concept paper.
- Would increases in water temperature bring about needs in cultured species, growth patterns?; if so how will these impact on total yield?
- Locations most at risk from climate change, and possible adaptation mechanisms?
- Locations where climate change could bring optimal production and benefit?

## Inland aquaculture

- What would be the warming effects on cold water species culture; mountainous regions etc.; will there be a need for alternative species; warm water species areas  suitable for culture become restricted and thereby impact on overall production
- Will the reproductive seasons be affected? Needing modifications in hatchery technologies?
- Will the distribution of wild populations get more restricted, resulting in low genetic diversity and impacting on broodstock management/ quality/ therefore seed quality/ overall yields
- Where are the vulnerable locations for extreme climate events and changes in rainfall patterns? What are the mechanisms for adaptation?

## Mariculture

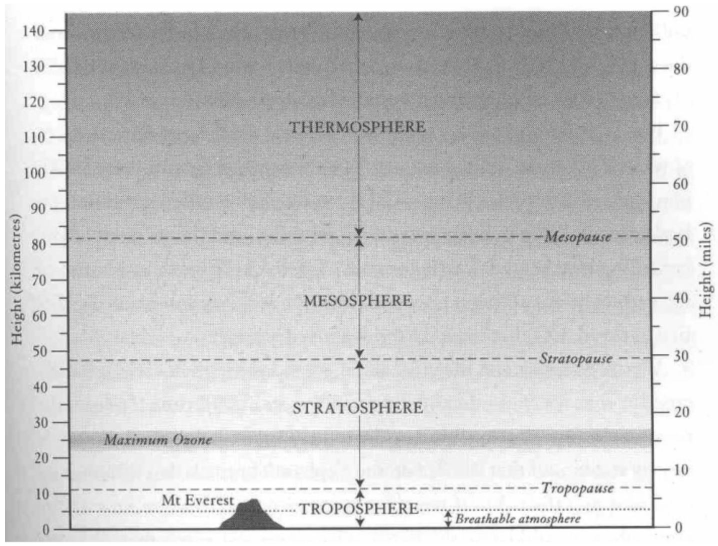
- Changes of currents and extreme events; where are the vulnerable locations and how can mariculture adapt; need to consider placement of cages and technologies; the need to work with oceanographers; map new regions for changed locations.
- Ways of combating dinoflagellate blooms and other water quality changes
- Where the most vulnerable brackish water locations and what are are the strategies to reduce vulnerabilities?
- Having identified the key issues for aquaculture, a further research need would be to identify the strategies, including costs benefits of investment and necessary policy to reduce impacts on the sector, and the people whose livelihoods depend on the sector.
- The opportunities for working with other sectors, for example agriculture, and in integration of aquaculture into watersheds and water conservation measures, also need to be further explored.

### *Aquaculture and carbon sequestration*

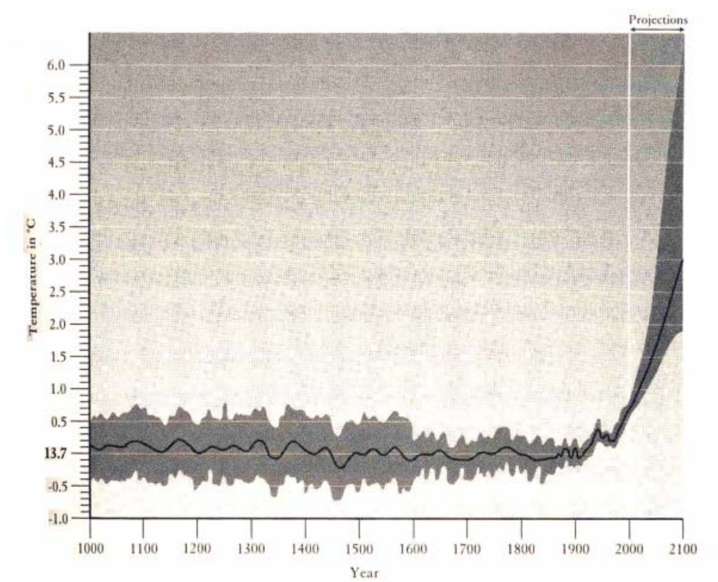
Increasing attention is being given to ways of reducing emissions of carbon dioxide, and even removal of carbon dioxide from the atmosphere. Businesses world wide are looking at reducing their carbon dioxide emissions, and also trading in carbon 'credits' in attempts to become "carbon neutral". In some countries, consumers are also being made increasingly aware of carbon dioxide pollution from the products they consume. To date, aquaculture has not featured in such discussions, but there are some relevant and interesting areas for future research:

- What is the amount of carbon dioxide released in production of aquaculture products? What is the potential for a carbon neutral food production through aquaculture? Such questions need to be answered through research on the whole farming system, including the discharges and impacts associated with delivery of farmed product to the consumer.
- What is the potential for some aquaculture systems to act as a sink of carbon, thus contributing, albeit in a small way, to efforts to reduce atmospheric carbon dioxide? For example, some recent analyses show significant amounts of carbon dioxide sequestered in the shells of mollusks. If some forms of aquaculture have potential to remove carbon dioxide, permanently, from the atmosphere, then would this open new funding arrangements for aquaculture development through offsetting the emissions of other industries?

The increasing public and business awareness of the concept of "carbon neutrality", whilst presently focused on carbon dioxide, may also lead to demands that aquaculture (and other food production systems) be environmentally "neutral" in other ways – e.g. in use and discharge of nutrients, in water use – likely leading to increased pressure on the aquaculture industry to implement ever more stringent measures to minimize and control environmental impacts. It is also possible that as aquaculture – along with other industries – is forced to pay for the environmental impacts caused, or at least offset them through carbon and nutrient absorption investments, that some traditional farming systems such as integrated farming may get a new lease of life (see concept note on IFS- the need to increase research from a different perspective). The economics of environmental damage being increasingly highlighted by the climate change debate will inevitably be incorporated into the economics of sustainable aquaculture businesses in the future.




*The four major parts of the atmosphere, and their associated boundaries. Only a small part of the troposphere is breathable air*




*This graph, known as the 'hockey stick', shows trends in the average surface temperature of Earth from AD 1000 to 2100.Prior to 1900 this was 13.7 degrees. The grey area conveys uncertainty, which is reduced around 1850 when the. Thermometer grid was established. The projections on the right give a range of probable temperature increases to 2100.*

# Alien Species and Biodiversity in Aquaculture

*Sena S De Silva, Thuy T.T. Nguyen and Simon Funge-Smith*

## *Preamble*

Alien species and biodiversity issues were an academic pursuit for a long time in the past, but became more prominent in association with development and sustainability as a sequel to the Brundtland Report, "Our Common Future' in 1987[18]. Presently, biodiversity impacts are no longer primarily measured through impacts on species disappearance/ displacement, but are now targeted at more detailed issues including; impacts on the genetic make-up of wild species/ strains, resulting from advertently or inadvertently mixing of stocks. This is now considered an equal threat to the simple loss of biodiversity. The impact of alien species/ strains in aquaculture on biodiversity should not be considered in isolation, especially with the envisaged impacts on biodiversity resulting from global/regional/climatic changes and the loss of environmental integrity due to increasing anthropogenic activities. ***Habitat loss or environmental degradation are perhaps most significant in the Asia-Pacific region, which is reputed to have the highest deforestation rate, highest degree of catchment destruction, highest numbers of dam construction, as well as considerable draining and modification of rivers and floodplains etc.[19].***

It is also foreseeable that the current focus on certification, food quality standards and eco-labeling, which are becoming a part and parcel of the importing country requisites of aquaculture produce, will increasingly be expanded to include, acceptably requirements related to biodiversity. ***Asian aquaculture will need to be proactive in this regard and commence introducing mitigating strategies in order to ensure it is adequately covered to remain competitive in the global markets.***

From an aquaculture development view point, it has been suggested that the utilization of alien species, the basis of most Asian aquaculture in the last two decades[20,21], has significantly impacted biodiversity [22,23,24] even though there is a

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[18] UNEP 1987. Our Common Future. The World Commission on Environment and Development, Commission for the Future. Geneva, Switzerland.

[19] De Silva, S.S., Abery, N.W., Nguyen, T.T.T. 2007. Endemic freshwater finfish of Asia: distribution and conservation status. ***Diversity and Distributions*** **13**, 172-184.

[20] De Silva, S.S., Nguyen, T.T.T., Abery, N.W., Amarasinghe, U.S., **2006.** An evaluation of the role and impacts of alien finfish in Asian inland aquaculture. ***Aquaculture Research,*** **37,** 1-17.

[21] De Silva, S.S., Subasinghe, R.P., Bartley, D.M., Lowther, A. **2004**. Tilapias as alien aquatics in Asia and the Pacific: a review. ***FAO Fisheries Technical Paper*** 453, 65 pp.

paucity of direct evidence in this regard. This is partly due to the lack of direct research focus on the issue, in particular, genetic investigations to evaluate impacts especially on the impacts on the gene pools of counterpart natural/ local populations/ species.

The situation is further exacerbated by the fact that the majority of Asian aquaculture is in freshwater, ecosystems which have the greatest vertebrate diversity and are under the greatest threat for loss of biodiversity.

### *Problems and related actions (?)*

In respect of aquaculture developments in the Asia-Pacific region a number of problems can be envisaged and there is a need to address these, urgently. Amongst the needs to be addressed are:

- A thorough evaluation of and assessment of the impacts, including biological, socio-economic and cultural impacts of alien species on aquaculture in the region, and developments of protocols for such future evaluations and continued monitoring.
- Lack of sustained monitoring of influence of impacts of alien species has hampered providing logical and explicit interactions with different "lobby groups", and therefore counteracting the perceived (by the public) "ill effects" of aquaculture developments in the region.
- It is a truism that there is significant degree of ill-informed and ill-conceived translocations for purposes of experimental trials and indeed for commercial aquaculture taking place in the region; how could these be minimized?
    - Is there a need to bring about more stringent policy changes and stricter implementation protocols to be adhered to by all nations in the region?

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[22] Moyle P.B. & Leidy R.A. (1992) Loss of biodiversity in aquatic ecosystems; evidence from fish faunas. In: *Conservation Biology: the Theory and Practice of Nature Conservation* (ed. by P.L. Fielder & S.K. Jain), pp.129-161. Chapman and Hall, UK.

