FAO Fisheries Circular No. 1017/3 FIRI/C1017/3

ISSN 0429-9329

REGIONAL REVIEW ON AQUACULTURE DEVELOPMENT
3. ASIA AND THE PACIFIC – 2005

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REGIONAL REVIEW ON AQUACULTURE DEVELOPMENT
3. ASIA AND THE PACIFIC – 2005

by

Network of Aquaculture Centres in Asia-Pacific
Bangkok, Thailand

With additional contributions from:
Wilfredo Yap
Consultant

Simon Funge-Smith
FAO Regional Office for Asia and the Pacific

Ben Ponia
Secretariat of the Pacific Community

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2006

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FOREWORD

The world population is on the rise, as is the demand for aquatic food products. Production from capture fisheries at the global level is levelling off and most of the main fishing areas have reached their maximum potential. Sustaining fish supplies from capture fisheries will, therefore, not be able to meet the growing global demand for aquatic food.

At present, the aquaculture sector contributes a little over 40 million tonnes (excluding aquatic plants) to the world aquatic food production. According to recent FAO predictions, in order to maintain the current level of per capita consumption at the minimum, global aquaculture production should reach 80 million tonnes by 2050. Aquaculture has great potential to meet this increasing demand for aquatic food in most regions of the world. However, in order to achieve this, the sector (and aqua-farmers) will face significant challenges.

A major task ahead for sustainable aquaculture production will be to develop approaches that will increase the contribution of aquaculture to the global food supply. These approaches must be realistic and achievable within the context of current social, economic, environmental and political circumstances. Accurate and timely information on the aquaculture sector is essential in order to evaluate the efficacy of these approaches and how they can be improved.

Under the FAO Fisheries Department's current work programme, the Inland Water Resources and Aquaculture Service (FIRI) of the Fishery Resources Division, using a wide-ranging consultative process, regularly conducts reviews on the status and trends in aquaculture development (FAO Fisheries Circular No. 886 – Review of the State of World Aquaculture and FAO Fisheries Circular No. 942 – Review of the State of World Inland Fisheries). The last review (both regional and global) was conducted in 1999/2000 and was published following the Global Conference on Aquaculture in the Third Millennium held in Bangkok, Thailand, in 2000 (NACA/FAO, 2001, Aquaculture in the Third Millennium). These reviews are seen as important milestones and the documents produced are recognized as significant reference materials for planning, implementing and managing responsible and sustainable aquaculture development worldwide.

As part of this continuing process and with the current objective of preparing a global aquaculture development status and trends review, FIRI had embarked on a series of activities. These are:

- National Aquaculture Sector Overviews – NASOs – in all major aquaculture producing countries in the world;
- five regional workshops to discuss the status and trends in aquaculture development in Asia and the Pacific, Central and Eastern Europe, Latin America and the Caribbean, Near East and North Africa, and sub-Saharan Africa; and
- seven regional aquaculture development status and trends reviews in Asia and the Pacific, Central and Eastern Europe, Latin America and the Caribbean, Near East and North Africa, North America, sub-Saharan Africa and Western Europe.

This document presents the Asia and the Pacific regional synthesis of all the information collected from the above activities.

ACKNOWLEDGEMENTS

The authors thank Rohana Subasinghe of the FAO Fisheries Department for his valuable comments and inputs. The participants of the FAO Expert Workshop on Regional Aquaculture Review: Asia (see Part II, Appendix A) are remembered for their critical evaluation of the review and inputs for its improvement. Editorial and page layout by Rine Sola of the FAO Fisheries Department is appreciated.

Network of Aquaculture Centres in Asia-Pacific.
Regional review on aquaculture development. 3. Asia and the Pacific – 2005.
FAO Fisheries Circular. No. 1017/3. Rome, FAO. 2006. 97 pp.

ABSTRACT

The FAO Fisheries Department conducts reviews of aquaculture development status and trends on a regular basis. This document is a result of such an exercise conducted during 2005 and 2006. The regional review is a synthesis of the National Aquaculture Sector Overviews (NASO) of 16 countries from five sub-regions of Asia and the Pacific and information from two additional countries, Japan and the Democratic People's Republic of Korea. The review also contains a brief description of the aquaculture development trends and issues in the Pacific island nations. The production volume and value data have been derived from the latest FAO FISHSTAT Plus database. As part of the review process, a regional expert workshop was conducted in Ramzar, Islamic Republic of Iran, in 2006, to discuss the regional aquaculture development status and trends. The report of this expert workshop is also included in this review.

The regional review provides a description of how the aquaculture sector developed in Asia and the Pacific over the past three decades. The review and analysis of data and information clearly show that the sector is growing and expanding and is predicted to meet the increasing demand for aquatic food products in the years to come, with a few clear trends. These are: (a) increasing demand for aquaculture products; (b) increasing intensification of production systems; (c) continuing diversification of production systems and species farmed; (d) increasing influence of markets, trade, consumers and consumption; (e) enhanced regulation and better governance; and (f) drive towards better management. The review also attempts to analyse the trends and look at the sector's sustainability and how the sector is behaving as a responsible food production sector in Asia and the Pacific.

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ABBREVIATIONS AND ACRONYMS

ABARE	Australian Bureau of Agricultural and Resource Economics
ACIAR	Australian Centre for International Agricultural Research
AFRI	Aquaculture and Fisheries Research Institute
AIMS	Australian Institute of Marine Science
AIZ	Aquaculture Investment Zones
AMFR	Agency for Marine and Fisheries Research Affairs
APEC	Asia-Pacific Economic Cooperation
BARC	Bangladesh Agricultural Research Council
BFRI	Bangladesh Fisheries Research Institute
BPPT	Agency for Study and Assessment of Technology
BRDB	Bangladesh Rural Development Board
BRS	Bureau of Rural Sciences
CIBA	Central Institute of Brackishwater Aquaculture
CIFA	Central Institute of Freshwater Aquaculture
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMFRI	Central Marine Fisheries Research Institute
CSIRO	Commonwealth Scientific and Industrial Research Organization
DAFF	Department of Agriculture, Fisheries and Forestry
DOST	Department of Science and Technology
ECR	Export Credit Refinancing Scheme
EU	European Union
FCR	Food Conversion Ratio
FFDA	Fish Farmers' Development Agency
FIRI	Inland Water Resources and Aquaculture Service
FNRI	Food and Nutrition Research Institute
FRDC	Fisheries Research and Development Corporation
FRTI	Fisheries Research and Training Institute
GDP	Gross Domestic Product
GIFT	Genetically Improved Farmed Tilapia
HACCP	Hazard Analysis and Critical Control Points
HRC	Highly Refined Carageenan
IBA	Industrial Building Allowance
IFPRI	International Food Policy Research Institute
IFRTO	Iranian Fisheries Research and Training Organization
ITA	Investment Tax Allowance
LALRD	Land Administration and Land Reform Division
LIPI	Indonesian Science Institutes
MOMAF	Ministry of Maritime Affairs and Fisheries
NAQDA	National Aquaculture Development Authority
NAQDA	National Aquaculture Development Authority
NARC	Nepal Agriculture Research Council
NARA	National Aquatic Resources Research and Development Agency
NASO	National Aquaculture Sector Overviews
NFRDI	National Fisheries Research and Development Institute
NIFNE	National Institute of Fisheries and Nautical Engineering
PARC	Pakistan Agriculture Research Council
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
PIMC	Primary Industries Ministerial Council
PNG	Philippine natural grade
RA	Reinvestment Allowance
R & D	Research and Development
SCP	single-cell protein

SEAFDEC	Southeast Asian Fisheries Development Center
SPC	Secretariat of the Pacific Community
SPF	Specific Pathogen Free
TESDA	Technical Skills Development Authority
WSSV	white spot syndrome virus
YHV	yellowhead virus

PART I
REGIONAL REVIEW ON AQUACULTURE DEVELOPMENT: ASIA AND THE PACIFIC – 2005

1. CHARACTERISTICS, STRUCTURE OF THE SECTOR

This report is a synthesis of the National Aquaculture Sector Overviews (NASO) of 16 countries from five subregions of the Asia-Pacific. The inclusion of Japan and the Democratic People's Republic of Korea[1] brings the total number of countries to 18. Although no NASO was prepared for Japan, the country is included in this synthesis in recognition of the importance of the country in aquaculture technology development and aquaculture production. Information on Japan were obtained from published materials. The country listing by species includes countries in Asia and the Pacific other than the 18 countries dealt with in this report to provide a broader view of the kind of aquatic organisms being cultured in the greater Asian region. Statistical data is based on the FAO FISHSTAT Plus database[2]. The countries included in this report are as follows:

Oceania
- Australia
- Pacific Island Nations

South Asia
- Bangladesh
- India
- Nepal
- Pakistan
- Sri Lanka

East Asia
- China (including Hong Kong and Macao Special Administrative Regions[4]) and Taiwan Province of China[5]
- Japan
- Republic of Korea[6]
- Democratic People's Republic of Korea[1]

West Asia
- Islamic Republic of Iran[3]

Southeast Asia
- Cambodia
- Indonesia
- Malaysia
- Myanmar
- Philippines
- Thailand
- Viet Nam

A brief description of the aquaculture development trends and issues in the Pacific island nations is included in this report, in the section on subregions. Aside from some production values from certain states in the region, production statistics from the Pacific island nations were not included, as these

[1] Democratic People's Republic of Korea: herewith after referred to as Korea (DPR).

[2] Additional analysis has been drawn from Sugiyama, Staples and Funge-Smith (2004) and the FAO/NACA Aquaculture Review (2004).

[3] Islamic Republic of Iran: herewith after referred to as Iran.

[4] China, Hong Kong Special Administrative Region and China, Macao Special Administrative Region: herewith after referred to as Hong Kong (SAR) and Macao (SAR), respectively.

[5] Taiwan (Province of China): herewith after referred to as Taiwan (PC).

[6] Republic of Korea: herewith after referred to as Korea (Rep.).

are too miniscule to provide any meaningful perspective for analysis other than their appearance of insignificance compared to the volumes and values reported for Asia. Status reports, analyses and plans developed by the Secretariat of the Pacific Community (SPC) and available in the SPC Web site (http://www.spc.org.nc/) would provide a more comprehensive overview of the Pacific region's aquaculture development status.

Grouping the countries by subregion is for data presentation purposes only. This report will not necessarily discuss each region separately. It is clear from the NASO's received that aquaculture did not develop similarly among countries within each subregion. On the other hand, the development in some countries in a particular subregion may in fact be more similar to that located in another subregion. This report instead tries to explore how certain factors may have influenced the aquaculture development processes in each country. In this manner, it is hoped that the synthesis will be more integrative rather than fragmented in treatment.

1.1 General nature and trends in culture practices (history and background)

Aquaculture in Asia can be characterized as extremely diverse not only in terms of species but also in terms of culture systems. Cutting across freshwater, brackishwater, and marine ecosystems – fish, shrimps, crabs, oysters, mussels, abalone, seaweeds, and even sea cucumber are cultured in various containment or holding facilities such as:

- earthen ponds
- concrete tanks
- raceways
- pens
- cages
- stakes
- vertical or horizontal lines, afloat or bottom set
- racks

In most of the countries in Asia, aquaculture had its start in the freshwater ecosystem for the culture of cyprinids. This is true in China, India, Thailand, and even Japan, but not in Indonesia and the Philippines, where aquaculture began in the brackishwater ecosystem – mainly mangrove swamps using tidal water for the culture of milkfish. In a brackishwater pond, multiple species culture or polyculture occurred as a natural consequence since there is hardly any control on the number and species of seedstock that comes in with the tide. Thus often, in traditional brackishwater ponds, milkfish are cultured together with penaeid shrimps. On the other hand, in the freshwater ecosystem, polyculture is practiced deliberately using carp species with different food niches in a clever strategy that optimizes the use of the available food in a pond environment simulating a natural ecosystem.

By and large aquaculture in Asia is done primarily in freshwater. In 2003 of 43 countries in Asia reporting at least one tonne of aquaculture production, 40 have freshwater aquaculture, 25 mariculture and 21 brackishwater aquaculture. Table 1 shows that the total aquaculture production from the marine environment is slightly greater than that from freshwater. However, about half of it consists of aquatic plants. Without the seaweeds, freshwater aquaculture production makes up 61 percent of total fish and shellfish output from farming. By value, marine aquaculture production is slightly ahead of freshwater aquaculture at US$28 825 million as against US$28 184 million with brackishwater aquaculture having the lowest value at US$10 304 million.

Table 1. Aquaculture production by ecosystem (2003).

	Freshwater	Brackishwater	Marine	Total
No. of countries	40	21	25	44
Fish and shellfish				
Prod. volume (tonnes)	22 955 892	2 213 974	12 408 275	37 578 141
% of total	61.1	5.9	33.0	100
Prod. value (US$1 000)	28 183 894	10 302 998	22 496 960	60 983 852
% of total value	46.2	16.9	36.9	100
Aquatic plants				
Prod. volume (tonnes)	-	14 192	12 385 635	12 399 827
Prod. value (US$1 000)	3	1 568	6 328 747	6 330 318
Total volume (tonnes)	22 955 892	2 228 166	24 793 910	49 977 968
Total value (US$1 000)	**28 183 897**	**10 304 566**	**28 825 707**	**67 314 170**

A word of caution however is called for on the difference between brackishwater and marine aquaculture production. What is classified as brackishwater aquaculture in one country is considered mariculture in another. This is particularly true with shrimp culture, which is classified in either ecosystem by some countries and in both by others. Meanwhile a few countries classify aquaculture only into two types: freshwater and marine.

Across Asia, or even within a single country, traditional systems relying on natural water supply, and producing no more than a few hundred kilograms per hectare, still exist. Along side such traditional ponds are highly intensive systems equipped with large capacity pumps and aeration, and producing several tonnes per hectare.

Traditional does not necessarily mean backward or low in productivity. The polyculture of carps in China can be considered traditional since this has been practiced for centuries, but is far from being backward or low in productivity. Polyculture is a sophisticated system, which takes advantage of the different food requirements of different fish species. In some cases, however, traditional practices verge on the primitive, so that even the seedstock may come in from natural sources. This was the case with the culture of milkfish and penaeid shrimps in brackishwater ponds that had been traditionally practiced in the Philippines and Indonesia, and continues to be practiced in isolated instances.

While traditional practices still exist, the trend has been towards intensification in pond culture driven by an increasing demand for fish and the decreasing land area suitable for expansion. Intensification entails the use of any combination or all of the following:

- Regulated stocking of hatchery-bred seedstock
- Use of seedstock which are product of selective breeding
- Fertilization to induce the growth of natural food
- Use of artificial feed either at a supplemental or total basis
- Use of pumps to augment or to replace natural supply of water
- Use of aeration device
- Use of biocides to control extraneous organisms
- Use of probiotics to maintain quality of pond environment

The use of hatchery-produced seedstock has been the norm in freshwater species, but is very new for marine and diadromous species. Thus, the development of hatchery technology for these species was an important milestone in the development of aquaculture in Asia.

As intensification in land-based culture systems continues there is also a trend towards expansion into open water for fish culture in cages or pens. While the use of open waters for aquaculture is not new for such species groups as molluscan bivalves and for freshwater fish, the use of cages to grow fish in a marine environment is relatively new in Asia, with the possible exception of Japan. Even in freshwater systems, fish cages have undergone fundamental changes from small box-like contraptions to hold several kilograms of fish to large net cages with steel or plastic frames that can contain several tonnes of fish biomass.

The use of large net cages requiring the stocking of several tens or even hundreds of thousands of large size fingerlings at one time would not have been possible had the hatchery technology not been developed for particular species. But, the development of hatchery technology did not necessarily go hand-in-hand with the development of specific domesticated strains of fish and other farmed species, even if breeding for specialized strains of fish has a very long history in Asia. This is because selective breeding in Asia in the past had focused more on the ornamentals than on food fish. In general, aquaculture in Asia has lagged behind agriculture and animal husbandry in terms of selective breeding and development of improved strains, both for aquatic plants and animals. In aquatic plants, there has been less impetus for developing improved strain since the macroalgae, which form the base of aquatic plant production, has not been subject to the same pressures as terrestrial crops. Selective breeding in cyprinids has had a long history, but only recently were “branded” strains of freshwater fish developed that required some form of licensing to use. This started with the Genetically Improved Farmed Tilapia (GIFT).

While domesticated stock is already the norm in the culture of freshwater species, domestication has occurred only in very few marine species such as milkfish, grouper, and seabass (*Lates calcarifer*). (“Domesticated” for the purposes of this review means species in which there is a closed cycle for production at all stages of the animal’s lifecycle). Penaeid shrimp aquaculture, which has been the most important in terms of value, is still dependent on wild-caught breeding stock. Thus, when viral diseases increased in prevalence to the extent that even the natural spawning stock were infected, the Asian shrimp industry welcomed an exotic species, the *Penaeus vannamei,* because domesticated breeding stock that are free from specific pathogens or SPF were already commercially available.

In shrimp culture lies one of the greatest paradoxes in Asian aquaculture. Asia has so far failed to domesticate any of the native Asian shrimp species so that farmers primarily use wild-caught breeding stock. Even Japan, which pioneered in the development of penaeid shrimp hatchery technology, continues to rely on wild-caught spawning stock of Kuruma shrimp. China, with centuries of experience in the domestication and breeding of cyprinids, is now the biggest producer of *P. vannamei*, and has recently started the domestication of the fleshy prawn, *P. chinensis.* There were attempts by at least two companies in the Philippines during the 1980s to develop specific disease free captive broodstock of the black tiger shrimp, *P. monodon*. But these attempts were abandoned. In Thailand the government and the private sector are engaged in parallel efforts to domesticate *P. monodon*. Indonesia likewise has an on-going Shrimp Breeding programme. In the meantime the farms are being stocked with *P. vannamei* for a number of reasons, some practical from the farmers’ point of view such as its less requirement for protein, some based on widely held perceptions such as its being more resistant to diseases than *P. monodon*, some driven by marketing strategies, and many by circumstances such as the scarcity of healthy *P. monodon* broodstock.

2. PRODUCTION, SPECIES AND VALUES

2.1 Range of culture species

The dynamic nature of Asian aquaculture is reflected not only by its sheer volume, but also by the number of and flux in the species being cultured. A total of 226 species is listed in FAO aquaculture statistics. Not all of these are cultured in any one year but the number has risen over the years. As of 1950, only 56 species were reported with more than 1 000 kg produced. By 2003 this increased three-fold to 177 (Table 2). By taxonomic grouping a 74 families are represented of which 44 are bony fishes. The aquatic plants alone consist of eight families, mollusks, and crustaceans are represented by nine families each. At one time during the late 1960s to early 1970s, even octopus was reported as being cultured in Japan. The inclusion of tortoise and sea cucumber in Asian aquaculture shows how diverse the tastes of Asians are for aquatic products. Some species such as the *Caulerpa* seaweed is cultured only in one country while others such as the cyprinids are farmed in 36 countries (Table 3). A few countries culture only one or two species but other countries culture a whole range (Table 4).

Table 2. Number of species farmed in Asia by FAOSTAT grouping.

Species Group	Total listed	1950	1960	1970	1980	1990	2000	2003
Aquatic Plants	15	6	8	10	13	15	15	13
Cephalopods	1			1				
Crustaceans	37	3	9	11	17	26	29	28
Demersal Marine	49	3	5	8	13	23	34	36
Freshwater and Diadromous	78	29	33	36	41	54	60	61
Marine Fish Nei	1	1	1	1	1	1	1	1
Misc. Aquatic Animals	7	2	5	6	6	6	6	6
Molluscs	30	10	10	18	22	23	25	23
Pelagic Marine	8	2	2	3	4	4	9	9
TOTAL	**226**	**56**	**73**	**94**	**117**	**152**	**179**	**177**

Several species are not accounted for in the reporting of production and value mainly because their volumes are very small and therefore do not figure in the official statistics of the countries (e.g. *Babylonia*, lobsters, crabs, and many niche species).

The largest group of species based on FAOSTAT grouping are the freshwater and diadromous fishes which at 22.82 million tonnes constitute 45.7 percent of total aquaculture production in Asia. Aquatic plants with 12.40 million tonnes constituting 24.8 percent is the second largest group followed closely by mollusks with 11.16 million tonnes constituting 22.3 percent. Crustaceans is a far fourth with 2.46 million tonnes constituting 4.9 percent of the total. The four other groups together with 1.14 million tonnes constitute only 2.3 percent (Figure 1).

By value, however, the contribution of freshwater and diadromous fish at US$22 529 million drops to 40.9 percent, aquatic plants at US$6 272 million to 11.4 percent, and mollusk at US$9 732 million to 17.7 percent. The contribution of crustaceans, on the other hand, at US$11 777 million increases to 21.4 percent while the four other groups with an aggregate value of US$4 794 million to 8.7 percent (Figure 2).

There is an issue with the generic reporting of groups of species (as seen in Table 2, marine finfish nei). Several species are grouped under marine finfish statistics, hence details of emerging species not available. There are also issues where the reporting of exotic white shrimp species is not distinguished and reported under the category of the native white shrimp.

The number of species cultured has reached 177 and, from experience, likely to increase. This raises several questions. For instance, should consolidation be encouraged? Will diversity in species cultured offer opportunities for sustainability and flexibility. Should diversity be seen as a niche opportunity for smaller scale farmers? Is developing a commodity exclusively to meet export market demand sustainable? Will diversity of species cultured offer small farmers with flexibility and more options? Will more diversity mean less opportunity for product standardization? Should there be a division of culture practices and species cultured based on market requirements? Considering the regional experience, should small farmers be encouraged to organize into clusters to meet increasing market demands and consumer requirements? Would development of a robust marine finfish hatchery system allow diversification and expansion of marine finfish culture in the region? Addressing the issues related to these questions would need careful and widely participatory regional and national assessments.

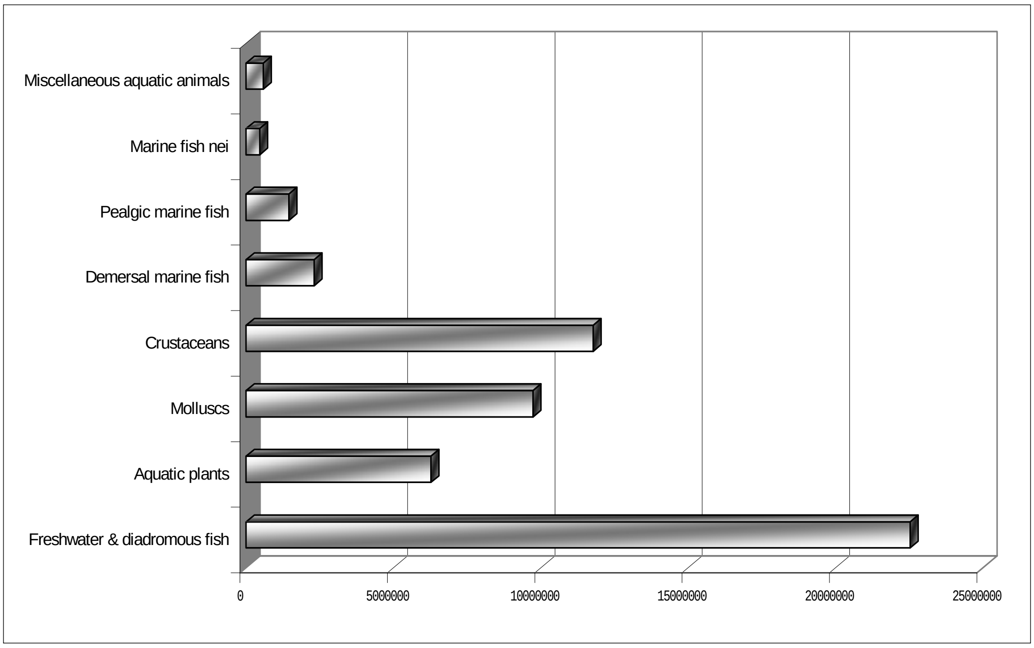

Figure 1. Contribution of different species groups by quantity to Asian aquaculture, 2003.

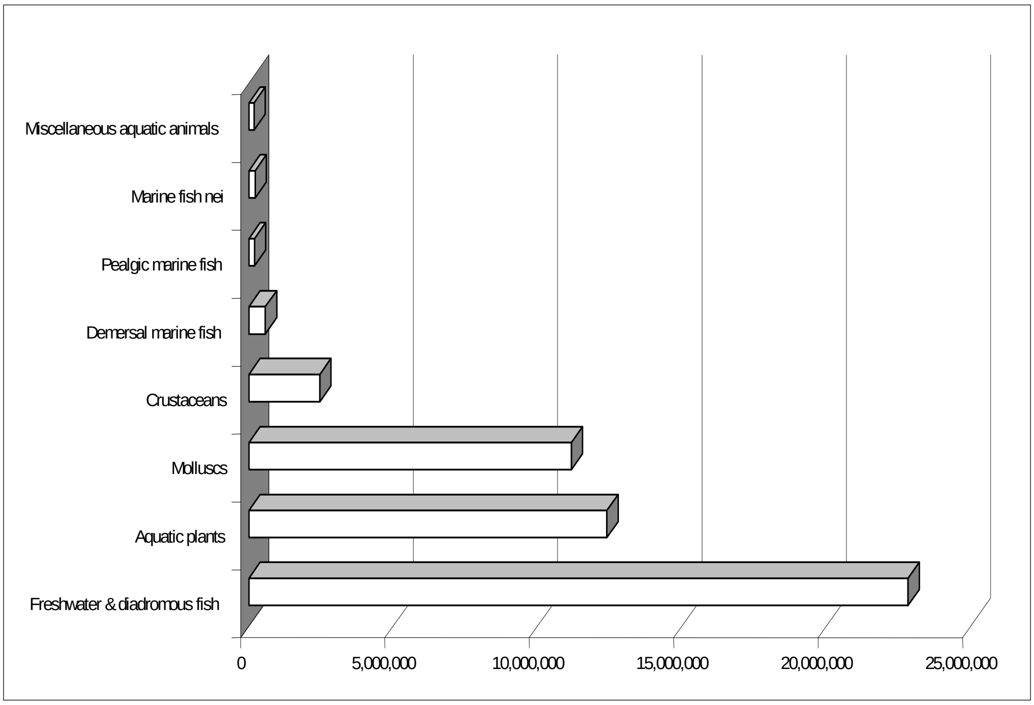

Figure 2. Contribution of different species groups by value to Asian aquaculture, 2003.

Table 3. Countries where each species group is cultured (2003). These are derived mainly from FAO FISHSTAT Plus database. Some groups which are not included in FAO FISHSTAT Plus, such as reptiles and pearl oysters have been included and some countries where either the production is too low to be specified or has reported the production under a generic rather than specific heading have been added based on personal sources and country reports.

Family	Common name	Countries
ALGAE		
Alariaceae	Wakame seaweed	1. Japan, 2. Korea (Rep.)
Bangiaceae	Laver (nori)	1. China, 2. Japan, 3. Korea (Rep.), 4. Taiwan (PC)
Caulerpaceae	Caulerpa	1. Philippines
Gelidiaceae	Gelidium seaweeds	1. Korea (DPR)
Gracilariaceae	Agar seaweeds	1. Viet Nam, 2. Taiwan (PC), 3. Philippines, 4. Korea (DPR)
Laminariaceae	Kelp	1. China, 2. Korea (DPR), 3. Japan, 4. Korea (Rep.)
Monostromaceae	Green laver	1. Korea (Rep.)
Solieriaceae	Eucheuma seaweed	1. Cambodia, 2. Fiji Islands, 3. Indonesia, 4. Kiribati, 5. Malaysia, 6. Federated States of Micronesia[7], 7. Myanmar 8. Philippines, 9. Tonga, 10. Solomon Island
AMPHIBIANS and REPTILES		
Crocodylidae	Crocodiles	1. Cambodia, 2. China, 3. Indonesia, 4. Myanmar 5. Philippines, 6. Thailand, 7. Papua New Guinea
Ranidae	Frogs	1, China, 2. Indonesia, 3. Japan, 4. Malaysia, 5. Taiwan (PC), 6. Thailand
Trionychidae	Soft-shell turtle	1. China, 2. Korea (Rep.), 3. Malaysia, 4. Taiwan (PC), 4. Thailand, 5. Viet Nam
MOLLUSCS		
Arcidae	Cockles	1. China, 2. Malaysia, 3. Thailand, 4. Korea (Rep.)
Atyidae	Sawtooth caridina	1. Korea (Rep.)
Buccinidae	Babylon shell	1. Thailand, 2. Viet Nam
Corbiculidae	Asian clams	1. Taiwan (PC)
Haliotidae	Abalone	1. Australia, 2. China, 3. Korea (Rep.), 4. Indonesia, 5. Myanmar, 6. New Zealand, 7. Philippines, 8. Taiwan (PC), 9. Thailand, 10. Viet Nam
Mytilidae	Mussels	1. China, 2. Thailand, 3. New Zealand, 4. Korea (Rep.), 5. Philippines, 6. Malaysia, 7. Indonesia, 8. Australia, 9. Singapore

[7] Federated States of Micronesia: herewith after referred to as Micronesia.

Family	Common name	Countries
Ostreidae	Oysters	1. China, 2. Japan, 3. Korea (Rep.), 4. Taiwan (PC), 5. Thailand, 6. Philippines, 7. Australia, 8. New Zealand, 9. Hong Kong (SAR), 10. Malaysia, 11. New Caledonia
Pteridae	Pearl oysters	1. Australia, 2. French Polynesia, 3. Indonesia, 4. Japan, 5. Philippines, 6. Thailand, 7. Cook Islands, 8. Fiji Islands, 9. Marshall Islands, 10. Micronesia
Pectinidae	Scallops	1. Australia, 2. China, 3. Japan, 4. Korea (Rep.)
Solecurtidae	Constricted tagelus	1. China
Tridacnae	Giant clam	1. Marshall Islands, 2. Tonga, 3. Palau, 4. Fiji Islands, 5. Micronesia, 6. Samoa, 7. Cook Islands, 8. French Polynesia, 9. Solomon
Veneridae	Venerid clams, or Manila clam	1. China, 2. Taiwan (PC), 3. Korea (Rep.)
FINFISH		
Acipenseridae	Sturgeons	1. China, 2. Iran
Anabantidae	Walking perch	1. India, 2. Thailand
Anguillidae	Eels	1. China, 2. Taiwan (PC), 3. Japan, 4. Korea (Rep.), 5. Indonesia, 6. Australia, 7. Malaysia
Bagridae	Bagrid catfish	1. Malaysia
Belontiidae	Gourami	1. Thailand, 2. Indonesia
Carangidae	Pompanos	1. Japan, 2. China, 3. Taiwan (PC), 4. Korea (Rep.), 5. Hong Kong (SAR), 6. Brunei Darussalam, 7. Philippines, 8. Singapore
Centropomidae	Perches	1. Thailand, 2. Indonesia, 3. Taiwan (PC), 4. Malaysia, 5. Australia, 6. Singapore, 7. Brunei Darussalam, 8. Hong Kong (SAR)
Chanidae	Milkfish	1. Philippines, 2. Indonesia, 3. Taiwan (PC), 4. Singapore, 5. Kiribati, 6. Cook Island, 7. French Polynesia, 8. Nauru, 9. Guam
Channidae	Snakeheads	1. India, 2. Thailand, 3. Philippines, 4. Indonesia, 5. Malaysia, 6. Singapore, 7. Korea (Rep.)
Cichlidae	Tilapia	1. China, 2. Philippines, 3. Indonesia, 4. Thailand, 5. Taiwan (PC), 6. Lao People’s Democratic Republic[8], 7. Malaysia, 8. Israel, 9. Sri Lanka, 10. Syrian Arab Republic, 11. Saudi Arabia, 12. Myanmar, 13. Hong Kong (SAR), 14. Korea (Rep.), 15. Jordan, 16. Cambodia, 17. Singapore, 18. Brunei Darussalam, 19. Lebanon, 20. Kuwait, 21. Fiji Islands, 22. Papua New Guinea, 23. Vanuatu, 24. Samoa, 25. American Samoa, 26. Guam, 27. French Polynesia

[8] Lao People’s Democratic Republic: herewith after referred to as Lao (PDR).

