

REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN ASIA-PACIFIC – 2010



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Regional Review on Status and Trends in Aquaculture Development in Asia-Pacific – 2010

by

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and

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Bangkok, Thailand

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PREPARATION OF THIS DOCUMENT

The present document “Regional review on aquaculture in the Asia-Pacific: trends and prospects – 2010” was prepared as a collaborative effort of FAO’s Aquaculture Service (FIRA) and the Network of Aquaculture Centres in Asia-Pacific (NACA). This review is based on the original manuscript developed by Sena De Silva which was presented at the Global Conference on Aquaculture, Phuket, Thailand, 22–25 October 2010. FAO/FIRA and NACA greatly appreciate the contributions of the following experts: Pedro B. Bueno, Yuan Derun, C.V. Mohan, Thuy Nguyen, Doris Soto and Simon Wilkinson. Additional comments were provided by Simon Funge-Smith, Raymon van Anrooy and Miao Weimin.

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ABSTRACT

This review covers the vast Asia-Pacific region comprising Oceania, South, Southeast, East and Central Asia. In 2008, the region produced 92.5 percent of the world's total aquaculture production by volume but also consumed 70 percent of the global output. It should produce an additional 30–40 million tonnes more by 2050 to maintain the current consumption in the region at 29 kg a year per person. From past performance, it is seen to be capable of doing so, but will have to resolve a range of productivity, environmental, social and market access issues. The status of aquaculture production, its stage of development and the relative importance of each issue are unsurprisingly diverse across the many countries and territories. The outstanding regional characteristics are the dominance (except in Central Asia) of small-scale mostly commercially oriented farms, the dominance of cultured freshwater species in number and output and, as a recent FAO survey reveals, the low productivity of labour and the low employment multiplier of aquaculture in general, except in Oceania. These are circumscribed by the diminishing availability of land and freshwater, climate change and globalization of trade. To cope, farmers in the region will have to become more efficient, environmentally and socially responsible and competitive. The governance of the sector has set them towards the proper direction to acquire these capacities; its main features are the increasing use of market-based incentives and the adoption by farmers of voluntary governance mechanisms that include better management practices (BMPs) and codes of conduct (CoCs), bolstered by their being organized into associations. Guided by progressive policies and regulations, these have shown that they can stimulate higher production, enable better returns, induce responsible farming practices, and produce higher quality and safer aquatic products. This, in capsule, is the major lesson from the region's recent history of aquaculture development. The challenge is to widely promote, adopt and sustain it in practice.

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ACRONYMS AND ABBREVIATIONS

ACC	Aquaculture Certification Council
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AIDS	acquired immune deficiency syndrome
AIT	Asian Institute of Technology
APEC	Asia-Pacific Economic Cooperation Council
APFIC	Asia-Pacific Fisheries Commission
ASEAN	Association of Southeast Asian Nations
BDS	Bangkok Declaration and Strategy
BMPs	better management practices
BOBP	Bay of Bengal Programme
CAR	Central Asian Republics
CBD	Convention on Biological Diversity
CBF	culture-based fisheries
CCRF	Code of Conduct for Responsible Fisheries
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CoCs	codes of conduct
EAA	ecosystem approach to aquaculture
EIA	environmental impact assessment
EU	European Union
EPA	Environmental Protection Authority
EUS	epizootic ulcerative syndrome
FAO	Food and Agriculture Organization of the United Nations
FAO SEC	FAO Subregional Office for Central Asia
FCR	feed conversion ratio
FIRA	Aquaculture Service of the FAO Fisheries and Aquaculture Department
GAA	Global Aquaculture Alliance
GAqP	good aquaculture practices
GDP	gross domestic product
GIFT	genetically improved farmed tilapia
GSIT	genetically supermale Indonesian tilapia
GTZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HIV/AIDS	human immunodeficiency virus/ acquired immune deficiency syndrome
Hong Kong SAR	Hong Kong Special Administrative Region
HYVs	high yielding varieties
ICT	information and communication technology
IMNV	infectious myonecrosis virus
INFOFISH	Intergovernmental Organization for Marketing Information and Technical Advisory Services for Fishery Products in the Asia and Pacific Region
IRA	import risk analysis

IRR	internal rate of return
KHVD	Koi herpes virus disease
LFFRT	live food fish restaurant trade
MPEDA	Marine Products Export Development Authority
NACA	Network of Aquaculture Centres in Asia-Pacific
NACEE	Network of Aquaculture Centres of Central and Eastern Europe
NaCSA	National Centre for Sustainable Aquaculture
NASO	National Aquaculture Sector Overview
NGOs	non-governmental organizations
nei	not elsewhere included
NTBT	Non-tariff barriers to trade
OIE	World Organisation for Animal Health
PCR	polymerase chain reaction
PICTs	Pacific Island Countries and Territories
PNG	Papua New Guinea
QAAD	Quarterly Aquatic Animal Disease Reporting System in the Asia-Pacific Region
R&D	Research and Development
SARS	Severe acute respiratory syndrome
SEAFDEC	Southeast Asian Fisheries Development Center
SEAFDEC-AQD	Southeast Asian Fisheries Development Center – Aquaculture Department
SPC	Secretariat of the Pacific Community
SPF	specific pathogen free
TCDC	Technical Cooperation among Developing Countries
TCP	Technical Cooperation Programme
TS	Taura syndrome
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNU-FTP	United Nations University Fisheries Training Program
USP	University of the South Pacific
USSR	Union of Soviet Socialist Republics
VAC	integrated garden (V), fishpond (A) and livestock (C) system (VAC in Vietnamese is <i>vuon, ao, chuong</i> , which means garden, pond and livestock)
VASEP	Vietnam Association for Sea Food Exports
VNN	viral nervous necrosis
WB	World Bank
WSD	white spot disease
WTD	white tail disease
WWF	World Wide Fund for Nature

EXECUTIVE SUMMARY

The Asia-Pacific region¹ contributes the major share to global food fish supply from farming; China continues to be the biggest producer. It and seven other countries in the region (India, Indonesia, Thailand, Viet Nam, Bangladesh, the Philippines and Myanmar) are in the top-ten ranked aquaculture producers in volume and value. The region has a high rate of food fish consumption, estimated at 29 kg per person per year. To maintain this level for the next three decades would require producing an additional 30 to 40 million tonnes of fish per year by 2050 to meet the demand from a growing population. It has demonstrated the capacity to do so; during this decade many of the countries have produced more food fish from aquaculture than from capture fisheries, and all six countries (China, India, Indonesia, Thailand, Viet Nam and Bangladesh) that have attained a production level of more than one million tonnes a year are in the region.

Aquaculture systems and species are diverse in the region, but the bulk of its food fish output comes from a few species groups that include cyprinids, tilapias and catfish. All three comprise freshwater species bred in hatcheries, feeding low in the trophic chain and cultured mostly in pond systems. The culture of marine finfish, raised mostly in small floating cages that are located in protected inshore waters is seen to grow rapidly. Large offshore operations using higher-technology cages have begun and are now adding to marine fish output; however, for technical reasons they are not expected to become widely adopted. The region remains the biggest producer of marine shrimp, now consisting mostly of whiteleg shrimp (*Litopenaeus vannamei*), a Latin American species introduced towards the end of the 1990s.. The production of aquatic plants for food, mostly in China and East Asia, is stable, whereas production of aquatic plants for biopolymer, largely in Southeast Asia, is increasingly driven by a rising world demand. Mollusc production is generally stable but has decreased in some countries. There are a growing number and volume of niche species.

The structure of the sector in much of the region is characterized by the predominance of small-scale independent farms distributed over wide areas and until recently, largely unorganized. The market is also fragmented. These make the management of its development complicated and underlines the importance of a strong progressive governance system. Improvements in the governance mechanism have been felt during the past decade, as indicated by fewer conflicts over resources and effluent discharges to public waters, reduction in crop losses from disease, and fewer non-tariff trade barriers faced by shrimp exports. These are largely the outcome of the sector becoming better regulated by a mix of command and control, market-based and voluntary management measures. Organized farmers adopting better management practices (BMPs) have been the key to this progress. The major driver has been market access; although small-scale, almost all of the farms in the region are geared towards producing part or all of the crop to sell to the neighbourhood, the local market or the world. Concerns for food safety and quality have heightened, largely driven by a more health and quality-conscious public whose purchasing power is becoming stronger. This has been abetted by the growth in coverage and influence of the modern retail chains. This pressure to produce safe and healthy products in an environmentally responsible way has come from buyers, regulators, civil society and the mass media, transmitted through trade.

Environmental and social issues persist. At the top of the causes of adverse public perception are the feeding of fish with fish and pollution. Substitutes for fish oil and low-value fish (fed directly or as fishmeal) are being developed and tested to mitigate the first issue. Better water and feeding management are helping lessen the volume and organic content of effluent. The region, as with the rest of the world, has shied from transgenics, but it has made effective use of biotechnology products such as vaccines, and of procedures particularly polymerase chain reaction (PCR), for health management.

¹ The regional scope of this review includes countries in the Southeast, South and East Asia, Central Asia and Oceania. "Oceania" comprises Australia, New Zealand, Papua New Guinea and the Pacific Island countries and territories. The section on production trends has a group "Other Asia" which consists of some nations from East Asia (Japan, Democratic People's Republic of Korea, Republic of Korea and Mongolia), some from Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) and the Islamic Republic of Iran.

Happily, the destruction of mangroves is now much less of an issue. The ecological and genetic biodiversity impacts of the introduction and transfer of species for culture across borders remain a deep concern among scientists but still needing incontrovertible proof that it has happened, except with the Mozambique tilapia (*Oreochromis mossambicus*) which was introduced into the Asia-Pacific region in the 1950s and has become a pest in fresh and brackishwater pond culture systems almost everywhere in the Pacific and in some areas in Southeast Asia. That said, most other introduced species developed for aquaculture have boosted productivity and profitability of farms and have not shown evidence of adverse impacts on biodiversity or the environment, except for a few ornamental fish and the golden apple snail. A slightly different issue is the positive impact of aquaculture on the conservation of marine species and protection of their marine habitats, mainly the coral reefs. This has to do with the increasing use of hatchery-bred seed of some of the species for the live food fish trade. Complete reliance on hatchery-reared seed would in the future likely abate harvesting methods that are destructive to marine life and reefs.