[23] Naylor R.L., Williams S.L. & Strong D.R. (2001) Aquaculture- a gateway for exotic species. ***Science*** **294,** 1655-1666

[24] Naylor R.L., Goldburg R.J., Mooney H., Beveridge M., Clay J., Folke C., Kautsky N., Lubchenco J., Primavera J. & Williams M. (1998) Nature's subsidies to shrimp and salmon farming. ***Science*** **282,** 883-884.

  - is the current risk assessment processes in place rigid enough/ if not ways of improving these processes?

- Are the stock enhancement processes currently used address long term influences on the genetic pools of native species? If not what should be done; is there a need for a regional program to be developed in respect of such monitoring, and what form should it take?
- A considerable quantum of translocations associated with the aquarium industry sector occurs in the Asia-Pacific region. The impacts of such translocations have received scanty attention to date, even though there have been instances of aquarium species establishing and impacting the environment and biodiversity, such as for example featherback (Chitala spp.) in Sri Lanka and pacu in Indonesia.
  - There is an urgent need to undertake such studies and also develop a monitoring system and the required protocols
- Often nations are faced with situations that some groups call for a relevant introduction whilst opposed by others. A case in point is the clamour by some to introduce Penaeus vannamei into India, primarily based on the success of the introduction of this species for example in Thailand, which transformed the shrimp farming sector in the latter25.
  - How does one proceed in such cases, apart from the application of current risk assessment protocols?
  - Is the application of risk assessment protocols by themselves sufficient to ensure long tem impacts of a translocation on biodiversity?
  - If not what needs to be done?

[25] Briggs, M., Funge-Smith, S., Subasinghe, R., Phillips, M. 2004. Introduction and movement of *Penaeus vannamei* and *Penaeus stylirostris*. RAPA Publication 2004/10, 79 pp.

# Broodstock and Genetic Resources Management in Aquaculture

*Thuy T.T. Nguyen*

## *Preamble*

The growing market demand for fish at a time of declining supply from the traditional capture fisheries has spurred considerable interest in aquaculture. Currently, Asia is considered the epicenter of global aquaculture, accounting for over 85% of global production and likely to continue its dominance well into the foreseeable future.

However, the aquaculture sector is facing public criticism about its impacts on biodiversity. Such impacts involve the risks associated with trans-boundary movements of species and strains, and release or escape of hatchery-produced seed which may dominate and displace the local counterparts.

Lack of understanding and appreciation on the importance of genetic resources has hampered the development of logical and appropriate management actions. The lack of coherent aquatic genetic resources management and of policies is becoming a serious problem because the recent rapid expansion of aquaculture and the overexploitation of many wild stocks have involved irresponsible use of natural resources and lack of consideration of the needs of other sectors, resulting in adverse environmental and social impacts, inter-sectoral conflicts and unsustainability. The bulk of aquatic genetic resources have not yet been characterized and it is a truism that information on aquatic genetic resources, even of major cultured species in the region, is inadequate.

In broodstock management in aquaculture, if attention is not paid on genetic issues as a part of aquatic genetic resources management, often lead to inbreeding and alteration of the genetic make-up in cultured stocks. This in turn could alter the gene pools of the wild counterparts. It is noted that the genetic make up of most cultured populations has often been altered through inbreeding, selective breeding, domestication and more recently through genetic modification such as transgenics. Such impacts in fact have been well documented in the last decade, particularly in respect of salmonids in North America[26]. In Asia, evidences of genetic deterioration and contamination in

[26] Hindar, K., Ryman, N., Utter, F., 1991. Genetic effects of cultured fish on natural fish populations. *Canadian Journal of Fisheries and Aquatic Science* 48, 945-957.

hatcheries as well as impacts of hatchery-produced stocks on the wild stocks have also become available[27, 28].

Development of strategies for improved hatchery-broodstock management practices is an important step in any aquaculture operation. Such strategies are necessary to minimize the potential impacts of hatchery-produced seed on the natural gene pool. On the other hand, these strategies could also optimize the production performance of hatchery produced eggs and larvae and as such satisfy the increased demand on good quality seed. Furthermore, establishment of a high-quality hatchery broodstock will reduce dependence on annual capture of wild brood fish and reduce inter-annual variability in broodstock condition. It also permits manipulation of their reproductive cycle resulting in the capacity for multiple annual spawning, increased hatchery and production, and improved economics.

As with the increasing development of aquaculture in Asia, demand on healthy seed would also increase. In addition, pressure from importing countries on biodiversity issues indicates the need to develop aquaculture in a sustainable manner. This could be achieved through proper genetic resources management in all countries in the region where aquaculture is practiced.

## *Problems and appropriate actions*

- One of the foremost problems facing the management of aquatic genetic resources today is the lack of information, especially genetic structure of many species, particularly in Asia. This is mainly due to inadequate research capacity in obtaining information on genetic resources, as well as in development appropriate management strategies based on information thereof. Although some information on genetic resources is available, but it is relatively incomplete and scattered compared to information on genetic resources of plants29. Furthermore, currently there are no existing aquatic biological databases that give adequate coverage to aquatic genetic resources. As such there is a need to improve information systems on aquatic genetic resources, this will necessarily involve better:
    - Capacity building in genetic resources assessment/ characterisation

[27] Senanan, W., Kapuscinski, A.R., Na-Nakorn, U., Miller, L., 2004. Genetic impacts of hybrid catfish farming (*Clarias macrocephalus* x *C. gariepinus*) on native catfish populations in central Thailand. *Aquaculture*.

[28] Kamonrat, W. (1996). Spatial Genetic Structure of Thai Silver Barb *Puntius gonionotus* (Bleeker) Population in Thailand. Ph.D. Thesis, Dalhousie University, Halifax, Canada.

[29] www.croptrust.org

- Characterisation of genetic resources of economically important/ cultured species, and species of conservation value. E.g.
  - grouper species (extensive translocations occurring)
  - Major carp species
  - Selected indigenous fish species with culture potential
- Information reporting
- Coordination among researchers, countries and institutions
- Should INGA be revived?

- Lack of coherent policy on genetic preservation at species level, and as such there is a need to develop an regional policy framework for management of aquatic genetic resources through analysis of the FAO Code of Conduct for Responsible Fisheries (CCRF):
  - The FAO CCRF is the world's most comprehensive and internationally agreed set of principles and guidelines applicable to the management and development of aquaculture and capture fisheries. However, there are gaps in its coverage as well as gaps in other international instruments that deal with aquatic genetic resources. For example, while covering well general fish genetic resources issues, CCRF has not yet been supplemented with a technical guidelines publication that gathers together and amplifies principles and practices for management of fish genetic resources. In addition, recent advances in molecular genetics and genomics and their implications for fish genetic resources are not currently adequately covered by any of the CCRF guidelines.
  - It is therefore timely that the FAO CCRF needs to be revised and updated to cover the above issues
- Similarly, no technical guidelines are available for broodstock management in aquaculture. The only technical paper available to date is of Tave (1999)30, which deal greatly with aspects of inbreeding in captivity but does not take into account information on available genetic resources. In addition, broodstock founding process and broodstock management for aquaculture are often conducted in a haphazard manner, i.e. does not based on knowledge of basic genetic information of targeted species.

[30] Tave (1999). Inbreeding and brood stock management. *FAO Fisheries Technical Paper* No.392. 122 pp.

    - More comprehensive guidelines on broodstock management need to be developed, step-by-step from procurement of broodstock that takes genetic and distribution information into account, and management of broodstock in hatchery so that genetic diversity is maintained.

- Similarly, in the case of stock enhancement, genetic diversity is crucial and there is no available guideline in this regard.
    - Special guidelines for broodstock management for stock enhancement need to be developed, including impact monitoring assessment.
- Risk assessment procedures/ guidelines of translocation involving movements of fish from a population to a new location within species distribution range, including movements between hatcheries, are currently not available. Only risk assessment guidelines for release of GMO are available in the ASEAN countries.
    - Appropriate risk assessment guidelines should be included in risk assessment procedures, taking into account the risk associated with movements of aquatic animals to a new location within species distribution range

# Aquaculture and Human Health hazards-Emerging Issues

*Peter Edwards and C.V. Mohan*

## *Introduction*

This concept paper attempts to provide some background information on this topic and address some of the emerging issues that have come to the forefront since the outbreak of major global disease events such as BSE and bird flu. The concept paper is developed to stimulate research ideas to address such emerging issues in the future.

The issue of safety and quality is of concern to all consumers in both producing and importing countries. Food safety must be an integral part of any aquaculture production system. In most fish exporting countries, special attention is paid to the safety of products meant for export, while products for domestic consumption receive less attention. This trend needs to be rectified through appropriate awareness and capacity building activities and supporting legislation.

This concept paper is presented in 2 sections. The first, deals briefly with the well known food safety hazards associated with fishery products including from aquaculture. The second section deals with some of the emerging issues that may have an impact on aquaculture.

## *Human health hazards from aquaculture*

Potential risks to human health and food safety from aquaculture products can come from various reasons. Food-borne parasitic infections, food-borne diseases associated with pathogenic bacteria and viruses, residues of agro-chemicals, veterinary drugs and heavy-metal organic or inorganic contamination have been identified as possible hazards in aquaculture products[31]. These hazards are usually associated with the aquaculture habitat, the species being farmed, the general condition of the local environment, and cultural habits of food preparation and consumption[32].

[31] Garrett, E.S., M.L. Jahncke and C.A.M. Lima dos Santos. 1997. Public and animal health implications of aquaculture. Paper presented at the International Life Sciences Institute Conference on Emerging Foodborne Pathogens: Implications and Control, Alexandria, Va., USA, March 1997

[32] Reilly, P.J.A. 1992. Review of the occurrence of Salmonella in cultured tropical shrimp. *FAO Fisheries Circular* No. 851. Rome, FAO. 19p

Human parasitic infestations caused by fish consumption is widespread. Around 40 million people in Asia are affected by fish and water borne parasitic diseases, especially trematodes. These are widespread in countries where consumption of raw fish is common (e.g. mainly in China, Viet Nam, Thailand and Laos). Of the three types of food-borne parasites (e.g. nematodes, cestodes, trematodes), trematodes are of greatest significance. Fish-borne trematode disease is endemic over a large area of the world, including East and Southeast Asia and Russia. WHO indications are that more than 50 million people may be suffering. Although the disease is seldom fatal, trematodes can cause serious complications in humans leading to fatalities. Use of human and animal wastes for fertilization of fish ponds and the continuation of traditional food habits tend to sustain the parasitic infections. Control requires more research on the epidemiology of infection, better means of identification of infested fish and better diagnostic methods.