Family	Common name	Countries
Clariidae	Catfish	1. Thailand, 2. Indonesia, 3. India, 4. Malaysia, 5. Philippines, 6. Syrian Arab Republic, 7. Cambodia, 8. Saudi Arabia
Clupeidae	Hilsa	1. India
Cobitidae	Pond loach	1. Korea (Rep.), 2. Taiwan (PC)
Cyprinidae	Carps	1. Armenia, 2. Azerbajjan, 3. Bangladesh, 4. Brunei Darussalam, 5. Cambodia, 6. China, 7. Fiji Islands, 8. Georgia, 9. Hong Kong (SAR), 10. India, 11. Indonesia, 12. Iran, 13. Iraq, 14. Israel, 15. Japan, 16. Jordan, 17. Kazakhstan, 18. Korea (Rep.), 19. Korea (DPR), 20. Kyrgyzstan, 21. Lao (PDR), 22. Lebanon, 23. Malaysia, 24. Myanmar, 25. Nepal, 26. Pakistan, 27. Papua New Guinea, 28. Philippines, 29. Singapore, 30. Syrian Arab Republic, 31. Taiwan (PC), 32. Tajikistan, 33. Thailand, 34. Turkey, 35. Turkmenistan, 36. Uzbekistan, 37. Viet Nam, 38. Papua New Guinea,
Eleotridae	Marble goby	1. Malaysia, 2. Indonesia, 3. Singapore, 4. Thailand
Gobiidae	Gobies	1. Taiwan (PC)
Helostomatidae	Kissing gourami	1. Indonesia
Hexagrammidae	Atka mackerel	1. Korea (Rep.)
Ictaluridae	Channel catfish	1. Lebanon, 2. Korea (Rep.)
Lutjanidae	Snapper	1. Malaysia, 2. Taiwan (PC), 3. Hong Kong (SAR), 4. Singapore, 5. Brunei Darussalam, 6. Philippines
Monacanthidae	Filefishes	1. Korea (Rep.)
Moronidae	Striped bass	1. Turkey, 2. Israel, 3. United Arab Emirates, 4. Cyprus, 5. Oman
Mugilidae	Mullet	1. Indonesia, 2. Korea (Rep.), 3. Taiwan (PC), 4. Israel, 5. China, 6. Hong Kong (SAR), 7. Singapore, 8. Saudi Arabia, 9. Oman
Muraenesocidae	Pike congers	1. Taiwan (PC)
Notopteridae	Knifefishes	1. Thailand
Osphronemidae	Giant gourami	1. Indonesia, 2. Thailand, 3. Myanmar, 4. Philippines
Pangasiidae	Pangas catfish	1. Indonesia, 2. Malaysia, 3. Myanmar, 4. Singapore, 5. Thailand, 6. Viet Nam
Paralichthyidae	Halibuts and flounders	1. Korea (Rep.), 2. Japan
Percichthyidae	Mandarin fish golden perch	1. China, 2. Korea (Rep.),
Plecoglossidae	Ayu sweetfish	1. Japan, 2. Taiwan (PC), 3. Korea (Rep.)
Polynemidae	Threadfins	1. Taiwan (PC)
Rachycentridae	Cobia	1. China, 2. Philippines, 3. Taiwan (PC), 4. Viet Nam

Family	Common name	Countries
Salmonidae	Trouts and salmons	1. Australia, 2. Armenia, 3. Azerbaijan, 4. Cyprus, 5. Georgia, 6. Iran, 7. Israel, 8. Japan, 9. Kazakhstan, 10. Korea (Rep.), 11. Lebanon, 12. New Zealand, 13. Turkey, 14. Taiwan (PC), 15. Papua New Guinea
Sciaenidae	Drums and croakers	1. China, 2. Israel, 3. Taiwan (PC)
Scombridae	Bluefin tuna	1. Australia
Scorpaenidae	Rockfish	1. Korea (Rep.)
Serranidae	Seabass and groupers	1. China, 2. Taiwan (PC), 3. Indonesia, 4. Malaysia, 5. Thailand, 6. Hong Kong (SAR), 7. Philippines, 8. Korea (Rep.), 9. Singapore, 10. Kuwait, 11. United Arab Emirates, 12. Papua New Guinea, 13. French Polynesia
Siganidae	Rabbitfishes	1. Philippines, 2. Saudi Arabia, 3. Cyprus, 4. Qatar, 5. United Arab Emirates
Siluridae	Amur catfishes	1. Taiwan (PC), 2. Kazakhstan
Sparidae	Seabreams	1. Japan, 2. China, 3. Turkey, 4. Taiwan (PC), 5. Korea (Rep.), 6. Israel, 7. United Arab Emirates, 8. Cyprus, 9. Oman, 10. Kuwait, 11. Hong Kong (SAR), 12. Bahrain, 13. Qatar
Synbranchidae	Spiny swamp eels	1. Thailand
Terapontidae	Silver perch	1. Australia
Tetraodontidae	Puffers	1. China, 2. Japan, 3. Korea (Rep.)
CRUSTACEANS		
Astacidae a	Northern crayfish	1. China
Grapsidae	Chinese river crabs	1. China, 2. Korea (Rep.)
Palaemonidae	Freshwater prawns	1. China, 2. India, 3. Thailand, 4. Bangladesh, 5. Taiwan (PC), 6. Malaysia, 7. Indonesia, 8. Myanmar, 9. Philippines, 10. Iran, 11. Brunei Darussalam, 12. Fiji Islands, 13. French Polynesia
Palinuridae	Spiny lobsters	1. Australia, 2. Japan, 3. Philippines, 4. Singapore
Parastacidae	Southern crayfish	1. Australia, 2. New Caledonia, 3. Indonesia
Penaeidae	Penaeid shrimps	1. China, 2. Thailand, 3. Viet Nam, 4. Indonesia, 5. India, 6. Bangladesh, 7. Philippines, 8. Malaysia, 9. Myanmar, 10. Taiwan (PC), 11. Saudi Arabia, 12. Iran, 13. Sri Lanka, 14. Australia, 15. Korea (Rep.), 16. Japan, 17. Cambodia, 18. Cyprus, 19. Singapore, 20. Brunei Darussalam, 21. Oman, 22. United Arab Emirates, 23. New Caledonia, 24. French Polynesia, 25. Fiji Islands, 26. Vanuatu, 27. Guam, 28. Commonwealth of Northern Mariana

Family	Common name	Countries
Portunidae	Swimming crabs and swamp crabs	1. Indonesia, 2. Japan, 3. Philippines, 4. Taiwan (PC), 5. Malaysia, 6. Singapore, 7. Sri Lanka
Scyllaridae	Slipper lobsters	1. Philippines
Sergestidae	Sergestid shrimps	1. Indonesia
CORAL		
Scleractinian	Hard coral, live rock	1. Fiji Islands, 2. Tonga, 3. Vanuatu, 4. Marshall Islands
	Sponge	1. Micronesia

Table 4. Species groups cultured in each country (2003).

Countries by subregion		Species
Oceania	Australia	1. Trouts and salmons, 2. Oysters, 3. Blue-fin tuna, 4. Penaeid shrimps, 5. Mussels, 6. Silver Perch, 7. Yabbies, 8. Abalone, 9. Eels, 10. Scallops, 11. Rock Lobsters
South Asia	Bangladesh	1. Carps, 2. Penaeid shrimps, 3. Freshwater prawns
	India	1. Carps, 2. Penaeid shrimps, 3. Catfish, 4. Freshwater prawns, 5. Snakeheads, 6. Hilsa
	Nepal	1. Carps
	Pakistan	1. Carps
	Sri Lanka	1. Penaeid shrimps, 2. Tilapia, 3. Swamp crabs
East Asia	China	1. Carps, 2. Kelps, 3. Oysters, 4. Manila Clam, 5. Scallop, 6. Pearl oysters, 7. Tilapia, 8. Laver, 9. Mussel, 10. Constricted tagelus, 11. Penaeid shrimps, 12. Chinese river crabs, 13. Cockles, 14. Freshwater prawns, 15. Eels, 16. Mandarin fish, 17. Soft-shell turtle, 18. Drums and croakers, 19. Seabass and groupers, 20. Cobia, 21. Pampanos, 22. Puffers, 23. Crayfish 23. Bull frog
	Japan	1. Laver, 2. Oysters, 3. Scallops, 4. Pomfrets, 5. Seabreams, 6. Wakame, 7. Salmons, 8. Eels, 9. Carps, 10. Ayu sweetfish, 11. Halibuts and flounders, 12. Puffers, 13. Penaeid shrimps, 14. Frogs, 15. Crabs, 16. Lobsters
	Korea (Rep.),	1. Oysters, 2. Wakame, 3. Halibuts and flounders, 4. Manila Clam, 5. Kelps, 6. Rockfish, 7. Mussel, 8. Cockles, 9. Seabreams, 10. Eels, 11. Mullet, 12. Salmon, 13. Mandarin fish and golden perch, 14. Penaeid shrimps, 15. Green laver, 16. Carps, 17. Abalone, 18. Pond Loach, 19. Tilapia, 20. Snakeheads, 21. Soft-shell turtle, 22. Seabreams, 23. Seabass and groupers, 24. Ayu sweetfish, 25. Scallop, 26. Chinese river crabs, 27. Atka mackerel, 28. Filefishes, 29. Sawtooth cardina
	Korea (DPR)	1. Kelps, 2. Carps
	Cambodia	1. Carps, 2. Catfish, 3. Tilapia, 4. Penaeid shrimps, 5. Eucheuma seaweeds

	Countries by subregion	Species
Southeast Asia	Indonesia	1. Carps, 2. Milkfish, 3. Penaied shrimps, 4. Tilapia, 5. Catfish, 6. Giant gourami, 7. Mullet, 8. Swimming crabs and swamp crabs, 9. Seabass and groupers, 10. Perches, 11. Kissing gourami, 12. Gourami, 13. Mudfish, 14. Sergestid shrimps, 15. Eels, 16. Freshwater prawns, 17. Pangas catfish, 18. Marble goby, 19. Crayfish, 20. Bullfrog, 21. Crocodile
	Malaysia	1. Cockles, 2. Clariid catfish, 3. Perches, 4. Snakeheads, 5. Tilapia, 6. Carps, 7. Marble goby, 8. Snappers, 9. Mussels, 10. Penaeid shrimps, 11. Freshwater prawns, 12. Pangas catfish, 13. Bangid catfish, 14. Penaeid shrimps, 15. Swamp crabs, 16. Seabass, 17. Groupers, 18. Eucheuma seaweeds, 19. Bullfrog
	Myanmar	1. Carps, 2. Penaeid shrimps, 3. Tilapia, 4. Pangas catfish, 5. Giant gourami, 6. River prawns, 7. Eucheuma seaweeds
	Philippines	1. Eucheuma seaweeds, 2. Milkfish, 3. Tilapia, 4. Penaeid shrimps, 5. Oysters, 6. Mussels, 7. Carp, 8. Swamp crabs, 9. Caulerpa seaweed, 10. Catfish, 11. Snakeheads, 12. Agar seaweeds, 13. Seabass, 14. Groupers, 15. Rabbitfishes, 16. Giant gourami, 17. Spiny lobster, 18. Pompanos, 19. Slipper lobsters, 20. Snappers, 21. Perches, 22. Giant clams, 23. Giant river prawn, 24. Crocodile
	Thailand	1. Penaeid shrimps, 2. Tilapia, 3. Catfish, 4. Mussel, 5. Carps, 6. Cockles, 7. Freshwater prawns, 8. Oysters, 9. Gourami, 10. Pangas catfish, 11. Perches, 12. Snakeheads, 13. Seabass, 14. Groupers, 15. Frogs, 16. Walking Perch, 17. Giant gourami, 18. Soft-shell turtle, 19. Lai fish, 20. Knifefish, 21. Marble goby, 22. Babylon shell, 23. Crocodile
	Viet Nam	1. Penaeid shrimps, 2. Agar seaweeds, 3. Carps, 4. Pangas catfish
Near East	Iran	1. Carp, 2. Trouts, 3. Penaeid shrimps, 4. River prawns

Of the 177 species listed, a much smaller group is really important in terms of quantity or value. Among the freshwater and diadromous species, the cyprinids are the most important both in China and the rest of Asia. All the cyprinids together with 16.8 million tonnes constitute 70.8 percent of freshwater fishes and 33.6 percent of total aquaculture. These consist mostly of Chinese carps with 61.7 percent of freshwater fishes, followed by the Indian major carps with 7.9 percent. The tilapias make up a far second at 5.8 percent. It should be noted however that there is more tilapia produced in Asia than in Africa where it originally came from. As of 2003, some 78 percent of the farmed tilapia in the world came from Asia.

Among the crustaceans, only three of the 28 species reported in 2003 made up 60 percent of the total crustacean production. Thus, all the other species contribute less than 25 percent of total freshwater fish production.

Shrimp aquaculture in Asia deserves a special mention due to a shift in the main species cultured. The black tiger shrimp or *Penaeus monodon* used to predominate over all other species. At the height of its dominance in 1994, *P. monodon* constituted 75 percent of total shrimp production in Asia. This has slowly waned so that by 2003, it has gone down to 43.5 percent, according to what has been reported to FAO. But the actual percentage maybe much lower considering that many of the Asian countries were not reporting or were underreporting their production of exotic species as will be discussed later.

What has taken its place is an exotic species, the Pacific white shrimp (*P. vannamei)* which is native to the Pacific coast of Central and South America. But even the figure of 43.5 percent may be less than the actual, since Indonesia has not reported its own *P. vannamei* production which has been widely regarded as sizeable, considering the large shrimp farm estates in that country which has shifted to the species. What is certain, however, is that by year 2002, more *P. vannamei* was being produced in Asia than in the Americas. Based on what has been reported, 53 percent of the world production of *P. vannamei* came from Asia in 2002. This increased to 64 percent in 2003. The situation is not unlike that of tilapia, another exotic species in Asia.

Among the mollusks, of the more than 20 species being cultured, only two, the Pacific cup oyster, *Crasssostrea gigas* and the Manila clam, *Ruditapes philippinarum*, make up more than 60 percent of total mollusk production. Among the 15 aquatic plant species, only three, *Laminaria japonica*, *Porphyra tenera,* and *Eucheuma cottonii* constitute 54.4 percent of the total production in 2003. It should be noted however that what is reported as *E. cottonii* is actually *Kappaphycus alvarezii* referred to as Zanzibar seaweed in FAO FISHSTAT Plus. The Kappaphycus used to be considered merely as a fast-growing strain of *E. cottonii* but was later determined to be another species altogether. Until now Kappaphycus is still referred to in the Philippines as the "cottonii" type of seaweed as opposed to the "spinosum".

The discrepancy in the total number of species listed and the actual number being farmed each year indicates that there is a continuing attempt to try a new species, only to be dropped probably because the technology is not quite ready, or the market value does not cover production cost due to certain developments such as high production inputs, market changes that include presence of substitutes, competition from other areas with a better comparative advantage, change in consumer preference, trade barriers, etc. Whether or not there is a market for it is probably less of a factor in dropping a species since an attempt to culture the said species may not have been made, had there been no existing or potential market. This implies that in Asia, it is the farmers who generally set the pace in aquaculture development. Research usually comes in after an industry has emerged and constraints to further development arise.

2.2 Production (species quantity and value)

As of 2003, Asia produced 49 976 million tonnes, representing 91.2 percent of world aquaculture production. China by itself with a production of 38 841 million tonnes already contributes 70.5 percent. The rest of Asia contributes 20.7 percent. Such magnitude often makes it necessary to discuss Chinese aquaculture production separately from that of the rest of the Asia-Pacific area. If aggregated with the rest of Asia, China's production has a distorting effect on the rest of Asia.

By value, China's aquaculture production amounted to US$36 215 million, and the rest of Asia, US$18 888 million representing 53.8 and 28.1 percent of the total value of world production, respectively. China's lower value is not due to the inclusion of aquatic plants. With aquatic plants excluded, the contribution to total value of global production even drops slightly to 51.6 percent in the case of China, and increases slightly to 28.5 percent for the rest of Asia. The significantly lower contribution to total production by value of China's aquaculture points out to the fact that the bulk of Chinese aquaculture production consists of low-value food fish, primarily cyprinids. On the other hand, the higher contribution by value for the rest of Asia is due to the production of shrimps.

Aquaculture in China has grown by volume at a mean annual rate of 13.3 percent and that of the rest of Asia at a rate of 5.0 percent between 1984 to 2003. The rest of the world grew at the rate of 5.9 percent. Growth by value, not surprisingly, is higher for the rest of Asia at 12.8 percent than for China at 8.9 percent, again, due to the higher proportion of shrimp production in the rest of Asia combined than in China. Furthermore, most of the rest of Asia farmed the black tiger shrimp, *P. monodon*, which with its larger size attained, commands a higher price in the world market than China's fleshy prawn, *P. chinensis*.

Aquaculture in Asia is growing in importance not only in terms of its growth rate but also relative to the development in capture fisheries. As shown in Figure 3, capture fisheries in China and the rest of Asia have reached their plateau. During the four years from 2000 to 2003, capture fisheries in China showed an annual average decline of 0.5 percent while that of Asia grew at a mere 0.7 percent. In contrast, aquaculture during the same period grew at an average rate of 6.5 percent and 5.6 percent respectively in China, and the rest of Asia. In Asia as a whole, aquaculture now contributes 51 percent to total fisheries production. This is due to the 69 percent contribution of aquaculture to Chinese fisheries production. In the rest of Asia, aquaculture contributes 28 percent. In the rest of the world, aquaculture contributes only 9.7 percent of total fisheries production.

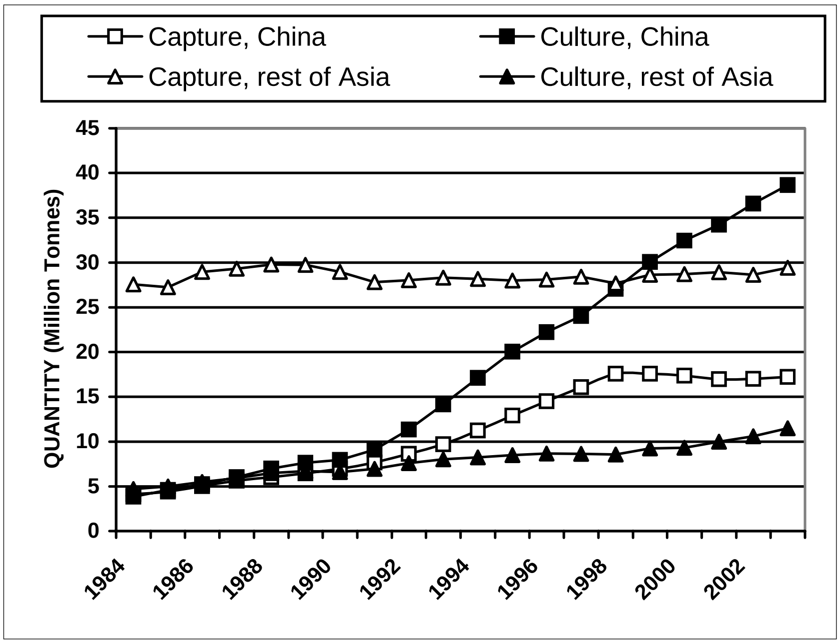

Figure 3. Comparative development of aquaculture and capture fisheries in China and the rest of Asia, 1984 to 2003.

2.3 Production by country and rates of growth

The aquaculture sector in Asia has grown tremendously during the last half century from one that produced fish totally to serve local demand, to one that has become, in many countries, a powerhouse for earning foreign exchange. Such growth and development is not uniform among countries and among species. As is widely known, the most spectacular growth in aquaculture is taking place in China.

In 2003, the volume of aquaculture production in Asia reached nearly 50 million tonnes of which 38.6 million tonnes came from China. Following China are India, Philippines, Japan, Indonesia, Viet Nam, Bangladesh, Korea (Rep.), Thailand and Korea (DPR) in that order to make up the top ten producing countries in Asia as shown in Table 5. By value, the total production in Asia reached US$54 827 million of which China produced US$36 193 million. Except for the Philippines and Korea (DPR) all the other countries among the top ten producers by volume are also among the top ten countries by value. Going up to join the top ten countries/territories by value are Taiwan (PC) and Myanmar as shown in Table 6. The top 16 counties by volume are the same top 16 countries by value although their rankings are not the same.

The shift in the ranking by value is due to the differences in the value of the major species produced. The Philippines and Korea (DPR) owe their high volume production to aquatic plants which have relatively low unit value. Furthermore, all the other countries are big shrimp producers, while Philippine shrimp production has remained comparatively low.

Rate of growth during the 20-year period between 1984 to 2003 has been variable from country to country (Table 7).

Table 5. Volume of aquaculture production by country in South Asia, East Asia, Southeast Asia, Iran and Oceania, 2003.

Country	Production quantity (tonnes)	Country	Production quantity (tonnes)
1. China[a/]	39 004 750	13. Iran	91 714
2. India	2 215 590	14. New Zealand	84 642
3. Philippines	1 448 504	15. Lao (PDR)	64 900
4. Japan	1 327 361	16. Australia	38 559
5. Indonesia	1 228 559	17. Cambodia	26 300
6. Viet Nam	967 502	18. Nepal	17 680
7. Bangladesh	856 956	19. Pakistan	12 061
8. Korea (Rep.),	839 845	20. Sri Lanka	10 156
9. Thailand	772 970	21. Singapore	5 024
10. Korea (DPR)	507 995	22. Hong Kong (SAR)	4 857
11. Myanmar	25 7 083	23. Kiribati (mostly live rock, export of which has stopped)	3 913
12. Malaysia	186 031	24. New Caledonia (all shrimp)	1 800

[a/] Inclusive of Taiwan (PC) and Hong Kong (SAR)

Table 6. Value of aquaculture production by country in South Asia, East Asia, Southeast Asia, Iran and Oceania, 2003.

Country	Production value (US$1 000)	Country	Production value (US$1 000)
1. China [a/]	37 124 252.60	13. Iran	273 855.00
2. Japan	4 428 962.00	14. Australia	251 327.20 (Pearl ca. 200.00)
3. India	2 515 592.50	15. New Zealand	246 836.80
4. Viet Nam	1 983 331.00	16. Lao (PDR)	129 800.00
5. Thailand	1 910 050.10	17. French Polynesia	98 111.80
6. Indonesia	1 715 901.30	18. Sri Lanka	65 575.30
7. Bangladesh	1 243 120.90	19. Cambodia	35 726.10
8. Korea (Rep.),	1 058 475.10	20. Nepal	21 661.50
9. Myanmar	790 550.00	21. New Caledonia	13 937.40
10. Philippines	668 514.00	22. Singapore	9 480.00
11. Korea (DPR)	302 612.30	23. Pakistan	7 848.09
12. Malaysia	302 007.40		

[a/] Inclusive of Taiwan (PC) and Hong Kong (SAR)

Within Southeast Asia, Myanmar has the highest growth with 29.5 percent and 42.5 percent by volume and by value respectively. The high figures are due to three reasons. One, rohu carp which is the country's major species making up almost 40 percent of 2003 production had grown tremendously from only 3 944 tonnes in 1984 to 100 000 tonnes in 2003. Two, the number of species Myanmar included in its production statistics varied from only one (rohu in 1992 to 1993) and two for 13 of the 20 year period under consideration (rohu and giant river prawn from 1984 to 1988 then rohu and giant tiger prawn from 1995 to 2000). During some years common carp and catla and some other species were reported but not in other years, Starting 2002 however 13 species were reported including unspecified freshwater fish which constituted 32 percent by volume in 2003 where there was none in 2001. The erratic omission and addition of species resulted in a wide oscillation of the yearly production figures partly also explaining the high average annual growth figures by volume. The wide disparity between the growth by volume and by value is due to the high valuation of US$246.8 million for the 82 262 tonnes of unspecified freshwater fish where there was none in 2001. This was also true for common carp which was valued at US$150 million where there was none in year 2000. Contributing to the high rate of mean growth by value is the production of giant tiger prawn which started only in 1995 with a value of US$14.85 million to reach US$76 724 million in 2003.

Table 7. Mean annual growth rate of top aquaculture producing countries in Asia and Oceania, 1984 to 2003.

Country	Volume		Value	
	Rank in 2003	Mean annual growth (%)	Rank in 2003	Mean annual growth (%)
China	1	13.3	1	12.2
India	2	7.9	3	9.6
Philippines	3	5.9	11	3.2
Japan	4	0.8	2	4.5
Indonesia	5	7.5	6	12.2
Viet Nam	6	12.7	4	14.9
Bangladesh	7	11.1	7	12.5
Korea (Rep.),	8	2.1	8	9.8
Thailand	9	11.4	5	20.3
Korea (DPR)	10	1.0	12	1.0
Taiwan (PC)	11	2.8	9	3.1
Myanmar	12	29.5	10	42.5
Malaysia	13	8.4	13	15.3
Iran	14	10.4	15	10.8
New Zealand	15	13.0	17	26.4
Lao (PDR)	17	19.0	18	24.7
Australia	18	8.0	16	14.4
Cambodia	19	21.3	23	17.9
Nepal	20	12.1	25	14.2
Pakistan	21	5.4	28	0.0
Saudi Arabia	22	64.1	19	63.5
Sri Lanka	23	7.7	20	25.7

Cambodia and Lao (PDR) also showed remarkably high average annual growth in both quantity and value. In Cambodia the high growth rate is due mainly to seaweeds which grew from nothing in 2000 to 7 800 tonnes in 2003 making up 30 percent of total production. Furthermore common carp production grew 12 fold from 460 to 5 117 tonnes between 1984 and 2003, grass carp eleven-fold from 100 to 1 142 tonnes, silver carp also eleven fold from 160 to 1 760 tonnes while Thai silver barb grew also at same rate from 620 to 6 890 tonnes as Cambodia normalized. In the case of Lao (PDR) the growth was propelled by tilapia which grew from a few hundred tonnes in 1984 to reach 29 205 tonnes in 2003 followed by the common carp which also grew from a few hundred tonnes to 16 225 tonnes.

By value, Sri Lanka, New Zealand and Thailand showed very high average annual growth rate of 26.4, 25.7, 24.7 and 20.3 percent respectively even if by volume the rate of growth was only moderately high at 13.0, 7.7, 13.0 and 11.4 percent. For Sri Lanka and Thailand the high growth rate by value is due to shrimp production. For New Zealand this is due to the surge in value of its green-lipped mussel which grew three-fold by value between 2002 and 2003 while remaining stable by volume.

The average annual growth rates in this synthesis may deviate from those reported in the NASOs because some of the country overviews computed the rate of growth by considering only the final year and the initial year instead of averaging the year to year growth.

The development over the years of the various species point out to the fact that traditionally, aquaculture in Asia was limited largely to food fish for local consumption. The emergence of large-scale culture of high value species primarily for export is a more recent development as shown in Figure 4. Increased world trade brought this about. Improved technology in refrigeration and transport have made it possible to ship fresh frozen seafood over long distances.

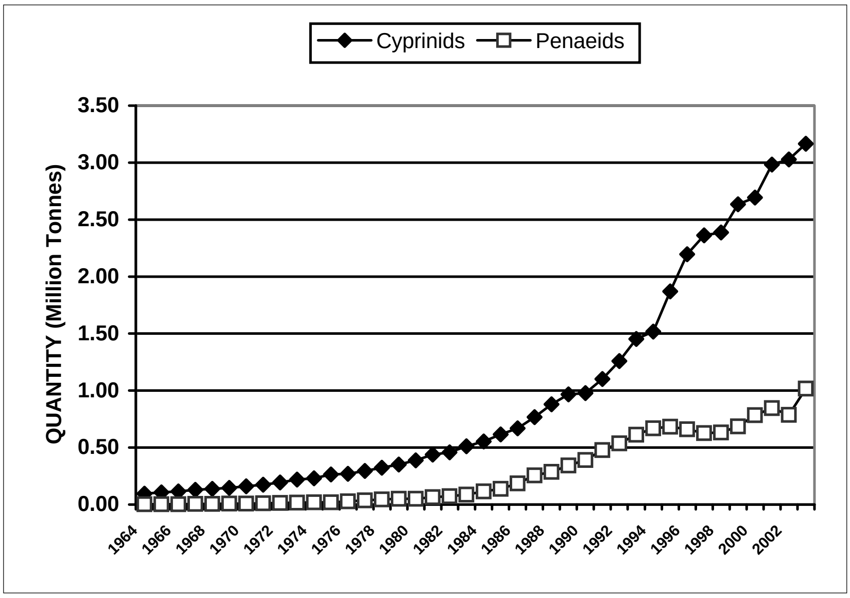

Figure. 4. Comparative growth of cyprinid and penaeid shrimp production in Asia and Oceania exclusive of China, 1964 to 2003.

Among the top ten aquaculture producing countries, Japan and Korea (Rep.), have the lowest mean annual growth rate by volume at 0.8 percent and 2.1 percent respectively although by value Korea (Rep.), production grew by 9.8 percent while that of Japan grew only by 4.5 percent. In effect actually Japanese aquaculture production has stabilized at between 1.3 to 1.4 million tonnes level since 1988 with the value remaining the same relative to the volume. That of Korea (Rep.) has stabilized at between 0.7 to 0.8 million tonnes after reaching a peak production of over 1 million tonnes between 1993 to 1997 while increasing in value relative to the volume. These contrasting growth rates can be explained.

Japan with more than 60 species farmed has probably the most diverse aquaculture industry. Development is very much market driven even if the government plays an important role in issuing appropriate regulations, financing, basic research, seed production and water quality management. In

May 1999, the government passed a law for sustainable aquaculture development to keep the culture environment in good condition and to prevent the spread of fish diseases. Japanese aquaculture faces two major problems: fish diseases on one hand and growing concern of consumers on product safety (Maeda, 2003). The irony it seems is that the solution to one problem is precisely what has given rise to the other problem.

In order to manage fish diseases the government allows the use of 26 antibiotics and chemotherapeutants. But the use of these drugs maybe one reason consumers preference for wild-caught fish even at a higher price. This has affected profitability since fish farmers are forced to sell their product with a narrow margin. There is a growing interest to extend Hazard Analysis and Critical Control Points (HACCP) even at the production level. While HACCP is now becoming a standard procedure in food processing plants this has not yet been applied to fish farms because of the perceived high additional cost of implementing such management procedures. Furthermore data for hazard analysis is still insufficient and procedures to monitor critical limits are still to be established. The interest on HACCP at the farm level is particularly keen in Japan where a large proportion of seafood is consumed raw.

Other reasons have been cited for the poor prospects for marine aquaculture aside from the extremely low price of products (Morikawa, 2001). These reasons include: (a) labour shortage due to the lack of interest from younger generation in aquaculture work, and (b) deterioration of the aquatic environment by industrial effluents and self-contamination by aquaculture in calm inner bays and sharp fall in sardine catch required to produce fishmeal. Moreover, all suitable areas for coastal aquaculture such as calm waters with favourable current are already fully utilized as aquaculture grounds.

Even with near zero growth during recent years, the ratio of aquaculture production to total Japanese fisheries production continues to increase since Japanese capture fisheries has been on a decline after reaching a peak production of 11 344 million tonnes in 1988. By 2003, this was down to only 4.71 million tonnes. Aquaculture production on the other hand has stabilized at between 1.3 to 1.4 million tonnes between 1988 to 2003 so that in effect the percentage of aquaculture to total production has increased from 12.6 in 1988 to 22 percent in 2003.

In the case of Korea (Rep.), there is a deliberate effort to shift from the production of low value species such as seaweeds to high value species. The government has been pursuing a long-term aquaculture development programme through the expansion of areas for aquaculture and the intensified development of both profitable and unexploited species. Already certain tidal areas in the southern provinces have been designated for shellfish culture. The number of aquaculture facilities will be reduced by 10 percent over the next five years, and new licences will not be issued for such products as laver, sea-mustard and “excessively-produced fishes”. Another reason for the slow down in growth is the lose of some aquaculture areas to industrial pollution such as the case with oysters.

By turning to more advanced aquaculture fisheries within the next five years, the Ministry of Maritime Affairs and Fisheries (MOMAF) plans to encourage the industry to reduce production costs so that it can compete favorably with its foreign counterparts. Between the last million tonne level production year in 1997 to 2003, aquatic plants dropped by 30 percent and Korea (Rep.) mussels by 75 percent. On the other hand demersal fish such as olive flounder and black rockfish increased by 78 percent. There has equally been an increased interest in farming of shrimps (*P. chinensis* and *P. japonicus*) and the mitten-handed crabs, heretofore the sole domain of China. As a result crustacean production has increased by 48 percent between 1997 and 2003.

One country that bears watching is Iran, which is giving great importance to aquaculture in spite of the harsh climate relative to that of Southeast and East Asia. In Iran there is a strong interest in shrimp farming and in diversifying to other species. Iran already has a sizeable trout production and intends to double trout production over the next five years. The country is starting to work on other marine fish species such as seasbass, seabream, grouper, mullets and cobia. Iran is also exploring the possibility of seaweed culture. Thus significant growth in aquaculture in this country can be expected in the long and medium term.

2.4 General production by species

For the purpose of this synthesis, the species are grouped by taxonomic families. Generally, species belonging to the same family require the same technology and cater to the same market. The most important group of species in China, as well as the whole of Asia, both by volume and by value, are the cyprinids. Although low in unit value, the huge volume produced each year boosted its total value to dominate over all other species groups. However, if China is disaggregated from the rest of Asia, it is the Penaeid shrimps that are the top species by value in the rest of Asia, although cyprinids still come a close second (Table 8).

Table 8. Top species groups by production quantity, China and rest of Asia and Oceania, 2003.

	Asia and Oceania		**China only**		**Rest of Asia and Oceania**	
Family	**Quantity (tonnes)**	**Percent**	**Quantity (tonnes)**	**Percent**	**Quantity (tonnes)**	**Percent**
Cyprinidae	16 796 839	33.5	13 631 321	27.2	3 165 518	6.3
Other	10 445 444	20.8	8 877 461	17.7	1 567 983	3.1
Laminariaceae	4 614 372	9.2	4 093 840	8.2	520 532	1.0
Ostreidae	4 234 457	8.5	3 668 237	7.3	566 220	1.1
Veneridae	2 605 741	5.2	2 546 133	5.1	59 608	0.1
Penaeidae	1 510 694	3.0	493 061	1.0	1 017 633	2.0
Cichlidae	1 315 428	2.6	805 859	1.6	509 569	1.0
Bangiaceae	1 258 461	2.5	727 530	1.5	530 931	1.1
Pectinidae	1 156 318	2.3	897 956	1.8	258 362	0.5
Solieriaceae	987 640	2.0			987 640	2.0
Mytilidae	893 468	1.8	683 237	1.4	210 231	0.4
Solecurtidae	672 402	1.3	672 402	1.3		
Chanidae	552 043	1.1		0.0	552 043	1.1
Arcidae	436 073	0.9	317 870	0.6	118 203	0.2
Grapsidae	368 050	0.7	368 036	0.7	14	0.0
Palaemonidae	279 615	0.6	187 252	0.4	92 363	0.2
Alariaceae	258 042	0.5			258 042	0.5
Anguillidae	222 981	0.4	161 299	0.3	61 682	0.1
Clariidae	220 767	0.4			220 767	0.4
Carangidae	176 100	0.4	11 572	0.0	164 528	0.3
Sparidae	162 251	0.3	42 276	0.1	119 975	0.2
Percichthyidae	152 664	0.3	149 886	0.3	2 778	0.0
Trionychidae	147 600	0.3	143 816	0.3	3 784	0.0
Salmonidae	112 861	0.2			112 861	0.2
Sciaenidae	104 275	0.2	103 609	0.2	666	0.0
Serranidae	51 915	0.1	26 790	0.1	25 125	0.1
All Others (43 Families)	368 634	0.7	26 622	0.1	342 012	0.7
TOTAL	**50 105 135**	**100**	**38 636 065**	**77.1**	**11 469 070**	**22.9**

2.4.1 Crustaceans

Whilst a number of crustacean species are cultured, the predominant commercial species are brackish-water shrimps, freshwater prawns and freshwater/brackish water crabs.