Shrimp continues to be an important earner of foreign exchange for many countries. Tilapia exports are increasing in volume, and the pangasiid catfishes (striped/tra catfish, *Pangasianodon hypophthalmus*, and basa catfish, *Pangasius bocourti*), whose sole supplier to the world market is Viet Nam, has entrenched its primacy in major European markets and the United States of America, despite a number of non-tariff barriers to its trade and adverse publicity. The spectacular growth of catfish aquaculture was not predicted, yet it has yielded a rich vein of lessons in policy, technology application, farm management, and marketing and trade. The core of the lesson lies in its being a relatively low-value fish that small farmers are able to culture at high intensity with yields that no other culture system has come close to achieving, and then its dominance of the markets for white fish in the west. Likewise, many of the achievements in aquaculture development in the region and the process by which they were achieved, the strategies followed and the tools used can be instructive for policy-makers, programme planners, scientists and technologists, advisers to farmers and students. They have not been easy nor cheap to carry out. This review also describes the constraints and adversities that the sector has faced, the setbacks it has suffered and the ways and means to overcome them. A short selection of cases illustrates some factors of success.

The region has done its part in implementing all of the 17 action recommendations put forward in the Bangkok Declaration and Strategy. A broad assessment would rate overall performance at above average. This was largely helped by the presence of active regional indigenous organizations, which jointly or individually, often with the technical and/or financial support of international agencies, implemented programmes inspired by the Declaration.

The best achievements were made in aquatic animal health management, pro-poor livelihood oriented aquaculture, small farmer development and inter-regional cooperation. Environmental responsibility is above average, largely due to the wider adoption of better management practices (BMPs) and codes of conduct (CoCs).

Although social responsibility cannot be separated from environmental responsibility, it does have one distinct element, labour. It is difficult to assess this aspect of the region's performance. The antidumping charges that have been leveled on shrimp and pangasiid catfish exports include this issue. It remains contentious and needs closer and dispassionate study. As to the complaint that the charges of social dumping are without science-based evidence or based on isolated cases, the sector could do well to provide its own evidence. The answer could come from the higher productivity, better access to market and more favourable image gained by the shrimp farming sector from having adopted BMPs and adhering to standards. The latter provides measurable evidence of responsibility in farming. The bigger implication for Asian aquaculture is whether its competitiveness has been helped by low-cost labor and, if the answer is yes, whether this is sustainable. As a corollary, should labour cost increase for any reason, what strategies could the sector adopt to remain viable and competitive? Greater efficiency of farming is one, value addition is another. The region employs 92 percent of the world's estimated 23 million direct and indirect labour for aquaculture. However, its productivity is very low, and it takes almost three direct jobs to create one indirect employment. The former reflects a low

labour efficiency and the latter a short market chain and little value addition along the chain. Innovations in farm management, logistics and technology are always a reliable option, but improvement of skills to increase labour efficiency and productivity should not be overlooked. This has to be delicately balanced with the need to create employment rather than reduce the need for workers, as a growing number of people are entering the labour force in almost every country in the region.

Marketing and trade would be scored above average, not because of the increase in trade flow from the region to the traditional major markets, the European Union (EU), Japan and the United States of America, but because of the higher awareness and adoption of food safety and quality standards. Risk management has shown mixed results. Prevention and mitigation of the impacts of biological risks (mainly from pathogens) have been met well by a systematic regional health programme. The risks to biodiversity are being addressed with a regional genetic and biodiversity programme which was the offshoot of an initiative that assessed the impacts of alien and introduced species. However, market-based insurance to enable especially the small farmers to mitigate or cope with the many and increasingly severe perils to their crop and farm assets is yet to gain headway. A regional initiative on insurance for small farmers has raised awareness and spurred a few activities, but with little progress so far.

Policy support to sustainable development rates an above average mark, with the widespread formulation, enactment and strengthening of policy and development plans for aquaculture and the enabling regulatory measures. This is region-wide, with the Pacific Island countries and territories (PICTs) to the Central Asian Republics (CAR) recently adopting national as well as regional aquaculture development policies and plans. Achievements have not been widespread in the three other basic supports to sustainable aquaculture development – education, research, and information. Manpower development has continued at a steady pace via academic training and specialized short courses. The programmes were geared to improving the culture of specific commodities and strengthening specialized support services such as health management, risk management, breeding, molecular genetics and environmental management. Personnel exchanges between Asia and other regions and within the Asian region proceeded at a steady pace.

Research did not enjoy a surge in investments from national, private and international sources. There have been very few breakthrough innovations (other than genetically improved farmed tilapia (GIFT) and no recent results that would advance the genetic potential of any species for culture), although a notable shift is the broadening of focus from productivity to the inclusion of environmental and social issues. As in other economic sectors, information development and exchange have been facilitated by the new information and communication technologies (ICT), and some innovative farmer-oriented communication and marketing strategies have been piloted using ICT. However, this has yet to spread, and extension is still largely carried out using the traditional approaches with little investment to improve the capabilities of aquaculture extension workers or agencies. Capacities for statistics and information collection, analysis and dissemination are strong in many countries but need improvement in most of the Pacific Island and Central Asian countries.

The core issue of the vast and diverse aquaculture sector of the region is the sustainability of the small-scale farmers that compose most of it. During this decade, governing the sector has gradually moved from compelling farmers to become responsible to providing them with the incentive to produce more with a higher sense of environmental and social responsibility. This needed a nuanced redirection of policy: BMPs, CoCs and market-based incentives began to be more frequently used for sector management and farmer motivation, whereas legal instruments were kept in the background but firmly enforced when needed. To make this governance framework effective, the capacity to provide technical services and management advice to farmers, and the farmers' capacity – by being trained and organized – to make effective use of these, were improved. This, the most important set of strategic lessons that the region has learned during the past two decades, has been internalized in this decade. It should spread and become institutionalized in all the countries.

1. INTRODUCTION

The regional scope of this review includes the countries of Southeast, South and East Asia, Central Asia and Oceania. The section on production trends has a group “Other Asia” which consists of some nations from East Asia, some from Central Asia and Iran. The groupings are as follows:

- South Asia (Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka);
- Southeast Asia (Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Viet Nam);
- China (including Hong Kong Special Administrative Region and Taiwan Province of China);
- Oceania (Australia, New Zealand, Papua New Guinea and the Pacific Island countries and territories [PICTS]); and
- “Other Asia” (Democratic People’s Republic of Korea, Iran, Japan, Kazakhstan, Kyrgyzstan, Mongolia, Republic of Korea, Tajikistan, Turkmenistan and Uzbekistan).

Aquaculture in the Asia-Pacific region accounted for 92.5 percent of the global production increase in the last 27-year period. Its contribution to the gross domestic product (GDP) of many nations in the Asia-Pacific region has exceeded that of capture fisheries. Its role in employment and food security is also increasing. To attain this level of importance in the economy of nations, it has had to overcome numerous constraints that impact on the growth and sustainability of a relatively young economic activity. These constraints are characterized and the strategies and tools by which the sector has been addressing them are described and analyzed in this review.² The context of its development and its primary contributions to society are described in this section.

1.1 Aquaculture in regional economies

The three major contributions of aquaculture to national economies that are illustrated in this section are GDP, employment and food security. On a community perspective, a recently initiated activity of the Food and Agriculture Organization of the United Nations (FAO) is the assessment of contributions of small-scale aquaculture to sustainable rural development (Bondad-Reantaso and Prein, 2009). Indicators³ developed in two expert meetings have been tested in seven case studies in three Southeast Asian countries (Philippines, Thailand and Viet Nam) and then applied in two scaled-up studies in China and Viet Nam. Indicative findings from the case studies are described in Section 6. One typology of small-scale aquaculture is Type 2, which applies to essentially small-scale farms that are commercially oriented.

Large or small, commercial farms contribute to social and economic development by supplying aquatic products for consumption, generating business profits, creating jobs, paying wages and salaries, and providing tax revenues (Hishamunda, Cai and Leung, 2009).⁴ By creating jobs and providing wages, commercial aquaculture helps alleviate poverty. Because this income can be used to

² The sources of information include the FAO database FISHSTAT Plus Version 2.32 (2009; www.fao.org/fishery/statistics/software/fishstat) (FAO, 2009a) for information on production and value of cultured commodities. Other information on features of the sector was accessed from individual country publications and other published data and information. The section on regional production was further supplemented by a review of aquaculture production trends from 1980 to 2008 carried out by FAO Regional Office for Asia and the Pacific and Asia-Pacific Fisheries Commission in 2010 (Lymer, Funge-Smith and Miao, 2010).

³ Fourteen indicators were tested for the contribution of small-scale aquaculture to the five livelihood capitals, namely, natural, physical, social, human and financial. The reports on the pilot studies were being reviewed for publication at the time of this review.

⁴ Ridler and Hishamunda (2001) define commercial aquaculture as “fish farming operations whose goal is to maximize profits, where profits are defined as revenues minus costs (perhaps discounted)”. The distinction between commercial and non-commercial aquaculture does not hinge on whether fish is sold or not. It relies primarily on the existence or absence of a business orientation, and on how factors of production such as labour are paid.

purchase food items, commercial aquaculture can improve food security. A significant contribution of commercial aquaculture to food security is its supply of nutritious aquatic food products. Through employment creation and income generation, commercial aquaculture enables more people, especially those in rural areas whose employment opportunities are generally limited, to share the benefits of growth. Therefore, it contributes to the well-being of citizens by providing intra-society equity. Tax revenues from commercial aquaculture constitute resources for stimulating growth, poverty alleviation and food security.

1.1.1 Gross domestic product (GDP)

The contribution of aquaculture to the GDP of a number of countries in the Asia-Pacific region has by-passed that of capture fisheries (Table 1).

Table 1: Estimated contributions of capture fisheries and aquaculture to the gross domestic product (GDP) in selected Asian countries, 2004–2006.

Country	Capture	Aquaculture
Bangladesh	1.884	2.688
China	1.132	2.618
Indonesia	2.350	1.662
Lao PDR	1.432	5.775
Malaysia	1.128	0.366
Philippines	2.184	2.633
Thailand	2.044	2.071
Viet Nam	3.702	4.00

Source: De Silva and Soto (2009).