There is increasing incidences of reported cases of food borne illness throughout the world associated with aquaculture products. Despite the incidence of food poisoning caused by fish, the safety of fish products carrying bacteria and viruses that are recognized as human pathogens is often questioned. The list of organisms includes: *Vibrio cholerae, V. parahaemolyticus, V. vulnificus, Salmonella, Shigella, Listeria monocytogenes,* pathogenic varieties of *Escherichia coli, etc.* To ensure food safety it is important to understand which of the organisms are indigenous and which contaminants are. When harvested in a clean environment and handled hygienically until consumption, aquaculture products are very safe. Unfortunately, unhygienic practices coupled with insufficient refrigeration and sub-standard processing practices can be at the origin of many outbreaks of fish-borne illnesses. It should be noted that non-indigenous bacteria of faecal origin can be introduced into aquaculture ponds via unavoidable contamination by birds and terrestrial animals associated with farm waters, in systems in which manures are not used for nutritional input.

Molluscs present a higher risk of causing human illness from bacterial or viral pathogens than do crustaceans and finfish. The greatest number of seafood-associated illnesses is from consumption of raw molluscs harvested in waters contaminated with raw or poorly treated human sewage[33]. Human viral diseases caused by the consumption of finfish and crustaceans appear to present a low risk, while viruses causing disease in fish are not pathogenic to man[34]. Filter feeders (e.g. oysters, mussels) can accumulate biotoxins (e.g. PSP) and become

[33] Ahmed, F. E. 1991. Symposium on issues in seafood safety. Institute of Medicine. Washington, National Academy Press. 239p.

[34] Hackney, C. R. and M. D. Pierson. 1994. Environmental indicators and shellfish safety. New York, Chapman & Hall. 523p

harmful to consumers. The extent of accumulation of these toxins by finfish and crustaceans in aquaculture production facilities is still not clear.

Chemicals and antimicrobials are used to treat culture water and fish to control diseases and pests. There is global concern about the consumption of low levels of antimicrobial residues in aquatic foods and the effects of these residues on human health. Plasmid-mediated antibiotic resistances among bacteria found in fish farms, and transfer of this resistance to organisms not directly in contact with the antibiotics are being increasingly reported. The increasing frequency of resistance has been associated with the excessive use of antibiotics in intensive aquaculture systems. The resistance can easily be transferred both to fish pathogens and human pathogens. The danger is that illnesses in humans caused by antibiotic-resistant organisms derived from aquatic products, or the environment of aquaculture systems, might not respond to medical treatment[35]. Emergence of antibiotic resistance should not be only associated with aquaculture practices. It is necessary to closely look into the widespread misuse of antibiotics in the medical and veterinary fields.

Aquaculture product also carries a risk of contamination from agro-chemicals, especially heavy metals and chlorinated hydrocarbons. Unfortunately, there is little information on their levels in cultured fish to allow risk assessment.

## *Emerging human health issues associated with aquaculture*

Aquaculturists have too often been blamed as adopting a "bury-your-head-in-the-sand" attitude when it comes to human disease threats. There are concerns that increasing intensification of aquaculture practices and its integration with other live stock may give rise to new problems and provide ideal circumstances for the emergence and/or spread of new human pathogens. In view of the recent speculation of bird flu virus transfers as a result of proximity to aquaculture or through integration of livestock and aquaculture, a detailed account on bird flu (H5N1) and its likely implications on aquaculture is provided below.

## *Bird Flu and Aquaculture*

Highly pathogenic avian influenza (HPA1), commonly known as bird flu, is mostly caused by the H5N1 strain of type A virus from the Orthomyxoviridae virus family. It is highly pathogenic i.e., easily spread, among both domestic fowl and wild birds. Flock mortality rates often excede 50% although domestic ducks

[35] Howgate, P. 1997. Review of the hazards and quality of products from aquaculture. Paper presented at the meeting of the Joint FAO/NACA/WHO Study Group on Food safety Issues Associated with Products from Aquaculture, Bangkok, Thailand, 22-26 July 1997

sometimes carry the virus asymptomatically. Infected birds excrete the virus in high concentrations in faeces and discharges from nose and eyes.

There is also major concern about the zoonotic impact of HPAI. The global WHO tally for human infection on 2 April 2007 was 288 cases with 170 deaths (59% mortality rate). Furthermore, there is a danger that a new strain may evolve that could be readily transmitted among humans. Estimated deaths that could be caused by a new influenza pandemic range from 2.0 – 7.4 million people.

FAO has classified poultry production systems into four sectors in relation to the probability of birds becoming infected with HPAI (Table 1)[36]. Farm management (biosecurity – bio-exclusion refers to measures to exclude infectious agents from uninfected premises) and the system used to market products are the two system variables :

- sector 1: industrial vertically integrated systems with high-level biosecurity and birds/products marketed commercially; farms are part of a vertically integrated production enterprise with clearly defined and implemented standard operating procedures for biosecurity
- sector 2: commercial production systems with moderate to high biosecurity and birds/products usually marketed commercially; in sectors 1 and 2 birds are kept indoors continuously, strictly preventing contact with other poultry or wildlife
- sector 3: commercial production systems with low to minimum biosecurity and birds/products usually entering live bird markets; birds are in open sheds and may spend time outside the shed
- sector 4: village or backyard production systems with minimal biosecurity and birds/products consumed locally.

Bird infection is most likely in sectors 3 and 4 but when sectors 1 and 2 get infected then there is a greater impact because of the larger number of birds. Adverse macroeconomic impacts are greater for major poultry exporting countries such as Thailand, with microeconomic impacts greater for countries with the poultry sector dominated by small-scale producers such as Cambodia, Laos and Vietnam[37].

[36] FAO, 2004. FAO recommendations on the prevention, control and eradication of highly pathogenic avian influenza (HPA1) in Asia. FAO Position Paper, FAO, Rome. 49 pp

[37] Rushton, J., R. Viscarra, E.G. Bleich and A. McLeod. Impact of avian influenza outbreaks in the poultry sectors of five South East Asian countries (Cambodia, Indonesia, Lao PDR, Thailand,

It has been stated that in many Asian countries there is a strong link between poultry and fish farming[38]. However, poultry are traditionally raised in scavenging flocks in the region (sector 4), with little to no horizontal integration with fish as bird manure is difficult to collect to fertilize fish ponds. With the relatively recent development of feedlots, raising chickens and ducks adjacent to or over fish ponds has developed to varying degrees in several countries (sector 3). As indicated in Table 1, sector 3 is the only one with relevance for direct horizontal integration with aquaculture although there is no firm information that poultry/fish direct integration has been involved in any HPA1 outbreak.

Table 1. Classification system for poultry production systems (FAO, 2004) and relevance for aquaculture

| | Sector 1 | Sector 2 | Sector 3 | Sector 4 |
|---|---|---|---|---|
| System | Industrial, integrated | Commercial | Commercial | Village, backyard |
| Bio security | High | Moderate to high | Low to minimal | Minimal |
| Bird and product marketing | Commercial | Usually commercial | Birds usually sold in live markets | Birds and products consumed locally |
| Relevance for aquaculture | | | | |
| - direct integration | None | None | Low to high | Minimal to none |
| - indirect integration | Low to moderate | Low to high | Low to high | Low to moderate |

There are two major types of integrated chicken/fish farms in Central Thailand: broiler and layer farms[39]. Broiler farming is exclusively on a contract basis with large companies providing day-old chicks and feed and buying back birds at harvest, much for export. Layer farms operate independently and sell eggs to middlemen for the local market. Both are open systems not screened from the

Vietnam) outbreak costs, responses and potential long term control. TCP/RAS/3010. FAO, Rome. 25 pp.

38 Feage, , C.J., 2006. Fish farming and the risk of spread of avian influenza. Wild Wings Bird Management. BirdLife International. 11 pp. http://www.birdlife.org/action/science/species/avian.flu/index.html

39 Belton, B., P. Edwards, J. Hambrey, K. Kaewpaitoon, D.C. Little, W. Turner and J. Young. 2005. Development and trends in the aquaculture production and marketing of Central Thailand. DFID AFGRP, University of Stirling. 109 pp

wider environment. Following the late 2003/early 2004 bird flu outbreak and slaughter of many birds in infected areas, contract farming companies stopped providing day-old chicks to broiler farmers operating open systems even though the Department of Livestock allowed some broiler farms to reopen after inspection as semi-closed systems with poultry quarters screened with plastic netting. Only layer farms appear to have been able to continue integration with fish in Central Thailand.

The Thai Government policy concerning the meaning of closed system as it relates to fishponds remained to be fully defined[4]. Without poultry manure farmers were unable to raise fish at relatively low cost.

HPA1 led to increases in prices for fish as well as beef and pork in early 2004 as many consumers were wary of consuming poultry products[2].

It is unlikely that HPA1 could infect cold blooded fish. There is rapid die-off of human enteric viruses in manured, green water ponds. According to WHO, human enteric viruses are only of low to medium relative importance in human excreta and wastewater-fed fish ponds[40]. The same should hold for poultry manured ponds. It is thus unlikely that HPA1 would be transmitted passively by fish to either birds or humans.

Poultry by-products are also used to feed fish indirectly via feather meal and by-product meal as ingredients in formulated feed. The potential for HPA1 virus transmission is unlikely because of high temperature in pelleted feed manufacture. Poultry bones from slaughterhouses are ground up to feed *Clarias* catfish in some countries in the region which could disseminate viruses in the environment.

According to FAO, "all commercial poultry farms should develop and implement a formal biosecurity plan as appropriate to the farm"[1]. However, FAO recognizes that banning feeding of farmed fish with poultry manure or poultry by-products might not be feasible for small-scale farmers who rely on poultry and cannot afford pelleted feed. There would be little likelihood of such bans being effective or practicable. Under such circumstances, a "targeted vaccination campaign for poultry at risk of being infected may be required in heavily infected countries"[1].