Penaeid shrimp culture

Marine shrimp continued to dominate crustacean aquaculture with 83 percent coming from Asia as of 2003. For a long time since shrimp aquaculture became a big industry starting in the late 1970s, one species, the giant tiger shrimp, *Penaeus monodon*, also know in the trade as the black tiger was the dominant species in Asia as well as worldwide. So that at its peak in 1994 the black tiger was 75.2 percent of Asian production and 63.7 percent worldwide.

Up to 1984, the second species worldwide was the Pacific white shrimp, *P. vannamei* with 19.4 percent, but none in Asia having been confined to the Pacific coast of South America where it is native to. But when China started flexing its aquaculture prowess in the coastal area by the mid-1980s, *P. vannamei* was dislodged in the second place by the Chinese fleshy shrimp, *P. chinensis* which made up 19.1 percent worldwide and 23 percent in Asia. In 1988 *P. chinensis* shared the number one spot with *P. monodon* when both species equally made up 41 percent of Asian shrimp production and 34.6 percent worldwide while *P. vannamei* made up only 13.4 percent worldwide and still zero percent in Asia. But as *P. chinensis* production increased in China so did *P. vannamei* production in Ecuador while still maintaining its second position. That was to last only until 1992. The next year *P. chinensis* production dropped precipitously due to the yellowhead virus (YHV) and the white spot syndrome virus (WSSV). The Chinese shrimp industry later staged a remarkable recovery. But it is now accepted the recovery became possible only with the introduction of *P. vannamei*.

At about the same time that China was having problem with the native species, so did Thailand, Indonesia and the Philippines with the *P. monodon* due to WSSV and luminescent vibriosis. Other major producers in Asia such as Viet Nam, India and Sri Lanka would later also encounter fluctuations in production which are primarily associated with the impact of WSSV. Thailand and Indonesia at first merely tolerated the entry and culture of P. vannamei but would later allow their culture after establishing guidelines on their importation. Malaysia made the culture of the species legal in March 2005 while the Philippines as of December 2005 is still in the species evaluation stage.

Although large-scale culture of *P. vannamei* in Asia, particularly in China, Thailand and Indonesia started during the late 1990s, their production were reported as that of the native species or lumped together with all other white shrimps. It was only in 2001 that China reported some production, with Thailand following suit in 2002. Up to 2003 however Indonesia still did not report *P. vannamei* production separately. It is believed that China's reported production of *P. chinensis* after 1995 is overstated and that most of it could actually be *P. vannamei*. Taking into consideration the non-reporting or under-reporting of *P. vannamei* on one hand and the over-reporting of native shrimp species production on the other hand it appears that *P. vannamei* may have overtaken *P. monodon* as the dominant farmed species by 2002 worldwide. Furthermore more *P. vannamei* is now being produced in Asia than in its region of origin.

Using what has been reported as of 2003, *P. vannamei* already constitutes 40.1 percent worldwide as against 36.9 percent of *P. monodon*. In Asia *P. monodon* appears to still dominate with 43.5 percent of total production as against 30.6 percent for *P. vannamei* if based on what has been reported to FAO as reflected in the FISHSTAT Plus database. However a new assessment by Miao (2005) shows that Chinese production may actually be twice as much as the previously reported 300 000 tonnes due to failure to include some 296 312 tonnes from freshwater farms. Tookwina, Chiyakum and Samsueh (2005) using industry sources also reported a production of 170 000 tonnes for 2003 for Thailand as against 120 000 in official statistics while Sri Paryanti and Budhiman (2005) reported a production of

49 413 tonnes for Indonesia. Using this as yet unofficial figures, it would appear that even in Asia, *P. vannamei* is already the dominant species at 45.3 as against only 34.3 percent for *P. monodon*.

Shrimp production levels in Asia reached 1 511 million tonnes by 2003 (accounting for more than 83 percent of total farmed shrimp and 47 percent of total landings). The production trends in the region have been increasing over the past 10 years for the major producers even as individual countries suffered major setbacks in the mid-1990s with the impact of viral diseases on shrimp culture. Since that time, production has slowly recovered. Generally the high international market demand has maintained interest in the culture of shrimp for export.

More recently, the growth has been led by *P. vannamei*. Chinese production of the species is 300 000 tonnes in 2003 based on officially reported figures but can be as high as 605 256 tonnes if production from freshwater farms is included (Miao, 2005). Other Asian countries with developing industries for this species include Thailand with 70 000 tonnes (Tookwina, Chiyakum and Samsueh, 2005), Indonesia (49 413 tonnes) Viet Nam (30 000 tonnes), Taiwan (PC), the Philippines, Malaysia and India (thousands of tonnes each) [9].

Thus it is estimated that total production of *P. vannamei* in Asia was approximately 854 000 tonnes in 2003, and may exceed one million tonnes in 2004, which would be worth some US$8 billion on the export market. However, not all the product is exported and a large local demand exists in some Asian countries. Most of the close to 300 000 tonnes production from freshwater farms in China is reported to be sold in the domestic market.

The main reason behind the importation of *P. vannamei* to Asia has been the poor performance, slow growth rate and disease susceptibility of the major indigenous cultured shrimp species, *P. chinensis* in China and *P. monodon* virtually everywhere else. Shrimp production in Asia has been characterized by serious viral pathogens causing significant losses to the culture industries of most Asian countries over the past decade. It was not until the late 1990s, spurred by the production of the imported *P. vannamei*, that Asian (and therefore world) production levels have begun to increase again.

There are problems associated with this dramatic increase in the production of *P. vannamei* in terms of the marketing of the product. With so many countries now producing essentially the same product (a relatively small white shrimp), global prices have dropped dramatically during 2002–2003. This has also had follow on effects regarding the actual value of the product sold and disagreements regarding possible “dumping” of shrimp onto markets.

The price of shrimps appears to be on a steady decline with the value of *P. monodon* eroding at a faster rate than that of *P. vannamei*. Whilst the unit value of *P. vannamei* started out higher than *P. monodon* in the 1980s, this plummeted below that of *P. monodon* in 1990. But in 2001 the unit value of both species started to decline. In 2000, the unit value of *P. monodon* worldwide was US$7.18/kg and *P. vannamei* US$6.32. By 2003 *P. monodon* has dropped to US$5.11/kg and *P. vannamei* to US$5.56. Consequently where in 2000 *P. monodon* in Asia was 62.8 percent of total production in the region and 70.1 percent by value, in 2003 it was 43.5 percent by volume and 42.8 percent by value. In contrast *P. vannamei* was 30.7 percent by volume but 32.9 percent by value (Figure 5).

Freshwater prawns

More so than the marine shrimps, the aquaculture of freshwater prawns, primarily *Macrobrachium rosenbergii*, is overwhelmingly Asian with 99.7 percent of the world 2003 production of 280 416 tonnes coming from Asia. Although it is grown in freshwater, the larval phase requires brackishwater. It first appeared in statistics only in 1975 with production coming from Malaysia

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[9] The reported production of *P. vannamei* to FAO in 2001 was 5 809 tonnes; only Taiwan (PC) officially reported the production.

where the hatchery technology was first developed through an FAO-assisted project. However it was in Taiwan (PC) and Thailand where production first topped the 10 000-tonne level in 1990 and 1992 respectively. It increased to 16 000 tonnes in Taiwan (PC) in 1991 and fluctuated between 6 000 to 8 000 between 1992 to 2002. Similarly in Thailand after 1992, production also fluctuated below 10 000 tonnes. Many of the erstwhile freshwater prawn hatchery actually converted to *P. monodon* in Thailand to serve the growing need for *P. monodon* PL. Growers also faced increasing competition from lower-priced wild caught stock coming from neighbouring countries.

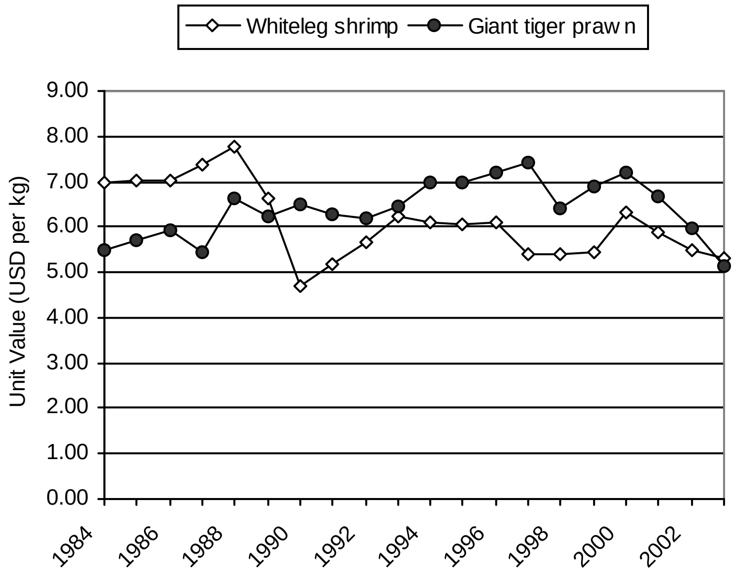

Figure 5. Comparison between the unit value of *Penaeus monodon* and *P. vannamei*, World 1984 to 2003 (FAO FISHSTAT Plus).

There is renewed interest for the species as production picked up in Thailand by 2000 so that by 2003 it reached 35 870 tonnes. China and India also entered the scene and became major players. In both Thailand and India, the renewed interest was fueled by the increasing disease problem of *P. monodon*. India first reported a production of only 178 tonnes in 1996 to grow to 35 870 tonnes by 2003. But Chinese production growth has been nothing short of spectacular with the volume starting at 37 363 tonnes in 1996 to reach 187 252 tonnes by 2003. Starting in 2000, China's production was boosted by another species, *M. nipponense* which is native to China unlike *M. rosenbergii* which is an introduced species. It is gaining popularity because it can be propagated completely in freshwater and has high consumer acceptance. In 2003 China produced more of this species than of *M. rosenbergii*. India also reports production of another species, *M. malcomsonii*, but production has been limited to less than 200 tonnes.

Bangladesh is another significant player with production steadily increasing to top 10 000 tonnes by 2003. Other producers have had relatively small productions of up to a few hundred tonnes. These include Indonesia, Malaysia, Myanmar and Iran. Brunei Darusalaam also reports some production. Viet Nam and Sri Lanka are known to be producing a significant quantity but has not reported its production. In the Philippines government promotion has met some reception from the private sector so that a few commercial hatcheries have emerged during the last few years but production has not yet emerged in the country's statistics.

The species is not as easy to intensify due to territoriality and divergent growth effects. Furthermore export markets for freshwater prawns are much smaller and less developed. For these reasons it has not attracted large companies in the same manner as the marine shrimps. Before the entry of China, the growth of this sector had been reasonably slow when compared to that of marine shrimps. In some countries the sector has shrunk as attention and resources have been diverted towards the brackishwater shrimp production. Whilst consumers elsewhere may not be used to these species, they enjoy quite good domestic markets especially in South and Southeast Asian countries.

The principal species, *M. rosenbergii*, does not suffer the same problems with viral disease that impacts the brackishwater shrimp industry so severely. It can be farmed with significantly less start-up capital than marine shrimps. For that reason the freshwater prawns offer a way of improving incomes in rural, inland areas through co-culture with lower value species such as carps and tilapia.

Other niche crustacean species

Of all the other crustacean species for aquaculture, none probably receives as much attention in terms of research and market interest as the mangrove crab, of which there are four species: *Scylla serrata, S. tranquebarica, S. olivacea* and *S. paramomosain*. Of these *S. serrata* has the highest market price due to its fast growth and large size. This species also commands the highest price for export. Mangrove crabs are attractive for export because they can be packed and shipped without water for a considerable length of time although the quality may suffer if not returned to water after more than a day.

Fattening of mangrove crabs in earthen ponds or in cages has a long history, almost as long as shrimp farming, in Southeast Asia and South Asia. There had also been sporadic work on its propagation, again almost as long as that of marine shrimps. But these early attempts were not sustained and the technology never attained commercial stage probably because the natural supply was still able to fill the existing market.

Lately however with increased international trade and local demand it is getting more difficult to catch the crab juveniles for further growing. This spurred the recent interest to develop the hatchery technology for the production of crab juveniles even on the part of donor institutions. Basic R and D work in the Philippines and Viet Nam with the Australian Centre for International Agricultural Research (ACIAR) funding has been completed and a workable hatchery technology giving more consistent results has been developed. But commercial venture on the technology has been slow and hesitant so that the research institutions Southeast Asian Fisheries Development Center (SEAFDEC) (Aquaculture Department in the Philippines and RIA-2 in Viet Nam) are still the main source of hatchery produced seedstock.

Sarawak had been for some years farming crabs in mangroves using pens to keep them in but preserving the natural environment. Fairly recently, the farming of the crabs in mangrove pens is being promoted in the Philippines. This system does not require cutting of mangrove trees, excavation and building of earthen dikes or bunds. Its mangrove friendliness and low initial capital requirement make it ideal for coastal communities. Mass production of crab juveniles in a hatchery is also being done for the purpose of enhancing natural stock.

Another crustacean receiving considerable interest is the freshwater crayfish that is referred to in Australia as “yabbies”. There are three major families of freshwater crayfish, Astacidae and Cambaridae in North America and Parastacidae in the southern hemisphere. Total production reported in Asia and Oceania as of 2003 was only 255 tonnes from Australia and Samoa. Indonesia is working on its own species endemic to Papua province. China exported 24 523 tonnes worth US$99.6 million in 2003 and is known to be the largest supplier of crayfish to the United States. Crayfish production figures in China does not appear in the FAO FISHSTAT Plus database but according to the China Fisheries Yearbook, China produced 51 593 tonnes of the red crayfish (*Procambarus clarkii*) in 2003. Other countries listed as exporters are Armenia (760 tonnes), Indonesia (580 tonnes) and Turkey (122 tonnes).

Pet shops in Asia also import crayfish. In the Philippines they are marketed as “fortune lobster”. A limited introduction for trial rearing has been made of the Australian *Cherax* sp. to the Philippines where they were subjected to an Import Risk Analysis before being released. There are some concerns on the possibility of the crayfish becoming a pest in the same manner as the golden apple snail (*Pomacea*). This is particularly so since the North Amercian crayfish are known to be raised in ricefields where they feed on the ratoon crop.

Other crustaceans that are now being grown from wild-caught juveniles or merely fattened in captivity are the lobsters. In the Philippines, fishers have ventured into the growing of both the spiny lobster *Panulirus* sp. and the slipper lobster in bamboo pens set in subtidal areas. Their high market value (ca. US$25/kg) live has made their venture profitable even if these are fed with raw fish.

2.4.2 Carnivorous finfish species or species requiring higher production inputs

Seabream

In Asia production of seabream (*Labrus* sp.) is confined largely to East Asia: China, Japan, Taiwan (PC), Korea (Rep.) and Hong Kong (SAR) with some production in West Asia particularly in the Mid-East probably using fingerlings coming from hatcheries in Spain. At the turn of the century but before 2003 when total world production was about 160 000 tonnes or less, Asian seabream production made up two-thirds of world production mostly coming from Japan. With the entry of some 65 000 tonnes from China in 2003 which boosted world production to 230 660 tonnes, Asian production came closer to three-fourths of all production even as European production also continued to grow. Even with the entry of China, Japan remains as the world’s top producer in 2003.

Carangids

After salmon and seabream, the carangids, which consist of jacks, caravelles and pompanos is the third largest group of fish cultured in marine waters. Unlike seabream where European production is significant, very little of the 176 189 tonnes world production of carangid is produced outside Asia. Some 96.7 percent of farmed carangid consist of one species, the amberjack, *Seriola quinqueradiata* of which 89.4 percent comes from Japan. The yellowtail, as it is also called, is the most important farmed species in Japan. Japanese production has stabilized at the 140 000 to 160 000 level since the late 1990s. China started reporting production of the species in 2003 with 11 572 tonnes. It is also produced in Korea (Rep.) and Taiwan (PC). As Chinese production of the species increases it is inevitable that it will become a source lower-priced yellow-tail for both Japan and Korea (Rep.).

One carangid gaining popularity is the snub-nosed pompano, *Trachinotus blochii*, also known as yellow pomfret. Fingerlings of this species first came out from hatcheries in Taiwan (PC) although suprisingly there is no report of production from Taiwan (PC). Its culture is gaining grounds in Brunei Darusalaam, Hong Kong (SAR) and the Philippines where fingerlings and locally made pellets are already available commercially. Although a carnivore it grows very well in cages with a Food Conversion Ratio (FCR) lower than 1.5. When sold live to restaurants it commands as good a price as live groupers in the Manila market.

Salmonids

The culture of salmonids in Asia and Oceania has quadrupled from 26 005 tonnes in 20 years from 26 005 in 1983 to 112 861 in 2003 with 86 percent grown in freshwater. The top producing countries are Turkey, Iran, Japan, Australia, New Zealand and Korea (Rep.) in that order. Thirteen other countries in Asia and Oceania are listed as producing or having produced salmonids but only 8 countries reported any production in 2003 including some Middle Eastern nations (Lebanon, Israel, and Cyprus) Central Asian nations (Armenia, Azerbaijan, Georgia and Kazakhstan). New Zealand differs from the four other countries in producing all its 4 800 tonnes of Chinook in marine waters. Japan produces 13 341 tonnes in freshwater (Rainbow trouts and Trouts nei) and 9 208 tonnes in brackishwater (Cohos). Except for Japan and New Zealand where production has declined lately, in all the four other major producing countries, production has been growing at a healthy rate. Iran is planning to double the production of salmonids (rainbow trout) over the next five years to meet an increasing market demand stimulated by a campaign to promote fish as health food.

Eels

Eel farming, as with most other major aquaculture, is overwhelmingly Asian with 96.1 percent of world production coming from Asia. Europe produces 3.8 percent. Topping the list of Asian producers is China with 161 299 tonnes followed by Taiwan (PC) (35 116 tonnes), Japan (21 742 tonnes), and Korea (Rep.) (4 312 tonnes). Indonesia, Australia and Malaysia together produced less than 600 tonnes. The main market for all these eels is Japan where eel or unagi is a very popular food item.

China's production appears to have levelled off. After reaching a peak of 167 098 tonnes, production has stabilized more or less at the 160 000-tonne level. In the case of Taiwan (PC) the present production is only about 60 percent of its former level of about 55 000 tonnes from the late 1980s to the early 1990s. Japanese production likewise has steadily declined from the 39 000 tonne level between 1985 to 1990. Only Korea (Rep.) has shown some growth but Korean production has never been very high. In all the other countries eel production has declined considerably. It appears that eel production in Asia has already stabilized at the 220 000 tonne level and may decline in the near future.

The main constraint is the supply of seedstock. Unlike most other major aquaculture species, eel culture still relies totally on wild caught seedstock. There are five species of eel that are farmed but only two species, the Japanese eel, *Anguilla japonica* and the European eel, *Anguilla anguilla,* make up 99.8 percent of world production in 2003. They have a long larval stage of 5 to 6 months during which they are known as glass eels before they metamorphose into elvers. At the glass eel stage they are at the mercy of the ocean currents. Glass eels of *A. japonica* are carried by the Kuroshio current from the China all the way to the shores of Korea (Rep.) and Japan. Along the way they are collected to be nursed into elvers and later sold to growers.

At first glance, it would seem that Asian production consists mainly of the Japanese eel species and indeed FAO FISHSTAT Plus database identifies production from Asia as predominantly consisting of *A. japonica*. However this is far from being the case because during the last forty years Japanese glass eel catches have been falling in Asia. In 1965 the catch of Japanese glass eels reached 140 tonnes. By year 2000 this has fallen to 40 tonnes. To make up for the shortfall Asian growers have been buying European glass eels. Japanese eel growers started this practice in 1973 after eel production in Japan fell (Japan Fisheries Association, 1975). In the 1980s European eels amounted to only 3 percent of the glass eel stocks in Asia. But in the mid-1990s Asian traders bought 75 percent of the European glass eel stock. By the end of the 1990s with European glass eel imports ranging from 200 to 300 tonnes, it is believed that up to 80 percent of the eels in Asian eel farms consisted of European eels (Klinkhardt, 2004). (For the European eels, 3 to 4 kg of glass eels are required to produce 1 kg of eel, and 2.5 kg for the Japanese species).

*Seabass (*Lates calcarifer *aka barramundi) and Japanese seabass*

Barramundi (*Lates calcifer*) has not really taken off like it should with total production in the region fluctuating between 20 000 to 26 000 tonnes from 1995 to 2003. In all the Southeast Asian countries where it is farmed production has either stabilized or has even declined during the last five years. Thailand's production has increased but now appears relatively stable at the 7 800-tonne level, probably due to limited site availability and market saturation. In Taiwan (PC) production hit the 10 000-tonne level in 1993 to 1995 but is now down to less than 5 000 tonnes since 1999. The production of Hong Kong (SAR) of some 200 tonnes between 1993 to 1995 is down to less than 10 tonnes since 2001. This may be due to a shift towards other high value species and limited site availability.

Production of seabass is increasing only in Australia (94 tonnes in 1991 to 1 486 tonnes in 2003) and Korea (Rep.) (797 tonnes in 1999 to 2 788 in 2003). The species reared in Korea (Rep.) is the Japanese seabass (*Lateolabrax japonicus*). Japanese hatcheries regularly produce fingerlings of the species (664 000 in 1995–1996 with 404 000 released for stock enhancement), but there is no report of its production from aquaculture. There does not seem to be a very large international trade in these species either live or processed and present expansion as in Australia and Korea (Rep.) appears to be based mostly, if not totally, on local or near-regional market.

The possibility of developing a market for seabass in Europe where seabass enjoys a good market is often raised as one way of widening the market. However the European seabass is a different speciesand is not all related to the Asian seabass. It belongs to another family altogether, the Moronidae.

Groupers

Groupers are valuable only when marketed live. Once dead, its price drops to less than 50 percent or even 30 percent of its price no matter how fresh. The biggest market for live grouper is in Asia, notably Hong Kong (SAR). It is not surprising therefore that the amount of grouper cultured outside Southeast Asia and East Asia is negligible. Grouper production has never been large. Until 2002 reported production was only 22 814 tonnes. This more than doubled to 51 915 tonnes in 2003 due to the entry of China with 26 790 tonnes. Very few countries report up to the species level so that only five species are found in the FAO FISHSTAT Plus database: *Epihephelus coiodes* (orange-spotted grouper), *E. tauvina* (greasy grouper), *E. areolatus* (Areolate grouper), *E. akaara* (Hong Kong grouper) and the *Plectropomus maculatus* (spotted coral trout) but many countries lump together their grouper production at the genus level. In the case of Indonesia most of the production actually consists of two species, the tiger grouper, *E. fuscoguttatus*, and the mouse or humpback grouper, *Cromileptis altiveles*. These are the two species where Indonesia has had remarkable success in seed production, the technology of which has been adopted down to the backyard scale level.

Elsewhere, the species of choice for grow-out has been either the orange spotted grouper or the greasy grouper although there is an increasing interest on tiger grouper. Although the humpback grouper commands a very high price in Hong Kong (SAR) it takes 18 months to grow to the 0.5 kg size preferred by the market. The other species can be harvested in eight months. Outside Indonesia hatchery production of grouper fingerlings is still largely confined to institutional or large commercial facilities and use of wild-caught fingerlings is still widespread. The coral trout, *Plectropomus leopardus* and the Napoleon wrasse *Chelinus undulatus* are raised or fattened in cages using various sizes of wild-caught juveniles.

Other carnivorous fish

Over 20 species of other carnivorous finfish are reported and are principally cultured in marine or brackish waters, usually in cages.

Cobia or sergeant fish (*Rachycentron* spp.) has increased rapidly in Taiwan (PC) to over 3 300 tonnes in 2001 from almost nil six years before. Culture of this species has also started in other countries such as the Philippines, Thailand and Viet Nam, possibly as a result of availability of fingerlings initially from Taiwan (PC) but increasingly from local hatcheries. Formulated diets are also available commercially. The rapid growth rate of this species (peak of one kilogram per month), docility, and relative hardiness in tanks and cages makes it an attractive species for aquaculture. Due to its size and white meat it was thought that it can be developed into an alternative sashimi species particularly for the lucrative Japanese market. However it appears that market acceptance has to increase before the species can take off. As this species is relatively recent, it is not yet reflected in statistics and there is currently little available production information.

Southern bluefin tuna in Australia has emerged as a significant industry for the country over the past 10 years reaching 9 051 tonnes in 2001. Although the volume is relatively low compared with the Japanese amberjack production, the very high value of this product makes it a significant economic activity where it is practiced.

Other marine finfish not elsewhere identified (nei)

This group of fish is of interest because of the large reported production from China. Since the individual species are not reported, trends cannot be determined. It is probably fair to assume that most of these are carnivorous and being fed on trash fish from the Chinese capture fisheries.

2.4.3 Finfish requiring lower inputs

Omnivorous and herbivorous fish, mostly raised in freshwater, have been important food fish for developing countries in the Asia Pacific Region. Traditional production methods have become diversified and intensified, starting with fertilized polyculture systems and moving towards systems using supplemental feeds and even complete feeds. As demand for fish increases and prices rise, the further pressure on intensification and use of feeding can be expected in many countries.

Backyard ponds are an increasingly common sight in many countries; however this production is frequently missed in national statistical surveys due to the small unit size and incomplete survey questionnaire. In many cases ponds may be below the size required for registration and is not viewed as a significant economic activity. The large numbers of these ponds and the aggregated production and value to the households engaging in the activity is probably very significant. The lack of reliable information from this part of the sector currently limits the evaluation of the grass-roots impact of rural aquaculture in the Asia-Pacific region.

It has been suggested that the wide range of species that are currently produced from aquaculture will decrease as greater rationalization and aggregation of production operations focus on a small number of species. This lesson has been taken from the livestock sector and is considered to be an essential part of the “industrialization” of aquaculture. This trend does not appear to be the case so far in the Asia-Pacific region with farmers increasingly seeking out new species that give them a marketing or profit advantage.

Tilapia

This “industrialization” trend is seen in some countries with species such as Tilapia. There is a trend towards standardization of size, feeds and production systems, some quality control, avoidance of off-flavours, and marketing into supermarket chains. However, even with Tilapia, there is still the flexibility of systems, strains and colours of fish. There is probably more diversity in Tilapia culture systems today than 10 years ago with a range of characteristics including:

- Colouration (red, white and black strains)
- Monosex and mixed sex
- Pellet fed, supplemental feed and fertilized greenwater
- Freshwater and brackishwater
- Cold tolerance
- Pond, cage, pens and hydroponics culture systems

Reported exports of tilapia are low. The continuing domestic demand and the high quality required for export targeted fish means that domestic marketing is still attractive in many countries. This is especially the case in the Philippines where the species has a long history of market acceptance. In spite of the fact that it is the third largest producer of tilapia after China and Egypt, the Philippines has not established an export market for tilapia unlike Thailand and Taiwan (PC). Philippine processors find it difficult to find a sufficient and consistent volume of large size fish (minimum of 600 g) at an acceptable farm gate price considering that the local market preference is for smaller size fish (200 to 350 g).

Carps and barbs (cyprinids)

Like all the other species groups, carps and barbs is very much an Asian fish with 97.6 percent of world production of 17.72 million tonnes coming from Asia. The group continues to be most popular species group among Asia Pacific countries dominating 8 ranks of top 10 species production from all environments and 9 out of top 10 freshwater species. Their production is particularly important in terms of vital supply of protein in major populous countries in the region such as China, India and Bangladesh.

Silver carp continues to be the top species Asia wide with grass carp a close second. In China however grass carp has edged out silver carp since 2000. The continued growth of silver carp outside China has kept it ahead. Common carp, the third largest production species, is also the most commonly cultured species in the region; 18 countries and areas have reported culturing this species.

Although production of most species in this group generally exhibits increasing trends, the rate of growth for some species has started to show signs of slowing down since 1997 (e.g. silver carp and bighead carp). There are reports that the profitability of farming these species in India and China is declining and farmers are starting to explore the production of alternative higher value species. Since the markets of these species are largely domestic, there is little opportunity for export, although India for example does export to neighboring Nepal and Bangladesh.

Milkfish

The Philippines and Indonesia are traditionally the largest producers of milkfish, which reflects the strong tradition for the species in both countries. However there is a stronger preference for the species in the Philippines than in Indonesia where freshwater species such as common carp and gourami are more preferred. There is a strong milkfish industry in Taiwan (PC) although production there has seen some reduction possibly because it is increasingly focusing on higher value species. There are also traditions of milkfish culture in some of the Pacific Islands (Kiribati, Nauru, Cook Islands and Palau). Singapore is also steadily developing its mariculture of milkfish.

There is a growing interest on the species in Viet Nam, India, Sri Lanka probably due to the perceived market potential as exports of value-added milkfish products from the Philippines continue to increase. Furthermore there has always been a market for small-size milkfish (80 to 100 g size) for use as bait-fish in tuna fishing.

Milkfish have typically been produced in brackish water ponds, but in the Philippines they are grown in lake-based freshwater pens and cages as well and there is an increasing trend to culture it in sea cages under intensive conditions. These cage systems are fed exclusively with extruded pellets and are part of the general trend of intensification of mariculture in the Philippines. Sea-grown milkfish generally commands a higher price than those raised in brackishwater pond or freshwater pens and cages because of their size (350 to 600 g) and their taste. Milkfish is a low trophic level species. In ponds they can be grown completely on natural feeds although supplemental feed is required at higher densities. However milkfish is never fed with trash fish. As supplemental feed, Philippine milkfish growers use stale bread from bakeries, broken ice-cream cones, unsold snack items that have gone beyond their shelf life and the like. For full feeding such as required in sea cages the use of pelletized feed is essential.

Until the 1990s, the milkfish aquaculture relied totally on wild-caught fry. The technology for its propagation in captivity was developed in the early 1980s but commercial milkfish hatcheries ventures had their first start in Taiwan (PC) followed by Indonesia where backyard scale hatcheries developed. The major market for the milkfish fry produced by these hatcheries is the Philippines. Ironically milkfish hatchery ventures in the Philippines started only in the later part of 1990s. Although several hatcheries are now in operation, import of fry from Indonesia continues due to the seasonality of spawning in the Philippines. In contrast the species spawn almost year round in Indonesia and being south of the Equator, their spawning peak apparently coincides with the low months in the Philippines. One difficulty with milkfish compared to tilapia for instance, is that it takes at least five years for the species to reach sexual maturity. Wild-caught mature fish do not reproduce as well in captivity as fish grown in ponds or sea cages, are difficult to handle and suffer high mortality in captivity.

Mullet

Although mullets are very similar to milkfish in terms of habitat and food niche, mullet culture has never really taken off. Grown mainly in brackishwater fishponds, Indonesia is the leading producer. But production has been in the 10 000 to 13 000-tonne level only. Taiwan (PC) produces some mullets but only at a few hundred tonne level with highest production topping only 2 000 tonnes at most. Korea (Rep.) is reporting increasing mariculture production in 2000 and 2001. Thailand used to produce a few hundred tonnes but this has dwindled to less than 100 tonnes by 1999 and has all but disappeared by 2003. Singapore now reports some mullet production from mariculture.

Rabbitfish

Probably one of the most under-rated fish are the siganids or more popularly known as rabbitfish or spinefoot. There was considerable interest on the species particularly among the Pacific island states in the 1970s to 1980s because of its herbivorous feeding habit. But such interest seems to have waned. Very few countries report any production of siganids. The Philippines is the top producer of the species but, although production is rising yearly, this amounted to no more than 84 tonnes in 2003. Saudi Arabia is the second biggest producer with 25 tonnes. Qatar, the United Arab Emirates and Cyprus all report some production of less than 0.5 tonne. Hatchery technology for the species is developed but so far has remained at the institutional level. The relatively low value of the fish is probably the reason for the lack of commercial interest. Operators of marine milkfish cages in the Philippines find the species useful as grazers to clean the net cages of algal foulers. They also command a higher price than milkfish. When cultured singly as a crop in itself they respond well to either tilapia or milkfish feed.

2.4.4 Macroalgae

Aquatic plant production can be divided into two distinct groups. The first consists of seaweeds of temperate waters solely and traditionally used for food purposes, the second consists of tropical species mainly processed as a source of commercially valuable biopolymers (carrageenan, agar) that are used for various food and non-food purposes. Among the aquatic plants the most important families, in volume and value, are the kelps, lavers, and carageenophytes.

Seaweeds for food

This group includes Japanese kelp, Laver (Nori), Green laver and Wakame. The production of these species is confined to East Asian countries and has a relatively stable production. The only exception is Japanese kelp culture; it has increased rapidly in recent years, probably due to continued expansion of culture areas in China. Production of Japanese kelp peaked in 1998 and since then has showed a decreasing trend. This might indicate that the rapid expansion of production area has reached a limit and further suitable sites are no longer available.

While all the species mentioned are grown in semi-tropical or temperate areas, there is at least one seaweed species cultured for food in the tropics – the *Caulerpa lentifera*. These are cultured in earthen ponds rather than in open waters. It enjoys a good market in the Philippines where it is eaten fresh as a salad.

Seaweeds for biopolymers

This group consists of *Eucheuma* for the production of carageenan and *Gracilaria* for the production of agar. It should be noted that Eucheuma is also eaten fresh in the Philippines and selling price of the seaweed for the fresh food market is substantially higher than when dried for processing. But the volume of such fresh product is low.