In most countries, except those in the Pacific and in Asia with large fishing fleets or significant inland fishery and coastal resources, aquaculture is narrowing its gap with capture fisheries. While this reflects as much the general stagnation in capture fishery as the steady growth of aquaculture on a regional level, it does underline the increasing role of the aquaculture sector in economic development.

1.1.2 Employment

Worldwide, aquaculture employs about 23.4 million full-time-equivalent workers, which include 16.7 million direct and 6.8 million indirect jobs (Valderrama, Hishamunda and Zhou, 2010). The Far East (plus India) accounts for 92 percent (21.5 million) of the world's total employment, which matches approximately its world aquaculture production share of 91 percent. Its labour productivity, however, is a low 3.36 tonnes/man-year, an indication of the comparatively greater supply of low-cost agricultural labour. In comparison, the labour production in North America and Europe is more than 55 and more than 20 tonnes/man-year, respectively. The multiplier of the Far East (plus India) is also low at 0.38, i.e. every direct employment creates 0.38 indirect jobs (or it requires about three direct jobs to generate one indirect job). The rest of Asia, with a production of more than 305 000 tonnes, has 66 500 employed in aquaculture, 32 200 directly, and a productivity of 9.49 tonnes/man-year. Oceania, with a production of 159 000 tonnes, has a total employment of 22 225, of which 13 700 are directly employed, and a productivity of 11.63 tonnes/man-year. Assuming an average family size of five members, the direct employment in Asia and Oceania would have supported the livelihood of some 84 million people (of the world's estimated 117 million dependent on aquaculture) (Valderrama, Hishamunda and Zhou, 2010)⁵.

The findings on labour productivity suggest that the mechanized operations of North America and Europe not only have a higher productivity per unit of labour but create more indirect employment, likely because the value chain for their output is longer and there is more value addition along the chain. For Asia, labour productivity is clearly an area for improvement, which has to be carefully balanced between capital investment and labour so that workers are not displaced or the need for them is not reduced. The small-scale farms, which employ family labour and very few, if any, hired labour,

⁵ Data analyzed were of the year 2005.

would need to increase efficiencies. The low employment multiplier is probably due to the short trip of the fish produced by small farms from farm gate to dinner plate and the low level of commercial activity needed to supply small farms with inputs. Except for a few commodities such as shrimp and pangasiid catfish, the products are sold directly to nearby markets, with hardly any value adding, aside from drying or smoking on a small-scale. Increasing the labour multiplier effect of aquaculture would help address rural poverty by increasing employment in rural areas.

1.1.3 Food security and nutrition

While the Asia-Pacific region produces much of the world's farmed aquatic products, because of its population, it also consumed nearly 70 percent of world production in 2007, an increase from 50 percent in 1980 (Figure 1).

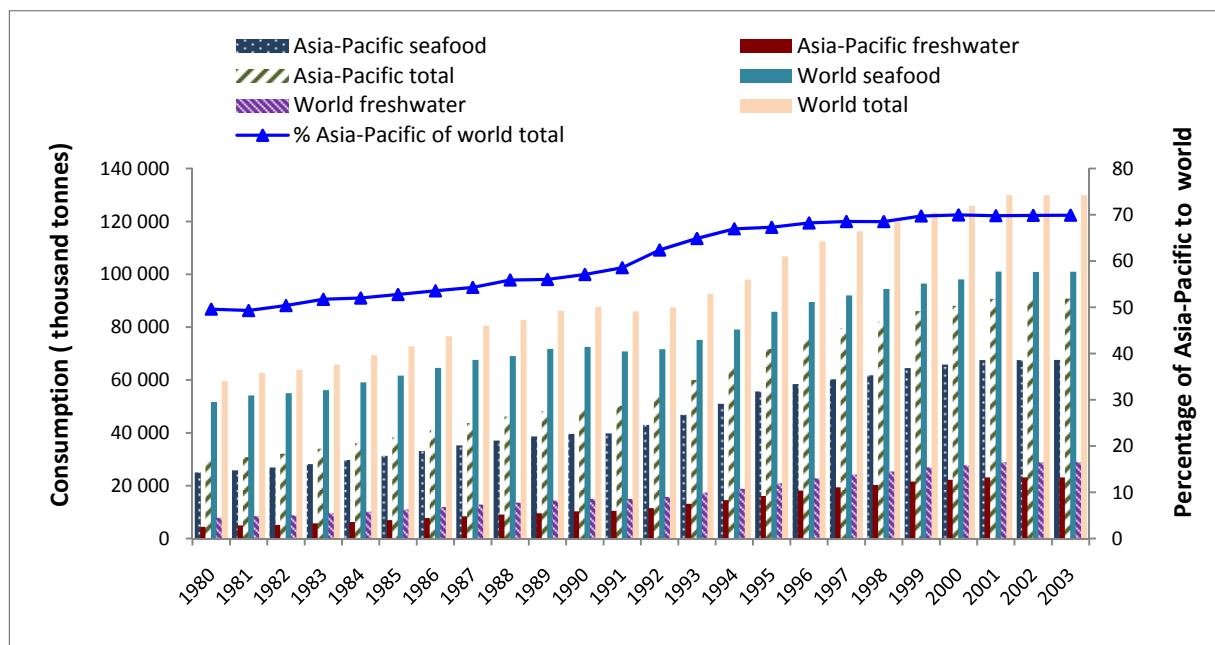


Figure 1: The trends in food fish consumption in the Asia-Pacific region and the world, and the percentage contribution of Asia-Pacific to total world consumption.

Source: FAO (2009a).

Consumption per person followed a comparable trend, increasing from 13 kg in 1980 to 44 kg in 2007 (Figure 2). However, the consumption level among countries varies from 6 kg in India to 71 kg per person in Japan. The notable changes are the large increases in consumption in Cambodia (from 4 to 52 kg per year) (Hortle, 2007) and China (from 6 to 35 kg) between 1980 and 2003.

The median prediction for population growth for the Asia-Pacific would result in a slight decline from its current level of 60 percent of the world population to 57 percent by 2050 (Figure 3). Based on the current per caput consumption of 29 kg/year, the predicted food fish needs, based on a constant level, are shown in Figure 4; nearly 30 million additional tonnes of food fish – locally farmed and fished or imported – will be needed in the region.

For the PICTs, a forecast made in 2007 of population growth and the quantity of fish needed for good nutrition for Pacific islanders for the period 2010–2030 projects that: Melanesia, Micronesia and Polynesia will (a) require 275 000, 40 000 and 45 000 tonnes, respectively, and therefore (b) these groups will need increases of 100 000, 10 000 and 5 000 tonnes, respectively, from the production levels estimated for 2010 (SPC, 2007).

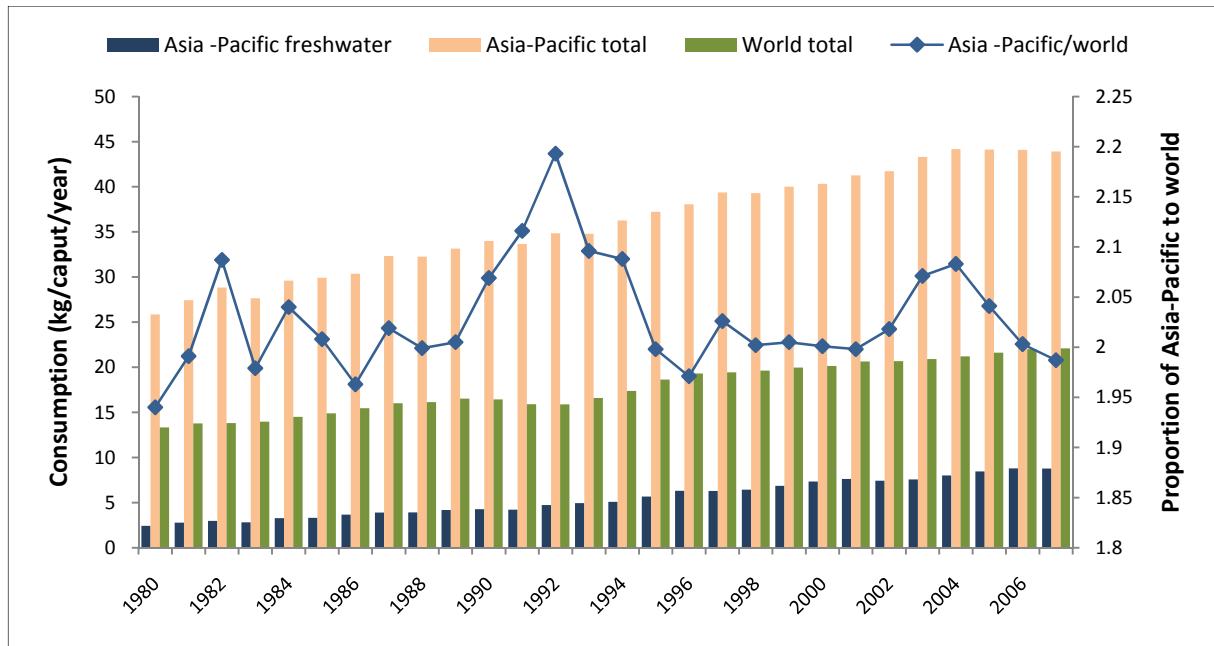


Figure 2: Trends in food fish consumption (kg/caput/year) in the Asia-Pacific region and the world, and the proportion of the Asia-Pacific consumption to the world consumption.
Source: FAO (2009a).