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[40] WHO, 2006. Wastewater and excreta use in aquaculture. Guidelines for the safe use of wastewater, excreta and greywater. Volume 3. WHO, Geneva. 140 pp

## *Aquaculture feeds and human health*

Use of organic manures as feed and fertilizer in fish ponds has always been speculated to be responsible for transmitting some of the human pathogens (e.g. Salmonella). Another area that has attracted recent attention is the use of bone meal in fish feeds. This is more so in view of the BSE outbreaks and the spread of the BSE pathogen in bone meals.

## *Other areas of concern*

Other areas of concerning include aquaculture increasing the risk of insect vector borne disease in humans. Poorly-managed fish ponds or abandoned fish ponds are suggested to become mosquito-breeding sites. Small impoundments greatly increase the overall aggregate shoreline of ponds, causing higher densities of mosquito larvae and cercaria, which can increases such as lymphatic filariasis and schistosomiasis, respectively. In addition, multi-species livestock production (e.g. pigs and poultry) integrated with aquaculture are thought to assist in possible mutations and spread of pathogens like bird flu virus

## *Problems and related actions (?)*

- To what extent are poultry integrated with fish, in what ways and to what extent have the practices been influenced by HPA1 virus? Studies have only been carried out on the implication of HPA1 to free range ducks in Indonesia[41] and Vietnam[42]. The proposed study could be incorporated in a study to be carried out by FAO on small-scale poultry production and HPAl virus[43].
- How have fish prices responded to lower supply and demand of poultry caused by HPAI outbreaks?
- How long does HPA1 virus survive when infected poultry manure is added to fish ponds (or spread on fields)?
- Do fish become infected with HPAI virus and excrete the virus?

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[41] CIVAS/FAO, 2006. A review of free range duck farming systems in Indonesia and assessment of their implication in the spreading of the highly pathogenic (H5N1) strain of avian influenza (HPA1). Final Report. CIVAS, Jakarta and FAO, Rome. 60 pp

[42] Edan, M., 2006. Review of free-ranging duck farming systems in Northern Vietnam and assessment of their implication in the spreading of the highly pathogenic (H5NI) strain of avian influenza (HPA1). Final Report. VSF-CICDA and FAO, Rome. 75 pp.

[43] FAO, 2007. Review of small-scale poultry production practices and its contribution to gender equity, food supply and food security, income generation and rural development. Proposed study FAO, Rome. 2 pp.

- To what extent are poultry by-products used in aquafeeds on-farm as well as in industrially formulated feeds? Is HPA1 virus killed in the process? Are such feeds imported/exported?
- Can the potential hazards at the production level be controlled by good farm management practices, and consumer education?
- Can the HACCP system be applied from production to consumption in the aquaculture sector to control food-borne hazards?
- In view of the large number of aquaculture commodities produced in the Asian region, can practical HACCP plans be developed for key commodities (e.g. shrimp, carps, catfish).
- Can the principles and concept of risk analysis be applied as basis for assessing, managing and communicating risks associated with food-borne hazards?

# Integrated Fish Farming

*Sena S De Silva & Miao Weimin*

## *Preamble*

Integrated fish farming (IFF) systems, combining livestock and agriculture crop production systems with farming of fish and other aquatic products are traditional farming systems, originating largely in China that have evolved over 2000 years. IFF systems have been viewed as environmentally friendly, making efficient use of water and organic material and nutrients derived from various livestock, poultry of agricultural crop wastes. They are also a low risk and sustainable method of food production suitable for small-scale producers in rural areas of developing countries. Through the pioneering work of IDRC[44] and other donors, the systems originating in China have now been widely adopted throughout many developing countries in Asia, creating much needed fish production and income for many thousands of small-scale farmers throughout Asia. They are recently also being promoted in Africa through pioneering south-south cooperation supported by the Chinese government.

Times are changing though for this important rural food production system; economic change in China is causing massive shifts in the farming systems as farmers orient towards high value crops; and increasing questions are being raised about the safety and future of certain integrated fish farming models, particularly fish farming directly integrated with livestock and poultry. The emergence of global health concerns, such as avian influenza, has focused attention on the bio-safety of integrated fish farming The discharge of livestock and poultry manure, the proximity of high densities of livestock close to common water reservoirs, and easy access of migratory birds to ponds has led some to postulate that integrated farming systems are a risk to spread of avian influenza. Production of aquatic animal protein based on livestock and poultry manure is also being questioned because of human health concerns related to transfer of antibiotics and growth promoters from livestock and poultry into the food chain, food safety of the final product from microbial and chemical contaminants, and risks of transmitting fish borne zoonotic parasites from the livestock manure into fish destined for human consumption.

On other hand, there has been positive development in integrated fish farming in the past couple of years. Good examples include the integration of biogas

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[44] http://www.idrc.ca/en/ev-27162-201-1-DO_TOPIC.html

generators for "clean and biosafe" use of livestock wastes, instead of direct discharge into fish ponds.

There is therefore a need for an analysis of the status and risks from integrated fish farming, and the development of scientifically based guidelines for its practice and future development. Environmentally sound and biosafe practices in integrated fish farming in the regions need to be identified and guidelines prepared to support responsible development of IFF systems. There is a need for the IFF systems which operate in rural areas and providing a basis for thousands of livelihoods to be improved upon if it were to meet the demands of the coming decades and beyond. With appropriate improvements brought about through R & D, IFF could be model for a rural based, low intensive "organic farming system". Also, considering the fact that the IDRC in the late 1980s to early 1990s was a main provider of funds for IFF R&D and training in the region, which enabled these practices to be improved and sustained, it will be logical for the

## *Needs*

- Assessment of status, benefits and risks of integrated fish farming in China and other selected countries in Asia, with special reference to environmental sustainability and bio-safety.
- Development of scientifically-based guidelines on integrated fish farming practices and management for widespread dissemination at regional, national and local levels.
- Strengthening of south-south cooperation within Asia and between Asia and Africa in promotion of safe and environmentally sound integrated fish farming.

## *Questions to be addressed*

- Integrated fish farming and human health - analyzing present and future hazards associated with human health such as avian influenza, zoonotic parasites, product quality etc. Where are the critical hazards and risks, and how can risk management be improved to reduce risk and improve quality?
- What is the present status and trends of integrated farming systems? How are economic changes in China and elsewhere driving the farming systems? Is this increasing or reducing environmental and bio-safety risks? What are the costs to farmers and society from such changes?
- Environmental issues and IFF – what is the present role of integrated farming systems in water and resource/biodiversity conservation. Is there

a future role for IFF habitats in biodiversity conservation? How can the environmental values of integrated farming systems be best captured, whilst minimizing risks?

- What are the market and economic factors driving change in IFF. Are these good or bad for the environment, or consumer? Are environmental benefits of IFF worth more investment in IFF? Can fish and non-fish products from IFF systems be promoted (e.g. through organic schemes etc) so that the environmental and biodiversity benefits be retained. Is there a market for organic products in China, or other markets, from IFF that has not been tapped?
- What are the regulative policy (e.g. effluent discharge) and public sector factors (e.g. extension and technical advisory services to farmers) driving the change in IFF. How have the overall technological development and improvement in aquaculture sector (such as improved accessibility to and better quality of input materials like feeds) impacted on traditional integrated fish farming systems.
- How successful has the transfer of IFF technologies been? What are the constraints in national, regional and inter-regional cooperation efforts? How best can south-south cooperation in environmentally sound and biosafe IFF be facilitated? What are the future opportunities and strategies for promotion of IFF, in Asia, but also opportunities for Asia-Africa extension and cooperation?

# Feed Development Needs

*Sena S De Silva*

## *Preamble*

There is a significantly rapid change in emphasis in Aquaculture developments in the Asia-Pacific, mostly dictated by the export markets, increasing of living standards in main aquaculture producing countries in the region, and limitation of physical, non-renewable resources inland. The shift is towards a major emphasis on coastal aquaculture of high valued species, in particular high valued finfish species such as groupers (Family Epinephalidae) snappers (*Pagrus* spp.), seabass (*Lates calcarifer*) together with shrimp (*Penaeus* spp). These species require external feed inputs, either in the form of commercial peleted feeds that have significant quantities of fish meal and fish oil, and or trash/ low valued fish.

Fish meal and fish oil are limiting, expensive resources and the global production of these commodities has almost reached plateau, at approximately 6 and 0.1 million tonnes annually, respectively. The use of these commodities in aquaculture has been increasing and has by-passed all other sectors[45]. Equally, this relatively high degree of usage in aquaculture has been a bone of contention over the years[46,47,48], even though the facts presents in this regard may often been distorted[49].

If the global status is much to be desired in the above regard the scenario in relation to aquaculture developments, in particular mariculture developments in the Asia-Pacific is even of even a greater concern. Some of the salient points[50] based on a regional review are:

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[45] TaconADJ., **2004.** Use of fish meal and fish oil in aquaculture: a global perspective. ***Aquatic Resources Culture and Development***, 1, 3-14.
[46] NewM., **1991**. Compound feeds- world view. ***Fish Farmer***, March/ April 1991: 39- 46.
[47] NaylorRL., GoldburgRJ., MooneyH., BeveridgeM., ClayJ., FolkeC, Kautsky N., Lubchenco J., Primavera J., Williams M. ,**1998**. Nature's subsidies to shrimp and salmon farming. ***Science*** **282,** 883-884.
[48] Naylor R.L., Goldburg RJ., Primavera J., Kautsky N., Beveridge M., ClayJ., FolkeC., Lubchenco J., MooneyH., Troell M., **2000.** Effect of aquaculture on world fish supplies. ***Nature*** **405,** 1097-1024
[49] HardyRW. ,**2001**. Urban legends and fish nutrition, Part 2. ***Aquaculture Magazine*** **27 (2),** 57-60.
[50] De SilvaSS, SimYS,TurchiniG (in press). Review on Usage of Fish, Directly and Indirectly as Feed Sources and Feeds in Asian Aquaculture. ***FAO Fisheries Technical Paper***