The Philippines has the highest production of these aquatic plants and Kappaphycus [referred to in the statistics as Zanzibar weed] production in Philippines far exceeds the production of other seaweeds (879 580 tonnes in 2003). Indonesia is also a major producer of Kappaphycus, with Malaysia a far third. Cambodia entered the market since 2001 and production has doubled to 7 800 tonnes by 2003. Kiribati has had a regular production of Eucheuma since 1986 although yearly production appeared to be on a declining trend after reaching a peak of 11 174 tonnes in 2000. Fiji also has regular production but like Kiribati annual production has declined to 20 tonnes in 2003 after reaching a high of 1 500 tonnes in 1999. Eucheuma production in Micronesia has been consistently within a few hundred kilograms and is probably used for direct human consumption. Access to the nearest market will probably prevent a full take off of the seaweed industry in the Pacific islands even if they have suitable sites.

New areas are being investigated for expansion in Myanmar, Viet Nam and the Pacific Islands since global demand for carageenan and other alginates are expected to continue to rise. It is now farmed even in the United Republic of Tanzania using high yielding cultivars from the Philippines.

The Philippines has the advantage of having developed a strong processing industry to produce highly refined carageenan (HRC) and the lower-cost “semi-refined” carageenan which is now traded internationally as Philippine natural grade (PNG) carageenan. The reclassification of the Philippine natural grade carageenan as fit for human consumption in the Codex Alimentarius greatly expanded the market for the product. This was a move that was opposed for many years by European processors since the PNG carageenan can be produced at a much lower cost and competes seriously with the HRC. Where previously all of the seaweed produced was exported in dry form mostly to European processors, most of the seaweed are now processed locally.

Philippine processors also import raw dried seaweed from Indonesia and Malaysia whenever there is a local shortfall. European processors continue to import seaweed for processing but in the form of alkali-treated chips which greatly reduces shipping cost due to reduced bulk and can be handled like grains. Some European processors have established processing plants in the Philippines as well to produce the PNG carageenan. The development of local processing capability has helped stabilize prices ending the pattern of boom and bust when all of the seaweeds were marketed in unprocessed dry form. Lately Philippine seaweed farmers are enjoying record high prices due to the entry of raw dried seaweed buyers for China-based carageenan refining plants.

2.4.5 Molluscs

Mollusc culture is split into low value species produced in extensive type systems (*e.g.* seeded blood cockle mudflats, mussel and oyster stake culture) through to high value species produced in intensive systems (fed systems, and possibly recirculation). Whilst it is possible to separate species such as abalone or giant clam as high value species, there are difficulties with some species such as mussels that may be cultured in low input systems in one country (Thailand) but relatively high input in another (New Zealand). Many countries report their mollusc production in a large grouping such as marine molluscs nei. Among the molluscs, the oysters, venerid clams and scallops represent the greatest value.

The IFPRI/WorldFish outlook on to 2020 (Delgado *et al.*, 2003) projected increasing mollusc production, although this may have been based on current production trends rather than the resource potential. The issue of site availability is likely to constrain development of mollusc culture in several countries as can be seen for the examples of Japan and Korea (Rep.). In these two countries, the productions of molluscs and seaweeds have been relatively stable for many years. This indicates that suitable sites are now all taken. Unlike fish culture, the intensification of mollusc culture is quite difficult and probably not economically viable. The trend in mollusc culture is more likely to be a shift from lower value species to higher value species in those areas where sites are suitable. A further dimension is the development of intensive on shore culture operations such as those for abalone although in the Philippines, Indonesia and Thailand abalone is grown in sea-based cages. On-shore culture operations end at the late juvenile stage. Myanmar is also reported to have started growing abalone while Viet Nam is still at the R & D stage. Aside from abalone another gastropod species being cultured is the Babylonia snail (a whelk) which is grown in China, Viet Nam and Thailand.

One major difference in the culture of bivalve mollusk and gastropods is in the source of seedstock. Where oysters, mussels and cockles rely mainly on natural spatfall, seedstock of both abalone and Babylon shell are produced in hatcheries. The giant clam is an exception among the bivalves in having the seedstock produced in hatcheries. The spawning of the giant clams in land-based tanks used to be a big undertaking due to their size. But a technique pioneered by Philippine marine biologists now makes it possible to spawn the clams in situ without having to move them. Since it takes years for the giant clams to grow these are seeded in natural habitats. Stocking success is related to the size they are stocked and the extent or degree of community organization and involvement in protecting the seeded area.

Pearl culture and export is a significant source of income in a numbe of countries in Oceania, as in the Cook Islands, French Polynesia and Australia. It is a growing industry in Indonesia. It has of course traditionally been a well-established industry in Japan and, for freshwater pearls, China. No comprehensive information on volume and value is available but its growing importance should warrant closer attention in future reviews.

2.4.6 Reptiles and amphibians

Reported species are soft shell turtle, crocodiles and frogs. China has greatly increased its reported production of soft-shell turtle in the past 5 years. Crocodile production is growing quickly in the region with Cambodia exporting juvenile crocodiles to both Viet Nam and China. Thailand, Indonesia, Malaysia and the Philippines also have crocodile farms which often also obtain revenues as entertainment parks. Papua New Guinea production targets the high value leather market in France and Japan. This production is rarely reported in fishery or aquaculture statistics. There is limited data on frog production, although frogs are being increasingly cultured in many countries. The small size of a typical frog farm (using small cement tanks or even pens) means that quantification of this type of operation is problematic.

2.4.7 Niche aquaculture species

There are a number of niche aquaculture species that this review does not cover with statistical information. These species are either cultured at pilot/experimental level or a simply not reported by many countries. Some of the species are not food type commodities (e.g. sponge and pearls, ornamental shells, ornamental fish) and are therefore not routinely monitored by the authority reporting fisheries information and may not be covered under the FAO global aquaculture statistics. Exceptions to this exist – the Cook Islands and French Polynesia report their pearl production in national statistics.

Pearls maybe the most important non-food species from aquaculture due to its high value. Pearls may be produced in marine and freshwater environment. Marine pearls from mother-of-pearl oysters are always more expensive although prices also vary widely based on the type of pearl. Japan pioneered in the production of cultured pearls and continues to be a leading producer and exporter but Japanese pearl production has fallen from 48 511 kg in 1997 to only 29 905 kg in 2001. As it exports, Japan is also a major importer although exports still outweighs its import. French Polynesia is the top exporter to Japan followed closely by Australia, then by Indonesia. However even as Japanese pearl exports has fallen (US$440 million in 2000 and US$308 million in 2001), so has imports from all sources from a total of US$327 million in 2000 to US$241 in 2001.

French Polynesia is the main producer of loose, South Sea black pearls with 95 percent share of world exports (9 tonnes in 1999). The pearls accounted for 95 percent of the country's export of goods. Exports to Japan alone in 2001 amounted to US$72 918 million. With such high value it would seem to be the ideal aquaculture product for many of the Pacific island states which do not have ready access to usual market for large volume fresh or frozen products since they are not usual ports of call of cargo vessels.

2.4.8 Marine and freshwater aquarium species

Ornamental marine species (corals, other invertebrates and fish) are collected and transported mainly from Southeast Asia, but also increasingly from several island nations in the Indian and Pacific Oceans, to consumers in the main destination markets: the United States, the European Union (EU) and, to a lesser extent, Japan. Whilst the collection and transportation of species is not strictly aquaculture, the culture of species for the aquarium trade is.

The marine aquarium trade is not confined to marine finfish, but also includes corals, and other invertebrate species. Coral species in seven genera (*Euphyllia, Goniopora, Acropora, Plerogyra, Catalaphyllia*) are the most popular, accounting for approximately 56 percent of the live coral trade between 1988 and 2002. Sixty-one species of soft coral are also traded, amounting to close to 390 000 pieces per year. An important distinction that can be made between the freshwater and marine aquarium trades is the level of reliance on capture of animals rather than culture. It is roughly estimated that the freshwater aquarium trade relies on cultured animals for 98 percent and only two percent of the products are captured[10]. The marine aquarium trade relies on capture for 98 percent of its production versus 2 percent culture[11]. There is therefore significant potential for increasing the contribution of aquaculture to the marine aquarium trade and the freshwater aquarium trade is also a significant aquaculture contributor in terms of value. By calculation – if the freshwater aquarium trade is 90 percent of total aquarium trade and 98 percent of that is cultured, then a crude estimate of the wholesale aquaculture value is approximately US$794 million. There are increasing trends to certify the aquarium trade if undertaken responsibly. There are opportunities for remote islands to benefit from this resource which is often one of the few livelihood options available to them.

Culture of giant clams for ornamental purposes in the Philippines suffered a setback with the passage of the Fisheries Code of 1998. The new law prohibits the trading of all species in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) list whether endangered or merely threatened and does not allow any exemptions for cultured stock. A similar problem faces seahorses.

[10] http://www.nmsfocean.org/chow/Best.pdf.

[11] Marine Aquarium Council Web site: http://www.aquariumcouncil.org/.

2.5 Seed supply

2.5.1 Freshwater fish

Seed production in hatcheries is the norm among freshwater fish species. For carps this has been done for centuries particularly in China and India. Freshwater fish hatcheries can vary from simple earthen ponds to indoor facilities with aerated concrete or fiberglass tanks. The fry are either produced through natural spawning and hatching or by hatching the eggs in incubators. All freshwater culture species are fully domesticated. Selection and hybridization is practiced to a certain extent in some species.

2.5.2 Marine fish

Seed production of marine fish species in hatcheries has a much shorter history than that of freshwater species. A significant amount of fingerlings are still caught from the wild for many of the marine fish now cultured. Considerable research work is often required to determine the proper way of handling the breeding stock, broodstock nutrition, the need to use hormone, type and dosage of hormone if required, type of natural food and artificial feeds, feeding rate, managing diseases, and even on proper way to pack and transport.

Broodstock of marine fish may be maintained in land-based concrete tanks or in sea-based cages. Spawning may be done also in cages as was done with milkfish during the early period of technology development although collection of eggs is more complicated and eggs of extraneous species may be included in the process. Rearing of larvae may be done in above ground tanks using natural feeds grown in separate tanks or in earthen ponds where natural food organisms are allowed to bloom.

Japan leads in the sheer number of species being propagated with most of the fingerlings produced released in natural waters for stock enhancement. Hatcheries in Taiwan (PC) advertise the availability of fingerlings of many species and are often the initial source for many of the Southeast Asian countries. Within Southeast Asia fingerlings for the following species can now be sourced from hatcheries: seabass, rabbitfish, milkfish, tiger grouper, orange-spotted grouper, humpback grouper, mangrove snapper, rabbitfish, cobia, and snub-nosed pompano. Work is still in progress for the giant grouper, coral trout and the Napoleon wrasse. While further refinement to improve survival rate may still be required among the groupers, part of the problem may be the lack of investments in such ventures. Yet significant refinement may come only once more private hatcheries get into the picture.

2.5.3 Crustaceans

Seedstock of giant river prawns and the penaeids now mostly come from hatcheries although a substantial amount of wild-caught stock may still be gathered in a few countries (*Penaeus monodon* fry in Bangladesh for instance). The “shrimp fever” in the 1980s fueled the establishment of many such hatcheries although as mentioned earlier until now penaeid broodstock are still caught from the wild. Although the hatchery technology for penaeid is considered mature, refinements continue to be introduced. One such refinement is the use of probiotics instead of antibiotics to maintain shrimp larval health. Many hatcheries for the giant tiger prawn around the region have closed down both due to the difficulty in catching high-health broodstock and the slump in the demand for postlarvae of the species as growers turn to the *Penaeus vannamei*.

The intricacies and expense in importing the Specific Pathogen Free (SPF) broodstock of *P. vannamei* from sources in the United States have limited seed production for this species to large companies. Some hatcheries in Thailand and Indonesia may be using second generation locally grown stock as brood animals – a practice which is not recommended by shrimp health experts and is often not sanctioned by authorities. However the inability of US suppliers to come up with the large number of brood animals required by Asian hatcheries often forces such practice in the light of huge local demand for PLs. The imported first generation SPF broodstock can be used only for about six months or so or up to ten spawnings and then replaced with new ones. At least Thailand and Indonesia have breeding programmes to develop local capability to produce SPF *P. vannamei* broodstock. One American company has established a grow-out facility for SPF stock in Singapore.

Among the crabs only the seedstock of Chinese river crabs appear to be mass propagated in hatcheries in a scale that has fuelled the development of the industry. Hatchery for mangrove crab (*Scylla* spp.) is still in its infancy and crab juvenile production is still largely in the hands of institutional hatcheries, but investments in this venture may soon increase due to the confluence of two factors. First, refinements in the technique have made survival rates more reliable even if still generally low. Secondly, wild stock of crab juveniles is getting scarce while demand for marketable crabs continue to increase both in the domestic and export market in most if not all countries in Asia. In the Philippines some localities that are rich source of crab juveniles have passed ordinances prohibiting the shipping out of the crab juveniles in order to protect both the local growers and the local crab resource. There is a growing interest in the region in the development of the hatchery industry for mangrove crab.

All lobsters now being grown still use wild-caught juveniles. Many grow-out activities maybe nothing more than fattening of full grown but underweight individuals. There is no report of any R & D work being done on lobsters in Asia.

2.5.4 Molluscs

Although hatchery technology is well established for many bivalve mollusks especially oysters, mussels and some venerids, it still makes more economic sense to collect natural spatfall. Except perhaps in Australia where some oyster spats are produced in a commercial hatchery and New Zealand for the green-shell mussel, by and large oyster and mussel farming in Asia and the Pacific relies on natural spatfall. The same is true for cockles and scallops. It is only among the gastropods (abalone and Babylon snail) that seeds are produced in hatcheries.

3. ECONOMICS AND TRADE

3.1 Contribution to economies

It is not possible to state with certainty and precision the dollars and cents contribution of aquaculture in the individual countries covered by this report. The information that have been contained in the NASO drafts are not comprehensive and very variable as to extent. This could be a reflection of most governments' having yet to consider aquaculture as a definite sector in itself, notwithstanding the general acknowledgement that aquaculture plays an important role in food security, providing employment and export earnings. Most if not all, of the countries covered in this report do not consider aquaculture separately from fisheries.

Table 9. Contribution of aquaculture to GDP[12] (2001)

Country	Aquaculture value as % of GDP
Lao (PDR)	5.775
Viet Nam	3.497
Bangladesh	2.688
Philippines	2.633
China	2.618
Thailand	2.071
Indonesia	1.662
Cambodia	0.893
Kiribati	0.752
India [13]	0.540
Sri Lanka	0.468
Malaysia	0.366
Nepal	0.345
Taiwan (PC)	0.324
New Zealand	0.189
Myanmar	0.167
Korea (Rep.)	0.145
Japan	0.108
Iran	0.105
Cook Islands	(a)
French Polynesia	(b)

(a) GDP figure is likely to be high – peak pearl production ca. 20% GDP
(b) French Polynesia has high GDP but pearls' share was declining

[12] GDP values calculated from ESCAP official statistics except Taiwan (PC).

[13] Data for the year 2000.

Reported export values of significant traded items (e.g. shrimp, catfish), hides a much broader range of other species (e.g. cobia, marble goby, *Macrobrachium rosenbergii*) traded between countries.

Aquaculture is a clear contributor to Gross Domestic Product (GDP) in many Asian countries accounting for over 1 percent of GDP in 7 of them (Table 9). Statistics related to export income from aquaculture products are not available and this constrains estimation of the contribution to foreign currency earnings through exports of aquaculture products. From the table of importance to GDP, it is clear that the country listings also closely match those countries which also export considerable amounts of aquaculture products (particularly shrimp). It has to be said though in the case of land-locked Lao (PDR) the high contribution of aquaculture to GDP maybe more due to the relative weakness of other production sectors.

In terms of employment, the figures vary from a few thousands (Australia) to millions (Bangladesh, China, Indonesia) as shown in Table 10. Not surprisingly China has the most number of jobs attributed to aquaculture at 4.3 million full time workers (employed more than 6 months of the year) and 6.0 million part time workers (engaged more than 3 months but less than 6 months a year). Bangladesh comes in strong also with 3.08 million fish farmers 0.6 million engaged in shrimp farming plus more than 1.0 million engaged in the gathering of fish and shrimp fry.

In the Philippines, the most recent (2002) Census of Agriculture and Fisheries counted only the number of aquafarm operators and establishment. The recent census show a six-fold increase in the number of operators from 27 280 in 1980 (the last previous Census) to 181 561 in 2002. Correspondingly the number of aquafarm establishments increased from 28 028 units in 1980 to 193 735 in 2002. The discrepancy in the number of operators and establishment indicate that some operators are involved in more than one establishment. An “aquafarm operator” is defined as “a person who takes technical and administrative responsibility of managing day to day operations of the aquafarm”. The number of workers in each establishment can range between a minimum of two for the smallest farm to more than one hundred in the larger establishments. Assuming an average of 3 persons per establishment, Philippine aquaculture could be directly employing about 600 000 persons.

Table 10. Employment in Asian aquaculture.

Country	Employment generated
Australia	4 221
Bangladesh	3.08 million fish farmers+0.6 million in shrimp farming+1.28 fry collectors
Cambodia	0.03 million fish farmers and seaweed farmers
China	4.3 million full time +6.0 million part-time
India	0.83 million FFDA + 0.3 million BW
Indonesia	2 384 million
Iran	18 749 or 11% of fisheries employment
Japan	117 733 (2003 fishery census)
Korea (Rep.)	63 570
Malaysia	21 114 directly employed (assume 4 hired workers per farmer)
Myanmar	0.026 million Registered Farm owners; Aquaculture sector employs over 612 000 and out of that 175 000 are full time workers, 437 000 are part time workers (Kyaw, 1998).
Nepal	0.022 million
Pakistan	1% of labour force
Philippines	600 000
Sri Lanka	0.057 million
Thailand	400 000 in FW aquaculture and allied industries, 78 000 in coastal aquaculture, 184 000 in processing plants and allied industries
Viet Nam	0.67 million

In Cambodia many coastal fishers have shifted to seaweed farming with an estimated more than 99 percent of the seaweed farmers having been fishers at one time.

In China, around half the people working in aquaculture have previously been involved in fishing. In the past people had been encouraged to convert rice farming areas to aquaculture. However, conversion of productive agricultural land to aquaculture is no longer allowed (a similar situation exists in India, although many countries in the region are now relaxing these policies). Where people leave aquaculture it is often because land has been re-zoned for other purposes. There is also a trend of men moving to cities to work while women take over the role of managing small-scale rural aquaculture activities.

Conversely, in Iran, people are moving into shrimp farming areas. Similarly India has a general trend of people moving into aquaculture with the government's emphasis on integrated aquaculture as a poverty alleviation measure in most states. Some aquaculture area is being lost to urbanization, as rising land values lead to conversion of land to other uses.

Exports are relatively better documented than other aspects of aquaculture. Here it can be seen that exports of individual countries range from a few hundred million US$ to a few thousand million US$ with China as the top exporter of aquaculture products with US$2 450 million in 2003 (Table 11). Thailand and Indonesia vie as second largest aquaculture exporters in Asia with some US$1 600 million followed closely by Viet Nam with US$1 555 million.

Table 11. Aquaculture export earnings from Asia and Australia, 2003.

Country	Major Export Commodities	Value (2003)
Australia	Blue fin tuna, Abalone, Shrimps, Salmon, Rock lobsters	AU$1 200 million
Bangladesh	Penaeid shrimps	US$288 million
Cambodia	Penaeid shrimps	US$2.7 million
China	Penaeid shrimps, various molluscs, seaweeds, unspecified. marine and freshwater fish fillet	US$2 450 million
India	Penaeid shrimps	US$800 million
Indonesia	Penaeid shrimps, live grouper,	US$1 644 million
Iran	Penaeid shrimps	US$32.65 million
Japan		
Korea (Rep.),		
Malaysia		
Myanmar	Penaeid shrimps, live grouper, crabs	US$317 million
Nepal		
Pakistan		insignificant
Philippines	Penaeid shrimps, Eucheuma seaweeds, live grouper, milkfish	US$200 million
Sri Lanka	Penaeid shrimps	SLR2 000 million
Thailand	Penaeid shrimps, tilapia	US$1 600 million
Viet Nam	Penaeid shrimps, Pangasius catfish,	US$1 555 million

Aquaculture export is focused on high value products, notably marine shrimps. Almost all the Southeast Asian and South Asian countries are shrimp exporters. The most notable success story in terms of non-shrimp export is that of the Pangasid catfish by Viet Nam. Although there were sporadic exports of a few hundred tonnes per year in the 1980s which stopped in 1984 but resumed in 1989 at few thousand tonnes, sustained large volume production started only in 1997 with 15 700 tonnes. This grew rapidly to reach 141 799 tonnes in 2003 earning for the country close to US$500 million. The main market for the *Pangasius* was the United States where it was competing with the catfish from the Southern states. Consequently the American catfish growers complained about dumping and lobbied successfully in Congress against its unrestricted entry. A law was passed allowing their imports only if these were referred to as “Basa fish” rather than catfish.

The paucity of economic data specific to aquaculture underlines the need to promote a good census and statistics as well as information gathering on aquaculture. While acknowledging its contribution to the economy and indeed promoting its development, little is being done by governments in actually monitoring aquaculture activities. Some efforts actually classify aquaculture activities as part of fisheries or of agriculture.

3.2 Exports

Fisheries dedicated to the live food fish trade, the ornamental trade, and local subsistence economies generate billions of dollars. The live reef fish trade has two main components-live food fish and ornamental aquarium fish. Accurate figures are not available on the total value of these trades, but extrapolation from partial estimates indicates that the total value of the aquarium trade exceeds US$1 billion per year.

There are concerns regarding the manner in which aquarium and live reef food fish are harvested from their environments. The methods for collection can be wasteful or harmful to other species and corals and techniques for transportation can be wasteful, although for some areas this is one of the few commercially exploitable resources. The total annual net benefit of sustainable coral reef fisheries across Southeast Asia is estimated to be US$2.4 billion per year.

3.2.1 The marine and freshwater aquarium trade

Southeast Asia is the hub of this trade, supplying up to 85 percent of the aquarium trade[14]. In 1985, the world export value of the marine aquarium trade was estimated at US$25 million to 40 million per year. Since 1985, trade in marine ornamentals has been increasing at an average rate of 14 percent annually. In 1996, the world export value was about US$200 million. The annual export of marine aquarium fish from Southeast Asia alone is, according to 1997 data, between 10 million and 30 million fish with a retail value of up to US$750 million, the actual value at point of sale is considerably higher.

By 2000, the global total wholesale value of live ornamental fish both freshwater and marine (live animals for aquarium only) was estimated at US$900 million, with an estimated retail value of US$3 billion (live animals for aquariums only). Asia provided more than 50 percent of the global total ornamental fish supply (FAO, 2000). Estimates place the value of the marine ornamental trade at US$200–330 million per year[15] and the overall value of the marine fish trade, accounts for about 10 percent of the international ornamental fish trade (marine and freshwater included)[16]. A total of 1 471 species of marine fish are traded worldwide but the ten “most traded” species account for about 36 percent of all fish traded for the years 1997 to 2002.

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[14] Useful references to marine aquarium trade can be found at:
Global Marine Aquarium Database: http://www.unep-wcmc.org/marine/GMAD/
http://marine.wri.org/.

[15] These trade figures were calculated by the UNEP report from export value of the top ten producers. Unofficial figures place these values much higher. There is also significant intraregional trade which also adds value.

[16] http://www.unep-wcmc.org/index.html?http://www.unep-wcmc.org/resources/publications/UNEP_WCMC_bio_series.htm~main.

4. CONTRIBUTION TO FOOD SECURITY, ACCESS TO FOOD NUTRITION AND FOOD SAFETY

4.1 Demand and market trends

The Asia-Pacific Region represents the most important region for aquaculture production, but also has countries with the highest per capita consumption. It is generally agreed that aquaculture production will continue to increase and that it is expected that fish supplies from capture fisheries have little room for further expansion.

Within each country, local population growth continues to fuel domestic demand for fish and other seafood. The per capita fish supply as derived from the population and fish production figures varies widely among the countries covered in this report from a low of 1.32 kg in Nepal to a high of 54.86 kg in Thailand as shown in Table 12. These figures are not adjusted for exports and imports so that the net per capita supply, which is often assumed to be the same as the per capita consumption may either be much lower or higher. Very few of the NASO's provided per capita consumption figures for the respective countries. Among these are Indonesia, Iran, Korea (Rep.) and Myanmar. Along these lines Korea (Rep.) and Myanmar are studies in contrast. In Korea (Rep.) the 52 kg per capita consumption reported far exceeds the per capita supply of 24 kg. This means the shortfall is being filled by exports. In Myanmar on the other hand the per capita supply of 32.13 kg exceeds that of the reported per capita consumption of 26.18 kg. This means a lot of the fish produced are being exported. Similarly the Philippines has a per capita fish consumption of 36 kg while the per capita supply is only 30 kg.

Table 12. Per capita fish supply (kg), selected countries in Asia and Australia, 2003.

Country	Per capita supply (kg) Capture	Culture	Total	Per capita consumption (kg)
Australia	10.48	1.92	12.40	10.9
Bangladesh	7.91	5.94	13.85	14.00
Cambodia	30.36	1.54	31.90	1.60
China	12.83	22.12	34.94	36.20
India	3.42	2.05	5.47	8.0
Indonesia	19.32	4.12	23.44	23.63
Iran	5.13	1.35	6.48	5.0
Japan	36.09	6.75	42.83	
Korea (Rep.)	23.10	0.89	23.99	52.0
Myanmar	26.98	5.14	32.13	26.18
Nepal	0.68	0.64	1.32	
Pakistan	3.48	0.07	3.55	2.0
Philippines	24.72	5.23	29.95	36[a/]
Sri Lanka	13.94	0.51	14.45	
Thailand	43.05	11.81	54.86	32 to 35
Viet Nam	19.95	11.22	31.18	

[a/] Food and Nutrition Research Institute (FNRI) Consumption Survey 1993.

The likely global trends for fish supply, demand and consumption have been forecast by the International Food Policy Research Institute (IFPRI) in collaboration with the WorldFish Centre (Delgado *et al.*, 2003). The conclusions are that consumption trends show an increase in the demand for fishery products for food, partly due to changing food habits and the increasing purchasing power of several developing countries. In the Asian region, it is expected that there will be a shift from the region being a net exporter of fishery products to being a net importer. Developing countries are expected to remain net exporters overall, but the percentage of their production exported is expected to decrease due to rising domestic demand. While there is a trend of decreasing fish consumption in developed countries due to increased urbanization, this does not seem likely to offset the increased demand for fish in developing countries.

Per capita fish consumption figures are available for Australia (10.9 kg), Indonesia (23.6 kg), Iran (5 kg), Myanmar (26.18 kg), Korea (Rep.) (52 kg), Pakistan (2 kg) and the Philippines (36 kg). In the other countries only the per capita fish supply or availability are reported. With the available figures from the NASO's plus other sources, fish and other seafood contribute 75 percent and 63 percent to animal protein intake in Cambodia and Bangladesh respectively. In China fish contributes only 32 percent of total animal protein intake. In the Philippines fish constitute 52 percent of animal protein intake (when milk and milk products are included).

The cost of fishery products is also expected to increase since in most of the projected scenarios developed in the IPFRI 2020 report as supply cannot keep up with demand. Projected rise in prices between 1997 and 2020 are about 15 percent. Since the yield from capture fisheries is not expected to increase greatly, there is great emphasis placed on the aquaculture sector ability to provide increasing quantities of fish to satisfy the increasing demand in all regions. Several conditions must be satisfied in order that aquaculture is able to achieve this expectation. The current reliance on fishmeal as a protein source for feeds for aquaculture is a potential constraint (this is discussed in the next section).

The massive expansion of aquaculture that is required to satisfy the increasing demand for fish requires increasing production area as well as greatly increased intensity of production. Obtaining the land and water may be possible if the value of fishery products increases so that aquaculture can challenge other production systems for the use of the feeds, land and water required to effect this production. Alternatively, increased efficiency in the use of water and intensified production will reduce land requirements. The current intensity of production in many countries of Asia is such that there is considerable scope for increased production per unit area. However, the increased feed usage and probable increased water requirement will be a constraint.

Aquaculture currently competes with the livestock sector for fishmeal for feeds. If fish value increases the "purchasing power" of aquaculture may draw this resource away from the livestock sector. There are calls for aquaculture to reduce its reliance on fishmeals and increase the efficiency of their utilization. Whilst more efficient use of fishmeal is possible, the reduced reliance may be more difficult. In the face of increasing purchasing power of aquaculture feeds, it may be the livestock sector which makes the greater progress towards reducing reliance on fishmeals.

It is general knowledge that demand for live, high value marine fish such as groupers continues to grow in Asia, particularly Hong Kong (SAR), and China as a whole. And that such demand is being served by many of the Southeast Asian countries. But the volume of exports is very low compared to the production volume of aquaculture in general. The live fish trade continues to grow but is still to a large extent dependent on wild-caught supply. Under such circumstances it is fair to assume that the supply of live fish will increasingly come from aquaculture.

There is a growing export of tilapia fillet primarily to the United States. Major tilapia exporters are China, Taiwan (PC), Thailand and Indonesia. Philippine tilapia growers and processors have made very limited inroads in the export of tilapia fillet. A case can be made of the Philippines on the roles of the local and foreign markets in promoting the production and export of a species such as tilapia: A robust local market which prefers small fish (200 to 350 g) which can be attained in four to five months is the biggest constraint for Philippine tilapia export. This means growers are unlikely to grow the fish for three more months to a minimum of 600 g required for the fillet market only to be selling it at the same price or even lower to the processor/exporter. Meanwhile the exports of deboned milkfish in various forms is a rising industry with more and more companies in the Philippines entering the market which caters mainly to the ethnic Filipino market abroad. Recently, China entered into the deboned milkfish export market using milkfish grown in Taiwan (PC), which on the other hand has started hiring Filipino deboners to do the work in Taiwan (PC).

Demand for fish, and therefore consumption, depends on food preferences, available supply, cost and purchasing power of the market. While it is not possible with the data at hand to make precise demand projections for the various countries it is safe to project that the demand for fish in general and farmed fish in particular is likely to rise in the short and medium term: One, in the countries that already have fairly high per capita fish consumption, the decline in capture fisheries has to be compensated for by increase in aquaculture production. Two, in those where fish consumption is still very low, an increase in fish consumption under certain circumstances is a real possibility. Indonesia used to have a per capita fish consumption of only 12 kg as late as 1980. By 2002, the fish consumption has doubled to 23 kg. Iran is reported to have had a per capita fish consumption of only 1 kg in 1980, by 2001 consumption had gone up to 5 kg.

For a very long time in Asia, the production of fish and other aquatic products was limited to serving local demand. This changed when an economically resurgent post-war Japan started to source high value seafood, especially marine shrimps from the neighboring countries in Asia. This started the demand for high value seafood products overseas. With increased world trade, and with increased demand for seafood products in Europe and the United States, it would seem that the export market could have expanded considerably for aquaculture in general.

However aquaculture production, by and large, appears to remain geared mainly towards domestic consumption with the possible exemption of penaeid shrimps, and to a lesser extent certain species of marine finfish especially groupers. This is evident from an examination of world commodities trade statistics. Trade statistics does not distinguish between capture and aquaculture products. But some of the commodities/species can be assumed to come exclusively from aquaculture. These include carps, tilapia and milkfish. In carps the volume of exports is minuscule, even from China, considering the overwhelming magnitude of production. Most of it is in live form, indicating that these are ornamentals rather than food fish. In tilapia and milkfish the export volumes each year are not commensurate with the production levels (Table 13).

Table 13. Production and exports of three major farmed fish species from Asia, 1994 to 2003.

	Selected commodities (Volume in tonnes)							
	Carps				Milkfish		Tilapia	
Year	**Live**	**Fresh/ frozen**	**Export total**	**Aquaculture production**	**Export total**	**Aquaculture production**	**Export total**	**Aquaculture production**
1994	326	379	705	8 495 694	217	380 883		521 914
1995	222	2	224	10 131 847	114	365 626	11	619 640
1996	893	48	941	11 713 932	6 684	370 809	16 307	715 602
1997	952	24	976	12 942 163	9 649	364 300	29 583	824 066
1998	756	12	768	13 617 397	9 564	379 621	35 155	814 407
1999	3 165	6	3 171	14 582 940	9 756	441 731	40 041	901 637
2000	3 227	-	3 227	15 075 534	7 477	467 608	31 088	997 046
2001	3 912	8	3 920	15 876 242	12 285	494 873	47 317	1 110 301
2002	5 237	47	5 284	16 272 870	8 531	527 869	47 969	1 174 619
2003	5 429	23	5 452	16 796 824	9 997	552 009	45 007	1 315 295

5. ENVIRONMENT AND RESOURCES

5.1 Fishmeal and other fish-based ingredients for aquaculture feed[17]

Table 14 presents the "apparent utilization" of fish based feed ingredients in Asia Pacific countries[18]. The trends in the usage of fishmeal for aquaculture and other sectors are stable in many countries of the region. The trend in global production of fishmeal appears to be relatively stable and currently available information suggests that there is little likelihood of increasing total global production. This means that the expanding aquaculture and livestock sectors will be competing for a resource that is not increasing. This situation has been referred to as the "fishmeal trap" (FAO, 2000 p. 115) and it is considered that given the apparently limited supply of fishmeal and fish oil, the expansion of some types of aquaculture will be constrained (or stopped). This assumes that there will be little improvement in the efficiency of use of fishmeal and fish oil. It is also argued however, that given stable (neither increasing nor decreasing) supplies of raw fish for fishmeal production, the growing demand for fishmeal will drive the price of fishmeal and fish oil upwards. This will eventually reach a level where fish and shrimp farmers may not be able to afford to buy fish feeds that contain adequate amounts of fishmeal and fish oil to effectively produce their animals.

Table 14. Net fishmeal usage in the Asia-Pacific region (2001).