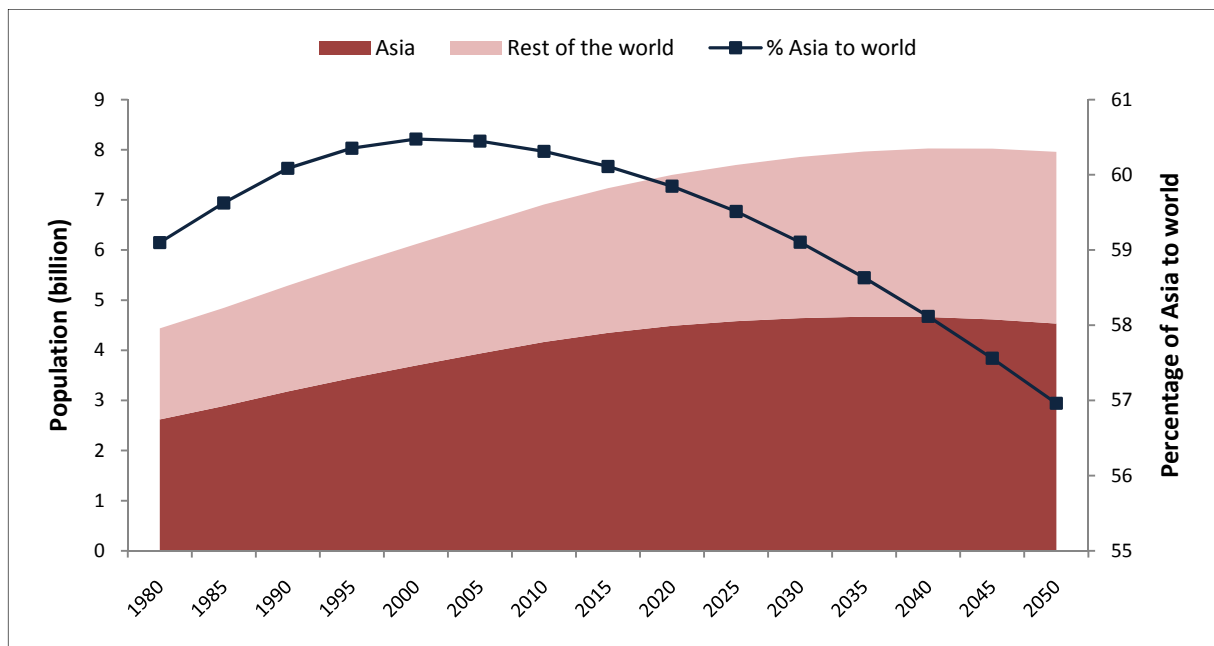


Figure 3: Global and Asian population trends to 2050 and the percentage of Asia to the world.
Source: UN (2009).

In Central Asia, the combined population of the five Central Asian Republics (CAR) (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) was 69 million in 2007. Their combined fisheries production from capture and culture varied in estimate from 57 000 to 65 000 tonnes, having plunged from the pre-independence level of 173 000 tonnes in 1989. Even a return to this level would still provide a much lower supply than the amount needed to raise consumption to 12 kg per person per year⁶. The yearly per caput supply of fish and fishery products decreased to 1.6 and 1.3 kg in 1998

⁶ National health and nutrition institutions in CAR base their advice on fish consumption on the figure of 12 kg of fish products per person per year recommended by the Nutrition Institute of the Academy of Science of the then USSR.

in Kazakhstan and Turkmenistan, respectively, to 0.2 kg in 2002 in Uzbekistan, 0.1 kg in Kyrgyzstan in 1993, and to less than 100 g in Tajikistan in the period 1995 to 2002 (FAO/SEC/FIEL, 2009).

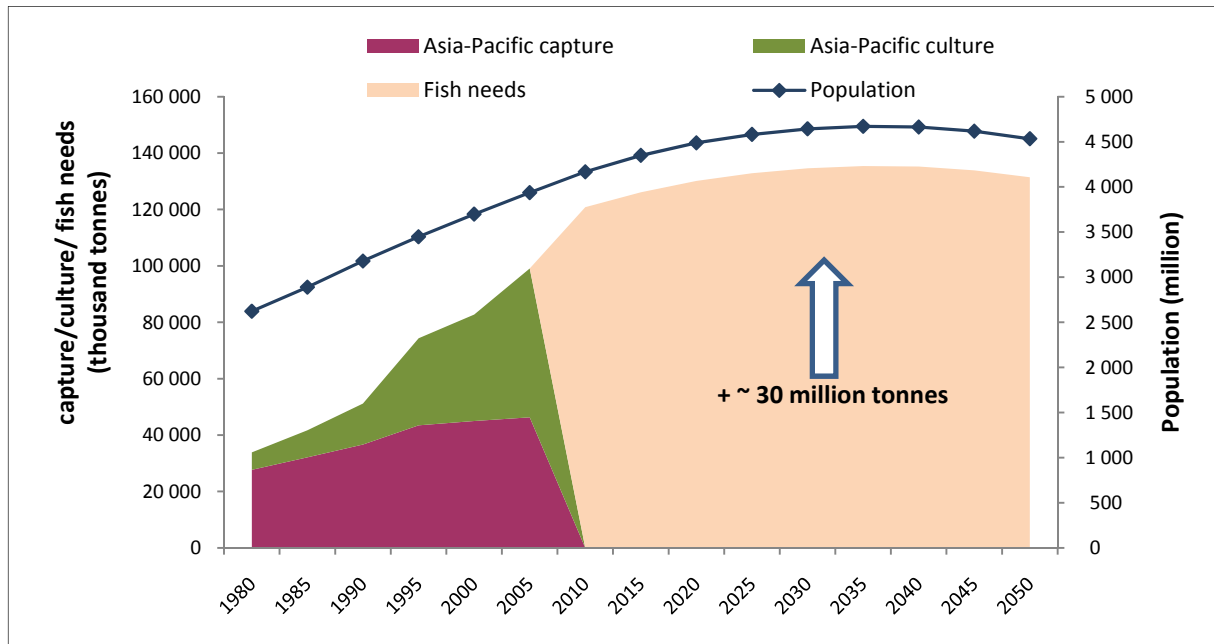


Figure 4: The contributions of capture fishery and aquaculture to the total food fish availability in the Asia-Pacific region, forecasted changes in the population levels in the region, and the food fish needs to 2050 based on the current per caput consumption in the region.

Source: Prepared based on the data from FAO (2009a, b) and UN (2009).

2. GENERAL CHARACTERISTICS OF THE SECTOR

2.1 Status and trends

This section presents the regional and subregional growth trends for aquaculture between 1980 and 2008. Comparisons are especially focused on the recent years, usually the periods from 2002 to 2006 and 2006 to 2008. Trends by culture environment (i.e. inland (freshwater) and marine (including brackishwater)) and by species are reviewed. Notable regional, subregional and country trends are highlighted and explained.

2.1.1 Quantity and value with and without aquatic plants

In 2008, the Asia-Pacific region produced 46.6 million tonnes of aquaculture products (excluding aquatic plants) or 89 percent of global aquaculture production. In value, the region's share is 79 percent of the total value of global aquaculture (Figure 5).

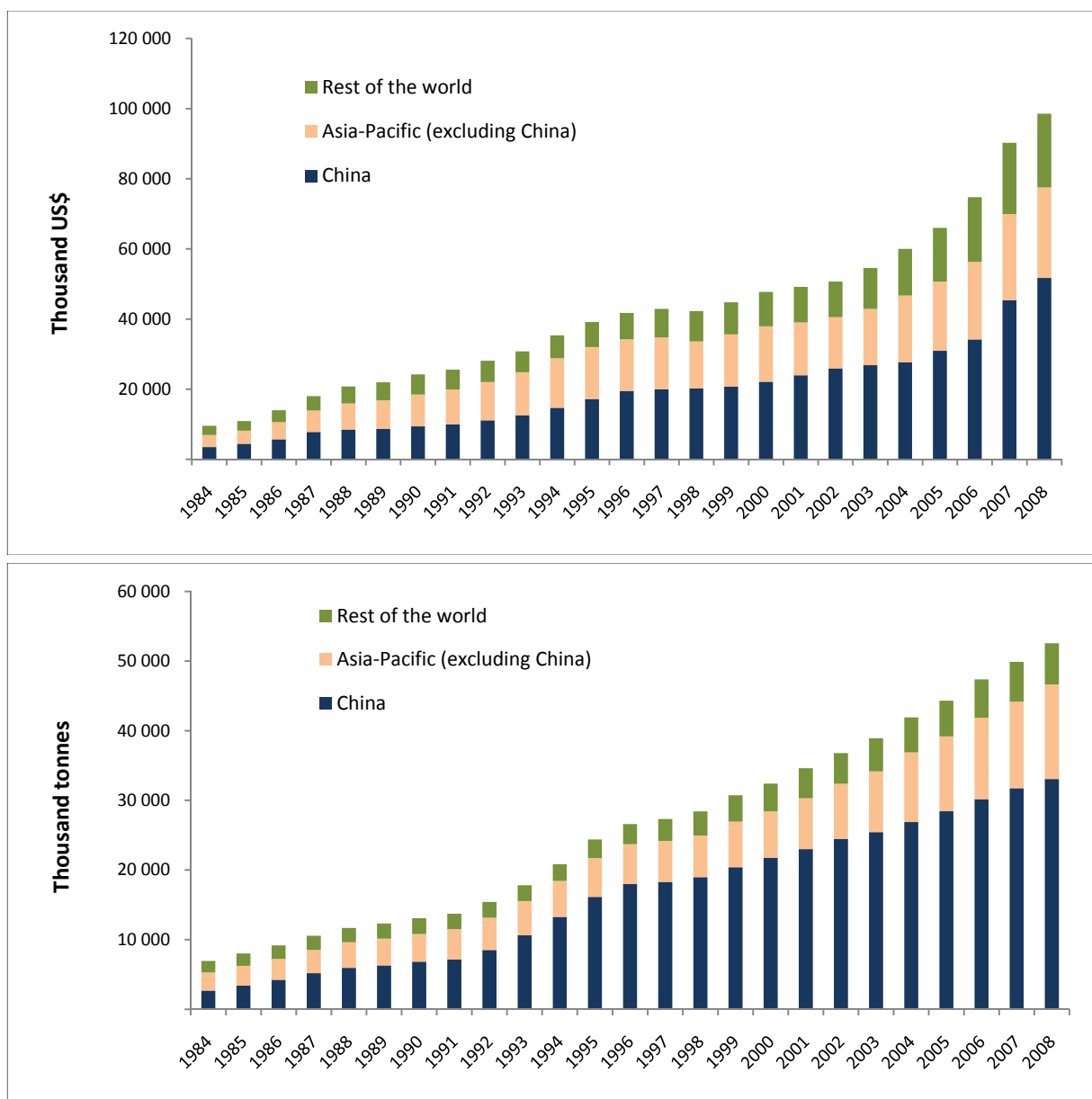


Figure 5: Trends in global aquaculture production (quantity and value) excluding aquatic plants, 1984–2008.