- Asia-Pacific is the biggest user of fish meal in aquaculture in the world, estimated at 2,388,058, and 2,096,561 (low) and 3,207,255 (high) and 2-3 x $10^6$ tonnes of trash fish (as direct feed source), currently and 2010, respectively.
- The region, however, produces only 1 x $10^6$ (PR China, Thailand, Myanmar etc.)tonnes of fish meal and is a net importer
- The region produces an estimated 4 million tonnes of trash fish/ low valued fish
- which is used directly and or in non-commercial feeds
- The trash fish/ low valued fish is almost solely used in mariculture, baring some usage as fish powder in animal feeds
- The use of trash fish/ low value fish in other feeds for feeding animals reared for non-human consumption is significant (estimated at 2- 3 x $10^6$ t) but has not received global attention

### *Immediate problems:*

- A need to reduce the reliance on trash fish in the growing mariculture sector
- A need to develop feed standard – there is a mushrooming of small scale feed plants in the region, which do not necessarily adhere to proper feed formulations- the label specifications not reflecting the actual composition; leading to wastage, poor performance, higher costs., more negative environmental impacts
- Feed development for the larval and fry stages of cultured marine species
- Lack of feed standards and complying legislative needs
- Poor feed management practices
- The vast majority of inland fish farming practices depend on "farm made " feeds; - an area which has received scant attention[51],[52]- but needs much attention; any improvements to such feeds will have a major impact on

[51] De Silva, S.S., Davy, F.B., **1992**. Strategies for finfish nutrition research for semi-intensive aquaculture in Asia. ***Asian Fisheries Science*** **5**, 129-144.
[52] New, M.B., Tacon, A.G.J., Csavas, I. (eds.), **1995**. Farm-made aquafeeds. ***FAO Fisheries Technical Paper*** **343**, 434 pp.

utilization of the resources and improved performance of the cultured stocks

### *Lessons to be learnt from elsewhere:*

The major strides made with respect to salmon feeds; an international collaborative effort; reduce fish meal inclusion by approximately 35%; improved feed utilization efficiency two fold (the average FCR in a properly managed salmon farm is 1: 1); reduced nitrogen and phosphorus discharge

### *Research needs?*

- Should there be a regional approach?
- Policy developments; regional guidelines on feed standards?
- Weaning off from direct use of trash fish?

# Effective Utilization of Inland Water Resources for Food Fish Production

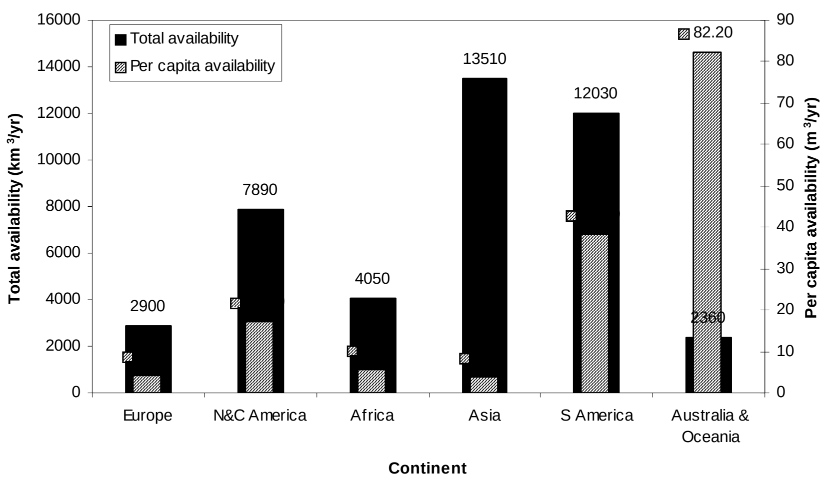
*Sena S De Silva*

## *Preamble*

### Water

Inland water is one of the most limiting natural resources on the planet. This planet:

- is estimated to have only 35,029,000 km$^3$ of freshwater, or only 2.5% of all water resources
- of the fw resources only 23.5% is habitable, the rest being ice caps and glaciers[53], [54]
- The amount of fw available as rivers, lakes, wetlands, etc. amounts only to 0.01% of the earth's water resources or only 113,000km$^3$.
- Asia is blessed with the maximum quantity of inland water amongst all continents
- But the amount available on a per capita basis is lowest (Figure 1)[55].




[53] Shiklomanov I .A. 1993. World freshwater resources. In: Gleick P.H. (ed), Water in Crisis: A Guide to the World's Fresh Water Resources. Oxford University Press, New York, pp. 13- 24.
[54] Smith D. I. 1998. Water in Australia. Oxford University Press, Oxford. 384 pp.
[55] Nguyen, T.T.T., De Silva, S.S., 2006. Freshwater finfish biodiversity and conservation: an Asian perspective. *Biodiversity and Conservation,* 15, 3543-3568.

- However, Asia also has the world's highest static/ lacustrine waters, the great bulk being man-made for other purposes; a resource that could be effectively utilized for the secondary purpose of food fish production.
- It is also important to note that the great bulk of such water bodies, perennial and non-perennial are located in rural areas, and these constitute an integral component in the livelihoods of the populations living around the vicinity.
- It is also estimated that water surface area, classified as small scale irrigation schemes, available in developing nations in Asia is 66,710,052 ha[56], a significant proportion of which is considered to be suitable for food fish production, on an extensive basis, but community managed- culture based fisheries[57].

## Inland food fish

- Inland fish production is estimated at around 10 x $10^6$ per annum (10% of total), and has been increasing steadily, with Asia accounting for about 70% of this production
- Inland fish is almost always consumed, fresh or processed, but rarely or never reduced into animal feed
- Inland fish accounts for about 20-25% of the animal protein intake, particularly in rural populations in the developing world[58].

## *Problem/ Status*

- In general, and globally, inland fisheries have taken back stage; possibly more often than not because these fisheries are artisinal and do not draw the attention of fishery managers and aquaculturists as a plausible means of significantly impacting on food fish production and or contributing to poverty alleviation.
- Lack of such attention by governments and developments agencies have therefore likely to have contributed to sub-optimal utilization of inland water resources for food fish production, for example this being

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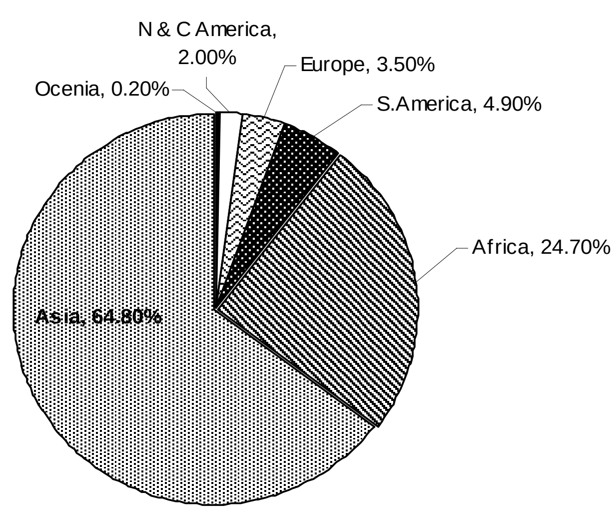
[56] (FAO, 1999b). FAO, 1999. Irrigation in Asia in figures. Water Reports 18, FAO, Rome, Italy, 228 pp.
[57] De Silva S.S. (2003) Culture-based fisheries: an under-utilized opportunity in aquaculture. *Aquaculture* **221**, 221-243.
[58] Delgado C.L., Wada N., Rosegrant M.W., Meijer S. & Ahmed M. (2003) Fish to 2020. Supply and Demand in Changing Global Market. International Food Policy Research Institute, Washington, D.C., 226 pp.

exemplified in the extreme range in capture fishery production variations in reservoirs in Asia within and between nations (from a high of mean production of about 160- 200 kg $ha^{-1}$ $yr^{-1}$, in Sri Lanka to as low as 45 kg $ha^{-1}$ $yr^{-1}$ in India and even less in Vietnam).

- The above differences in production ac not be fully accounted for by biological reasons only; reasons fro these differences need to be researched and understood, and appropriate measures introduced to increase fish production.

## *Research needs?*

- A regional approach for bringing about effective utilization of such water bodies for fish production?
- Exchange of expertise
- Management regimes; an assessment/ evaluation of current ones; what improvements are needed
- Address problems/ constraints of seed stock supplies
- Address marketing aspects (high seasonality in inland fish production)
    - Value addition?




**Inland fish production by continent- 2004**

# Some Socio-Economic and Policy Research Themes

*John Kurien*

What is listed below is basically a random list of themes from a novice in aquaculture for the consideration of the august body of experts who will meet in Rayong **(author's wording!!- not the editors")**

## *Role of state, market and community in planning for aquaculture expansion*

In the Asian region, given the greater scarcity of land and water and competing alternative uses for the same, the decisions on land and water use patterns are best taken in a context where state, market and community are cooperatively involved. Expansion of aquaculture activities should be motivated by the engine of market forces but within a mutually agreed regulatory framework steered by the state and anchored by the community. This can be achieved by participative planning (particularly in the context of the decentralization policies in most Asian countries) which can yield optimal results and greatly reduce social conflict.

## *Aquaculture as a means to maximize the use of scare water resources*

The scarcity of water resources is slated to be the problem of this millennium. In this context the ecological, economic, social and nutritional contribution of aquaculture will be greatest in areas where it can contribute to maximize the sustainable use of scare water supplies. ***If water is considered the limiting factor, then maximizing the returns from a unit of water should be the focus of any development effort in which water use is a central consideration***. In the context of climate change, the expansion of aquaculture into the large dry zones in Asia can be a beneficial strategy for development of these regions. Needless to say, the type of species choice must be made judiciously. Viewing aquaculture from this perspective may help to identify new areas for its expansion in Asia

## *Factoring protein preferences into demand estimates*

Demand estimates on which much of the discussions about the future role of aquaculture are based need to be more carefully refined. The implicit assumption in most such estimates is that the whole population of a country eats fish. Quantity demanded is estimated by taking an average per capita consumption and multiplying it by the total population of the country (making different assumptions about price behaviour). The varying protein preferences in a country need to be assessed using consumption surveys so as to obtain more realistic demand estimates. Such demand analysis will help to make more targeted projections of the spatial dimensions of demand in a particular country or region. These will not only help to make more refined demand analysis; it will also help in planning for more targeted marketing of aquaculture products.