Country	Tonnes
China	1 622 136
Japan	688 396
Thailand	496 316
Taiwan (PC)	303 691
Philippines	156 126
Indonesia	104 479
Australia	104 012
Iran	68 096
Korea (Rep.)	59 578
Pakistan	33 742
Viet Nam	28 262
India	18 897
New Zealand	17 412
Sri Lanka	12 444
Bangladesh	6 358
Cambodia	2 200
Malaysia	1 316
Korea (DPR)	898
Papua New Guinea	792
Brunei Darussalam	328
New Caledonia	310
Macao (SAR)	301
Myanmar	257
Lao (PDR)	244

It was recently estimated that the global aquaculture industry uses about 35 percent of total fishmeal supply (Figure 6). This is a significant increase over estimated use in 1988. By 2010, the same author estimates aquaculture share of fishmeal usage will be 48 percent (Barlow, 2002). Globally, prices of fishmeal and fish oil are all expected to increase – by about 18 percent by 2020 (and at a faster rate than fish prices which are expected to increase only 15 percent overall). Efficiency of use of fishmeal is expected to rise as a reaction to increasing prices and competition between the livestock sector and aquaculture sector for the resource. It should be pointed out that to date, the greatest advances in the area of reducing the reliance on fishmeals appear to have been in the livestock sector.

[17] This section is drawn mainly from the conclusions and presented papers of the APFIC regional workshop on "Low value and "trash fish" in the Asia-Pacific region", Hanoi, Viet Nam, 7–9 June 2005.

[18] There are some important considerations when interpreting this information which are as follows:

- "Apparent utilization" is the sum of the quantities produced and imported, less the exported and re-exported quantities.
- Many countries do not submit complete information (e.g. Philippines does not report national production).
- These feed ingredients have various uses and are not solely used as aquaculture feeds.
- These ingredients do not include so called "trash fish" which are small, low market value species landed as part of fisheries catches and which are utilized directly as feeds and not transformed into meals.

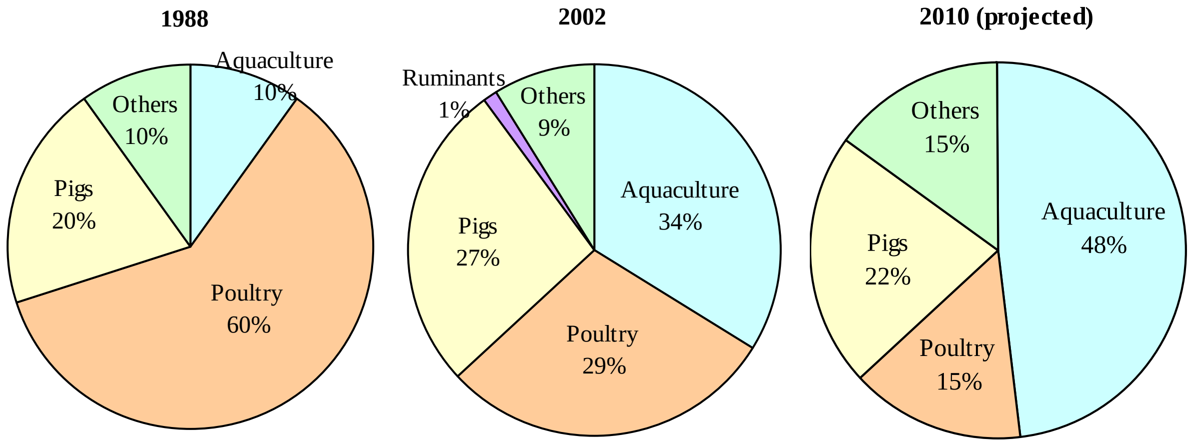

Figure 6. Share of total fishmeal use between sectors

Projections show that the rising cost of wild fish will also see aquaculture prices rising. The higher price for fish products may enable aquaculture to command a higher share of the fishmeal market. There is no doubt that the high value sector of aquaculture is growing and this sector is the most reliant on feeds containing fishmeal and fish oil. Even within the aquaculture sector there are likely to be shift in feeding and feed composition since the freshwater aquaculture sector has a greater opportunity to use non-marine sourced feed ingredients (particularly slaughterhouse wastes, brewery wastes and agricultural milling by-products). The purchasing power of maricultured fish and crustaceans will enable this part of the sector to afford higher fishmeal prices as demand increases. Combining the total aquaculture production of carnivorous fish species and crustaceans cultured in all types of environment[19], the approximate requirement for fishmeal for the Asia Pacific region including China in 2000 was over 1.2 million tonnes.

The fishmeal requirement of freshwater fish aquaculture is far more difficult to estimate, since such feeds vary from complete feeds containing fishmeal to supplemental feeds with no fishmeal whatsoever. It is clear from the Chinese statistics that China is already quite dependent upon imported fishmeal and this situation will become an increasingly important feature of the Chinese aquaculture industry. The inescapable conclusion is that even though fish prices will rise, the price of fishmeal will rise even more quickly and therefore there is considerable pressure on aquaculture to reduce its reliance on feeds containing fish meal and also increase the efficiency of its current usage of this resource.

Low value/“trash fish” feeding is a traditional method of feeding marine carnivorous fish throughout the Asia-Pacific region. These fish are typically landed at a single point (port) and typically in a poor state of preservation or severely damaged from the capture method used. Utilization of this fish is either through conversion into fishmeal or direct use for livestock or aquaculture in the general vicinity of the landing site. Low value/“trash fish” remains the method of choice for many farmers and especially for those farming presently low-volume species such as snapper (*Lutjanidae* spp.), grouper (*Epinephelus* spp. and other serranids) and many other marine fish where aquafeed manufacturers find it difficult to develop economically competitive pelleted feeds as an alternative to trash fish. For high-volume species such as yellowtail/Japanese amberjack (*Seriola quinqueradiata*), sea breams (*Sparus*/*Pagrus* spp.) and Asian seabass (*Lates calcarifer*), compounded, soft-dry, dry or extruded feeds are available as alternatives to trash fish and increasingly are becoming the preferred source of feed. But the availability of a compounded feed for a particular species will not necessarily mean that farmers will use it if trash fish is also available. For example, even though more than 120 000 tonnes of compounded feed are currently being fed to cultured yellowtail in Japan, farmers still prefer raw fish for yellowtail of 3+ kg (Lovatelli and New, 2004).

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[19] Freshwater, brackish water and marine water.

Diversification of aquaculture feeds

There will be an increasing availability of appropriate formulated feeds (farm made and commercial pellets) in the region. However, the formulated feeds for shrimp, fish fingerlings, marine finfish and lobsters still require high quality trash fish for fishmeal production If prices of fishmeal rise substantially this will also be accompanied by and increasing substitution of fishmeal, fish oil, "low value/trash fish". This will be most quickly seen in feeds for less carnivorous species. There is still currently limited knowledge of the nutritional requirements for many culture species.

Direct feeding of trash fish to pellet feeding – time to change

Whereas growth in the use of trash fish is not sustainable, the growth in aquaculture production is because aquafeeds can be used. At present the conversion of "low value/trash fish" to pellets which are more efficient feeds is not an economic proposition, but this may well change in the future. Feed development for shrimp is a good example of what the industry can achieve if there is sufficient demand. Feed formulations for tilapia and catfish feeds are relatively simple. The diversity of marine fish species requires different feed formulations (e.g. specific feed formulations for sea bass, various groupers and cobia) and this represents a constraint to the level of the demand for a specific feed. Currently formula aquafeeds contain much fishmeal though dependence on fishmeal can be reduced in the future. Although for rearing species such as grouper, fishmeal will continue to be needed, dependence on "low value/trash fish" can be greatly reduced through the use of pelleted feeds. Such a change will be essential for aquaculture expansion to continue.

Fish oil supplies are likely to run out long before supplies of fishmeal. Alternatives to fish oil in aquafeeds need to be sought urgently. At present, Viet Nam does not produce fish oil except for Pangasius oil (low value) and imports all fish oil required. Attention was drawn on the constraints in the availability of fish oil and on its importance as a primary source of nutritional element in particular of Omega III fats.

5.2 Water and land

The three basic issues on water and land as production factors are access, competition and degradation. Pollution of water resources is now joined by the scarcity of, and the fiercer competition over water resources. The issue of maximizing water use efficiency has been addressed by schemes of water re-use or recycling, adding value to water through integrated farming, and – in the case of inland water bodies – by sound culture-based fisheries. The problem of pollution, apart from better management and use of less polluting feed, is being addressed by such measures as low-cost treatment systems of discharges, zoning, regulations on location and densities of aquaculture facilities, as well as standards and regulations on water and effluent discharges and codes of practices on water and effluent management. The basic issue however remains to be the ability of small farmers to have access to these resources, which is an issue linked to property rights and distributional regimes.

The use of reservoirs for fish culture in cages is commonly practised in the Philippines and in Indonesia. Alternatively a reservoir can be stocked with fingerlings, managed as one big community fishpond. This setup requires a good organization. In freshwater aquaculture the problem of pollution need not crop up even in highly intensive systems. The nutrient waste discharge can be used to irrigate crops. Indeed agricultural crops can be a good nutrient sink (one commercial wheat farm in Al-Gassim, Saudi Arabia deliberately used ground water to culture tilapia intensively before releasing it to the wheat field). It becomes a problem only if discharged directly into a river or lake. Using fishpond discharge for irrigation is one way of maximizing water use efficiency through water re-use.

It is however not as easy in brackishwater or marine water aquaculture. Due to the saline nature of the water it cannot be used for irrigation. Thus some form of mitigation to reduce sediment and organic load is necessary before this can be discharged either directly to the sea or through tidal creeks. Low discharge or zero discharge systems is increasingly in use in shrimp farms. One impetus for shrimp farmers to recirculate their water instead of releasing and changing it with new water is the increasing threat of disease. The less new water introduced the less the risk of introducing disease organisms. Thus bio-security to protect the shrimp crop has proved to be beneficial to the environment as well.

The problem of conflicting resource use is even more acute for land. With increased population, urbanization and conversion of land for residential and industrial use is inevitable. Land resource is finite and land borders immutable. Traditionally some countries discourage the conversion of agricultural land to aquaculture due to concern on rice self-sufficiency. In such countries a shift in policy to allow conversion of agricultural land to aquaculture is allowing diversification (e.g. Viet Nam 2000). In other countries, conversion of agricultural land to aquaculture is strictly regulated under law or is currently an issue of concern and increasingly subject to regulation/zoning. In the Philippines conversion of agricultural land to fishpond needs prior clearance from the Department of Agrarian Reform since all fishponds are exempted from land reform. Furthermore aquaculture development is no longer allowed in the remaining mangrove forests.

As land becomes scarce the open waters of the sea becomes more and more attractive. Cage culture in open waters (nearshore and offshore) has been technically feasible for some time although in varying degrees of adoption among Asia-Pacific countries. The technical constraints for near- and offshore cage culture are still significant, but increasing scarcity and cost of land-based resources would likely make it an attractive investment option for governments and private sector. The Philippines is promoting the concept of mariculture parks where an area is identified and infrastructure in the form of moorings is pre-installed. This system pre-empts haphazard development with the resulting over-crowding and later fish kills as has happened several times in certain areas.

5.3 Genetic resources

As well as the natural resources, the maintenance of the biological, particularly, genetic resources for aquaculture have become an increasing concern. This issue is a complex one: it has links with management and use of the wild stocks (in fact with capture fishery management as a whole), breeding and domestication programmes, movements and introductions of species, release programmes and activities that are either part of an enhancement programme or associated with cultural and religious traditions. The bottom line for aquaculture is that farmers are assured a reliable supply of healthy, viable (preferably hatchery-produced) seed.

One issue that has received scant attention in the region is that of escapees of exotic species from aquaculture farms and hatcheries. In contrast, the issue of Atlantic salmon being raised in the Pacific side of the Americas is receiving considerable attention. This lack of interest is probably due to the fact that most of Asian aquaculture consists of exotic species anyway. However the introduction and massive use of an exotic shrimp species, the Pacific white shrimp has recently put the issue to the forefront. This is most likely due to the relatively strong opposition to its introduction by environmentalist afraid that it may bring equally exotic diseases and worse even alter local biodiversity by displacing a local species in a particular ecological niche.

Trade is the principal pathway by which exotic species are introduced both intentionally and unintentionally. One active entry point of exotics are the ornamentals. Perhaps due to the usually small number involved and the assurance (false it always turns out) that the animals will not go beyond the confines of aquaria and fish tanks, authorities are quite liberal in allowing them in without any need for import risk analysis. The common pleco or *Plecostomos* spp., a freshwater tropical fish belonging to the Armored catfish family (Loricariidae) from South America, was introduced in the Philippines by aquarium hobbyists in the last decade. It is popular for its propensity to clean the sides and bottom of tanks as it feeds so that it is more commonly known as janitor fish. But they have now proliferated in two river systems where they grow to half-meter size. Fishers complain that their raspy armor- like skin tears fish nets.

Concern on the issue is growing in the region. An Action Planning Workshop on Invasive Alien Species organized by the Asia-Pacific Economic Cooperation (APEC) was held in Beijing, China, 19–22 September 2005. The workshop was participated in by countries from the Asia-Pacific region such as Australia, Brunei Darussalam, China, Indonesia, Japan, Malaysia, New Zealand, Papua New Guinea, Korea (Rep.), Thailand and Viet Nam. Other countries who participated are Bangladesh, Chile, India. Italy, South Africa, United Kingdom and the United States.

5.4 Chemicals and drugs

The increase in intensification has lead to increased use of drugs and chemotherapeutants in aquaculture. This issue goes beyond aquaculture since food safety is a public health issue as well. For products intended for export the strict quality requirement on the part of the importing countries have served to raise local concern on the issue. Increased concern in turn has led to reduced use. Instead of antibiotics and chemicals there is an increasing use of microbial inoculants and probiotics which are intended to improve the water and soil quality, minimize the risk of bacterial infection through exclusion, or improve feed utilization. Also increasing is the use of herbal products to replace chemical therapeutants.

6. LEGAL INSTITUTIONAL AND MANAGEMENT ASPECTS

6.1 Promotion and management of the sector

This particular section will refer to “government” in general without specifying the specific levels and institutions involved as to its role in promoting and managing the sector. The characteristics of the institutional framework will be dealt with in the next section.

In most of Asia where the practice of aquaculture preceded governmental institutions aquaculture ventures were initiated by anyone with the means, inclination and opportunity to do so. To a large extent this still occurs especially in non-land dependent culture systems, i.e. cages and pens in open waters, even if permitting and licensing systems are already in place. How much of this is due to weak governance as to the normal disdain of people for bureaucratic procedures and payment of licences is beyond the scope of this report.

This does not mean however that governments in Asia no longer exert any effort to promote a specific technology. Most if not all of the countries allocate resources for promoting aquaculture development. Common to all of the countries is the promotion or introduction of a technology that involves all or any combination of the following activities:

- Establishment of a hatchery and making seedstock available
- Establishment of a demonstration and training farm
- Training of farmers
- Selecting and giving full assistance to a key farmer to apply and showcase a specific culture system
- Fielding of extension workers
- Provision of special loan programme
- In rare instances, marketing assistance
- Financial incentives for large-scale development

One approach which is not too common but has helped jumpstart development in an orderly and rational manner is the setting aside of public land for managed aquaculture development. The government through the existing institutions or a quasi-governmental corporation then undertakes the physical planning and development before distributing farm lots or ready to operate farms to smallholders. On the other hand this may be left to a private investor under specific development guidelines. A common central facility to produce seedstock, feeds as well as to process and market the harvest often, but not always, comes with such development. Such development approach had been taken in Indonesia, Iran and Brunei Darusalaam.

In Indonesia the government has a policy of allowing large-scale development only if allowance is made for the participation of small-scale holders through a nucleus-estate type of development. Individuals or companies going into brackishwater aquaculture are limited to 30 hectares within Java and 50 hectares in the outer island. Beyond such size the development has to follow the nucleus-estate concept wherein the excess area is developed into viable farm units for distribution to qualified smallholders.

This concept was applied in the development of tens of thousands of hectares of swamplands into shrimp farms in southern Sumatra. Upon development, half-hectare farms were transferred to qualified farmers. The companies operated hatcheries to supply shrimp postlarvae, feedmills to produce feed, and bought back the shrimps for processing in their own processing plants and eventual export. On the surface it looked ideal in that the farmers were not even required to put in any equity beyond their own labour. However a few years into the operation social problems erupted over the issue of pricing both of the inputs and the harvest and transparency in general. The developer had to abandon the 9 000-hectare farm when violence erupted. This failure is not an indictment of the concept since it has a number of positive attributes among which is equitable allocation of and access to resources.

In order to launch the development of the shrimp culture industry in Iran, the government pre-identified thousands of hectares of coastal desert lands along the Persian Gulf and allocated these for shrimp farm development. The government undertook the design, engineering and construction of common supply and drainage canals, pumping stations, road network and electrical grid. The area along the canals were then subdivided into 20–hectare lots and awarded to war veterans or their dependents. Financing was provided for the recipients to develop their respective farms according to a prescribed design. Production of shrimp fry and milling of feeds are left to private investors with the government merely providing financing. Marketing of the shrimps is likewise left to private traders. The government provided technical support to both hatchery operators and growers in terms of laboratory analysis and allowed them to hire foreign technicians. In certain instances the government itself hired foreign technicians and fielded them alongside their own extension workers who may not have any experience in shrimp farming but could at least act as interface between the foreign technician and the shrimp farmers, and learn in the process

Brunei Darussalam undertook an approach similar to Iran in promoting shrimp farming albeit on a much smaller scale. Areas were also identified and the government undertook the environmental impact studies. Roadways and electricity were provided and the selected area subdivided into farm lots. Actual design and construction of the farms were left to individual investors to undertake.

In Malaysia the effort of the government has been limited to identifying and classifying areas as Aquaculture Investment Zones (AIZ). Investors locating in the AIZ are entitled to financial incentives offered to large-scale agriculture development and production which is extended even to seed and feed production. These incentives include the following:

- Pioneer Status
- Investment Tax Allowance (ITA)
- Reinvestment Allowance (RA)
- Agricultural Allowance
- Deduction for Capital Expenditure on approved projects
- Export Credit Refinancing (ECR) Scheme
- Double Deduction for Export Credit Insurance Premium
- Double Deduction for Expenses on Promotion of Export
- Industrial Building Allowance (IBA)
- Incentives for Research and Development

In the Philippines the government has taken the planned development concept to the open waters through the mariculture parks. Marine waters within coves and bays that are relatively sheltered from strong wind action are identified and set aside for mariculture park development. Development consists of provision of mooring facilities at pre-set distances for sea cages. This has three purposes. One, it serves to limit mariculture activity to a pre-identified area. Two, the mooring system pre-sets the distances between cages as well as the number and size of cages. Three, it reduces the start up cost for fish cage operators since the mooring can take up even more than half of the capital cost in setting up the sea cages. Fish cage operators pay a yearly user fee part of which goes to upkeep, security and technical assistance. For those who lack the capital to put up their own cages, pre-installed cage frames are provided for a yearly fee so that the farmer need to invest only on the net-cages, fingerlings and feed.

In India, the establishment of the Fish Farmers' Development Agency (FFDA) at the district level has been credited in popularizing freshwater and brackishwater aquaculture. As many as 442 such FFDA's had been set up. They organized farmers for more focused provision of extension and other technical services.

In Bangladesh the effort of the government has been on culture-based fisheries rather than on aquaculture itself. Increased production of higher value fish species in Ox-bow lakes and the 68 000 ha man-made Kaptai lake has been attributed to a regular stocking programme with major carps and exotic carps.

Viet Nam fast-tracked aquaculture development through policies that addressed five areas of concerns (Tran Van Bom, 2003): (1) Allow long term (15 to 20 years) lease of lands at a low rate (US$28/ha) for aquaculture use; (2) Encourage investors to avail of soft loans to finance large seed production farms and diversify their investments; (3) Strengthen and nurture a close working relationship and cooperation between Viet Nam and international bodies particularly in aquaculture; (4) Solicit support from advanced countries in matters of high technology on larval culture, and (5) Urge stakeholders in aquaculture (farmers, investors, teachers, aquaculture professionals, extension officers) to improve their English language skills in order to be able to participate meaningfully in international training courses and read aquaculture materials published in English.

Since 2004 however, a new law to govern fisheries came into effect in Viet Nam. The new fisheries law consolidated, amended and harmonized all previous policies, rules and regulations on fisheries and aquaculture. Criteria for safe and clean aquaculture areas will be standardized. Monitoring and quality control of aquaculture seeds, feeds and chemicals will be improved and community-based management of aquaculture areas will be implemented.

In many instances promotion of aquaculture has largely met little problem in most parts of Asia. On the other hand, if a certain aquaculture venture turns out to be profitable, governments had often found it difficult to control or stop runaway development until a catastrophic mass mortality and other related problems occur. Viewed in this light, industry growth is self-limiting. This occurred in shrimp farming in almost all the countries in Southeast Asia as well as in China. It is still happening with regularity in fish cage and fish pen operation in the Philippines both in freshwater lakes and shallow marine waters. The problem in Asia often is not as much one on promotion as it is on management. Beyond issuance of permits and licences governments in Asia are increasingly realizing the need to protect the environment and manage aquaculture resources in a sustainable manner. In New Caledonia a rigid system of self-regulation applying to all prawn farmers (*P. stylirostris*) has been put in place in order for the industry to meet the high quality standards demanded of its niche markets in Japan and France. In New Caledonia, a strict system of sef-regulatin among shrimp (*L. stylirostris*) farmers has been put in place to meet the high quality standards demanded of its niche markets in Japan.

Thus while maintaining policies to encourage the development or further develop the aquaculture industry through liberal land use policies with long-term and low-cost lease options, liberal financing, technology development, and other incentives, most of the countries in Asia, are also trying to mitigate the negative consequences of runaway development by instituting rules and regulations on the following:

- Environmental impact assessment
- Ban on further clearing of mangrove forests for aquaculture development
- Imposition of a green belt along the shoreline and river banks
- Licensing of all aquaculture operations including hatcheries with the licence often required by banks for loan applications
- Allowable size of fish cages and spacing between such cages
- Banning the use of a specific list of chemicals and therapeutants
- Inspection of and imposition of quarantine procedures on movements of live fish

Increasingly many of the countries in Southeast Asia are already promoting voluntary compliance to a code of conduct for responsible aquaculture. In the Philippines major elements of responsible fisheries has been codified into one law through the Philippine Fisheries Code of 1998. Awareness and understanding of the FAO Code of Conduct for Responsible Fisheries among the Southeast Asian countries has been one of the major concerns of the SEAFDEC. This was done through the formulation of regional guidelines on the Code of Conduct for Responsible Fisheries covering aquaculture as well as fishing technology and fish processing.

6.2 General characteristics of the institutional framework

In aquaculture management it is well to distinguish between policy concerns, international trade and directions from the day to day activities of administration such as licensing, permitting and enforcement. Policy, international trade and directions are always national concerns. In all of Asia, national concerns on aquaculture are always administered at the sub-ministerial level. In some countries this can be at the second level of government (directorate-general or bureau), or at the third level (directorate or division) (Table 15a).

Most of the Pacific islands manage aquaculture at the ministerial level within the same umbrella responsible for capture fisheries. Few countries have ministries specific for aquaculture although in 2001 French Polynesia established a separate pearl ministry responsible to the President in recognition of the national importance of this industry.

In managing aquaculture the relevant national agency directly concerned with aquaculture often has to relate and work with other national agencies. This is unavoidable since aquaculture activities always require other non-fisheries services. In Australia the Department of Agriculture, Fisheries and Forestry (DAFF) interfaces at the highest level with the Primary Industries Ministerial Council (PIMC) on issues of national importance to better integrate Australia’s conservation and sustainable production objectives. In Bangladesh leasing of public water bodies is under the jurisdiction of the Land Administration and Land Reform Division (LALRD) while aquaculture as part of rural development is carried out through the Bangladesh Rural Development Board (BRDB). The use of mangrove forests in the Philippines is administered by the Bureau of Forestry under the Department of the Environment and Natural Resources which also enforces environmental compliance of all aquaculture activities through its Environmental Management Bureau.

Exports and trade issues on aquaculture products are handled by the agency concerned with trade in general such as the Export Promotion Bureau in Bangladesh and the Bureau of Export Trade Promotion of the Department of Trade and Industry in the Philippines. In India a special body called the Marine Product Export Development Authority under the Ministry of Commerce was created expressly to promote exports of shrimps and other fisheries products.

It is in the day-to-day administration where the countries vary greatly from each other. In countries with a federal form of government such as Australia and India all of the aquaculture management functions including extension are left to each State. In Malaysia the federal government still maintains control over aquaculture in marine waters with land-based aquaculture lying with the state governments. The non-peninsular states of Sabah and Sarawak however have control over all aquaculture activities whether land-based or sea-based. There is a proposal to extend the same degree of control to all the other States. As can be seen in Table 15b, some countries such as China, Indonesia and the Philippines, the day-to-day administration of aquaculture is delegated to the local government. In China licensing and permitting are done by the people's government at the county level or higher, in Indonesia at the provincial level and in the Philippines at the municipal level (except in the issuance of fishpond lease agreements for public lands which is done at the national level). Extension remains a national government function in most of Asia including China and Indonesia. The Philippines is the only exemption with the entire agriculture extension service devolved in 1991 to the municipal governments.

Table 15a. Institutions involved in the management of aquaculture – Asia and Oceania.

Country	Policies, directions, coordination, quarantine	Permits, licences, enforcement	Extension
Australia	Federal government Fisheries and Aquaculture branch of DAFF	State Government	State Government
Bangladesh	Department of Fisheries under the Ministry of Fisheries and Livestock	Department of Fisheries under the Ministry of Fisheries and Livestock	Department of Fisheries under the Ministry of Fisheries and Livestock
Cambodia	Department of Fisheries under the Ministry of Agriculture Forestry and Fisheries	Department of Fisheries under the Ministry of Agriculture Forestry and Fisheries	Department of Fisheries under the Ministry of Agriculture Forestry and Fisheries
China	Bureau of Fisheries under the Ministry of Agriculture	People's govt at county level or higher	Nat. Fisheries Extension Center under Bureau of Fisheries
India	Div. of Fisheries under the Department of Animal Husbandry and Dairying of the Min, of Agriculture	Fisheries Departments of respective States	Fisheries Departments of respective states and Fish Farmers Devt Agency
Indonesia	Dir. Gen of Aquaculture under the Ministry of Fisheries and Marine Affairs	Provincial Marine Fisheries Service	
Iran	Shilat under the Ministry of Jihad for Agriculture	Shilat under the Ministry of Jihad for Agriculture	Shilat under the Ministry of Jihad for Agriculture
Japan			
Korea (Rep.)	Fishery Resources Bureau of the Ministry of Marine Affairs and Fisheries (MOMAF)	Fishery Resources Bureau of the Ministry of Marine Affairs and Fisheries (MOMAF)	Fishery Resources Bureau of the Ministry of Marine Affairs and Fisheries (MOMAF)
Malaysia	Department of Fisheries under the Ministry of Agriculture	DOF but only for aquaculture in marine waters. No permit needed for land based. Being proposed is uniform licensing at State level.	

Country	Policies, directions, coordination, quarantine	Permits, licences, enforcement	Extension
Myanmar	Department of Fisheries under Ministry of Livestock and Fisheries	Department of Fisheries under Ministry of Livestock and Fisheries	Department of Fisheries under Ministry of Livestock and Fisheries
Nepal	Directorate of Fisheries Devt, under the Ministry of Agriculture and Coops	Directorate of Fisheries Devt, under the Ministry of Agriculture and Coops	
Pakistan	Fisheries Development Commission under the Ministry, of Fisheries, Agriculture and Livestock (MINFAL)	Provincial Department of Fisheries	Provincial Department of Fisheries
Philippines	Aquaculture Div. of the Bureau of Fisheries and Aquatic Resources under the Department of Agriculture	Municipal Government except for issuance of Fishpond Lease Agreements for public lands	Municipal Government
Sri Lanka	Nat. Aquaculture Devt. Authority (NAQDA) under the Ministry of Fisheries and Aquatic Resources	NAQDA	NAQDA
Thailand	Department of Fisheries under the Ministry of Agriculture and Coops	Provincial branch of DOF	Provincila Branch of DOF
Viet Nam	Ministry of Fisheries	Ministry of Fisheries	Nat Fisheries Extension Center

Table 15b. Institutions involved in the management of aquaculture – Pacific Islands.

Country	Policies, directions, coordination, quarantine	Permits, licences, enforcement	Extension
Cook Islands	Ministry of Marine Resources	Local government (Island Council)	Ministry of Marine Resources
Fiji	Ministry of Fisheries and Forests	Ministry of Fisheries and Forests	
French Polynesia	Ministry of Fisheries, Ministry of Pearl		Ministries of fishery and of pearl
Kiribati	Ministry of Fisheries and Marine Resources Development		Ministry, Atoll Seaweed Company (govt cooperation)
Marshall Islands	Marshall Islands Marine Resources Authority		Authority
Micronesia	Department of Economic Development		State Departments
Nauru	Nauru Fisheries and Marine Resources Authority		
New Caledonia	Provincial Government	Provincial government	Provincial government
Palau	Bureau of Marine Resources		

Country	Policies, directions, coordination, quarantine	Permits, licences, enforcement	Extension
Papua New Guinea	National Fisheries Authority Department of Agriculture and Livestock Provincial Governments.	Provincial government	Provincial government
Samoa	Department of Agriculture, Forests, Fisheries and Meteorology (Fisheries Division).	Department of Agriculture, Forests, Fisheries and Meteorology (Fisheries Division).	Department of Agriculture, Forests, Fisheries and Meteorology (Fisheries Division).
Solomon Islands	Ministry of Fisheries	Ministry of Fisheries.	Ministry of Fisheries.
Tonga	Ministry of Fisheries.	Ministry of Fisheries.	Ministry of Fisheries.
Vanuatu	Ministry of Agriculture, Livestock, Forestry and Fisheries	Department of Fisheries	Department of Fisheries

In the Pacific, there is a general absence of aquaculture policies at regional and national levels; the majority of countries have no legislation deasling with aquaculture, often relying on provisions of other statutes, particularly those on fisheries. In some cases, countries with no aquaculture seem to have an over-prescription of regulations compared to countries with a more advanced aquaculture. Some common issues that need to be addressed in policy and legislation include allocation of space, statutory rights on the sale of cultured fish and collection of broodstock and spat, renewable licensing for environmental effects, devolution to local government units of monitoring and enforcement of controls, and food safety.

The poor uptake of commercialization from research and development efforts could be attributed to the lack of policy and regulatory framework to support aquaculture entrepreneurship. This can be explained by the fact that the government agencies responsible for aquaculture are essentially fisheries departments with a tradition of harvesting from the wild rather than agriculture background, which would be more applicable to aquaculture. This situation is exacerbated by the entire aquaculture service being housed in a small section of a national breeding facility with poor or no links to the broader fisheries extension service.

6.3 Status of governing regulations and issues relating to implementation

The countries covered in this synthesis already have adequate laws for the routine administration of aquaculture. What they usually lack are well designed programmes to propel development towards a specific vision. Or, where there is a specific vision and programme, actual implementation is hobbled by lack of funding support at the institutional and farm levels. This is exacerbated by the lack of trained field personnel.

The lack of personnel is particularly true in extension work which is invariably undermanned and under-funded. In practically all of the Southeast Asian countries it is the field technicians of feed companies who become the surrogate extension agents, and are generally seen as more knowledgeable and better experienced (as well as motivated) than government personnel. Part of the blame may lie in attempts to streamline the bureaucracy as conditions to structural loan packages. This has impacted on the fisheries extension systems. For example, in Indonesia and the Philippines the extension service under their respective fisheries agency were integrated with agricultural extension with the idea of having one extension officer to take care of fisheries, crops, livestock, forestry, etc. Agricultural technicians were given training in aquaculture and fishing and fisheries technicians were given training in crops or livestock. A fair conclusion as to the effect of this is that the expertise becomes shallow and focus of service greatly diffused. Add the generally low remuneration level for extension workers and you have a greatly diminished effectiveness of the entire service.

In terms of licence, permits and enforcement centralized issuance from the national agency seems to be the rule in Asia. Provision of local branches where most fisheries business can be transacted mitigates the centralized system. Giving the fisheries administration to the local government as is the case in Indonesia, China and the Philippines has the net effect of bringing the service closer to the people and reducing the bureaucratic chain. However how well this function is carried out depends very much on the technical capability of the local government. In the Philippines the devolution agriculture and fisheries administration including extension has had an uneven result. In local government units with enlightened leadership and the right priorities, the needs of farmers and fishers are attended to very well and there is a degree of dynamism in the implementation of agricultural and fisheries programmes.

Whatever the deficiencies or shortcomings of the fisheries bureaucracy in Asia it is still better than having no such bureaucracy at all. This much is evident based on the experience of Sri Lanka. In July 1990 the government of Sri Lanka “withdrew state patronage from inland fisheries and aquaculture”. In effect the whole bureaucracy involved in inland fisheries and aquaculture was deleted and the implementation of the aquaculture part of the National Fisheries Development Plan discontinued. Shrimp farming and ornamental fish breeding continued since these were completely in the hands of the private sector. With seed supply, extension and technical support terminated the production from inland fisheries and aquaculture dropped from 39 900 tonnes in 1990 to only 12 000 tonnes in 1994. Sri Lanka has since resumed its inland fisheries and aquaculture programme with the establishment of the National Aquaculture Development Authority (NAQDA) in 1998.

In the Pacific there is a general absence of aquaculture policies both at regional and national levels. The majority of countries do not have legislation dealing with aquaculture, often relying on provisions in other statutes, particularly fisheries legislation. In some cases countries with no aquaculture would appear to have an over prescription of regulations compared to other countries where aquaculture was more advanced. Some common issues that need to be addressed in policy and legislation include: (1) provision of effective means for allocation of space; (2) provision of statutory rights for sale of aquaculture fish and collection of broodstock and spat; (3) renewable licensing for environmental effects; (4) devolution of monitoring and enforcement of controls, and (5) seafood safety controls.