Source: Lymer, Funge-Smith and Miao (2010).

Almost all of the world's seaweed production originates in the Asia-Pacific region, so that the inclusion of aquatic plants boosts the region's share to 91 percent of global aquaculture production by quantity and 80 percent by value. Compared with 2006, the share of production remains unchanged (91 percent in 2006), but the share in terms of value increased from 77 percent in 2006 to almost 80 percent in 2008.

Figures 6 and 7 show the contribution of the four major aquatic commodities (including aquatic plants) in terms of volume and value to the region's aquaculture output. "Others" include amphibians and niche species.

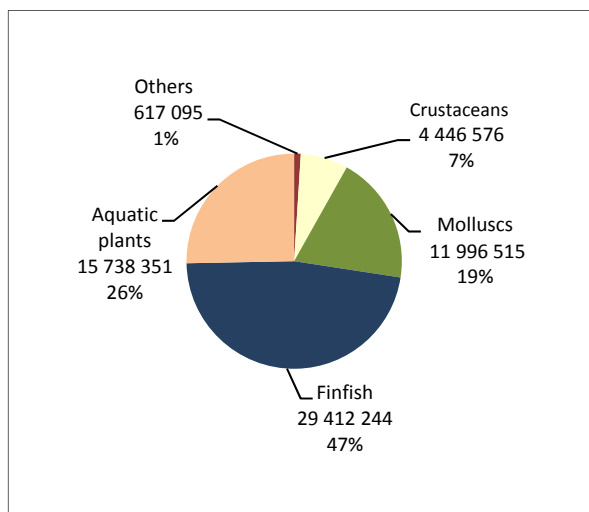


Figure 6: Volume (tonnes) and percent contribution of each commodity group to the total aquaculture production in the Asia-Pacific region, 2008.
Source: FAO (2010).

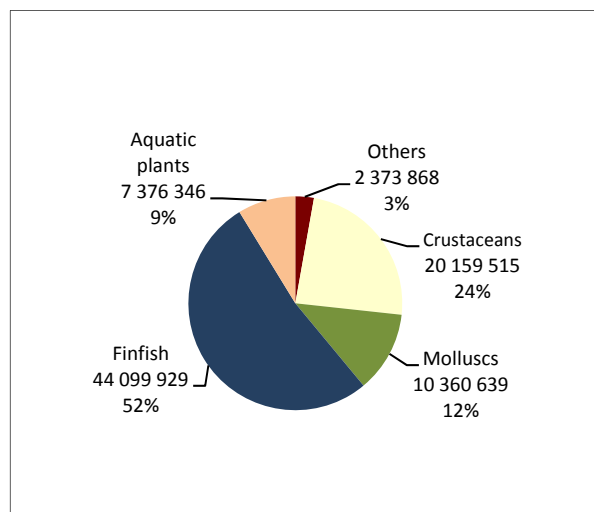


Figure 7: Value (thousand US\$) and percent contribution of each commodity group to the total aquaculture production in the Asia-Pacific region, 2008.
Source: FAO (2010).

Globally, the top-ten aquaculture producers by quantity (excluding aquatic plants) in 2008 were China, India, Viet Nam, Indonesia, Thailand, Bangladesh, Norway, Chile, Philippines and Japan; Asian states hold the top six positions. By value, the top-ten producers were China, India, Viet Nam, Chile, Norway, Japan, Indonesia, Thailand, Bangladesh and the Philippines (Table 2).

Table 2: Top-ten global aquaculture producing countries in 2008 by quantity and value, excluding aquatic plants.

	By quantity (Thousand tonnes)	By value (million US\$)
China	32 736	50 639
India	3 477	5 044
Viet Nam	2 462	4 510
Indonesia	1 710	4 503
Thailand	1374	3 119
Bangladesh	1006	3 104
Norway	844	2 824
Chile	843	2 202
Philippines	741	1 766
Japan	732	1 576
Other	6 642	19 187
Total	52 568	98 564

Source: Lymer, Funge-Smith and Miao (2010).

The table below (Table 3) of aquaculture production in Asia-Pacific and some CAR and Caucasus countries gives a broad view of the status of production in the three subregions that are covered by

FAO regional and subregional offices⁷. Some Pacific Island countries appear to have no aquaculture output, which is as much caused by lack of statistical reporting as lack of production. It has been acknowledged that information capacities for aquaculture in the PICTs (FAO/SAP and SPC, 2010) and for fishery and aquaculture in the Central Asian states (FAO/SEC/FIEL, 2009) need a great deal of strengthening.

Table 3: Aquaculture production of countries in the Asia-Pacific region, 2008.

China	32 735 944	Cambodia	40 000	French Polynesia	44
India	3 478 690	Nepal	27 250	Vanuatu	40
Viet Nam	2 461 700	Sri Lanka	7 474	Tajikistan	26
Indonesia	1 690 121	Hong Kong SAR	4 754	Palau	20
Thailand	1 374 024	Singapore	3 518	Turkmenistan	16
Bangladesh	1 005 542	Uzbekistan	3 418	Kiribati	5
Philippines	741 142	New Caledonia	2 108	Samoa	3
Japan	732 374	Armenia	2 001	Solomon Islands	1
Myanmar	674 776	Brunei Dar.	473	Tonga	1
Republic of Korea	473 794	Kazakhstan	321	Bhutan	–
Taiwan Province of China	323 982	Fiji Islands	228	Tuvalu	–
Malaysia	243 081	Georgia	180	Cook Islands	–
Pakistan	135 098	Guam	162	Micronesia	–
New Zealand	112 358	Kyrgyzstan	92		
Lao PDR	78 000	Papua New Guinea	92		
Democratic People's Republic of Korea	63 700	Azerbaijan	89		
Australia	57 152	Timor-Leste	51		

Source: FAO/SEC/FIEL (2009), Lymer, Funge-Smith and Miao (2010), FAO/SAP and SPC (2010).

2.1.2 Growth rates with and without China

The growth rate of aquaculture production in the region remained very strong at 11.4 percent between 2006 and 2008 (Figure 8). This growth used to result mainly from the continuously increasing production of China. However, the growth rate of Asia-Pacific (without China) overtook that of China during 2006–2008, 16.1 percent compared to 9.4 percent. Asia-Pacific produced 2.9 million tonnes. By tonnage, the countries that have shown the largest increases include Viet Nam (49 percent), Indonesia (31 percent), India (9 percent), Philippines (19 percent), Bangladesh (13 percent), Myanmar (17 percent) and Malaysia (44 percent).

However, aquaculture production is not increasing in every country, some countries having registered negative or zero growth during 2006–2008. These include the Republic of Korea (-7.74 percent), Thailand (-2.34 percent) and Japan (-0.21 percent). The negative growth from the Republic of Korea and Thailand is a result of the reduced production of molluscs (some 45 000 tonnes less for Republic of Korea and 30 000 tonnes less for Thailand). In some cases, this reflects the reduction in the intensity of production or the restriction of culture areas.

China produced 43 million tonnes in 2008 (including aquatic plants), representing 63 percent of world aquaculture production. Although China's production is still increasing, its world market share decreased slightly from 67 percent in 2004 to 65 percent in 2006.

By commodity group, Figure 9 shows that China's share of the total Asia-Pacific production of molluscs, finfishes and aquatic plants is declining, while its share of crustaceans and other species groups is still increasing.

⁷ These are the Asia-Pacific (RAP) Regional Office, Pacific Islands (SAP) Subregional Office and Central Asia (SEC) Subregional Office. A regional fisheries commission for Central Asia and the Caucasus has recently been established with its Secretariat in FAO/SEC in Ankara.