### *Aquaculture: Food for Nutrition or Luxury Protein?*

Quantity-wise much of Asian aquaculture is destined as food for nutrition in the region. However, in terms of value, much of Asian aquaculture flows to countries outside the region as luxury protein. The economic calculations, ecological implications and social dimensions of these two broad end-uses of aquaculture products need to be compared and contrasted for a meaningful understanding of the trends for the future in each of the countries of the region. Very broadly speaking, aquaculture as food for nutrition is a case of production by the masses for the masses and aquaculture as luxury protein is a case of production by an elite for the elite.

### *Analysis of the sources of growth of the value of exports from aquaculture*

The valuable foreign exchange earnings from exports of aquaculture products are often portrayed in many developing Asian countries as an important reason for the unequivocal support being given to the aquaculture industry. At times the growth rates of the total value of exports can be a misleading indicator because it does not adequately disaggregate the sources of the growth of value. The total change in the value of exports (over any period of time) is made up of growth of value from three sources (1) total volume changes; (2) product composition changes; and (3) price changes. A periodic disaggregated analysis of the total export value into these three sources will give a more realistic picture of the economic and ecological impact of aquaculture export trade. For example, an analysis of sources of growth of total value of exports of marine products from India revealed that over time the greater share in the increased total value of exports came from price changes alone. This could indicate greater vulnerability to external market changes. On the other hand, if in a country, volume changes were the major contributor to total value of exports, we would need to examine the resource sustainability issues more closely. The desirable situation will be to have a balanced contribution by all three sources.

### *The food security impact of regional trade patterns in aquaculture products*

The impact of international fish trade on food security has recently become a subject of concern. In this context there is a direct aspect of food security (fish as food) and an indirect aspect of food security (fish as source of employment and income) which needs to be examined. In the Asian context, there is a considerable (and growing) amount of regional trade in aquaculture products. In this case the direct and indirect aspects of food security are in a more delicate balance because the fish producers, the numerous small traders and the consumers in the countries involved in the trade are largely in the same socio-economic class. Assessing the food security implications of aquaculture in this context deserves special attention.

### *The ecological footprints of Asian aquaculture*

Much controversy has been raised over the ecological impact of Asian aquaculture. This has been particularly worrying in the context of new forms of coastal shrimp aquaculture. The analysis of the ecological impact has been largely concerned with the problems in the immediate vicinity of the shrimp farms. The ecological footprint analysis helps to enlarge the realm of impact analysis to the widest circle of influences so that we can obtain a macro-picture of the ecological impact. ***This would cover inter alia the marine upwelling ecosystem area; the agricultural ecosystem area; the mangrove support area; the carbon sequestering area etc needed for a unit area of aquaculture operations***. Comparison of ecological footprints for different types of aquaculture within a country can also help policy makers to make informed choices on how and when to allocate public investments to help create more sustainable aquaculture practices in the country.

### *The sources and sustainability of fish feed for aquaculture*

The role of the fishmeal trap in curbing the growth of intensive aquaculture is well documented. What is less well documented is the intrinsic link between industrial aquaculture and industrial marine fisheries -- both of which are, from a natural resource perspective, wholly unsustainable. This linkage is an important cause for the vicious circle of ecological damage both at sea and on land. Very few studies have examined this linkage. Some specific case studies in the Asian region will be instructive to show how industrial aquaculture helps to give a longer lease of life to unsustainable industrial fisheries. The example of trawling in the Gulf of Thailand could be a case in point.

### *Multi-criteria approach to assess the externalities of intensive aquaculture practices*

Aquaculture activity generates a considerable range of externalities (unintended effects imposed on others without compensating them for the effects) which need to be recognized, assessed and managed if aquaculture is to get a "good name".

Externalities can be assessed through a variety of econometric valuation analyses. However, these quantitative assessments are incapable of taking cognizance of valid expressions and understandings about externalities which are qualitative in nature. Valuation exercises which adopt a weighted multi-criteria approach to assessment of externalities need to be more widely practiced in the Asian context. This is needed because the externalities from aquaculture -- particularly the negative, uni-directional and inter-temporal externalities -- affect a very wide cross-section of the population whose valuations (assessments) of these impacts are not always quantifiable in monetary terms. There is always the conflict between the public objectives of economic performance, ecological sustainability and social acceptability – each with different indicators for measurement and languages of valuation. Use of multi-criteria approaches can greatly improve our ability to consider the different perspectives of the large number of stakeholders involved in and affected by Asian aquaculture.

### *The welfare of workers in intensive export-oriented aquaculture ventures*

The labor absorption capacity of intensive export-oriented aquaculture has been a subject of considerable debate. There are very few good estimates of the number of workers; the nature of their work or their conditions of work. Agencies relating to aquaculture promotion rarely provide a macro picture of work organization; labor conditions or labor productivity in such aquaculture units. We may obtain a good picture of the returns to capital but rarely an idea of the returns to labor in intensive export-oriented aquaculture. With increasing consumer focus on social issues this is a realm which is likely to become an area of contention with implications for export to developed countries. Export promotion agencies and associations of the industry will do well to permit good economic and labor welfare studies being undertaken so that the facts about the welfare of workers are more transparent and better documented. This is the first step needed to improve these conditions.

### *Factors facilitating the economic concentration of aquaculture production*

Asian aquaculture is generally pictured to be largely small-scale in nature. This may be a valid description of the freshwater culture of products which are largely destined for the internal markets in their respective countries. In export oriented aquaculture (of all types) the tendency for economic concentration has been noticed in most Asian countries. Understanding the dynamics of this and the causes for the same is important. ***Is there a case for aquarian (~agrarian) reforms in aquaculture?*** Does the inverse size-productivity phenomenon, which has been a strong argument for agrarian reforms, valid for aquaculture? What is the relationship between globalization of the aquaculture industry and its economic concentration within the nation state?

## *March of folly: why we don't learn from others' experiences*

It is said that the learning curve can be characterized as an exponential function. Learning is initially slow but rapidly increases with time. ***The boom and bust phenomenon in realms such as shrimp aquaculture highlight that this learning curve is not transferred across countries -- Thailand did not learn from Taiwan and India did not learn from Thailand. Each opted to go through the same boom and bust experience with almost predictable precision.*** This may seem to be irrational behavior of economic agents. However, there is more to this than meets the eye. The economic interests which push for intensive aquaculture are often large industrial oligopolies who are not committed to any particular geographic territory. They are globalized in their pursuit of profit. ***The case of aquaculture feed manufacturers is a case in point --booms and bust are in their interest.*** But to encourage aquaculturists to learn from the (bad) experiences of others is not! Understanding the varied nature of economic interests which promote aquaculture in a country warrants close analysis and study.

# Innovations in mariculture (Three Specific Concepts)

*Fatchuri Sukadi*

## *Improving lobster aquaculture as a potential research area*

### Justification

The global demand for lobster is growing, and the lobster culture in South East Asia is based on wild collected seed. Global supply of lobster mostly came from capture fisheries. Irrational lobster fisheries will be one of the threats to the sustainability of coral reef ecosystems. In Indonesia, the collection of lobster seeds and growing them in cages is a common activity in Nusa Tenggara Barat (NTB) and started in 2001. The production of lobster from its culture is still low and reached around 60 ton per year. In Vietnam, lobster culture probably is already more advanced. Research on lobster reproduction in hatchery has been done in Australia which is one of the tasks to provide seeds.

The development of lobster culture will contribute to the strategies for aquaculture development beyond 2025. Since lobster culture is a new development of capture based aquaculture in Asia, this activity is included under the strategy of applying innovations in aquaculture, and is that to provide alternative income generations for the poor in coastal areas. Lobster culture is also a means to integrate capture of seeds with its culture and other sources of fisher or farmer income through capture fisheries like *bagan* light fishing. However, the activity of lobster culture, its constraints and opportunity for culture development in Asia and Pacific has not well documented. Hence, study on lobster aquaculture is one of important research area that should be developed in Asia Pacific.

### Objectives

The objectives of research on lobster aquaculture are to identify potential areas for lobster culture, species available and being cultured, improvement in seed procurement through hatchery and collection from wild, grow-out techniques, marketing and trade in Asia Pacific region.

### Possible countries to be involved

Indonesia, Australia, Vietnam and others. Research Network among related institutions in the regions is required. ACIAR and Vietnam currently has a project relating sustainable tropical spiny lobster aquaculture (Clive Jones, personal communication). Indonesia and ACIAR is formulating the project for smallholder aquaculture development through Support to Market Driven Research.

## *Research on resource efficient farming systems in aquaculture*

### Justification

Improving environmental sustainability is an important strategy in aquaculture development. Policies and practices that ensure environmental sustainability are needed.

The development of intensive aquaculture like in shrimp culture or many kinds of fish which located in inappropriate land or coastal areas have made a negatively impacted the environment or to other users. The farmer frequently uses land, water and more input in intensive culture to get high production without any consideration about margin analysis and environmental impacts. Utilization of land, seed, feed inputs efficiently and as suitable for individual species has not been well documented. It is understood that to use species feeding low in the food chain is effective. However, aquaculture of such species is rather limited. There are many more species of seaweed, mollusks and finfish which are still undetermined as good species for culture in efficient farming systems. On the other hand, the integration of aquafarms into marine and coastal area management or inland watershed management plans still has to be established or improved. The exploration of species for aquaculture like seaweed, abalone, sea cucumber and its future trade is important to be made.

### Objectives

- To determine ways to make efficient use of water, land, seed and feed input through study on land or marine area suitability and carrying capacity for aquaculture;
- To explore the potential for commercial use of species feeding low in food chain in freshwater, coastal and marine aquaculture.
- To mitigate impact of intensive culture on the environment
- To identify appropriate enhancement techniques

## *Improving food quality and safety in shrimp aquaculture*

### Justification

There is now an increasing demand among consumers in importing countries for high-quality, eco-friendly, and safe aquaculture products. However, in becoming an important contributor to the markets, the shrimp aquaculture industry has become increasingly subjected to rigid food safety and eco-friendly production and processing requirements (e.g. Traceability, HACCP, GAP). In the light of these recent trends, small-scale Asian fish farmers, especially in developing countries and countries in transition, have encountered difficulties in meeting such requirements. Therefore, empowering them through technological innovations, guidelines and standards on food safety/traceability, and policy and support services has become necessary to enable them to continue to participate in the network of fisheries and aquaculture production, marketing and trade.

Diet, feeding regimes which applied for safety food product is still need to be investigated. There is still a difficulty on the application of HCCP and traceability in small scale farming practices, and hence the study on possible techniques for these purposes is needed.