The poor uptake of commercialisation from research and development efforts can often be attributed to a lack of proper policy and regulatory framework to support aquaculture entrepreneurship. In this is explained by the fact that the government ministries responsible for aquaculture are essentially fisheries departments with a tradition of harvesting from the wild rather then an agricultural farming background which is more applicable to aquaculture. This situation becomes more exacerbated where the entire aquaculture service is housed exclusively within a small section or a national breeding facility which has poor or no links to the broader fisheries extension services which interface with public.

6.4 Applied research

Aquaculture research can be carried out by a division within the fisheries agency as is the case in Iran. However in most of the countries covered in this synthesis aquaculture research is often carried out by a dedicated fisheries research agency such as the National Fisheries Research and Development Institute (NFRDI) in the Korea (Rep.) and the Philippines or the Aquaculture and Fisheries Research Institute (AFRI) of Pakistan. Sri Lanka also has its own National Aquatic Resources Research and Development Agency (NARA). Indonesia also has an Agency for Marine and Fisheries Research Affairs (AMFR) under the Ministry of Fisheries and Marine Affairs which is not under the Directorate General for Aquaculture (Table 16a).

Table 16a. Number of research institutions and personnel – Asia and Oceania.

Country	Research centers
Australia	1. Commonwealth Scientific and Industrial Research Organization (CSIRO) 2. Fisheries Research and Development Corporation (FRDC) 3. Seafood Services Australia 4. Bureau of Rural Sciences (BRS) 5. Australian Bureau of Agricultural and Resource Economics (ABARE) 6. Australian Institute of Marine Science (AIMS)
Bangladesh	1. Bangladesh Fisheries Research Institute (BFRI) 2. Bangladesh Agricultural Research Council (BARC)
Cambodia	
China	210 research institutions under the Chinese Academy of Fishery Sciences
India	1. ICAR, the nodal agency for agricultural research has eight fisheries research institutions but three are concerned with aquaculture: a. Central Institute of Freshwater Aquaculture (CIFA) b. Central Institute of Brackishwater Aquaculture (CIBA) c. Central Marine Fisheries Research Institute (CMFRI) 2. National Research Centre for Coldwater Fisheries
Indonesia	1. Agency for Marine and Fisheries Research Affairs (AMFR or BRKP) 2. Agency for Study and Assessment of Technology (BPPT) 3. Indonesian Science Institutes (LIPI)
Iran	Iranian Fisheries Research and Training Organization (IFRTO) affiliated with the Iranian Fisheries (Shilat) has nine research centers and two training centers
Japan	
Korea (Rep.)	1. National Fisheries Research Development Institute (NFRDI) 2. Pukyong National University
Malaysia	
Myanmar	
Nepal	Nepal Agriculture Research Council (NARC)
Pakistan	1. Pakistan Agriculture Research Council (PARC) 2. Aquaculture and Fisheries Research Institute (AFRI) 3. Fisheries Research and Training Institute (FRTI)
Philippines	1. Southeast Asian Fisheries Development Center – Aquaculture Department 2. Philippine Council for Aquatic and Marine Research and Development Council 3. National Fisheries Research and Development Institute 4. Bureau of Agricultural Research 5. Marine Science Institute, University of the Philippines 6. Central Luzon State University 7. University of the Philippines Visayas 8. Mindanao State University
Sri Lanka	National Aquatic Resources Research and Development Agency (NARA)
Thailand	59 Freshwater Fisheries Research Institutes/Centers/Stations, 26 Coastal Fisheries Research and 6 Aquatic Animal Genetics Research and Development Institutes/Centers/ Stations
Viet Nam	1. Research Institute for Marine Fisheries 2. Institute for Fisheries Economic and Planning 3. Research Institute for Aquaculture No. 1, 2, and 3

Table 16b. Number of research institutions and personnel – Pacific Island countries.

Country	Research centers
Cook Islands	Tongareva Marine Research Center; Araura Marine Research Station
Fiji	Naduruloulou Aquaculture Research Station; Makogai Island Research Station; Institute of Marine Resources
French Polynesia	IFREMER; Rangiroa
Kiribati	Ministry of Fisheries
Micronesia	National Aquaculture Center
New Caledonia	Saint Vincent Research Station
Palau	Palau Mariculture Development Center
Papua New Guinea	Aiyura Freshwater Aquaculture Center Erap Agricultural Station Kiunga Lowland Aquaculture Development Center
Samoa	Toloa Aquaculture Center
Tonga	Sopu Aquaculture Center

In Viet Nam aquaculture research is done by the Research Institutes for Aquaculture of which there are three to cover north, central and south Viet Nam. In sheer number Thailand has the most, with 59 Freshwater Fisheries Research Institutes, Centers or Stations, 29 Coastal Fisheries Research Centers and 6 Aquatic Animal Genetics Research Centers or Stations.

Aquaculture research may also be carried out also through a national agency for research and development as is the case in Australia through the Commonwealth Scientific and Industrial Research Organization (CSIRO). The Philippines has a similar institution called the Department of Science and Technology (DOST) under which is the Philippine Council for Aquatic and Marine Research and Development (PCAMRD).

Universities especially those with fisheries or marine programmes often have their own research programmes. Oftentimes the problem is not the lack of research centers but more a surfeit of research centers chasing after the same pot of money from the same central source of funding. Unless well coordinated this often results in duplication of efforts and inefficient use of limited funds for research.

Many Pacific Islands have national centers dedicated to aquaculture research. However these facilities were often established under aid projects with a short term objectives leaving government struggling to fund operations or realign activities into ongoing programmes once the project ended. Most centers are only modestly equipped and staffed. The focus tends to be on mariculture.

Because of the low population base in the region it is not untypical for only a few staffs with aquaculture portfolios within the entire national public service. Therefore there is no lack of opportunities amongst staffs to access specialized training or higher education opportunities from neighboring metropolitan countries or Asia. However these staffs are often promoted, or assigned alternative duties not related to aquaculture resulting in periods when capacity is not available or thin. Another factor impeding delivery and reflecting the low human resource base is that key staffs are often burdened with multiple responsibilities from provincial, national and regional levels.

6.5 Education and training

Most of not all of the countries represented in this synthesis have some form of post secondary education in aquaculture (Table 17). Typically this will be a two or three-year Diploma Course in Fisheries major in Aquaculture or a full four-year baccalaureate course. Such courses are given in Fisheries Schools or in regular government universities. In the Philippines the Technical Skills Development Authority (TESDA) administers non-degree courses in Fisheries and aquaculture. In Sri Lanka this type of education is given exclusively by the National Institute of Fisheries and Nautical Engineering (NIFNE). Australia offers a good mix of non-degree and degree courses in aquaculture in and out of its university as shown in Table 18.

Many of the countries represented in this synthesis also offer graduate degrees at the masters and doctorate level in fisheries, aquaculture or other allied fields. The countries include Australia, China, India, Indonesia. Japan, Korea (Rep.), Malaysia, Philippines, Thailand and Viet Nam.

Table 17. Number of educational institutions in fisheries.

	Number of schools			
Country	**Diploma level**	**Bachelor's degree**	**Master's degree**	**Doctorate degree**
Australia	6	7		
Bangladesh	6	5	1	1
Cambodia				
China	10	30	9	5
India		2		
Indonesia	27	10		
Iran	1	20	6	6
Japan				
Korea (Rep.)				
Malaysia				
Myanmar				
Nepal				
Pakistan	4			
Philippines				
Sri Lanka				
Thailand	There are at least 16 universities around the country that offer aquaculture and related courses from Diploma to Ph.D.			
Viet Nam				

Short, practical training courses are also often given by government fisheries or aquaculture research centers on very specific topics: i.e. shrimp hatchery operation, tilapia fingerling production, crab growing, culture of fish in cages, etc. Such courses can be as short as one day or two if conducted in seminar format with some demonstration and plant visits. However those which are conducted on a hands-on basis could last a few weeks to cover the entire duration of larval rearing from breeder selection and spawning all the way to harvesting, packing and transport in the case of seed production. Hands-on training for grow-out operation is often abbreviated to cover the most crucial steps such as pond preparation, water management, stock monitoring, computing for feed ration, feed preparation, feeding management and harvesting. In this manner the training need not last the whole length of grow-out operation which could take four to five months.

Table 18. Course on aquaculture in Australia.

Course/degree/diploma/ certificate	University/TAFE/ technical school	Campus, State
Seafood Industry Studies	TAFE NSW	Various campuses, NSW
Hatchery Production of Temperate Marine Finfish	WA Maritime Training Centre	Fremantle, WA
Certificate II in Seafood Industry (Aquaculture)	TAFE NSW	Moruya, Trenayr, NSW
	TAFE QLD	Various campuses, QLD
		Various campuses, WA
	TAFE WA	Port Lincoln, SA
	Australian Fisheries Academy	
	National Fishing Industry Education Centre	Grafton, NSW
Certificate II and III in Aquaculture (Freshwater)	Murray Institute of TAFE	Roseworthy, SA
Certificate III in Seafood Industry (Aquaculture)	TAFE SA	Spencer Institute, SA
	TAFE NSW	Various campuses, NSW
	TAFE QLD	Various campuses, QLD
	TAFE WA	Various campuses, WA
	National Fishing Industry Education Centre	Grafton, NSW
Certificate II and III in Seafood Industry (Fishing Operations	Australian Fisheries Academy	Port Lincoln, SA
Certificate IV in Seafood Industry (Aquaculture)	TAFE NSW	Various campuses, NSW
	TAFE QLD	Various campuses, QLD
	TAFE WA	Various campuses, WA
	National Fishing Industry Education Centre	Grafton, NSW
Certificate II, III, IV and Diploma in Aquaculture	National Aquaculture Training Institute	SA
Diploma of Aquaculture	University of Tasmania	Launceston, Tasmania
Certificate of Tropical Aquaculture	Northern Territory University	Casuarina, NT
Associative Diploma of Applied Science	Northern Territory University	Casuarina, NT
Graduate Diploma in Marine Finfish Hatchery Management	WA Maritime Training Centre	Fremantle, WA
Bachelor of Agribusiness	Curtin University	Bentley, WA
Bachelor or Aquaculture	University of Tasmania	Launceston, Tasmania
Bachelor of Applied Science	Southern Cross University	Lismore, NSW
	James Cook University	Townsville, QLD
	University of Tasmania	Launceston, Hobart, Tasmania
Bachelor of Science (Aquatic Resource Management)	Central Queensland University	Rockhampton, QLD
Bachelor of Science (*Aquaculture related only*)	Curtin University	Bentley, WA
	James Cook University	Townsville, QLD
	Deakin University	Warrnambool, Victoria
Bachelor of Technology (Aquaculture)	Flinders University of South Australia	SA
Bachelor of Science (Marine Biology)	Flinders University	SA

Course/degree/diploma/ certificate	University/TAFE/ technical school	Campus, State
Practical Course in Commercial Warm Water Aquaculture	East Gippsland Institute of TAFE	Bairnsdale Campus, Victoria
Freshwater Fish Farming	Northern Melbourne Institute of TAFE	Victoria
Bachelor of Environmental Science (Fisheries Management and Aquaculture)	Deakin University	Warrnambool, Victoria

Education obtained in schools whether for a degree course or a Diploma course that are commonly referred to as formal education has an established system of certifying completion through written or practical examination and other means. However non-school based training, such as on-the–job training often has no system of certifying as to satisfactory completion beyond mere physical attendance. It should be noted that a formal education and a competency-based training programme are not mutually exclusive. Many university graduates are in fact ill equipped to be involved directly in production runs without undergoing hands-on training. On the other hand it is not easy to determine a person's competency to perform specific tasks required in aquaculture operations.

Of all the countries represented in this synthesis, Australia has the most systematic and structured system in skills certification for aquaculture workers from technicians to operators and supervisors. Different skills required to operate either a hatchery or grow-out facility are broken down into competency levels. The specific skills required for a person to be certified for each competency level are well defined and quantified leaving very little room for subjective assessment. This is one model of skill certification that could well be adopted by the other countries in Asia to standardize jobs in aquaculture.

7. TREND ISSUES AND DEVELOPMENT

7.1 Subregional trends in aquaculture production (key species/systems)

7.1.1 Australia

The industry set itself a vision at a National Aquaculture Workshop held in Canberra in August 1999, which stated that by 2010 a vibrant and rapidly growing Australian aquaculture industry will achieve $2.5 billion in annual sales by being the world's most efficient aquaculture producer. Issues identified and discussed as highest in priority were:

- Industry coordination and organization
- Promoting the industry and ensuring it had access to resources
- Environmental issues
- Markets and marketing
- Research and development

To address these issues, the workshop adopted a ten-point strategic initiatives as follows:

- Strategic initiative 1 - Making a National Aquaculture Policy Statement
- Strategic initiative 2 - Promoting a regulatory and business environment that supports aquaculture
- Strategic initiative 3 - Implementing an industry driven Action Agenda
- Strategic initiative 4 - Growing aquaculture within an ecologically sustainable framework

- Strategic initiative 5 – Protecting the aquaculture industry from aquatic diseases and pests
- Strategic initiative 6 – Investing for growth
- Strategic initiative 7 – Promoting aquaculture products in Australia and globally
- Strategic initiative 8 – Tackling the research and innovation challenges
- Strategic initiative 9 - Making the most of education, training and workplace opportunities
- Strategic initiative 10 - Creating an aquaculture industry for all Australians

7.1.2 East Asia

There is a general trend in East Asia including China to expand to new species for culture particularly for premium species. The phenomenal growth of the river crab and Mandarin fish in China are indications of such trend. Production of the river crab first appeared in the statistics only in 1989 but it was during the second half of the 1990s that production really took off. It was during this time that the Mandarin fish also first appeared in Chinese aquaculture. Production of high value species is now accounting for about 30 percent of the total aquaculture production compared with only 1 percent in 1979.

In Korea (Rep.) there has been a great increase in production of high value fish species, such as olive flounder and black rockfish during the last few years and a new interest in culturing penaeid shrimps. The vision of Korea (Rep.) is a restructured aquaculture industry with an optimal production system and enhanced competitiveness. While doing this, Korea (Rep.) will be reducing by 10 percent production facilities devoted to high volume products such as laver and sea-mustard with no new licences to be issued during the next five years.

Reduction in China can be expected in its facilities for producing high volume species such as cyprinids, perhaps not deliberately as is the case in Korea (Rep.), but due to market forces as competing land use and urbanization may affect the competitiveness of freshwater aquaculture in certain areas. However reduction in freshwater aquaculture areas may partly be offset by expansion in marine areas particularly for the culture of relatively higher value species.

There is a greater concern on the wholesomeness of aquaculture products and on making aquaculture operations environmentally benign. Furthermore instead of high yield per unit area aquaculture in the subregion is now aiming more on efficiency, cost efficiency and competitiveness. In shrimp farming there will be redoubled effort to have the capability to locally commercialize the production of SPF and SPR broodstock both of *Penaeus vannamei* and the local *P. chinensis*. Already reports of cross breeding are filtering out although these remain unverified.

7.1.3 South Asia

Of the five countries making up South Asia, one, Nepal, is completely inland and has the least developed aquaculture. The subregional trend therefore does not apply to Nepal where the main concern is to increase aquaculture activities and intensify existing operation. Elsewhere freshwater aquaculture is likely to continue, primarily for food rather than for cash although the culture of the giant freshwater prawn may increase as interest picks up.

In brackishwater aquaculture the ambivalence towards shrimp farming continues in the sense that its contribution to the economy is recognized even as its negative effects on the environment, actual or perceived, is decried. Such situation will likely lead to the adoption of environmentally friendly technologies such as zero discharge or low water exchange systems. Thus the use of bio-remediation in shrimp culture may increase and become a standard practice. On the other hand heavy use of wild-caught fry which is particularly true in Bangladesh is likely to persist unless alternative livelihood is found for the hundreds of thousands of fry gatherers.

7.1.4 Southeast Asia

The infatuation with shrimps is likely to continue. This time the object is wholesomeness (safety and quality) rather than just high volume production. The region will have come to terms with *P. vannamei* as at the moment only the Philippines has held out against its legalization although it is making initial steps to lift the ban on its culture. With the continued inability of the American breeding farms to supply the massive number of SPF brood animals required, many of the hatcheries in the region are forced to use locally grown second or third generation stock. This will persist until local capability to commercially produce SPF stock is established.

The growing scarcity of high health *P. monodon* broodstock that was one of the impetus for embracing the *P. vannamei,* has driven the various countries in the subregion to finally follow the lead of Thailand in giving high priority to broodstock development of the native species. Developing a captive breeding stock of *P. monodon* had not been a high priority in Indonesia, Malaysia and the Philippines since wild-caught broodstock that are healthy enough had been readily available. Once high health captive *P. monodon* breeding stock becomes commercialized and consistent in quality many farms in the subregion will likely revert to the native species. But the species is not likely to again become the predominant species of choice. Instead the species mix will likely be shaped by the market and relative competitiveness.

There is a trend towards expansion into open marine waters using sea cages as is being done in the Philippines, but the growth of such development is unlikely to be high. In the Philippines the sea cages are attractive because of the high local demand for milkfish. Elsewhere the interest for sea cages is more for the higher value species such as grouper. This is especially so in China, Viet Nam, Malaysia, Thailand and Indonesia. There are an estimated 1.12 million cage units in these countries producing 550 000 tonnes of finfish, 85 percent of which is marine species (Chawalit, Thammasart and Lohawatankul, 2005).

The rapid growth of the carageenan refining industry in China with its high demand for *Eucheuma* will fuel further expansion in seaweed farming in the subregion. Chinese processors are driving farm-gate price for dried *Eucheuma* to record levels in the Philippines.

7.1.5 Near East

Interest on producing shrimps will continue to be high in the subregion. But the constant threat of diseases is also driving the major producing countries such as Saudi Arabia and Iran to look into alternative species. In Iran some shrimp producers are looking into *P. vannamei* as an alternative to *P. indicus*. How this will develop will depend both upon government policy and how well the species will fare in the high salinity environment and harsh climate.

Already the subregion is no longer totally dependent on wild-caught broodstock of *P. indicus* since breeding stock of the species can readily be grown in ponds. The practice now is to merely use unselected first generation breeders. There will be high interest in moving on towards a breeding programme similar to what is now happening in Southeast Asia.

The subregion is also looking into the culture of various marine finfish species such as grouper, sea-bream and sea-bass as alternative species. Saudi Arabia, Iran and the United Arab Emirates are already developing capability to propagate marine finfish and pursuing the recruitment of experienced people from Southeast Asia and training of their own nationals. European fish cage manufacturers and suppliers are making some inroads in the region.

7.1.6 Pacific Islands

Aquaculture in the Pacific is undergoing a state of rejuvenation with the emergence of significant commercial activity and commodities suitable for rural development. Many governments lack the strategic framework required for aquaculture development. Policies, legislation and strategic planning have not been properly addressed. Many failures in the past of government or private sector ventures have been attributed to poor economic and financial planning, leading to non profitable scales of investment or unrealistic market expectations.

The Pacific label as a pristine and clean green image could be a marketing drawcard. The *L. stylirostris* prawns marketed in Europe under the brand "Paradise prawns" is a successful example. The marine ornamental trade also has the potential to increase its benefits from proper use of labelling and certification, and with operators employing ecologically sustainable techniques. Examples of sustainable practices being pilot-tested include pre-settlement larval capture systems and tendering of coral gardens. Cultured black pearl requires a significant investment in marketing. There is a trend in some countries towards integrating this effort with their national tourism marketing campaign.

There is an increasing realisation of the role aquaculture can play to supply fish protein, particularly for inland rural villages where access to fresh fish is limited and lack of electricity does not allow the long-term storage of food. Some parts of the Pacific, particularly the large Melanesian countries are facing a food crisis situation from increasing population pressure, which is leading to poor nutrition and health. Generating another primary food source would help alleviate the reliance on imported processed, i.e. tinned, foods. Aquaculture is increasingly seen as a viable alternative source of essential cash needs (for school fees, social obligations and other expenditure items) and as a back-stop to declining fisheries revenues.

Drawing on indigenous farming practices and indigenous resources will be important to developing aquaculture appropriate to local needs and scales, in particular to addressing subsistence and semi-commercial needs, and extensive and small scale farming. For example the region is trialling integrated freshwater shrimp with swamp "dalo" farming.

Biosecurity will become a key issue. Because the Pacific does not have a tradition of aquaculture there are few domesticated species which the region can draw on, and the introduction of new genetic material and translocation of species will be an integral aspect of the development efforts in aquaculture. Bearing in mind the high regard for biodiversity in the region there is a strong need for responsible practices. Addressing biosecurity will involve cross-sectional approaches, for example fisheries, quarantine, veterinary and environment agencies. Given that many governments in the region have a relatively flat structure there is ample opportunity for the Pacific to showcase the applicability of inter-agencies collaboration.

7.2 Trends in environment and availability of resources

The following factors will need to be looked into:

- Competition for land and water. Will this lead to higher degree of integration of agriculture and aquaculture? Is there an increasing trend forwards rice-fish culture? In Saudi Arabia one agricultural company uses groundwater for raising tilapia before using it for wheat farming.
- High energy cost. Will this lead to lower stocking density to reduce aeration need? Perhaps it will be a matter of cost effectiveness since lowered density and production will affect production volume but can improve harvest size. This will require a greater degree of fine-tuning to achieve high economic yield. On the other hand will it lead to greater use of alternative energy sources like wind or perhaps solar at the farm level? Energy cost for pumping can be greatly minimized with the combined use of bio-remediation and low

discharge or even zero discharge technique. With so many competing commercial brands and bio-remediation techniques there is still no one way of doing it. Can this be standardized?

- Continued reliance on fishmeal. Will the search for alternatives eventually result in greatly minimized requirement? Although the use of fish protein has been greatly minimized through the use of proteins from terrestrial animals or vegetables there are limits to the level that non-fish proteins can be used. Milkfish can grow using feeds with less than 5 percent fishmeal, but better growth is achieved at the 10 percent fishmeal level. Even with minimized per unit usage, total requirement may still grow with increased production levels. So much hope had been raised on single-cell protein (SCP) but its commercial viability still remains to be seen. Its viability will ultimately depend upon the supply and price of fishmeal as much as on more efficient mass production technology.
- Biosecurity. Countries continue to introduce species or strains for aquaculture. This will also be accompanied by development of specific strains. With this trend will there be growing awareness and concern on more responsible introduction and movement in those countries where aquaculture is very dynamic? In other countries will there be efforts to minimize introductions where it is perceived to negatively affect indigenous species or eco-systems. Overall, the mechanisms for introduction will need to become more stringent and Import Risk Assessment will need to increasingly become a standard tool for ensuring responsible movement and introduction of species and strains for aquaculture. This will require significant capacity building and training to mainstream its use and ensure that it is used effectively.
- Genetic Improvement and Domestication. Improved management demands genetic improvement of main aquatic species including indigenous species). The “domestication” or genetic selection of desirable characteristic relating to growth, health, etc. is now receiving attention. The need to establish systematic breeding programmes for clean healthy and genetically sound broodstock (for key species) is now recognized. These will be achieved through a variety of mechanisms such as:
  - Government pilots (national broodstock centres)
  - Public/private sector partnerships
  - Investment in research
  - Promotion of awareness of value of good quality broodstock through training and extension and communication with farmer groups

The current focus of interest in the region is the domestication of native penaeid shrimp species particularly the *Penaeus monodon*. Work is on going in many countries in Asia. Simultaneously the major *P. vannamei* producing countries such as China, Thailand and Indonesia are developing local capability to produce their own Specific Pathogen Free breeding stock. On a smaller scale there is also an on going work on genetic improvement of the giant freshwater prawn, *Macrobrachium rosenbergii* through collaborative work between Indonesia, Philippines and Thailand.

7.3 Economics and trade

One very important factor is the capability of the different countries to analyze for “contaminants” or “impurities” at the level of precision required by the importing countries. This includes antibiotics, pesticides and heavy metals. Another is the capability of each country to apply HACCP in the production process including traceability. The third is the possible adoption of a uniform standard for aquaculture products whether for export or for domestic consumption.

Can some form of “parts and product complementation” now being practiced by the manufacturing industry (automotive, electronics, etc.) be applicable to aquaculture? This will help mitigate the ruinous effect of competition between countries for the same product(s) and for the same market(s). One approach of course is “national branding”. Here the production and marketing capability of each country will be put to severe test in the open global market arena. In a related vein is the growing trend towards "eco-labeling". For lack of any standards and certification scheme eco-labeling is often considered as no more than a marketing tool. With the increasing concern on the environment among consumers worldwide, products that are grown in a responsible manner that does not harm the environment will have a competitive edge particularly in the developed countries. But in order for it to be recognized and accepted it is not enough to have a certification mechanism. It will also be essential to have an accreditation system for the certifiers.

7.4 Social impacts and employment and poverty reduction (aquaculture's likely future subregional contribution to food security; access to food, nutrition)

Expansion into marine waters for the production of food fish is a likely approach as competition for land and water becomes more acute. Aquaculture as source of food rather than income is more related to freshwater aquaculture with the exception of the Philippines where the most important food fish species – milkfish is produced primarily in brackishwater and efforts are underway to produce a fast growing saltwater-tolerant strain of tilapia. While the red strain of tilapia is known to be salt tolerant this is not too well accepted in the local Philippine market.

Ultimately in all countries the increased contribution of aquaculture to local food supply will be driven by local preference and acceptance of certain products and economic cost of producing them, as well as a growing purchasing power. Aquaculture is less labour intensive than agriculture. But jobs can be created by increasing the degree of processing and value adding for aquaculture products. Processed fish also have a longer shelf life, that would help stabilize prices and even out food fish supply year round.

One scenario considered in the IFPRI/WorldFish report is that a rapid expansion of both scale and efficiency of aquaculture could lead to decreasing fish prices (this was the only scenario where fish price decreased). The efficient culture of herbivorous/omnivorous fish is already a reality, however, it is apparent that current trends seem to indicate that the tendency that aquaculture is drifting towards higher value species that present greater profit margins. This trend is even being seen in species that are traditionally considered to be relatively low input species such as tilapia. The production of tilapia in several countries is moving away from the green water fertilized systems towards pellet fed intensified systems. This may be a reflection on the available areas for aquaculture and increasing restriction on water availability and to some extent environmental requirements. The production of higher value aquaculture species allows investment in more intensive production systems and their associated effluent treatments. The higher value products may also be easier to market and often have greater export potential.

As fish prices rise, there will be a tendency for poorer parts of national populations to shift towards cheaper form of meat such as chicken and pork. The question is whether fish, particularly cultured fish, will remain a common (and even central) part of the diet of most people in the region or increasingly become a luxury food item.

7.5 Institutions to support responsible development of aquaculture

The government continues to be the mainstay in the promotion of responsible aquaculture. However the important role of the Non-Governmental Organizations in Bangladesh and Cambodia is worth looking into. The development and promotion of codes of practices, certification systems, and standards will also require the strengthening of farmers, through their being associated and thus better empowered for their role in carrying out sustainable aquaculture. The desired status is that the various stakeholders participate and have co-ownership in the development of policies and R & D programmes to attain such objectives as equitable access to resources and share of the returns from aquaculture, environmentally friendly and socially responsible farming, harmony and cooperation.

Micro-finance institutions can widen their portfolio to include not only trading and processing but even for providing working capital to small-scale aquaculture ventures. Responsible aquaculture practice can be one of the criteria used in loan approval.

Pilot studies and a number of in-country experiences are even now providing concepts and methodologies that could be shared and adopted over wider areas where voluntary codes of conducts, as well as best practices, are jointly developed and promoted by government, civil society and farmers associations, promoted for adoption by farmers through their associations, and with evidence that productivity, profitability as well as quality of produce have improved.

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PART II

Report of the
FAO EXPERT WORKSHOP ON
REGIONAL AQUACULTURE REVIEW: ASIA

Islamic Republic of Iran, 27–29 September 2005

BACKGROUND

1. The Second Session of the Committee on Fisheries Sub-Committee on Aquaculture held in Trondheim, Norway, 7–11 August 2003 agreed that the Secretariat should provide a prospective analysis of future challenges in global aquaculture as a basis for a discussion of the longer term direction of the Sub-Committee's work. As a response to this request and also to take the advantage of conducting a global review of aquaculture development trends, which is generally compiled on five-yearly basis, the FAO Expert Workshop on Regional Aquaculture Review: Asia (Workshop) was held to review the aquaculture development trends, and discuss the issues, opportunities and challenges for the future aquaculture development in the Asia-Pacific region. The information obtained through the National Aquaculture Sector Overviews (NASO), which is an on going activity of the Regular Programme of the FAO Fisheries Department, together with information received with respect to a comprehensive questionnaire from regional countries were used during the review process.

2. Taking advantage of the Eighth Technical Advisory Committee (TAC-8) meeting of the Network of Aquaculture Centres in Asia-Pacific (NACA), which was planned to be held in Iran, the Workshop was jointly organized in collaboration with NACA and the Iranian Fisheries Organization, back-to-back with the NACA TAC-8.

DATE AND VENUE

3. The Workshop was held from 27 to 29 September 2005 at the Grand Hotel, Ramsar of the Islamic Republic of Iran.

PARTICIPANTS

4. The Workshop was attended by 46 aquaculture experts from 13 countries from Asia-Pacific, two persons from the Republic of Georgia and several resource persons from the Food and Agriculture Organization of the United Nations (FAO), NACA, South Pacific Community (SPC), and the Aquaculture Department of the South East Asian Fisheries Development Centre (SEAFDEC-AQD). The List of Participants is given in Appendix A.

WORKSHOP WORK PROGRAMME AND PROCEDURE

5. The Workshop Programme is given in Appendix B.

6. The Workshop was formally inaugurated during an opening ceremony held in the morning of day one, 27 September, which was graced by the Honourable Deputy Minister of Fisheries Mr Lotfollah Saeedi. Following the formal opening and at the beginning of the technical session, Mr Ebrahim Maygoli was appointed as the overall Chair of the Workshop. The Workshop process consisted of several plenary presentations and discussions and working group discussions and presentation. The participants were provided with a draft review of aquaculture development trends in Asia-Pacific, which was prepared by synthesising NASOs and other information as mentioned in the Introduction. The participants were requested to review the document, make amendments, and suggest improvements to the document. They were also requested to identify major trends in the development of aquaculture in the Asia-Pacific and to recommend actions for sustainable development of the sector in Asia-Pacific. The Terms of Reference for the Working Groups are given in Appendix C.

PLENARY AND WORKING GROUP DISCUSSIONS

7. The participants in three Working Groups identified gaps in the draft Regional Review and made suggestions to improve it. The secretariat undertook to revise the document taking into considerations the suggestions, and to send the revised document to the participants for approval. It was also agreed that the NASO authors will be contacted to improve/revise the NASOs based on the suggestions made by the workshop. The Working Group reports (presentations) are given in Appendix D.

8. Based on the results of the above, the participants, this time in two Working Groups, discussed aquaculture development trends in Asia-Pacific and suggested a series of actions to mitigate negative impacts arising from such trends and the measures to promote positive impacts originating from those trends. The joint Working Group report consisting of major trends, opportunities and challenges, which was agreed by the participants, is given under Major Trends.

9. The participants recommended that the Secretariat use all the information gathered during the Workshop, in particular the identified trends, opportunities and challenges during preparation of the Prospective Analysis of Future Aquaculture Development.

10. They also suggested that the conclusions of the workshop be considered for the deliberations of the TAC-8 meeting in view of their relevance to the task of TAC-8, which is to recommend the technical basis for the regional aquaculture development programme of NACA.

EXPECTED OUTPUTS AND FOLLOW-UP ACTIONS

11. The Secretariat will publish the Workshop Report and the Regional Aquaculture Review: Asia following final completion of the documents.

12. The Secretariat will present both documents arising from this Workshop and similar workshops held in other regions of the world: (a) FAO Global Aquaculture Review 2005 and (b) Prospective Analysis of Future Aquaculture Development to the third session of the Committee on Fisheries Sub-Committee on Aquaculture which will be held in New Delhi, India, in September 2006.

MAJOR TRENDS

Restricted aquaculture expansion will tend towards increasing intensification

Intensification

13. As availability of sites for aquaculture is becoming increasingly limited and the ability to exploit non-agricultural land is restricted there will be a trend towards intensification of aquaculture. Intensification is also driven by general economic development in the country and rising production costs.

14. Intensification may sustain profitability of farming operations, but this comes at a cost. There will be water and health management issues that accompany intensification and the environmental carrying capacity and regulatory concerns that relate to increased numbers or intensity of farms.

A reverse trend away from intensification will occur in a few cases

15. Not all farmers are able to intensify and as production costs rise part of the sector may reduce intensity to lower costs or reduce vulnerability to health or environmental problems. Under appropriate circumstances there are opportunities for organic aquaculture to play a role and this may become an economically viable form of management.

Continued diversification of species and need for their responsible use

Indigenous species/biodiversity and conservation

16. Aquaculture will continue to explore new species options for culture. Indigenous species offer some potential either as national or regional commodities or even as niche products.

17. The development of indigenous species production for enhancement or restocking will also continue and even be promoted as a means for improving livelihoods for people that rely on fisheries as part of their livelihoods.

18. Stock enhancement programmes of inland waters will increasingly look towards the use of indigenous species as concern and awareness over biodiversity issues increase. As part of this, restocking programmes will need to pay more attention to the use of with appropriate strains and ensure that genetic diversity of wild stocks is not impacted.

Introductions/exotic species

19. Countries will continue to introduce species or strains for aquaculture. This will also be accompanied by development of specific strains aquaculture. There will be a trend towards more responsible introduction and movement in those countries where aquaculture is very dynamic. In other countries there will be efforts to minimize introductions where it is perceived that this will negatively affect indigenous species or eco-systems. Overall, the mechanisms for introduction will become more stringent

Import Risk Assessment

20. Import Risk Assessment (IRA) will increasingly become a standard tool for ensuring responsible movement and introduction of species and strains for aquaculture. This will require significant capacity building and training to mainstream its use and ensure that it is used effectively.