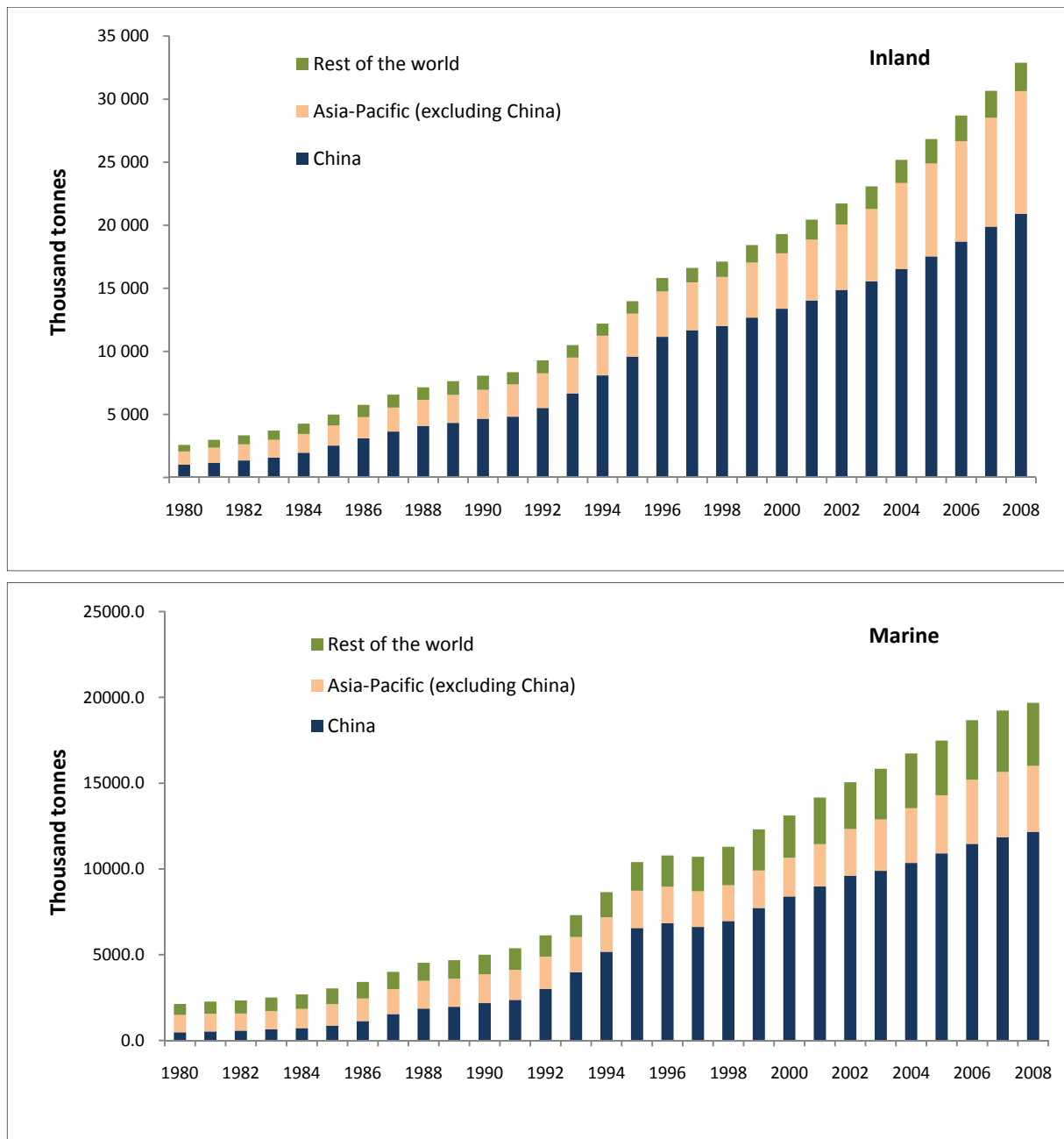


Figure 8: Trends in aquaculture production (by volume) in the Asia-Pacific region by environment, 1980–2008.

Source: Lymer, Funge-Smith and Miao (2010).

If China's aquaculture production were excluded, the Asia-Pacific region still remains as an important production area for aquaculture, showing a steady growth in all culture environments. Inland aquaculture production tripled from 3.1 million tonnes in 1994 to 9.7 million tonnes in 2008 and marine production increased by more than 90 percent in the same period. These increases far exceed the growth of aquaculture in the rest of the world. Freshwater aquaculture production achieved much faster growth (23 percent) than marine/brackish aquaculture production (4 percent), if aquatic plants are excluded, during 2006–2008. Figures 10 and 11 show the trends in the contribution of Asia-Pacific with and without China, in terms of volume and value.

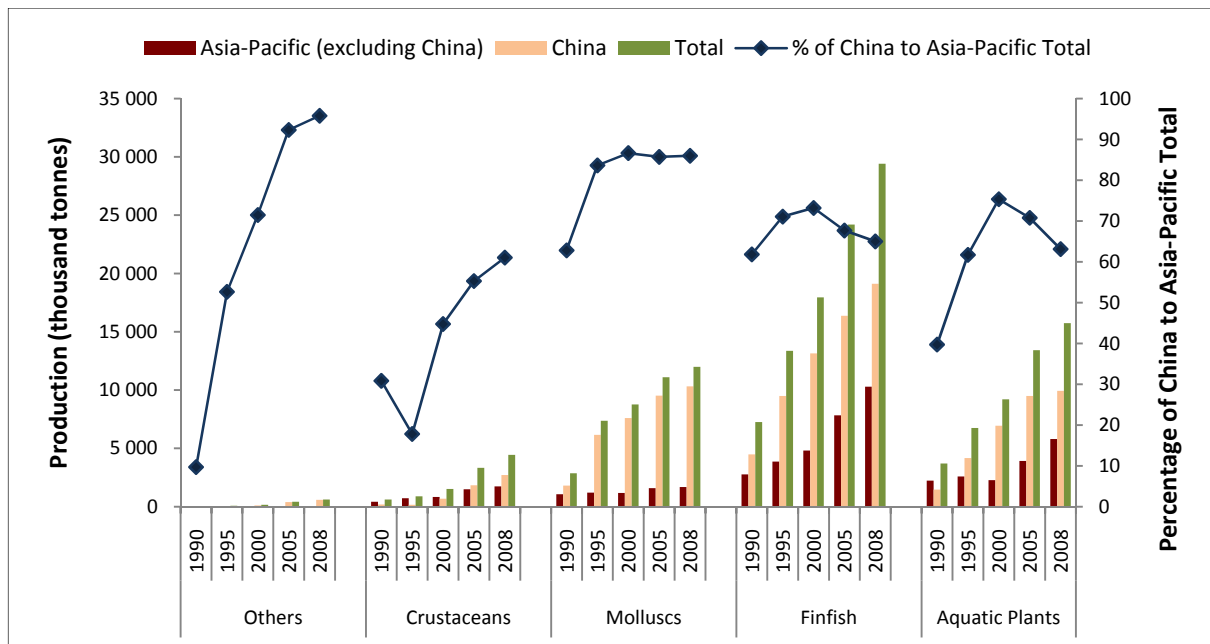


Figure 9: Trends in production of the main aquaculture commodities in (i) the Asia-Pacific region without China, (ii) in China, and (iii) in the Asia-Pacific total and (iv) the percent contribution of China to Asia-Pacific total ("Others" refers to amphibians, invertebrates, others).

Source: FAO (2010).

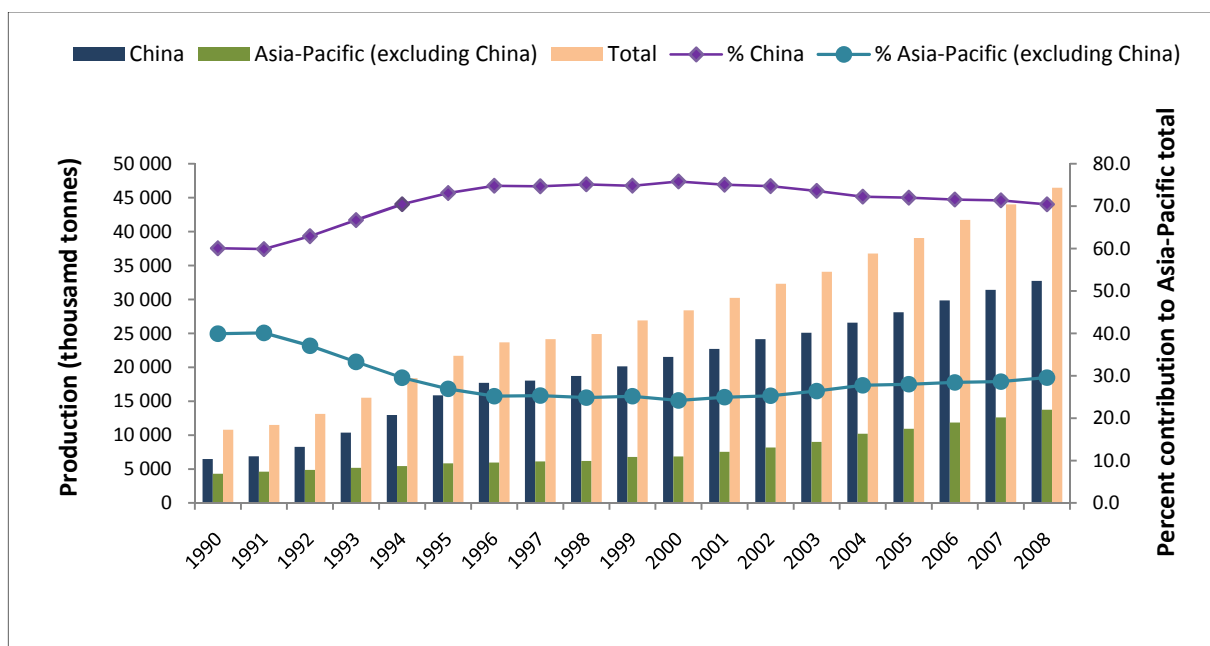


Figure 10: Trends in the volume of aquaculture outputs of Asia-Pacific and China and the percent contribution of China and Asia-Pacific (excluding China) to Asia-Pacific total.

Source: FAO (2010).

2.1.3 Subregional status and trends

The subregional trends are reflected in Figure 12 and show that (i) much of the growth in South Asia is based on freshwater culture; (ii) while its aquaculture species are highly diversified, Southeast Asia's growth is based mainly on marine shrimp and catfish (mainly pangasiid species); (iii) China's growth has slowed down but is still at a good rate of 9.6 percent, mostly from inland culture, particularly of Nile tilapia (*Oreochromis niloticus*); (iv) Other Asia's growth was dominated by