### Objectives

- To improve diets, feeding regimes and harvesting strategies to enhance product quality and its nutritional value.
- To study the potential role of HCCP and its application to production system, the use of drugs and chemicals at farmer level and appropriate storage technology at middlemen level.
- To assess the existing traceability of product and to study the constraints and opportunity to improve the systems in the shrimp supply chain management those allow good traceability of products, and provide good information on packaging, processing and production conditions.

# The successful development of backyard hatcheries for crustaceans: A case study from Thailand

*Hassanai Kongkeo, Michael B. New and Naruepon Sukumasavin*

## *Introduction*

One of the important milestones in **freshwater prawn** farming occurred in the **late 1970s** when the United Nations Development Programme decided to fund a three-year FAO-executed project, named 'Expansion of Freshwater Prawn Farming', in Thailand[59]. This project built on the earlier work of the Thai Department of Fisheries (DOF), led by Somsak Singholka and his team at the Chacheongsao Coastal Fisheries Research and Development Centre (formerly Chacheongsao Fisheries Station) in Bangpakong, Chacheongsao Province. At first it was assisted by one of the pioneers of global *Macrobrachium* culture, Takuji Fujimura, together with visiting FAO project manager, Herminio Rabanal. Michael New was appointed by FAO in 1979 and Somsak Singholka and he co-managed the project until 1981, after which the Thai government continued this initiative. As a result of these efforts, farmed freshwater prawn production expanded from less than 5 t/yr before the project began (1976) to an estimated 400 t by the time it ended in 1981[60]. Soon afterwards (1984), the DOF was reporting to FAO that Thai production had exceeded 3,000 t/yr[61], a very rapid expansion indeed.

This DOF-FAO project not only enabled the establishment of a significant aquaculture sector in Thailand but also benefited the development of freshwater prawn farming globally. One output was the publication of a technical manual on the topic[62],[63] that was translated into many languages. In addition, the Thai

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[59] New, M.B., 2000. *History and global status of freshwater prawn farming*. pp. 1-11 In: M.B. New & W.C. Valenti (eds), Freshwater Prawn Culture. Blackwell Science, Oxford, England

[60] Boonyaratpalin, M.,Vorasayan, P., 1983. Brief note on the state of the art of Macrobrachium culture in Thailand. NACA Working Paper WP/83/7. NACA, Bangkok, Thailand.

[61] FAO, 1989. *Aquaculture production 1984-1986*. FAO Fisheries Circular, 815. FAO, Rome, Italy

[62] New, M.B., Singholka, S., 1985. *Freshwater prawn farming: a manual for the culture of Macrobrachium rosenbergii*. FAO Fisheries Technical Paper No. 225, Rev 1. FAO, Rome, Italy. [Also published in Farsi, French, Hindi, Spanish & Vietnamese]

[63] New, M.B., 2002. *Farming freshwater prawns: a manual for the culture of the giant river prawn (Macrobrachium rosenbergii).* FAO Fisheries Technical Paper No. 428. FAO, Rome, Italy. [Also published in Mandarin, with Arabic, French, Malayalam and Spanish versions in preparation]

Department of Fisheries hosted 'Giant Prawn 1980', the first international aquaculture conference ever held in Thailand[64], which was attended by 159 international participants from 33 countries, as well as 200 local farmers. Many Thai experts later advised *Macrobrachium* projects and ventures elsewhere in Asia.

By 2005, the aquaculture production of *Macrobrachium rosenbergii* in Thailand had risen to 30,000 t/yr (valued at US$ 79 million) and to more than 205,000 t/yr globally[65]. In addition, a similar quantity of a related species, *M. nipponense*, was produced in China in 2007. In total, the global farm-gate value of freshwater prawn farming had reached almost US$ 1.84 billion/yr by 2007.

Though there was no seawater available, the Bangkok Marine Laboratory, which has been now allocated by DOF to the Bangkok Fish Market, had successfully cultured ***Penaeus (Fenneropenaeus) merguiensis, P. semisulcatus, P. latisulcatus, Metapenaeus monoceros*** **and** ***M. intermedius*** to postlarvae by **1972**[66]. Seawater had to be brought from offshore by boat. All gravid female shrimp were captured in the Gulf of Thailand. Experiments on pond culture of artificially bred seed were carried out at private shrimp farms in Samutsakorn Province and Bangpoo (Samutprakarn Province), but the results were not satisfactory.

In **1973**, the Phuket Coastal Fisheries Research and Development Centre (formerly Phuket Marine Fisheries Station) sucessfully bred ***P. monodon*** by induced spawning from broodstock caught from the Andaman Sea. Postlarvae of the early batches were stocked in semi-extensive ponds in Bangkrachai (Chantaburi Province), Klongdaan (Samutprakarn Province) and Klongsahakorn (Samutsakorn Province). This brought shrimp farming the much needed technique that enabled farmers to have better control of their crop and sustainable production, instead of reliance only on wild seed for stocking in an extensive culture system. This important research later led to the highest peak of *P. monodon* production of 304,988 mt in 2000[67] before the gradual replacement of *P. monodon* by *Penaeus (Litopenaeus) vannamei* as the major cultured marine shrimp species in Thailand.

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[64] New, M.B. (ed.), 1982. *Giant prawn farming.* Developments in Aquaculture and Fisheries Science, 10. Elsevier, Amsterdam, Netherlands.

[65] FAO, 2007. Fishstat Plus, version 2.32. FAO, Rome, Italy. [http://www.fao.org/fi/website/FIRetrieveAction.do?dom=topic&fid=16073]

[66] Cook, H.L., 1973. FAO Report to the Government of Thailand on Shrimp Farm Development. FAO Report No. TA 314. FAO, Rome, Italy.

[67] Kongkeo, H., 2006. *Responsible shrimp farming: a critical overview*. p. 358 In: Abstracts of AQUA 2006, 9-13 May 2006, Florence, Italy.

## *Hatchery production of crustacean post-larvae*

The major extension thrust in the DOF-FAO project was the provision not only of technical advice but also of free *M. rosenbergii* postlarvae (PL) for stocking the initial grow-out operations on each farm. Freshwater prawns were distributed by road and rail all over Thailand. Large quantities of PL were produced for this purpose in a series of huge concrete tanks sited at the fisheries station in Bangpakong. However, many of its technical staff also began to produce PL successfully in other, less conventional and smaller containers, such as the 'klong pots' used for storing potable water. Before long, some of the stilted houses on the site had small production units underneath their living quarters. Even non-scientific staff learned the necessary techniques quickly. Soon, the first commercial 'backyard hatcheries' began to spring up in nearby areas of Chacheongsao Province. One of the reasons why these backyard hatcheries were to prove so successful was the ability of Thai entrepreneurs to follow changing market requirements. Unlike the massive species-specific hatcheries that were set up in the 1970s and 1980s for fish and crustacean species elsewhere, which were almost impossible to modify, many of these simple backyard hatcheries were easily able to adapt themselves cheaply to produce marine shrimp PL (*P. monodon*) and seabass fingerlings (*Lates calcarifer*), according to demandT.

Backyard hatcheries are generally managed with simple but efficient technology, mainly by farmers with little education. The technology that was originally developed for *M. rosenbergii* can easily be switched to *P. monodon, P. vannamei*, or the nursery of seabass and grouper fingerlings if prices of existing species drop or disease problems are faced. The initial investment for land, construction and equipment, as well as operation costs is very low because of the simple techniques used. Fortunately, Thai farmers have had a long experience and tradition of aquaculture and crop production. They are also enthusiastic to learn and practise advanced technologies that have been successfully developed at the research scale by government institutions or large-scale entrepreneurs. They always have new ideas for development or modification to suit local conditions and are eager to experiment on their own. Sometimes they start to do experiments on new culture techniques by themselves and learn from their mistakes. The present success of Thailand in the shrimp and prawn industry is testimony to the persistence and ingenuity of Thai farmers in utilising applied science to its utmost potential. It is a good example of blending the results of government research work with farmers' enthusiasm in the adoption of new technology.

Due to the long distance of hatcheries from the sea, hypersaline water from salt farms is transported to them by truck and subsequently diluted to the desired salinity by disinfected freshwater. This hypersaline water is pathogen-free and virus carrier-free, due to its high salinity. These hatcheries purchase *P. monodon* or *P. vannamei* nauplii from nauplii producers who are located near the open sea areas where better water quality is available and the improved circulation needed in the maturation process is feasible. For *Macrobrachium*, hatchery operators use spawners both from grow-out farms and the wild. Small hatcheries run by owners and families are more efficient than the large hatcheries that are run by paid workers, due to the sense of belonging. The decrease in the price of shrimp fry caused by the spread of these backyard hatcheries also helped to stimulate the rapid expansion of grow-out ponds.

When problems occur, production can be discontinued, even for long periods, without undue loss. These family businesses are in contrast to large-scale sophisticated hatcheries, in which the cost of wages, power supply, supporting facilities and other overheads still has to be borne during the closure. Periodic discontinuation of operations is in fact necessary for both hatchery and grow-out, in order to facilitate the reconditioning, drying and disinfection of tanks, ponds, aeration and water systems.

The successful development of small-scale hatcheries was similar to that of small-scale intensive ponds which spread all over the country. More than 80% of Thai marine shrimp production comes from approximately 12,500 intensive farms with a total production area of 27,000 ha[68]. These small operators run one or two ponds, each ranging in size from 0.16-1.6 ha. However, during the early stages of development, large-scale operators are always required to pioneer research work on their own or through the adaptation of new technologies from government or overseas; this serves as a prototype for further development by small-scale operators. The income from operations has also provided considerable socio-economic benefits to these small-scale operators who mainly live in coastal regions. Thus local communities directly gain considerable benefits.

After long development in Thailand, this small-scale hatchery technology has been transferred regionally in order to sustain shrimp production, through the assistance of FAO, NACA, UNDP, the Thai Government, the private sector and feed manufacturers. It has been successfully adapted in Indonesia, Vietnam, India, Bangladesh, and Myanmar. Some countries have modified the technology by using direct seawater because they have had better seawater supply sources.

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[68] Kongkeo, H., 1995. *How Thailand made it to the top*. INFOFISH International, 1/95:25-31.