21. The implementation of the IRA guidelines will benefit form cross-sectoral collaboration (or inter-regional collaboration, particularly form sectors or countries where IRA is used routinely and there is existing experience.

Informed decision-making

22. Farmer’s perceptions of risks of introductions and the benefits of different species and strains are not always based on accurate information. There is a need for both better information on potential species and strains and also the benefits and risks associated with their use.

Continued diversification of production systems

Small-scale aquaculture as a means for wealth creation will increase

23. As some traditional agricultural systems become increasingly uneconomic there is a trend to promote or enable diversification. This may take the form of conversion from agriculture to aquaculture (e.g. rice land for aquaculture), or the integration of aquaculture into existing farming systems.

24. As aquaculture typically requires access to land and/or water resources, the goal of aquaculture promotion will be to provide a means for wealth creation for agricultural farmers. The intended effect would be as a means to offset poverty rather than the use of aquaculture as a means of poverty alleviation. Rural aquaculture for wealth creation will not be effective everywhere and requires enabling features such as access to finance markets, fish seed and knowledge; state support to this generally only occurs if the state has recognized aquaculture's potential contribution to local economies and livelihoods.

New systems and new environments (e.g. particularly the movement into mariculture)

25. In countries where aquaculture is well established, the sector is continually looking for new ways to use environments for production. The exploration of new systems requires the identification of suitable areas and will require the use of tools such as: surveys; studies of carrying capacity; remote sensing/GIS and water quality monitoring.

26. Critical to ensuring longer term commitment to aquaculture and avoidance of destructive practices is the existence of farmer-friendly tenure systems. Increased terms of lease is often required and specific zoning of areas (e.g. mariculture parks) can provide and enabling environment for investment in aquaculture. Subsequent spin-off effects of employment and service sector opportunities also accompany this.

27. New systems require the development and dissemination of seed production technology (particularly the development of marine hatchery systems) and broodstock management for key species. The development and dissemination of growout technologies is also needed as new systems may not be based on modifications of existing culture techniques.

28. Appropriate infrastructure and services such as land based handling and processing facilities (landing and holding facilities, transport and cold chains) are essential to success.

29. Polyculture (particularly in marine systems) offers a means for diversifying products from a system and can reduce the effects of nutrient loadings. There is still a need for research and technology transfer on marine mixed plant/animal systems.

Increasing influence of markets, trade and consumption

Fish consumption

30. There is a trend of increasing fish consumption in Asian countries and this domestic and regional demand will compete with export markets. Producers and processors will move toward greater value adding and development of processed products. Species choices for farmers targeting urban markets will tend towards more standardized products and "easy to cook" or "supermarket type" fish products.

Markets and marketing

31. Markets will continue to develop and domestic demands will increase in Asian countries. New regional markets will also emerge (e.g. the newly independent countries, etc.).

32. As high value species will increasingly be exported and low value products will be imported to the region, there will be a greater need to improve and facilitate access to markets by farmers. This would offset the impact of potentially cheaper imports and, particularly, sustain or enable access to export markets. The choice of species may be increasingly directed towards those that have export (regional or intern-regional) potential.

33. With more stringent requirements of export markets small scale operators will face increasing difficulties producing for export and may leave the sector as they become uncompetitive. A strategy to offset this is the formation of producer associations, which among other advantages enables small farmers to attain economy of scale.

34. For some export commodities exporting countries may start to look at quota systems or mutual agreements on production limits in order avoid destabilization of market prices.

Increase the capacity of farmers to access and use market information

35. There is a need to build capacity within the region to enable countries and/or farmers groups to become capable of initiating or accessing market research. Processing and product diversification will be developed in response to better market information.

Food safety and quality

36. The international and national demand for safe and higher quality fish will increase and there is need region wide to improve product quality and safety. There will be improvements in cold chains. Control systems for ensuring product quality and safety will increasingly be put in place. Certification/tracing systems are already required for some commodities and traceability systems will be developed: There is a need to raise awareness among farmers of the need for this. Certification and quality standards (Hazard Analysis and Critical Control Points (HACCP) etc.) will be introduced or required and this challenges the sector to:

- Develop standards
- Accredit certifiers
- Develop framework for certification
- Establish laboratory infrastructure and train the personnel to run the laboratories

Enhanced regulation and better governance

Regulatory framework/legislation and policy

37. As aquaculture matures as a sector there is an increasing requirement to enforce existing legislation. In situations where enforcement continues to be constrained, there will be strong emphasis placed on self-regulation by farmer associations and by the sector, in general.

Land use, planning, zoning and tenure

38. As aquaculture often co-exists with agriculture in inland areas and with coastal and wetland natural resources elsewhere, there will be a trend towards more integrated land use planning and registration of farms for aquaculture. This will require the establishment of farmer friendly tenure systems and appropriate environmental planning (e.g. land use surveys and development of specific zoning/aquaculture zones).

Specific aquaculture legislation

39. It is clear that in some countries there is need for specific aquaculture legislation to better regulate the sector. The increasing requirement for traceability and certification will see mandatory registration of aquaculture ponds/farms for parts of the sector.

40. Implementation of regulation with respect to the use of drugs and chemicals (achieved through legislation, farmers groups, monitoring and surveillance, sharing experiences in regulation models).

Codes of practice

41. As an essential part of self regulation of the sector, there will be development of codes of practice and BMP in collaboration with farmers. This also requires appropriate mechanisms for dissemination and communication of codes of practice though farmer organizations.

Increasing environmental protection

42. Aquaculture does not exist in isolation and increased regulation of the sector also requires that its external effects be moderated. Against a trend of increasing intensification and increasing numbers of farms in some areas there will be requirement for environmental impact assessment and routine environmental monitoring. Increasingly there will be requirements for aquaculture to “pay the real cost”; for the ecological services that it utilizes. Mechanisms such as “polluter pays” and “resource rents” (user pays) will be put in place. This requires improved capacity for monitoring and concurrent development of laboratory infrastructure and capacity building within the competent agency/organizations. There will be need to properly assess the costs that users should pay as well as a mechanism to transfer the benefit of such scheme to society.

Improved information systems for regulation

43. Effective regulation is only possible with an effective information system. This requires improved quality of aquaculture information and statistics. The types of information collected should be targeted at specific needs for management of the sector. There will be a concurrent need for information management systems that are sufficiently decentralized to enable use of the information for local management.

Drive for better management

44. The combined effect of the above trends will be to drive the sector towards improved or better management. This will be seen at the individual farm level as well as specific sub-sectoral levels. It will not occur simultaneously throughout the aquaculture sector, but rather will materialize as different pressures i.e. regulatory, market, environmental or social, etc., are applied.

Need to use water and land sustainability

45. There is a recognized need fro more efficient use of water and land and aquaculture must respond to this. Within this context there is a need to mitigate conflicts between water and land users.

Increasing system/production efficiency

46. As production costs raise aquaculture mist become more efficient. This can be achieved through a variety of strategies such as:

- Reduction of cropping time
- Minimizing disease/improving health
- Reducing feed costs
- Growing higher value species

- Intensifying production
- Practicing integrated aquaculture for lower cost and reduced environment impact

Genetics/stock improvement

47. Improved management demands genetic improvement of main aquatic species (*including indigenous species). The "domestication" or genetic selection of desirable characteristic relating to growth, health and other attributes requires attention. Systematic breeding programmes for clean healthy and genetically sound broodstock (for key species) are required. These will be achieved through a variety of mechanisms such as:

- Government pilots (national broodstock centres)
- Public-private sector partnerships
- Investment in research
- Promoting awareness of the value of good quality broodstock; training and extension and communication with farmer groups

Hatchery management/seed certification

48. Good broodstock are an essential starting point for quality stock, but this can all be lost though poor hatchery practices. As farmers demand better quality seed there is a need for hatchery certification schemes. Improved seed quality (performance and health) requires management improvement as well as access to good quality stocks. With newly emerging systems such as marine hatcheries there are specific research needs to develop the systems. The hatchery sector in Asia is extremely diverse and there are many small scale operators, so that an urgent need is to upgrade skills and transfer techniques to the small-scale hatchery sector.

Better on-farm management practices that focus on enhanced product quality and safety

49. With the large numbers of smaller scale farmer, which typifies aquaculture production in so many countries in Asia there is a need to promote and strengthen farmers associations. This can be achieved by:

- Encouraging formation of groups
- Supporting entrepreneurs
- Creating awareness of the benefits of associating
- Promoting self-regulation/co-regulation schemes through farmer associations
- Giving aquaculture equal government support/recognizing it as legitimate user of resources

50. Farmers associations offer the opportunity for the promotion and implementation of better management principles and practices. The process for the development of acceptable practices that are economically viable and acceptable to both the producers and society at large requires consultation and dialogue for their development. Dissemination and promotion requires awareness programmes and convincing extension strategies. This often requires concrete demonstration in the locality of the farmer or "learning through doing type approaches". Incentives to enter best management practice schemes are usually financial and revolve around increased prices for products, entry to previously inaccessible markets, or higher probability of making a profit or its converse, which is less risk of losing money. The linking of farmers to markets and awareness of the demands of these markets are critical features in this process.

Improving feeds

51. Feeds are a major part of the production cost in most aquaculture systems. As production costs increase the greatest opportunity to reduce this is through more efficient feeds and feeding. The sector needs to develop feeds that giver lower FCR and systems for feeding that increase feed use efficiently. Aquaculture feeds for many species are based around fishmeal or direct feeding of fish. Expansion and

sustained production of the marine finfish sector will require wider availability of floating feeds for marine finfish. The reduction or replacement of fishmeal in feeds is another priority for the intensive or carnivorous species part of the sector.

52. Elsewhere, particularly in the rural aquaculture sector there are opportunities to promote locally made feeds and feeds from local ingredients (non commercial feeds). This offers the greatest opportunities where aquaculture is close to or integrated with crop and livestock farming.

53. There is still a need to invest in feed research as the private sector cannot undertake this alone. This is particularly important with the newly emerging systems and species:

- Nutritional requirements
- Economical feed formulations
- Feeding strategies/utilization
- Alternative feed ingredients

Increasing environmental protection

54. Aquaculture management will be required to reduce its external impacts. A critical condition to achieving this is strong awareness within farming communities.

Strengthen economic planning and access to finance

55. Entry to aquaculture, diversification and up-scaling typically requires some access to investment. This is not often available in appropriate forms (loan duration is too short or too long, inadequate amount or unreasonable collateral requirements, too bureaucratic loan application systems). In many situations loans are not available to aquaculture as it is considered high risk or because the lack of experience with aquaculture by lending institutions leads to over-caution. There is a strong need for educating extension officers and investment bankers so they are able to assess economic risk and assist farmers in adopting appropriate production strategies. The existence of case studies and mutual assurance through farmer organizations are systems that have demonstrated success. Software tools for financial planning can facilitate this.

Technology

56. There are diverse aquaculture technologies that can be applied to support the further development of aquaculture. Specific examples of useful technological tools that can be utilized are:

- Genetic markers for broodstock management, strain identification
- Vaccines development can greatly reduce risks in finfish production
- Disease probes
- Recirculation systems
- High health/bio secure hatcheries
- SPF/SPR strains of broodstock
- Microfeeds for hatcheries

It is important however to understand the limitations of technology and that in most cases the development of aquaculture is not primarily constrained by the lack of technology.

The following comments were made by the participants.

57. The trends identified by the two working groups were very similar. The members of the workshop agreed that the six trends identified should form the basis for developing action plans for submission to COFI subcommittee meeting on aquaculture in 2006. Related to the identified trends, discussions were held on the following issues.

- Considering the importance of *marine finfish culture* in the region, the basis for placing it as the sixth priority by the first working group, was questioned by few of the members. In response, the process used for prioritizing the identified trends were provided by the group.

- The need for regulations to implement responsible aquaculture was recognized as very important. However, some members sought clarifications on the concept of bringing together of state regulation and self regulation to implement responsible aquaculture. Regulatory framework for aquaculture is available in most of the countries, but unfortunately their enforcement is weak. In the face of dwindling resources and the difficulty and expense in enforcing regulations, voluntary self regulation was suggested as the best option. It was recognized that considerable extension efforts are needed to promote adoption of voluntary self regulation through practical means (e.g. farmer groups).

- It was recognized that the identified trends would happen naturally over the next five years and all of them would have positive and negative impacts. The national governments, regional and internationals agencies should explore possibilities to develop and implement practical action plans to mitigate the negative impact and at the same time attempt to promote the positive impacts associated with each of the identified trend.

- Clarifications were sought for the rationale for forecasting the trends. Members suggested that mere forecasting of trends and letting the industry take its own natural course would lead to serious damages. It was suggested that international agencies like FAO and NACA, should not stop at just identifying and forecasting the future trends, but guide the national governments to take appropriate action plans to promote the positive aspects of the trend and advocate precautions to mitigate the associated negative impacts.

- The issue of aquaculture contributing to poverty alleviation was discussed at length. Several view points were presented and deliberated. It was generally agreed that very poor people do not have the resources to take up aquaculture. On the other hand, aquaculture generates significant income for rural people dependent on aquaculture both directly and indirectly for their livelihoods. This has a significant positive impact on rural economy and contributes to improving the living standards of rural communities and leads to rural development. The members were informed that in countries like China and Viet Nam, aquaculture is taken up as a strategy for rural development and to increase the income of farmers.

- It was recognized that aquaculture is responsible for providing cheaper and affordable fish to large segments of the fish consuming population of the world. On the other hand, members also argued that if the cost of cultured products increased, it might become unaffordable for resource-poor people.

- In addition to supporting livelihoods, the role of aquaculture in contributing to conservation of endangered species and limiting the impact of fishing on wild fisheries was highlighted in support of aquaculture.

ADOPTION OF THE WORKSHOP REPORT

58. The Workshop Report was adopted by the participants at the final session of the Workshop on 29 September 2005.

APPENDIX A

List of Participants

CAMBODIA

Hav Viseth
Chief of Aquaculture Division
Department of Fisheries
#186 Norodom Blvd, PO Box 835
Phnom Penh
Tel/Fax: (855 23) 996 380
E-mail: aqua@online.com.kh

CHINA

Yang Ningsheng
Director, Information Center
Chinese Academy of Fishery Sciences
No. 150 Qingta Cun, South Yongding Road
Beijing 100039
Tel: (86 10) 6867 1246
Fax: (86 10) 6867 3931
E-mail: nsyang@cafs.ac.cn

Miao Weimin
Director, Asia-Pacific Regional Research and Training Centre for Integrated Fish Farming
Deputy Director, Freshwater Fisheries Research Centre, CAFS
Qitang, Wuxi, Jiangsu 214081
Tel: (86 510) 555 8719
Fax: (86 510) 555 3304; 555 5796
E-mail: miaowm@ffrc.cn

GEORGIA

George Miqaberidze
Deputy Head of Fisheries Department
Ministry of Agriculture of Georgia
Room 609 41 Kostava Street
Tbilisi 0123
Tel: (995 77) 997 999
E-mail: gmiqaberidze@yahoo.com

Maia Metreveli (Ms)
Fisheries Policy and Sector Development Specialist
Ministry of Agriculture of Georgia
Room 609 41 Kostava Street
Tbilisi 0123
Tel: (995 32) 334 662/(995 99) 115 591
E-mail: metreveli.fidi@caucasus.net
mmetreveli@yahoo.com

INDIA

Niranjan Sarangi
Director, Central Institute of Freshwater Aquaculture
PO Box Kausalyagang, Bhubaneswar
Orissa, 751002
Tel: (91 674) 2465 421
Fax: (91 674) 2465 407
E-mail: sarangi012@yahoo.com
cifa@ori.nic.in

INDONESIA

Mamat Rahmat Ibrahim
Secretary, Directorate General of Aquaculture
Jl RM Harsono No 3 B, Building
Ragunan Pasar Minggu, Jakarta 12550
Tel/Fax: (62 21) 780 4066
E-mail: rahmatibrahim@telkom.net

Endhay Kusnendar Mulyana Kontara
Director, Aquaculture Production
Directorate General of Aquaculture
Jl RM Harsono No 3 B, Building
Ragunan Pasar Minggu, Jakarta 12550
Tel/Fax: (62 21) 7883 1914
E-mail: endhay@rad.net.id

IRAN (ISLAMIC REPUBLIC OF)

Hosseini
Deputy for Aquaculture
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 0692/6694 1671
Fax: (98 21) 6694 3870
E-mail: hosseini@iranfisheries.net

Ebrahim Maygoli. N
Adviser to Head and Director
Public and International Relations
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 1671/6694 0692
Fax: (98 21) 6694 3870
E-mail: maygoli@iranfisheries.net
maygoliebrahim@yahoo.com

S. Rezvani Gilkolaei
President
Iranian Fisheries Research Organization
PO Box 14155 – 6116, Tehran
Tel: (98 21) 6694 5577 – 8
(98 911) 2084176
Fax: (98 21) 6642 0732
E-mail: Rezvani@ifro.org

Mehdi Shirazi
Deputy Director, Public and International Relations
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 1674/694 2575
Fax: (98 21) 6694 1673
E-mail: mnshirazi@gmail.com

Abdolhay Hossein
Director for Stock Enhancement
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 1366
Fax: (98 21) 6694 3870
E-mail: abdolhay@yahoo.com

Kakoolaki Shapour
Director for Extension Division, Deputy of Aquaculture
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 3854-5
Fax: (98 21) 6694 3870
E-mail: bsh443@yahoo.com

Abbas Matinfar
Head of Aquaculture Department
Iranian Fisheries Research Organization
Ministry of Jihad-e-Agriculture
No 297 Dr Fatemi St, Tehran
Tel: (98 21) 6694 5140
Fax: (98 21) 6642 0732
E-mail: a_matinfar@hotmail.com

Mohammad Pourkazemi
Director, International Sturgeon Institute
PO Box 41635-3464
Rasht
Tel: (98-131) 660 6503
Fax: (98-131) 660 6503
E-mail: pkazemi_m@yahoo.com

Hamid R Alizadeh
Ichtyology Researcher
Iranian Fisheries Research Organization
Ministry of Jihad-e-Agriculture
No 297 Dr Fatemi St, Tehran
Tel: (98 21) 6691 8000
Fax: (98 21) 6642 0732
E-mail: alizadeh@ifro.org

Jasem Gh. Marammazi
Director, Scientist Research
Southern Aquaculture Research Center (SARC)
Ahwaz: PO Box 61645/866
Tel: (98 612) 327 3200–4
Fax: (98 612) 327 3202
E-mail: g_marammazi@ifro.org
jmarammazi@yaho.com

Homayoun Hosseinzadeh
General Director of Fish Culture
Aquaculture Department
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 3714–5
E-mail: h_hosseinzadeh@yahoo.com

Mohammad Afsharnasab
Research Deputy, Aquatic Animal Health Specialist, Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6691 9132
Fax: (98 21) 6642 0732
E-mail: m_afsharnasab@ifro.org

M.S. Rohani
Aquatic Animal Health and Disease Specialist
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6691 9152
Fax: (98 21) 6642 0732
E-mail: rohani@ifro.org

M. Garshtassbzad
Head of Directorate
Union of the Warm and Freshwater Fish
Propagation and Culture of Iran
Ave Jarnaizadeh
Bagherkhan St No 21, Tehran
Tel: (98 21) 6694 7507
Fax: (98 21) 6693 0222
E-mail: gashtasbzad@yahoo.com

Vahid Tofighi
Web Administrator of Shilat
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 3873
Fax: (98 21) 6694 3872
E-mail: vtofighi@gmail.com
vtofighi@yahoo.com

Ali Farzanfar
Manager of Scientific Communication
Iranian Fisheries Research Organization
Ministry of Jihad-e-Agriculture
No 297 Dr Fatemi St, Tehran
Tel: (98 21) 6691 9133
Fax: (98 21) 6642 0732
E-mail: afarzanfar@ifro.org
afarzanfar@yahoo.com

Ali Beigi
Stock Enhancement and Culture-based Fisheries Officer
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 3867-8
Fax: (98 21) 6694 3870
E-mail: ali_beigi2002@yahoo.com

Masoud Reza Khezri
In-charge of International Professional Agencies
Iranian Fisheries Organization
Ministry of Jihad-e-Agriculture
No 250 – West Fatemi Avenue, Tehran
Tel: (98 21) 6694 1674
Fax: (98 21) 6694 1673
E-mail: msr_khezri@yahoo.com

Abbas Afshar
Coordinator , Iranian Fisheries Research Organization
Ministry of Jihad-e-Agriculture
No 297 Dr Fatemi St, Tehran
Tel: (98 21) 6694 1674
Fax: (98 21) 6694 1673
E-mail: abb_af@yahoo.com

MALAYSIA

Hj Rosly bin Hassan
Head , Freshwater Fisheries Research Center
Dept of Fisheries
71650 Titi, Jelebu, N Sembilan
Tel: (60 6) 317 1131
Fax: (60 6) 317 5705
E-mail: roslyffrc@hotmail.com

MYANMAR

U Kyaw Myo Win
Director (Aquaculture), Department of Fisheries
Ministry of Livestock and Fisheries
Ahlone Township, Sinmin Road, Yangon
Tel: (95 1) 222 962; 228 624
Fax: (95 1) 228 258
E-mail: dof@mptmail.net

NEPAL

Gagan Bahadur Nhuchhe Pradhan
Senior Aquaculturist, Directorate of Fisheries Development
Central Fisheries Bldg
GPO Box 8068, Balaju, Kathmandu
Tel: (977 1) 435 0833
Fax: (977 1) 435 0662
E-mail: dofd@mail.com.np
Gaganbnpradhan03@yahoo.com

PAKISTAN

Muhammad Hayat
Fisheries Development Commissioner
Ministry of Food, Agriculture and Livestock
8th Floor, Shaheed-e-Milat Secretariat
Blue Area, Islamabad
Tel: (92 51) 920 8267
Fax: (92 51) 921 2630
E-mail: drmuhammadhayat@yahoo.com

PHILIPPINES

Nelson A. Lopez
Chief, Inland Fisheries and Aquaculture Division
Bureau of Fisheries and Aquatic Resources
860 Quezon Avenue, Quezon City
Metro Manila 1103
Tel/Fax: (63 2) 373 0792
E-mail: nlopez@bfar.da.gov.ph
munchkin@edsamail.com.ph

SRI LANKA

D.E.M. Weerakoon
Director General
National Aquaculture Development Authority (NAQDA)
758 Baseline Road, Colombo 09
Tel: (94 11) 2675 316/17/18
Fax: (94 11) 2675 435/2675 317
E-mail: aqua2@eureka.lk
demweerakoon@yahoo.com

THAILAND

Ms Jiraporn Kasornchandra
Director, Coastal Aquatic Animal Health Research Institute
Pawong Sub district,
Songkhla 90100
Tel: (66 74) 334 156–8
Fax: (66 74) 334 515
E-mail: jibkasorn@yahoo.com

VIET NAM

Nguyen Thanh Phuong
Dean, College of Aquaculture and Fisheries, Cantho University
Campus 2, 3/2 Street, Ninh Kieu District
Cantho City
Tel: (84 71) 835 701
Fax: (84 71) 830 323
E-mail: ntphuong@ctu.edu.vn

AGENCIES/ORGANIZATIONS

Food and Agriculture Organization of the United Nations (FAO)

Simon Funge-Smith
Aquaculture Officer
Aquaculture and Inland Fisheries
FAO Regional Office for Asia and the Pacific
Maliwan Mansion, Phra Atit Road
Bangkok 10200, Thailand
Tel: (66 2) 697 4149/(66 4) 120 1021
Fax: (66 2) 697 4445
E-mail: simon.fungesmith@fao.org

Jia Jiansan
Chief, Inland Water Resources and Aquaculture Service
FAO Fisheries Department
Viale delle Terme di Caracalla
00100 Rome, Italy
Tel: (39) 06 5705 5007
Fax: (39) 06 5705 3020
E-mail: jiansan.jia@fao.org

Rohana Subasinghe
Senior Fishery Resources Officer (Aquaculture), Inland Water Resources and Aquaculture Service
FAO Fisheries Department
Viale delle Terme di Caracalla
00100 Rome, Italy
Tel: (39) 06 570 56473
Mob: (39) 348 154 1351
Fax: (39) 06 570 53020
E-mail: rohana.subasinghe@fao.org

Network of Aquaculture Centres in Asia-Pacific (NACA)

Pedro Bueno
Director General
Network of Aquaculture Centres in Asia-Pacific
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak
Bangkok 10900, Thailand
Tel: (66 2) 561 1728–9
Fax: (66 2) 561 1727
E-mail: pedro.bueno@enaca.org

C.V. Mohan
Aquatic Animal Health Specialist
Network of Aquaculture Centres in Asia-Pacific
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak
Bangkok 10900, Thailand
Tel: (66 2) 561 1728–9
Fax: (66 2) 561 1727
E-mail: mohan@enaca.org

Simon Wilkinson
Information Specialist
Network of Aquaculture Centres in Asia-Pacific
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak
Bangkok 10900, Thailand
Tel: (66 2) 561 1728–9
Fax: (66 2) 561 1727
E-mail: simon.wilkinson@enaca.org

Koji Yamamoto
Research Associate, Coastal Aquaculture
Network of Aquaculture Centres in Asia-Pacific
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak
Bangkok 10900, Thailand
Tel: (66 2) 561 1728–9
Fax: (66 2) 561 1727
E-mail: koji@enaca.org

Nguyen Thuy Thi Thu
Research Associate, Genetics and Biodiversity
Network of Aquaculture Centres in Asia-Pacific
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak
Bangkok 10900, Thailand
Tel: (66 2) 561 1728–9
Fax: (66 2) 561 1727
E-mail: Thuy.nguyen@enaca.org

Flavio Corsin
Aquatic Animal Health Specialist
SUMA Office
10 Nguyen Cong Hoan
Ba Dinh District
Hanoi, Viet Nam
Tel: (84 91) 277 6993
Fax: (84 4) 771 6517
E-mail: flavio.corsin@enaca.org

Chen Foo Yan
105 Cairnhill Circle
#04-115 Singapore
229810 Singapore
Tel: (65 6) 732 2855
E-mail: Chen_foo_yan@hotmail.com

Southeast Asian Fisheries Development Center - Aquaculture Department

Wilfredo G. Yap.
Head, Research Division
SEAFDEC Aquaculture Department
Tigbauan Iloilo, Philippines
Tel: (63 2) 372 9133;372 3980
Fax: (63 2) 372 3983
Fax: (63 33) 511 9070
E-mail : wgyap@aqd.seafdec.org.ph

Secretariat of the Pacific Community

Ben Ponia
Aquaculture Adviser
Secretariat of the Pacific Community
BP D5-9884 Noumea Cedex
New Caledonia
Tel: (687) 262000
Fax: (687) 263818
E-mail: benp@spc.int-

APPENDIX B

Workshop Programme

Programme of the FAO Regional Expert Review of Aquaculture Development: Asia-Pacific

27th	Activity	Responsibility	Remarks
1030	Introductions Appointment of Overall Workshop Chair and Vice Chair	Participants	• Self-introductions
1040	Overview of the workshop: rationale for activity; objectives; outputs and workshop arrangements	Rohana Subasinghe	• General introduction
1100	Presentation of Asia-Pacific Aquaculture Development Trends Synthesis	Fred Yap Simon Funge-Smith	• Trends • Issues
1200	Plenary discussion		
1230	Lunch Break		
1400	Introduction to Working Groups	Rohana Subasinghe	• Guidelines and TORs
1410	**Working Group Session 1**		
	Working Group I 1. Characteristics and the structure of the sector 2. Production, species and values 3. Economics and trade	Elect a facilitator Appoint a rapporteur Designate a presenter	• Use synthesis as main working paper for discussion and the "Emerging issues impacting on aquaculture development" reports prepared for GC 15 as an experiences publication. • Review the synthesis, identify gaps, and suggest improvements. • Brain storm on issues, opportunities and development challenges pertaining to the above two subject areas.
	Working Group II 1. Contribution to food security; access to food, nutrition and food safety 2 Social impacts, employment and poverty reduction	Elect a facilitator Appoint a rapporteur Designate a presenter	• Use synthesis as main working paper for discussion and the "Emerging issues impacting on aquaculture development" reports prepared for GC 15 as an experiences publication. • Review the synthesis, identify gaps, and suggest improvements. • Brain storm on issues, opportunities and development challenges pertaining to the above two subject areas.

28th	Activity	Responsibility	Remarks
	Working Group III 1 Environment and resources 2 Legal, institutional and management aspects of the aquaculture sector		• Use synthesis as main working paper for discussion and the "Emerging issues impacting on aquaculture development" reports prepared for GC 15 as an experiences publication. • Review the synthesis, identify gaps, and suggest improvements. • Brain storm on issues, opportunities and development challenges pertaining to the above two subject areas.
1600	Working Groups continued		
1900	Welcome Dinner		
28th			
0900	Presentation of the three Working Group Reports	Chair Presenters	• Each working group presents their findings and major conclusions
1100	Presentations continued		
1230	Lunch break		
1330	**Working Group Session 2**		
	Working Group I and II Trends in aquaculture development	Two Co-Chairs Two Rapporteurs Presenter	• Follow the TOR
1600	Working Groups I and II continued	Two Co-Chairs Two Rapporteurs Presenter	• Follow the TOR
1700	Working Group I and II presentations in plenary		
29th			
0800	Field visit		
1530	Plenary Session	Chair	Adoption of the report and way forward
1800	End of the Workshop		
29th			
1230	Lunch Break		
1400	Presentation of Working Group reports		
29th	**Activity**	**Responsibility**	**Remarks**
1530	Conclusions Recommended action: • Recommendations for national action and international support to address identified issues • Milestones – deadlines for additional work		
1700	Closing Activities		

APPENDIX C

Terms of Reference for Working Groups

Working Group 1

1. Elect a facilitator
2. Appoint a rapporteur
3. Designate a presenter
4. Review the following sections of the Draft Asia Regional Review (Synthesis) documents provided to you:
    - Characteristics and the structure of the sector
    - Production, species and values
    - Economics and trade
5. Use the synthesis document as a main working paper for discussion and the "Emerging issues impacting on aquaculture development" reports prepared for TAC 8 as an experiences publication during the discussions.
6. Review the synthesis, identify gaps, and suggest improvements.
7. Brain storm on issues, opportunities and development challenges pertaining to the above three subject areas.
8. Make a presentation of finding in plenary

Working Group 2

1. Elect a facilitator
2. Appoint a rapporteur
3. Designate a presenter
4. Review the following sections of the Draft Asia Regional Review (Synthesis) documents provided to you:
    - Contribution to food security; access to food, nutrition and food safety
    - Social impacts, employment and poverty reduction
5. Use the synthesis document as a main working paper for discussion and the "Emerging issues impacting on aquaculture development" reports prepared for TAC 8 as an experiences publication during the discussions.
6. Review the synthesis, identify gaps, and suggest improvements.
7. Brain storm on issues, opportunities and development challenges pertaining to the above two subject areas.
8. Make a presentation of finding in plenary

Working Group 3

1. Elect a facilitator
2. Appoint a rapporteur
3. Designate a presenter
4. Review the following sections of the Draft Asia Regional Review (Synthesis) documents provided to you:
   - Environment and resources
   - Legal, institutional and management aspects of the aquaculture sector
5. Use synthesis as main working paper for discussion and the “Emerging issues impacting on aquaculture development” reports prepared for TAC 8 as an experiences publication.
6. Review the synthesis, identify gaps, and suggest improvements.
7. Brain storm on issues, opportunities and development challenges pertaining to the above two subject areas.
8. Make a presentation of finding in plenary.

Working Group Session 2

Working Groups 1 and 2

1. Task 1 - list 6 FUTURE TRENDS that specifically concern Asia-Pacific
2. Can be for :
   - a specific species/group of products (e.g. carnivorous finfish or for tilapia)
   - an issue/characteristic of the sector (e.g. access to water for culture)
   - a country/regional group (e.g. south Asia/China, etc.)
3. Task 2 - RANK these in terms of critical importance
4. Task 3 - Identify 1-3 PRIORITY ACTIONS for each trend
5. Task 4 - for each priority actions indicate a PRACTICAL mechanism for implementing this.
6. Make a presentation in plenary

APPENDIX D

Working Group Reports

Working Group 1 - Report

Components included for discussion

- Characteristics and the structure of the sector
- Production, species and values
- Economics and trade

Report is in four parts

- Important issues identified to form the basis for further discussions (for today) on development of action plans.
- Suggested revisions for the document.
- Identified other relevant issues that may be considered while revising the document.
- Suggested action plans for revising the document.

1. Important issues

Missing species

- Several species are not accounted for in the reporting of production and value mainly because their volumes are small and does not warrant reporting. Hence `do not figure in the official statistics of the countries (e.g. Babylonia).

Non-food commodities

- Including non food commodities into FAO aquaculture production statistics should be considered. Considering the high value of the industry, several important non-food commodities (pearls, ornamental fish, and sponges) should be considered in the reporting system.

Generic reporting

- This does not make a distinction between native and exotic species (e.g. reporting under penaeids).
- Several species grouped under marine finfish statistics, hence details of emerging species not available (e.g. turbot culture in China).
- Distinguishing between pearl and mother of pearl in production statistics (different in terms of value and weight).

Diversity of cultured species (PAFAD should consider the following):

- Large number of species cultured 177. Should there be a tendency to consolidate?
- Will diversity in species cultured offer opportunities for sustainability and flexibility?
- Should diversity be seen as a niche opportunity for smaller scale farmers.
- Is developing a commodity exclusively to meet export market demand sustainable?
- Will diversity of species cultured offer small farmers with flexibility and more options?
- Will more diversity mean less opportunity for product standardization?
- Should there be a division of culture practices and species cultured based on market requirements.
- Considering the regional experience, should small farmers be encouraged to organize into clusters to meet increasing market demands and consumer requirements.
- Would development of a robust marine finfish hatchery system allow diversification and expansion of marine finfish culture in the region?