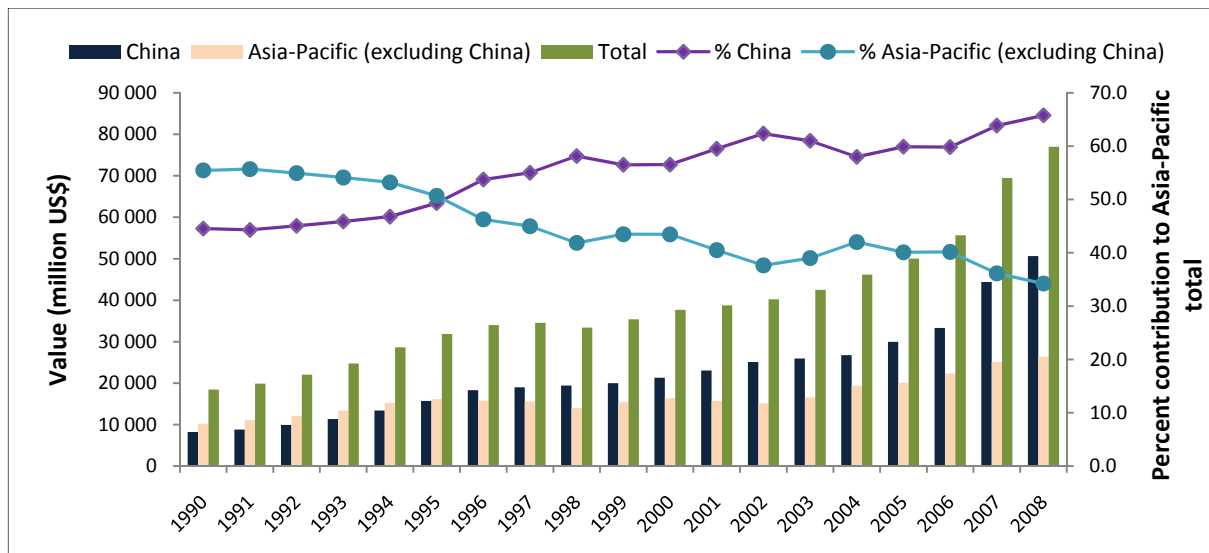
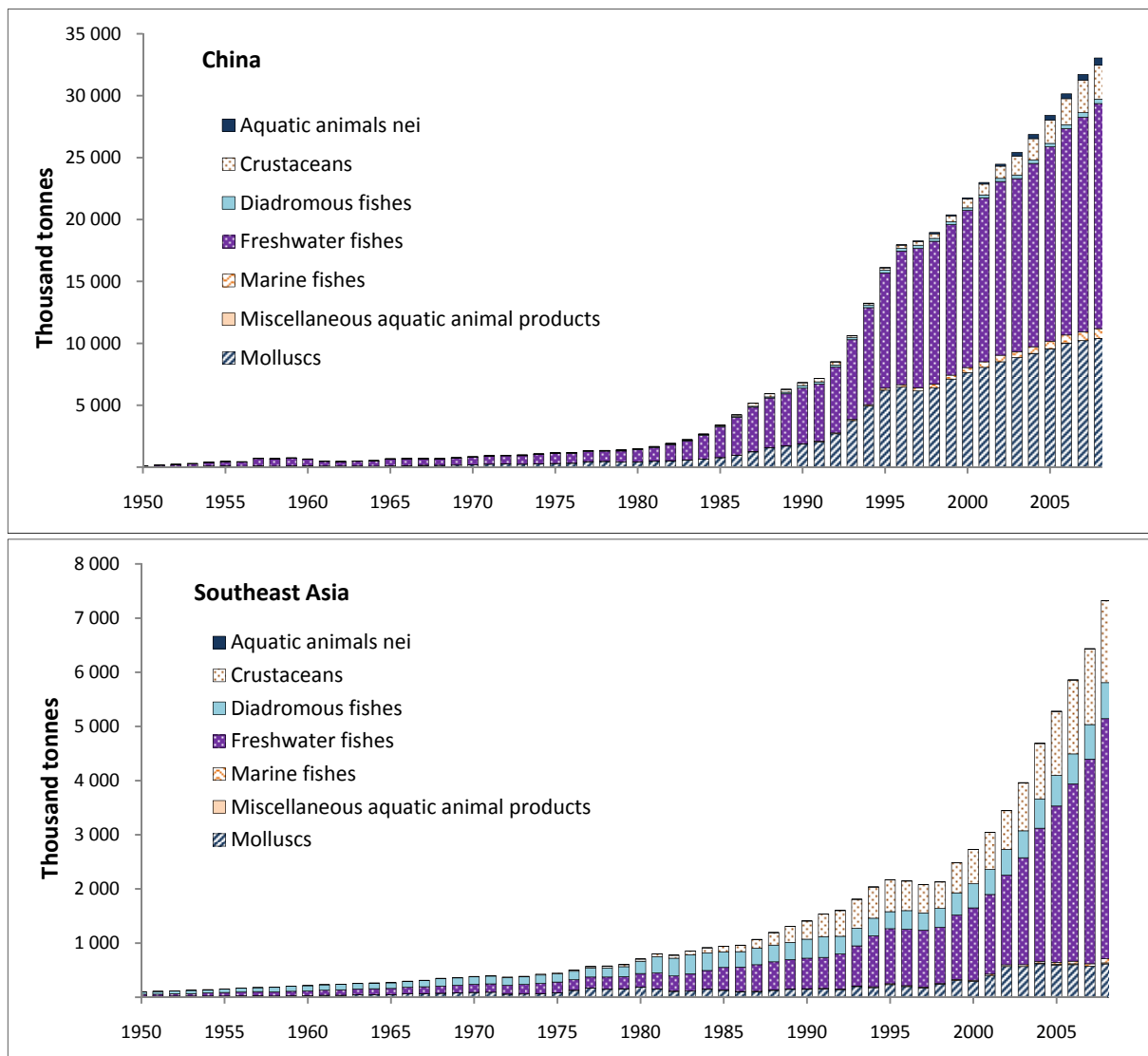


Figure 11: Trends in the value of aquaculture outputs of Asia-Pacific and China and the percent contribution of China and Asia-Pacific (excluding China) to Asia-Pacific total. Source: FAO (2010).



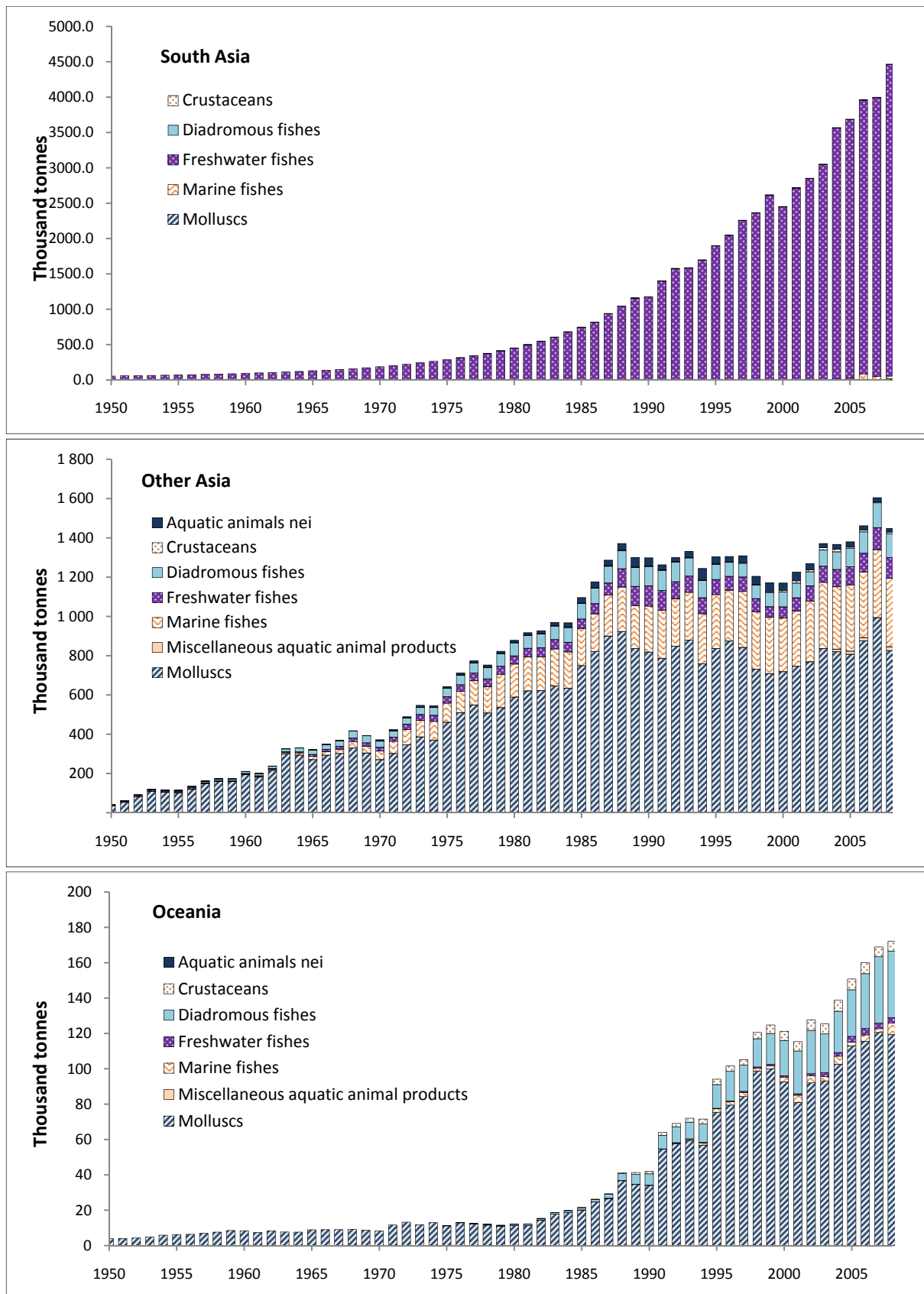


Figure 12: Trends in aquaculture production in the Asia-Pacific region by major species-groups, excluding aquatic plants.

Source: Lymer, Funge-Smith and Miao (2010).

seaweeds followed by molluscs and high-value marine finfish; and (v) Oceania's production mostly comes from New Zealand and Australia. The details are as follows:

South Asia's aquaculture production has seen major increases in the last 20 years, from 1.1 million tonnes in 1988 to 4.6 million tonnes in 2008. The majority of production comes from freshwater herbivorous finfish, which means this increase is not heavily dependent on marine sources of feed. Production of giant tiger prawn (*Penaeus monodon*) and other penaeid shrimp increased steadily until 2006 when it reached 210 000 tonnes but has since declined (145 000 tonnes in 2008). In general, the level of diversification of cultured species is relatively low in South Asia. Marine finfish production has been limited, but it has increased to 37 000 tonnes in the last years for which statistics are available.

Southeast Asia's aquaculture is highly diversified. In 2008, production of 94 different species was reported, the number of cultured species having increased from 70 in 1996 and 80 in 2003. In terms of value, high-priced crustaceans saw their share of the total production increase by 43 percent, followed by freshwater fish at 41 percent. The relatively low volume of crustaceans gives a high value in return, whereas freshwater fish have a relatively low value but are produced in large quantity. Freshwater finfish culture has increased from 0.6 million tonnes in 1991 to 4.4 million tonnes in 2008.

The production of aquatic plants has shown a strong growth. *Eucheuma* sp. is still the most widely cultured aquatic plant in the region, with a production of 1.9 million tonnes in 2008 (an increase from 1.05 million tonnes in 2006). It is closely followed by Zanzibar seaweed (*Eucheuma cottonii*) with 1.4 million tonnes (an increase from 1.3 million tonnes in 2006). The massive growth of aquatic plants in this region reflects the strong promotion and good conditions in the Philippines and Indonesia and the improvement of market chains.