Over 2,000 small scale hatcheries in Thailand, including those in the Chacheongsao, Cholburi and Phuket provinces, generate a very significant proportion of national production - more than 80 billion/year of marine shrimp post-larvae (90% of the total). They have had sustainable production and survived through many shrimp crises during the past 20 years. It is a shame to learn that they are now suffering from the monopoly in the supply of SPF post-larvae that is held by large-scale hatcheries. These large hatcheries introduced SPF and disease-resistant technologies, biosecure systems, raceway systems, etc., from overseas. To cover their high investment costs, these large-scale hatcheries have to make maximum profit by selling post-larvae directly to grow-out farms instead of selling nauplii to backyard hatcheries as before. The traceability of broodstock and certification, which are now mainly demanded by the developed countries, have also become problems for these backyard hatcheries because they purchase nauplii from nauplii producers. Though nauplii producers can issue PCR-negative certificates, it is difficult for them to sort out the source of origin for individual backyard hatcheries because producers usually mix nauplii from various sources for easy distribution and economy.

The Thai DOF has tried very hard to solve the problems faced by these small-scale operators. A farm registration system and CoC and GAP certification systems have been implemented since 2003. At this moment, 98 and 727 hatcheries have been certified with CoC and GAP standards, respectively, including some backyard hatcheries. Furthermore, the use of the "Movement Document" and tracability system at the grow-out farm level has been recently implemented and is expected to be properly functional and to cover the hatchery level in the next few years. As the fact that overseas SPF technology assures the organism being free of specific disease only in its specific environment, its popularity may decrease if there are more evidences of disease infection similar to cases in Indonesia. At that moment, the opportunity for the backyard hatcheries may return if they are all certified and operated under the traceability system.

# Concept Note on Gene Technology in Aquaculture

*K.C. Majumdar*

## *Preamble*

The aquaculture industry is growing at a rate of 9-10% annually whereas capture fisheries has been stagnant for last decade and a half. Global populations increase along with an increased preference for use of crustaceans, molluscs, and fish as food necessitates higher production. To keep the prices of these products under control, which is, set to increase further (about 4%) a concomitant increase in productivity is a need of the hour. By the year 2020, it is expected more than 40% of the total supply will be derived from aquaculture.

Modern biotechnology methods can help reduce the gap between supply and demand. Biotechnology should be used judiciously in 'aquaculture' to increase production. Greater emphasis should be placed in exploring new avenues for pollution-free productivity techniques in aquaculture operations with a reduced overall cost.

Gene technology is being used in several areas to increase productivity in aquaculture. Areas like production, health, disease prevention, species/strain identification, biopharming are chief among them.

## *Production*

**Transgenesis**: Transgenic organisms have foreign DNA inserted into their genome. Chinese scientists were the first to report results with transgenic fish. They introduced human growth hormone (GH) gene and mouse metallothionein promoter as a chimeric gene construct into the fertilized eggs of gold fish (*Carassius auratus*) by microinjection. Many reports are since available on the success in enhancing growth in different fish species by GH transgenesis. Transgenesis has also been successfully used in fishes for enhancing phosphate utilization, cold resistance, sterility, antibacterial activity etc. Transgenesis is a molecular method that involves isolation of promoter and gene sequences; construction of chimeric transgene DNA fragment; transfer of the transgene into the host genome; detection and quantitation of the transgene copy in the founder population and breeding of founder population to obtain a homozygous stock.

Different types of promoters like constitutive, inducible and tissue specific are available. Before designing the transgenic constructs it is important to decide on the type of promoter to be used in such studies. For example, a constitutive promoter will allow the gene to be functional but at levels lower than an inducible promoter. Although an inducible promoter can make more quantities of the product but it will require an inducer, which will add to the cost of production. On the other hand, tissue-specific promoters are preferred when a gene is to be expressed specifically in a particular tissue. If DNA sequence information is available then Polymerase Chain Reaction (PCR) technique can be used for isolation of the promoter and the gene. Suitable primers can be designed to the desired region of the promoter and the gene with its regulatory regions. If DNA sequence data is lacking, cross hybridization techniques can be used, which will allow identification of orthologous sequences from the desired species.

Once the specific promoter and gene are isolated, then chimeric constructs can be prepared by regular ligation and screening methods. Care should be taken to ensure that the reading frame of the structural gene is 'in frame'; and that all the regulatory sequences of the promoter and the structural gene are intact and in order.

There are several methods to transfer the chimeric gene constructs into germ cells to obtain a transgenic organism. Techniques like microinjection to nucleus or cytoplasm of eggs, germ cell electroporation, lipofection of germ cells, particle bombardment of fertilized eggs, transfection with retroviral vectors, nuclear localization signal mediated transfer and stem cells modification are popular. Each of these methods has certain advantages and disadvantages that should be kept in mind while making a choice for a certain application. Microinjection of DNA into the cytoplasm has been the method of choice in fishes and has been used extensively like nuclear injection in mammal. This is because the nucleus of the fish egg is not easily visible and so microinjection is done into the cytoplasm, necessitating higher quantities of DNA to be injected. There are reports of other techniques being used to enhance gene integration like attaching the nuclear localization signal peptide to the DNA before microinjecting it into the cytoplasm. A major drawback of this method is the time taken for microinjecting individual eggs. Mass gene transfer methods like electroporation, lipofection of the germ cells or particle bombardment of fertilized eggs, on the other hand, are preferred for its speed but the low frequency of integration of transgene into the host genome can prove to be a hindrance in its use.

In the putative transgenic individuals gene transfer has to be confirmed initially by identification of the presence of the transgene and further by the number of copies integrated in their genome. This can be accomplished by PCR amplification of the target gene from DNA isolated from different tissues of the transgenic individual.

Southern analysis or quantitative PCR can be done for identifying the copy number of the gene. To identify the site of integration, inverse PCR and fluorescence *in situ* hybridization (FISH) can be used where the former method shows contiguity of genomic DNA sequences with the transgene and FISH analysis shows physical localization of the transgene on the chromosome.

Breeding experiments to obtain homozygous transgenic stocks can follow identification of the transgenic founder population. Performance related tests would indicate the superiority of the transgenic individual with respect to the selected character over the wild type individual.

## *Health*

**Pathogen identification**: Disease caused by specific pathogens can be detected by PCR method that identifies the pathogen's DNA sequence in the DNA isolated from the tissues of the affected organisms. In the absence of such specific information on a pathogen's DNA sequence, ribotyping can be done to identify the putative infective organism. Quantitative PCR can further determine the levels of infection thereby helping to decide on the course of action to overcome the infection.

**Disease prevention:** Vaccines: Vaccination is among the best methods for disease prevention. In classical vaccination procedures a whole inactivated organism or components of the causative organism are injected to provide immunity. There is a compelling need to identify, isolate and culture the infective organisms for which PCR based techniques can be used in identifying the species and the strain of the microorganism.

- DNA Vaccines: DNA vaccine is an upcoming therapeutic that has the potential to replace or supplement conventional vaccines. In this case the antigen producing gene/DNA sequence is put under the control of a promoter that is active in the tissue, which receives the vaccination. DNA vaccine is produced as a plasmid in a bacterial host; therefore, production of large quantities of vaccine through microbial fermentation technology is easy and economical. Besides, such vaccines do not require refrigeration during transport, which helps in reducing the overall cost. Vaccines derived by this technology can be used conveniently in large fish farms to protect/treat infections.
- RNAi method: RNA interference is another powerful molecular technique that can be used to prevent infections in fish. In this method, the double stranded RNA when introduced into the cells is cleaved into 21-23 bp fragments by 'Dicer'. This double stranded RNA (siRNA) binds with a protein complex forming RNA Induced Silencing Complex (RISC). The

ATP-dependent RNA helicase then unwinds the double stranded siRNA into single stranded RNA. The antisense strand guides the RISC to the homologous mRNA, which is cleaved at a single site by an endoribonuclease of the RISC. In future, it is expected that by combining transgenesis and RNAi technology it may be possible to develop transgenic organisms that are resistant to specific viruses.

## *Species/strain identification*

Identification at the level of genus, species, or individuals of a species can be done DNA fingerprinting that depends on the detection of variability in the genome. The DNA fingerprints of different species are being continually upgraded for several varied applications in areas of phylogeny, breeding biology, migration and forensic analysis etc. DNA fingerprinting can be performed by two different methods, either by the hybridization based or by the PCR based. Hybridization based method requires some knowledge of the complexity of the genome whereas the PCR based methods can be done without any prior knowledge of the sequence information. These methods generally deal with the nuclear DNA however recent developments in DNA sequencing have allowed the use of non-nuclear DNA (mitochondria and chloroplast DNA) sequence analysis for the identification of species/individuals. Here, a part or the total genome can be amplified and sequenced for comparison. Analysis of both nuclear and non-nuclear DNA provide information regarding the true identity of the individual/species/strain which have been used to solve forensic as well as controversial IPR issues.

The other types of variability present in the genome are STR (short tandem reports) and SNP (single nucleotide polymorphism). Both these types of sequence markers have revolutionized genome mapping and are being used in marker-assisted selection of commercially important characters. Marker-assisted selection is superior to conventional selection, because individuals carrying the markers can be detected and less number of crossing experiments is required to reach the selection goal.

## *Biopharming*

Genetically manipulated fishes can be used as bioreactors to obtain a specific product. For example polyunsaturated fatty acids are abundant in marine fishes. The gene complex coding for polyunsaturated fatty acids be isolated and incorporated into fishes, which in fresh water aquaculture production will produce the desired product. Besides, similar value additions can be done to fishes, which are not commercially important to make them attractive to the consumers.

## *Priority areas for research*

- Genetically modify organisms used in fish feed for increased nutritional enrichment and as a replacement for fishmeal in the fish feed.
- Genetically modify the colonized gut flora in fish with an aim to increase production of essential amino acids that will reduce its requirements in the feed.
- Gene transfer technology.
- Embryonic stem cells and cloning.
- Bioactive molecules from aquatic sources.
- Genome sequencing.

**Recommendations and further discussions:**

- Research in the above-mentioned areas requires higher technology input. It is possible to set up a few institutions/laboratories that can initiate these projects. Funding can be provided by collaborating countries (with financial assistance from international agencies). The technology when developed can be shared by the collaborative countries and be made available at a price for use by other countries.
- Ethical issues on the use of transgenic organisms for commercial purposes need to be addressed.