Characteristics of the systems

- Diversity of systems in Asia is very high. Land usage pattern is becoming an issue in many countries.
- Difficult to forecast the present/future trend- new farming areas or intensification of existing culture systems.
- Shifting policy of concern over conversion of agricultural land to aquaculture is allowing diversification in some countries (e.g. Viet Nam 2000) while in some countries, conversion of agricultural land to aquaculture is strictly regulated under law.

Trade

International and intra-regional trade

- Reported export values of significant traded items (e.g. shrimp, catfish), hides a much broader range of other species (e.g. marble goby, *Macrobrachium rosenbergii*) traded between countries. Need to distinguish between traded commodities.

Niche species

- Some lower value rice field species (e.g. climbing perch) are now becoming increasingly popular and is produced under intensive conditions for local market. Intensification of lower value species to meet local demand should be considered in trend analysis and projections.

Access to markets

- Small scale farmers farm species targeting domestic markets while large scale farmers, who can afford product standardization target export market (exception is shrimp).
- Access to international market for small and medium scale producers is difficult and this may force them to produce commodities to cater to the domestic market.
- When countries try to produce a product for international market, the cost of meeting the international requirements (e.g. HACCP, traceability) increases the cost of production and the production of the commodity becomes no longer economically viable (e.g. milk fish in the Philippines).

Ornamentals

- There is tremendous potential for future development of ornamentals. Countries are trying to maintain genetic stocks for property right purposes and prevent others from breeding. Narrow marketing chains are a major limitation.

Some future country trends

- Iran is planning to boost aquaculture production of sturgeon for export.
- Iran is planning to double the production of salmonids (rainbow trout) over the next 5 years to meet the increasing market demand. (Fishmeal imported from Peru and some other countries). More comments to be included on progress made in Iran.
- Myanmar- promoting mud crab and eel aquaculture for export.

Economics

Impact on economy

- No clear picture available on the level of investment by national governments relative to the value of aquaculture.
- For promotion of export oriented aquaculture, some countries have invested huge sums of government funds (e.g. Iran, Sri Lanka), while there is limited support for culture of species meant for domestic market.
- Calculating contribution of aquaculture to GDP is not an easy task. Need to address this issue.

Employment figures are CRITICAL

- Need to ask countries (NASO authors) to go back to the employment figures and also get some indication of figures from processing and service sector.
- Unless fisheries and aquaculture is properly integrated into some form of structured census process, it is difficult to get accurate employment figures. Other agencies responsible for labour should be encouraged to make available such information.

2. Suggested revisions for the document

Seaweeds

- Myanmar is starting culture of *Eucheuma* seaweed. Should be reflected in Table 3.
- Need to reconfirm whether Viet Nam is the largest *Gracilaria* producing country?
- Need to consider culture of mono-cellular algae (e.g. *Spirulina*). Potential as a niche market.

Amphibians and reptiles

- Soft shell turtle is produced in Viet Nam (should be included in Table 3).

Molluscs

- Babylonia (snail) should be included in Table 3 (China and Viet Nam undertake active culture).
- Viet Nam should be added under cockle culture in Table 3.
- Both marine and freshwater pearl culture, by production and value, needs to be included under aquaculture.
- Giant clam culture done on commercial scale in Philippines for ornamental purpose (consider including in production statistics).

Fish

- Anabantidae- Climbing perch (not walking perch).
- Viet Nam is culturing Snakehead and climbing perch. Should be included in Table 3.
- Iran doing commercial culture of sturgeons, *Barbus sharpeyi* and some other indigenous cyprinids. Should be included in Table 3.
- Cobia cultured in Viet Nam and also Thailand. Quite recently became an important commodity. No information on production figures.
- Large number of unspecified species included under marine finfish. No information on several species cultured. (E.g. European turbot and sturgeons in China). Request China for break down of Chinese marine finfish production.
- Include an additional group on Pompanos (Pomfrets).
- Production of eel in Japan and Taiwan Province of China has decreased while from China it has increased. Need to seek clarifications from China on seed source, since eel farming is still largely dependent on wild elvers. There is no information on source of elvers and their trade in the region.
- Depending on the country, seabass is fed on either pellet or trash fish. There appears to be limited international market for *Lates calicarifer*, while Nile perch enjoys significant market in Europe. Need to understand the reasons for the lack of international market for *Lates calcarifer*.
- Production of Japanese amberjack is stable in Japan. Need to understand the reasons, including whether it is still fed on minced fish or pellet.

Crustaceans

- Reporting of all the penaeid shrimp together is making it difficult to distinguish the production levels of tiger shrimp, white legged shrimp, etc. It may be necessary to disaggregate between important cultured shrimp (*P. monodon, P. indicus, P. chinensis, P. vannamei,* and *P. stylirostris).*

- All countries culturing freshwater prawn should be included (Viet Nam, Philippines, Sri Lanka missing in Table 3).
- Need to re-examine the present status of Macrobrachium culture in the region. (India known to produce large volumes for export market).
- Mangrove crab- fattening does not get reported.
- Include Viet Nam for Spiny Lobster.
- Yabbies should be changed to freshwater crayfish.
- Freshwater crayfish is cultured in some countries.

3. Actions required to revise the document

- Revise the synthesis document in the light of the working group findings.
- Seek additional information, where required from NASO authors.
- Send synthesis report to all the working group members/workshop participants to go through in detail and give feed back, after consulting available information at the country level.

4. Other issues of relevance (may be considered while revising the regional synthesis document)

Seaweeds

- Iran has commenced commercial seaweed culture at R&D level (*Gracilaria* for agar).
- Japan cannot expand seaweed culture due to limitations on site availability, hence expansion of seaweed culture is shifting to other countries in the region.
- Moratorium on expansion in mangrove areas in Philippines (Future expansion should be only off shore).
- Seaweeds culture is normally taken as the last choice-as returns are low and it labour intensive.
- In some countries, culture taken up as dual employment along with fishing.

Amphibians and reptiles

- Culture of crocodiles is not generally recorded. Many countries are actively involved in crocodile farming (Myanmar, China, Cambodia, Thailand). Should consider including.
- Not recorded as these commodities are locally marketed and not produced at levels to be captured by formal statistics.

Molluscs

- Provide a distinction between high value and low value species cultured. Need to assess the market potential for high value mollusc. For high value species (scallops, abalone, oysters) it is possible to go for intensification and is evident in some countries.
- Cultured molluscs are mostly marketed fresh with some exceptions. Have a very good domestic market. Health and safety requirements for commercially traded mollusc is very stringent, hence developing a strong export market is a difficult challenge.
- Myanmar has started abalone farming.
- Abalone in Viet Nam in R&D stage.
- Oyster spat stocking for natural pearl production in pilot level in Iran.
- Programmes on restocking of reefs with giant clam spats not successful.

Fish

- Indian carp and tilapia culture at R&D level in Iran.
- Grouper, sea bream (indigenous species *Sparrus*) *Macrocephalus* and *Barbus gripus* at R&D level in Iran.
- Intensification of omnivorous species culture on the increase (area under culture coming down but production increasing). Increased use of intensive production systems for omnivorous

species (either cages or using pellet feeds). Shift to intensification in carp culture appears to be more economical compared to low input systems.
- Mixed production systems, appear to be more economical.
- Secondary purpose of milk fish culture is for bait fish for tuna fishing, not for food. Sri Lanka and some Pacific islands interested in developing this industry (Note: Tuna bait industry is not very stable).

Crustaceans
- Penaeidae production should be qualified by two dominant species as *Chinensis vannamei* (references to all *P. vannamei* should be checked against *P. chinensis*).
- Philippines and Viet Nam working on mud crab hatchery technology.

Aquaculture growth in the region
- Japan and Korea are major aquaculture commodity producers but their rate of growth is slow. Need to understand reasons for the slow down.
- New Zealand has a very fast growth rate. Need to go back to New Zealand and seek clarifications on their growth and species.
- Mean average growth rate for Myanmar, Saudi Arabia and Cambodia also very high. Need to seek clarifications on reasons for high growth rate (species, new areas, etc.).

Working Group 2 - Report

Social impacts, employment and poverty reduction

Chair: Gagan PN Pradhan, Senior Aquaculturist, Directorate of Fisheries Development, Nepal
Facilitator: Wilfredo G. Yap, Head, Technology Verification Division, SEAFDEC Aquaculture Department
Rapporteurs: Simon Wilkinson and Pedro Bueno, NACA

Members:
(Ms) Jiraporn Kasornchandra, Director Coastal Aquatic Animal Health Research Institute
Abbas Matinfar, Deputy for Aquaculture Research IFRO
M.S. Rohani Aquatic Animal health Specialist, IFRO
Jiansan Jia, Chief FIRI, FAO
N.S. Yang, Director, Information Center, CAFS
Endhay Kusnendar Mulyana Kontara, Director Aquaculture Production, DGA, Indonesia
N. Sarangi, Director, CIFA
Hav Viseth, Chief, Aquaculture Divsion, Cambodia

1. Contribution to food security: Access to food, nutrition and food safety

Do you have quantitative information on fish consumption trends (especially in urban vs. rural societies) in your country?
Information on trends in fish consumption is useful tools for planning, policy and "advocacy" for resource allocation for aquaculture in government. Unfortunately quantitative information on fish consumption trends is generally not available in the fisheries sector, although some data may be held by non-fisheries related agencies (such as the Institute of Food and Nutrition in the Philippines). Studies/surveys of fish consumption may be available for Australia. "Ballpark" estimates based on gross production divided by population do not give a representative picture of consumption of aquaculture products.

Can you provide, with a few examples, market prices of wild fish vs. culture fish species?
Wild caught aquatic products are generally more expensive than cultured products, as often the case with shrimp, Asian seabass and grouper. There are often obvious differences in quality characteristics such as taste, texture, etc. between farmed and wild product, which is often perceived as superior by consumers. Price differentials may also reflect other factors such as poor handling (e.g. trawled shrimp in the Philippines receive a lower price than farmed product). However, wild/farmed products are not always directly equivalent (may be different sizes, grades, etc.).

Do you have any demographic data and/or trends which have relevance to aquaculture? Movement of people into or out of aquaculture areas etc?
Not much hard data is available. However, there is a trend for fishers to move into aquaculture.

- In Cambodia, many marine fishers have taken up seaweed farming as their primary source of employment (more than 99 percent of farmers are ex-fishers).
- In China, around half the people working in aquaculture have previously been involved in fishing and there is still movement of people into the sector due to encouragement of people to convert rice farming areas to aquaculture; where people leave aquaculture it is often because land has been re-zoned for other purposes. There is also a trend of men moving to cities to work while women take over the role of managing small-scale rural aquaculture activities.
- In Iran, people are moving into shrimp farming areas.
- India has a general trend of people moving into aquaculture with the government's emphasis on integrated aquaculture as a poverty alleviation measure in most states. Some aquaculture area is being lost to urbanization, as rising land values lead to conversion of land to other uses.

Do you have any information on comparative consumption of fish vs. terrestrial meat in rural and urban societies?
Some information is available; this is an area that needs to be addressed as part of improvements to collection of information trends and statistical data.

Food quality and safety

- Must consider the impact of other industries on aquaculture – is there adequate legislation in place to protect aquaculture from pollution generated by other industries?
- Food safety standards - there is a discrepancy in the stringency of standards between exported product and product for domestic consumption. This is also true for other agricultural commodities and is invariably imposed by importing countries.
- Food quality depends on consumer awareness and concern. It is difficult to regulate.
- Food safety standards are becoming more stringent, also raising the cost of production as farmers and processors try to meet these standards. If the producer is expected to bear the cost there is a danger that small-scale producers will not have the economic capacity to meet requirements.
- The poor are generally more concerned with food security than food safety. Nonetheless, while the domestic market may tolerate less stringent food safety and quality standards, it is no less important to pay attention to food safety and quality standards. It was also noted that with increasing buying power, the domestic consumers are also becoming more aware and demanding of better quality and assurance of safe food products.

2. To employment and poverty reduction

Is there a trend in shifting from small-scale operations to larger commercial operations in aquaculture in your country? If so, what is driving or encouraging this?

- In the context of social equity, this question is interpreted as looking for a trend towards consolidation of small operations into big commercial and even corporate enterprises. It is not clear if there is a trend of consolidation or not. There has been some consolidation in Australia in some sectors of the aquaculture industry (e.g. shrimp) as multinational companies acquire farms under pressure from price slumps, and these consolidated farms are often the less efficient producers. However, the response in other countries can be different. For example, the Thai shrimp industry has also been under considerable pressure from the global price slump, but Thai farmers are more flexible and – rather than selling the farm – respond with such strategy as looking for alternative employment or switching into other business. Once conditions improve they return to shrimp farming.

- Small-scale farmers can gain economies of scale and increase their negotiating power and economic viability by forming associations and cooperatives. In China, cooperatives of small-scale farmers supply large companies specialising in food processing on a contract basis. Farmer cooperatives are also common in India although the small-scale farmers tend to be less well organized; some quantifiable local-level data is available from MPEDA/NACA demonstrating increased economic performance on the production side through application of better management practices by clusters of farmers cooperating through "Aquaclubs".
- In the Philippines and Indonesia, farmers may enter into contract farming with land, inputs or credits supplied by the processor in exchange for the right to buy the harvest, typically at the prevailing market price. However, crop failure can lead to a debt trap, as farmers participating in these schemes are very vulnerable to economic and natural shocks because, typically, they do not have much capital.

Do you have any information on the ownership of aquaculture operations; e.g. Family owned vs. large industrial/commercial operations?
This information is generally not available. As a general trend freshwater aquaculture is more often small-scale or family-owned whereas brackish and marine aquaculture tends to be larger scale and more industrial (although there are also a large number of small-scale operators in brackish and marine environments).

- The Philippines has information on farm sizes, but not on ownership (family-owned vs. industrial); even large farms may be family owned.
- Iran can obtain the data but not easily.
- In India, small farmers are generally more numerous (i.e. comprise the largest proportion of total number of farms), but probably have less total area than that of the larger farms.
- Freshwater aquaculture tends to be small scale enterprises, marine and brackish water tends to be dominated by industrial aquaculture.

Do you have any information on aqua farms owned by the farmers vs. farmed in leased land/water?
In general for most countries the majority of farms are situated on land or water publicly leased from the government.

- The Philippines can supply this information for public land, but not for private lands as there are no records. Most leased farms are in brackish water.
- In India, Nepal and Bangladesh, village ponds are mostly leased out.
- In Iran land for shrimp and large fish farms are mostly leased. Trout farms must also pay for water usage.

Do you have any information on aquaculture's contribution to employment (full and part time) in rural and coastal areas? If so, is it off-setting/alleviating fishing or other livelihoods that are in decline?
Some information is available but it is variable between countries. Employment information could be improved and augmented using data from other agencies e.g. the labour ministry. Most countries do not break down aquaculture employment statistics by full/part time and gender, with the exception of China, which has provides information on full and part-time employment. Non-registration of farms, particularly small-scale operators, makes it difficult to get accurate information.

- Approximately half of China's aquaculture labour force was people that transferred from fishing.
- Many marine fishers in Cambodia have switched to seaweed farming as their primary occupation (more than 99 percent of seaweed farmers are ex-fishers). This has also happened to some extent in the Philippines.

- Displaced fishers in India tend to go into fish processing and mollusc culture.
- Indonesia conducts a 10-year census on agriculture with a specific section on aquaculture.
- Australia has general information on aquaculture employment (not sure how recent) but probably not the details on proportion of full/part time workers. Data is probably available on a per-state basis.
- The southern bluefin tuna farming industry in Australia was founded entirely by fishermen. Their catch was limited by a quota on the wild fishery, so they turned to cage-based fattening to increase the value of their quota. Almost 100 percent of the wild catch quota is now fattened. In the Australian shrimp farming industry, based mostly in Queensland, many farms are built on and owned by sugar cane farmers (often as the primary business).

Do you have any information on the distribution of benefits from aquaculture and equity in aquatic production sector in your country?
There are two general trends: In some countries small farmers operate in isolation and are often exploited by middlemen. In others where farmers get together in collectives, they have greater negotiating power and tend to take a greater share of the benefits.

- In general, farmers tend to get a poor share of the benefits, particularly the smaller ones who endure greater risk, and lower returns. Middlemen usually have the better share of margins. Larger farmers benefit from economies of scale.
- In Iran, the producer, middlemen and retailer each get about one-third of the benefit.
- Vertically integrated farms usually get much more of the margin but this approach is not always appropriate (best for shrimp industry). A case can be made for segmentation of production processes or stages (i.e. broodstock, hatchery, nursery, or even more than one stage of nursing) as it generates more employment, distribute risk and allow specialist handling/expertise at every step.

Do you have any information on involvement of women and children in aquaculture i.e. Numbers vs. income?
Quantitative data is not available as countries cannot disaggregate data by gender, full and part time etc. However, women and children are heavily involved in all countries except Iran, and play an important role particularly in processing and marketing, and in operation/management of small-scale/family run aquaculture.

- India, Nepal and Cambodia: Women tend to be paid less than men and may also have to work more hours. Children are often involved in collection of wild seed.
- Philippines, Thailand and China: Women and men receive equal pay. In China women are involved in nearly all aspects of aquaculture. In rural areas there is a trend of men moving to the cities to find employment so women are playing a leading role in managing aquaculture operations.

Data sources
The Fisheries Research and Development Corporation has published at least two previous studies on fish consumption trends in Australia. They are likely to have updated this information. Data may also be available from the Australian Bureau of Statistics (http://www.abs.gov.au/). The data is unlikely to distinguish between fisheries/aquaculture products.

"Out-of-the-box" but related questions:
There probably is little argument on aquaculture's role in contributing to food security and earning for people and governments more income, but is aquaculture really contributing to poverty alleviation. How? Where and Why? Where it might be seen as not contributing to poverty alleviation, why not? Are there circumstances when aquaculture is not really the answer to poverty alleviation?

No doubt aquaculture generates wealth, but is it shared equitably? Why not? What might be the approaches, within the context of democratic processes, to distribute the benefits equitably?

Might there be a case where in fact aquaculture is contributing to keeping some people or sectors in poverty or preventing or making it extremely difficult for them to earn a better livelihood?

More generally, is aquaculture improving the net worth of society? Might the wealth it generates not offset by the damage it inflicts on other sectors and on the environment, and on its own ability to continue?

Working Group 3 - Report

Facilitator: Rohana Subasinghe
Rapporteurs: Ben Ponia and Flavio Corsin

Participants:
Koji Yamamoto
Miao Weimin
Mhd. Hayat
Rosly Hassan

Introduction
There is a perception of environmental organizations that aquaculture development is unsustainable. Source of concern generates from:

- Sustainability of the use of fishmeal and fish oil.
- Trends towards intensification and the associated increased demands on the environment.

1. Fishmeal and other fish-based ingredients for aquaculture feed

There is a perception particularly being propagated by environmental NGOs that fishmeal is unsustainable. Why feed fish with fish they ask and is there sufficient fishmeal to account for the future growth rate of aquaculture?

- It is noted that the trend for expansion is towards high valued marine species which are carnivorous and will require feeds high in protein.
- Furthermore the environmental impacts of fish aquafeeds are greater in marine systems compared to freshwater.
- Whilst soya bean oil has been touted as a substitute the conversion and digestibility rates vary between species and can be quite poor amongst some.
- An issue which will have to be addressed is whether to incorporate genetically modified soyabean oil. This will have to merge with the preferences of consumers, whilst it was noted that GMOs are quite common in the US market the same may not be true of Europe.
- Feed formulation research appears not to have attracted sufficient funding or the necessary attention from private sector.
- The demand of fish oil is likely to increase and drive up prices hence there will be logical incentives to find substitutes.
- Some of the solutions or alternatives to using fishmeal and oil may emerge from other industries – particularly the livestock and poultry sectors which have quite influential and well funded institutions.
- There is a good assessment of global requirements and use of fishmeal but disaggregating the statistics at a national level (for example usage between aquaculture, livestock and poultry) is poor.

The United States has recently begun to establish the legal regime to farm in their EEZ. But there are no standards for managing the effluents being produced from aquafeeds, effluents which eventually may have international repercussions

- Phosphorus and nitrogen compounds are important indicators of effluent discharge and aquaculture most take its global responsibility in reducing or monitoring their discharges.
- We need national and regional standards to ensure that there is an equal standards being adhered to.
- Offshore mariculture is still in its infancy in Asia although some countries do have deep sea cages.
- Tuna fattening is a lucrative farming practice in Australia and it is likely that this type of offshore farming could spread to other countries. At present Australia uses pilchards from the US as its main feed. Questions are raised about the environmental sustainability of this type of feeding regime.
- There are new technologies being developed that will enable free drifting submerged cages within the EEZ.
- Perhaps one solution to addressing the eutrophication is to develop polyculture systems which will produce species that can mitigate/absorb nutrients e.g. seaweed.

Are there alternatives farming systems? For example organics which are been investigated as a solution to formulated feeds.

- There are several drawbacks to organic farming systems such as it is less effective and there is no proper system of certification.
- There is a concern that once farms get the branded, they will substitute the real product with fakes.
- Organic market is a niche market and will not meet everyone's requirements.

What is the future for trash fish?

- There is a concern that the high production targets set by many countries does not take into account the limited trash fish resource, some targets will effectively use all of the available trash fish resource.
- Often the approach is to focus on the target (i.e. x amount of tonnes by the end of the year) not at the implications.
- Some countries are currently using trash fish because they are just starting out, eventually they too will have to address the trash fish issue.
- Can countries producing fish for their fish oil purposes, example of Pangasius.
- Other species such as snails (associated with trash fish) also being used as feeds.
- Can we change feeding traits of target species feeding traits to reduce their reliance or preference towards fishmeal?
- Other replacements for fishmeal suggested include offal (noting HACCP concerns), pro-biotics, palm oil, and supplementary fertilization.

2. Genetic resources (seed and broodstock)

The key question is whether seed will be sufficient to sustain the growth of the aquaculture sector and what actions may be required to sustain the required seed production.

Crustacean seed
The availability of shrimp seed has already been widely debated and concerns the large dependence on wild broodstock for some species (e.g. *P. monodon*), for which in some countries quantity is a limiting factor. Hence the attempts conducted worldwide to produce domesticated broodstock. Scarcity of shrimp seed has often also quality implications.

Domestication has been achieved successfully for other shrimp species (e.g. *P. vannamei*, *P. chinensis*, *P. indicus*) and has lead to the widespread production of some of these species outside their range (e.g. *P. vannamei* in Asia). This trend has so far experienced a high success in terms of production, but with some concerns regarding its sustainability especially from an environmental and socio-economic point of view.

Domestication has also been achieved for *Macrobrachium rosembergii* and broodstock centres have been established.

Serious concerns also rise from the harvest of wild seed for species for which the production of hatchery seed is not possible or not economically viable (e.g. lobster).

Marine fish seed
In view of the expansion of mariculture foreseen in many countries in the region, the availability of seed for mariculture is a concern that needs to be addressed. The importance of this issue is highlighted by the fact that production targets are often set by countries without proper consideration on the seed required to sustain the targeted production.

The evaluation of the present situation of seed availability and production is hampered by the scarcity of data, especially concerning the amount of seed produced in hatcheries by species.

Production of seed in hatchery is possible for several species of marine fish (e.g. seabass) and hatchery seed production has shown a sharp increase in several countries in the region (e.g. Indonesia, China). However, aquaculture production of some marine fish (e.g. some groupers, mullet, etc.) is still relying on wild seed because of the insufficient technical expertise to achieve hatchery production.

Rearing wild seed (e.g. wrasse) in submerged cages and has also been adopted as a way to sustain diversification.

Freshwater fish seed
Although freshwater seed availability does not seem to be a major concern, it is widely recognized that the quality of seed (e.g. grass carp) available to farmers has deteriorated over the years. This is sometimes due to genetic deterioration, although in some occasions (e.g. the reduce performance of *Clarias* in spite of the broad genetic pool available) other factors may play a role. Genetic improvement programmes have been put in place and have sometimes proved effective (e.g. tilapia). However, in spite of some attempts conducted by some governments (e.g. China) to support financially broodstock centres, poor broodstock management within those centres has also lead to genetic deterioration and the resulting poorer growth and yields (e.g. grass carp). Some countries have conducted introductions of broodstock from other sources (both farmed and wild). This practice raises a number of concerns associated with the risk of disease introductions. The presence of disease reduction strategies (quarantine, etc.) is recognized, as it is also the often poor effectiveness and implementation of those strategies. Some countries address the disease issues by selecting sources of broodstock from outside the region (e.g. common carp introduced from Hungary to Indonesia), which are perceived as “cleaner”.

It appears clear that efforts towards the production of better quality seed have been conducted and are ongoing. However the process is often slow and not very effective and the need for a regional programme to address this issue is recognized by several countries.

With some exceptions (e.g. KHV in koi carp), the quality of freshwater seed in terms of pathogens does not seem to be a major concern, although this may reflect the scarcity of production records available at the farm level and the identification of diseases associated with less apparent losses.

Molluscan seed
There is a general perception that hatchery seed for molluscan species is often poorly available. Although this is often true hatchery seed is available for at least some species (e.g. abalone, babylonia, pearl oyster, etc.).

Other issues associated with seed

Standards and protocols for shrimp seed production are in place in several countries. With the exception of shrimp, the scarcity of standards and protocols for seed production has also been recognized. It is suggested that NACA plays a significant role in developing such standards and protocols.

Development of protocol and standards for seed production would also support the effort towards certification of seed. Certification of shrimp seed and have proven to be effective in controlling the quality of seed being produced in some countries (e.g. in Sri Lanka).

The importance of certification and quality assurance as a tool to support farmers in identifying better quality fish seed is increasingly been recognized and the fact that some countries (e.g. China, India) already initiated processes in this direction is acknowledged.

Standards and protocols should also satisfy the need for compliance to traceability, which may soon become mandatory for aquaculture products produced in the region.

Concerns associated with the difficulties of small-scale producers to comply with traceability should also be addressed. Creation of larger units, e.g. farmer groups is an option on this regard.

3. Land and water resources

Aquaculture is heavily reliant on land and water. The expansion of the sector raises some questions about the availability of these important resources and the importance of addressing these issues is recognized in the region.

Land

In recent years countries have shown different behaviours towards the expansion of aquaculture land and the government position towards conversion of agricultural land for aquaculture. Some countries (notably China and India) have imposed restrictions towards conversion of agricultural land. Other countries like Iran, allow aquaculture only on areas not used for agriculture. On the contrary, recently Viet Nam has allowed a massive conversion of land used for salt and rice production into shrimp farming, and this strategy is responsible for the massive production observable over the past 4–5 years. It is however perceived that a future increase in the amount of land used for aquaculture is unlikely.

The scarcity of available land and the increasing demand for fisheries products coupled has contributed to the increasing efforts devoted by some countries towards the development of aquaculture planning, although plans often are not comprehensive of all the aspects needing consideration (e.g. seed and feed availability, water quality, etc.). The development of effective aquaculture plans have also been hampered by poor knowledge on carrying capacity. Implementation of plans has also proven difficult, sometimes because of administrative discrepancies between who makes the plans and who has jurisdiction on the land (e.g. Malaysia).

Although aquaculture plans have generally dealt mainly with land-based aquaculture, some countries (e.g. Malaysia) are increasingly paying efforts to near-shore aquaculture planning.

Water

The availability of fresh water for aquaculture appears to attract increasing concerns. Scarcity of water is often site specific and led some countries (e.g. Pakistan, Australia) to establish quotas or rights for water use for aquaculture or agriculture production. Water scarcity in some areas has been addressed by some countries like China through the development of major irrigation programmes. Some countries with sometimes limited freshwater resources (e.g. Iran) are increasingly exploring the use of reservoirs for aquaculture. On the contrary, the increasing requirement of water for human consumption has led countries like China to eliminate aquaculture facilities from reservoirs to improve water quality and the conflict of interest associated with water use may increasingly be an issue. The impact of using groundwater for aquaculture purposes has also to be addressed.

In spite of some exceptions, it is recognized that at present farmers do not pay for water consumption. This situation may however change in the near future. Sri Lanka is presently discussing the possibility of charging farmers for water use. This creates a precedent in the country. Nevertheless, it is possible that other countries will follow this trend in the future and the need to improve the efficiency of aquaculture systems is recognized.

Availability of water for mariculture should also be considered, especially in terms of carrying capacity. Although governments are increasingly concerned about the resulting environmental problems, the conducive policy of some countries (e.g. Viet Nam and China) towards mariculture have led to uncontrolled development of the sector. The need for a more harmonized approach within countries is recognized.

4. Other environmental issues

Chemicals and drugs

Although the use of chemicals and drugs (antibiotics, etc.) in aquaculture is primarily an issue of food safety, in view of the increased intensification of aquaculture systems and the resulting increased health problems, the potential impact on the environment also requires being addressed. Increasing concerns on the use of chemicals and drugs in aquaculture has generally led to a reduction in the use of those substances. However, it is recognized that marine fish production is running into the risk of following similar steps to shrimp aquaculture, with increased intensification, health problems and chemical use. The need for more effective control and for seeking alternative treatments such as Better Management Practices and/or alternative medicine (e.g. herbal medicines, probiotics, etc.) is recognized and some countries are actively conducting efforts towards their adoption.

Releasing of aquaculture reared animals into the wild

The interaction between farmers and wild populations, especially in terms of voluntary or involuntary releases, also needs to be discussed. Restocking activities have been conducted by several countries in the region. A notable example is Thailand, where restocking has lead to more than 90% of wild population of silver barb being produced in hatcheries. Involuntary introductions however raise some environmental concerns especially when dealing with exotics for which the impact on the ecosystem has not yet been fully understood (e.g. *P. vannamei*) or for the genetic implications of involuntary releasing genetically improved strains (e.g. tilapia, salmon, common carp).

It is perceived that countries in the region are not yet paying due attention to this issue, which on the contrary, this issue is highly considered among importing countries such as European and North American countries, shown especially by the huge interest on salmon escapees and on their impact on natural salmon populations. Policy on this subject is scarce in the region, and the development of policy appears needed. This should be coupled with the collection of baseline data, with continuous monitoring and the development of tools capable of assessing the environmental impact.

The introduction of pathogens to wild populations through escapees (e.g. shrimp), but also through the direct discharge of effluent water into the environment has to be considered.

Animal welfare

It is recognized that the international community pays increasing attention to animal welfare. This is shown by the development of a, animal welfare section within the OIE. Although not directly an environmental issues, animal welfare needs to be given due consideration. Welfare is likely to be promoted on a voluntary basis, although market pressure may lead to a shift in management practices to allow compliance to welfare issues. Consumer pressure may be generated owing to perceived inhumane practices (e.g. broodstock ablation), although crustaceans are not yet considered under welfare legislation.

The need for discussion on developing a strategy to improve consumers' perception of aquaculture practices and to improve animal welfare does not appear to be premature.

Other environmental issues
Other issues touched upon during the working group discussion identifies also the importance of the following:

- Introductions of exotics and associated pathogens
- Importance of ballast waters and the implications for the sector
- Importance of ornamentals

5. Legal institutional and management aspects

5.1 There is extensive legislation and policies already in place but what about recent developments?

- Increasing requirement for licensing of various types of culture systems, (cages, ponds, etc).
- However one problem lies with licensing small aquaculture facilities that may be hidden within large agriculture facilities and hence are not being accounted for. If you should multiple the cumulative effects of all these small aquaculture ventures then this could be quite a significant amount of leases. May need to enter partnership with agriculture sector.
- Licensing is become more technical and may require permits from different government offices such as aquaculture, environment and water departments.
- Many countries still have not sorted out the allocation of water and these rights need to be sorted out prior to the allocation of licenses.
- At local level of the authorities have a list of who is farming and hence local control measures are more easily enforced compared to farming in high population density areas.
- Mandatory licensing can be encouraged by making it a prerequisite to have a permit before the bank will issue a loan.

5.2 Is access to credit in Asia really limiting if the industry still continues to expand?

- In Asia there is lack of subsidies compared to US/Europe however the growth rates for aquaculture are still high in Asia. This would suggest that subsidies do not encourage expansion of the industry.
- In some countries such as China, food production policies have made big impact, for example removal of special taxes affecting aquaculture has boosted entry into the sector.
- In some countries cheap loans are offered through agricultural banks for special food production schemes under which aquaculture falls.
- Similarly lack of insurance for aquaculture has not disadvantaged growth:
    - Perhaps because low cost commodities such as carp
    - Iran offers govt insurance scheme
- Most banks refuse to give preferential treatment to aquaculture sector because they have had bad experiences from past failures – i.e. shrimp is high risk.

5.3 Future population demand requires an additional 50 million tonnes of fish by 2020, what critical bottlenecks must aquaculture address?

- It is likely that the first constraint will be space. This poses the question, will we have to go to the sea? Some countries such as Philippines offer incentives for farming in the sea or zonation plans for aquaculture parks, etc.
- Intensification will have to occur in order to increase density within space constrained systems. This will require better technology and improved efficiency.

- Small increases in farm yield when multiply at national scale could significantly boost production figures, this is especially so for the large countries such as China.
- It is essential that government provide adequate support through policy measures and ensuring that research and development are linked.
- Alternative sources of energy must be found so that the energy budget of production is reduced and similarly to maximise the use of water.
- Some of increased production will be required to address the needs of poor people, therefore it is important to understand what exactly their requirements are. For example it may not be appropriate to focus on high value species where poor people are involved.
- It is important that the sector does not continually reinvent the wheel. One mechanism to avoid this is to encourage inter-country collaboration and hence sharing of past mistakes learnt or building on successes.
- Restocking of inland fisheries and reservoirs has a lot of potential to provide food fish.
- Given the poor state of aquaculture it is possible that aquaculture actually produces more then is properly being accounted for. This would suggest that the future demand is actually greater then the 50 million tonnes forecasted and hence raise the bar even higher for aquaculture production in the future.

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