Apart from aquatic plants, pangas catfishes *nei* is the top produced species, having recently surpassed the previous top species, whiteleg shrimp (*Litopenaeus vannamei*) and giant tiger prawn (*Penaeus monodon*).

China's rate of production increase during 2006–2008 slowed to 9.6 percent from 12.2 percent during 2004–2006. Nonetheless, China's aquaculture production still increased by 2.9 million tonnes and has now reached about 33 million tonnes or 63 percent of the total world aquaculture production in 2008 (excluding aquatic plants) (Table 2, Figure 5). Growth in inland culture has continued, mainly from increased production of finfish (particularly tilapia) and crustaceans. This increase is being achieved through the intensification of existing systems rather than increase in area. Because of species diversification and faster development of culture of high-value finfish and crustaceans in the past two decades, the contribution of carps to the total production declined to 33.6 percent in 2008 from 40.9 percent in 1998. Nonetheless, production of cultured carps in China still increased by nearly one million tonnes between 2006 and 2008, reaching 14.5 million tonnes. Carp farming remains a major source of fish for consumers of all income classes in China.

China is currently reporting to FAO the production data of some 110 cultured species or species groups; most are high-value species and indigenous species newly developed for aquaculture. Among the four major cultured groups, crustaceans achieved outstanding growth (29 percent) in production during 2006–2008, followed by finfish (10 percent). Increases in the production of aquatic plants and molluscs were much lower, with rates of 5 percent and 4 percent, respectively. In the past, growth in production from marine waters has come from the culture of molluscs and aquatic plants. The production of aquatic plants has leveled off in the last two years.

In Other Asia, aquatic plants continue to dominate aquaculture production, particularly in East Asian states, accounting for 56 percent of total production. This is followed by molluscs (25 percent) and marine finfish (11 percent). However, the high economic value of marine finfish makes this species group the largest contributor in terms of value, contributing 43 percent of total production value. Excluding aquatic plants, aquaculture production in this region has been stable for the last ten years.

However, aquatic plant production, which peaked in 1993 at 2.3 million tonnes and then dropped by almost 35 percent to 1.3 million tonnes in 2000, has since climbed back to 1.8 million tonnes in 2008. The percentage of carnivorous fish in the total fish production is very high in this subregion (72 percent in 2008) compared with South Asia, Southeast Asia and China, which all have levels below 10 percent.

Aquaculture production in Oceania is limited. In 2008, it was 174 000 tonnes excluding aquatic plants, almost exclusively from New Zealand and Australia. Molluscs and diadromous fish are the main cultured groups. The main cultured species are New Zealand green mussels (*Perna canaliculus*) and different salmon species, and these also make up the bulk of the production. However, live reef fish, aquarium fish, marine shrimp and pearls bring significant income to some Pacific Islands countries, although relatively small in quantity. Giant clam culture for the ornamental trade is widespread throughout the region, and the total export is probably 30 000 to 50 000 pieces a year.

The PICTs are also a major supplier of “live rock” (rock encrusted with coralline algae), with approximately 50 000 pieces being cultured in the Fiji Islands. Zanzibar seaweed culture is well established in some Kiribati outer islands and is being rejuvenated in the Solomon Islands and Fiji. Interest in freshwater aquaculture is growing, particularly among the larger Melanesian states such as Fiji and Papua New Guinea. Vanuatu has a nascent tilapia aquaculture. Marine shrimp, mostly *Penaeus stylirostris* and almost all of it grown in New Caledonia is the second biggest cultured species in value after marine pearl. Region-wise, the economic importance of pearl and shrimp is such that in 2007 they combined for more than 95 percent of the total estimated value of aquaculture production in the PICTs of US\$211 million. Most of the cultured South Sea pearls come from French Polynesia and the Cook Islands, with a growing contribution from Fiji (SPC, 2007).

In Central Asia, aquaculture production in the five Central Asian republics has been very low, as earlier noted. Most of the farmed species consist of common carp and Chinese carps and mostly includes common carp, grass carp, silver carp, bighead carp and black carp. Statistics on fish production usually combine farmed and capture (including from stocked lakes and reservoirs with no defined ownership). Production from both subsectors plunged after independence following the breakup of the Union of Soviet Socialist Republics (USSR), but efforts intensified recently to improve regional capacities for policy, management, research, information and production with the establishment of the FAO Subregional Office for Central Asia (FAO/SEC) and the formation of a regional commission on fisheries and aquaculture in Central Asia and the Caucasus known as Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (FAO/SEC/FIEL, 2009).

2.1.4 Species composition and production growth

There has been considerable change in the top-20 cultured species in the region between 1990 and 2008, excluding aquatic plants and molluscs (Table 4). There are six new members (whiteleg shrimp, pangas catfishes nei, Chinese mitten crab (*Eriocheir sinensis*), cyprinids nei, red swamp crawfish (*Procambarus clarkii*) and black carp (*Mylopharyngodon piceus*)) in the top 20 species compared to 1990, although inland water species, mainly common, Chinese and Indian carps, still hold the top seven positions. There has been a significant change in the order of the top 20. For instance, whiteleg shrimp and pangas catfishes nei are now among the top-ten species.

The production trends of selected species in the region are summarized as follows:

2.1.4.1 Freshwater carnivorous species requiring high input

Catfishes. This is the most widely cultured freshwater species group that is carnivorous or dependent on relatively high-protein feed. This group includes the pangasiid catfish, *Clarias* spp., *Mystus* spp. and some introduced species (e.g. channel catfish [*Ictalurus punctatus*] from the United States of America, North African catfish [*Clarias gariepinus*] and hybrid catfish [*C. gariepinus* x *C. macrocephalus*]). The total volume exceeds the global production of salmonids. The top five

producers are China, Viet Nam, Thailand, Indonesia and India. Total production in the Asia-Pacific region in 2008 was 2.4 million tonnes, a 70 percent increase over 2006 (1.4 million tonnes). Viet Nam has seen a dramatic increase in the production of tra/striped catfish (*Pangasianodon hypophthalmus*) and basa (*Pangasius bocourti*), with a 140 percent increase in production over the past two years. Production statistics for tra and basa catfish are not segregated, but the available information indicates that tra catfish contributes to the bulk of catfish production in Viet Nam. The production in 2008 reached a record 1.25 million tonnes.

Table 4: Top-15 culture species in the Asia-Pacific region by quantity (thousand tonnes) excluding aquatic plants.

Inland waters				Marine waters			
1990		2008		1990		2008	
Silver carp	1 432	Grass carp	3 761	Milkfish	434	Whiteleg shrimp	1 277
Grass carp	1 042	Silver carp	3 726	Giant tiger prawn	290	Giant tiger prawn	708
Common carp	678	Common carp	2 767	Fleshy prawn	185	Milkfish	676
Bighead carp	672	Bighead carp	2 318	Japanese amberjack	162	Japanese amberjack	159
Rohu	245	Catla	2 282	Silver seabream	52	Penaeid shrimp nei	125
Catla	235	Crucian carp	1 956	Banana prawn	33	Giant mud crab	119
Crucian carp	216	Nile tilapia	1 829	Metapenaeus shrimps	29	Aquatic invertebrates nei	104
Nile tilapia	199	Pangasiid catfishes nei	1 381	Sea squirts nei	28	Japanese seabass	98
Japanese eel	164	Rohu	1 159	Coho salmon	24	Japanese sea cucumber	93
Wuchang bream	162	Wuchang bream	600	Penaeid shrimp	20	Swimming crabs, etc. nei	84
Mrigal	160	Whiteleg shrimp	547	Aquatic invertebrates	12	Banana prawn	80
Mud carp	80	Chinese mitten crab	518	Kuruma prawn	9	Silver seabream	79
Tilapias nei	80	Cyprinids nei	505	Bastard halibut	7	Lefteye flounders nei	78
Silver barb	47	Mrigal	464	Indian white prawn	7	Groupers nei	70
Mozambique tilapia	42	Red swamp crawfish	365	Japanese jack mackerel	6	Large yellow croaker	66
Freshwater fish nei	800	Freshwater fish nei	1 218	Marine fishes nei	39	Marine fishes nei	390

Source: Lymer, Funge-Smith and Miao (2010).

Snakeheads. This species group has been eclipsed by the rise of the pangasiid catfish. Total production in Asia-Pacific in 2008 was 373 080 tonnes. The top four producers are China, India, Indonesia and Thailand. In 2008, China produced 87 percent of the total Asian production for snakeheads. China's production has increased by 24 percent to 324 000 tonnes since 2006. The snakehead species, although generally popular in some countries, do not enjoy a large export market, even within the region. There is no intraregional trade.

Eels. Some 98 percent of the world's production of 477 704 tonnes was produced in Asian farms, an 18 percent increase from 2006. Europe had been supplying Asia with glass eel elvers, but the listing of European eel (*Anguilla anguilla*) under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II, which came into effect in March 2009, means that export outside of Europe is now restricted. The Asia-Pacific region should see a significant decline in European eel production from Asian countries that lie outside of its natural range and therefore cannot import elvers from Europe. The Asian swamp eel (Synbranchidae) production is also high at 212 000 tonnes for 2008 in China, with minor production reported from Thailand and Cambodia.

Perch-like species. China reported a production of 229 000 tonnes of mandarin fish (*Siniperca chuatsi*) in 2008. The production has been steadily increasing since 1995 when it was first reported in China. Other reported species in this family are Murray cod (*Maccullochella peelii peelii*) from Australia and golden perch (*Macquaria ambigua*).

Salmonids (family Salmonidae). Production of freshwater salmonids such as trout in the region has developed rapidly in the last four years and reached 93 628 tonnes in 2008, a 27 percent increase from 2006. This is partly caused by two developments: the growth of the rainbow trout (*Oncorhynchus mykiss*) industry in Iran, with a production that more than doubled in four years (to 62 630 tonnes) and the salmonid (trout) production in China, which now amounts to almost 17 000 tonnes (an increase

from 10 247 tonnes in 2004). Trout is now also produced in small volumes in other Asian countries (e.g. Afghanistan, India, Nepal, Republic of Korea, Thailand and Viet Nam).

Knifefish and gobies (order Osteoglosiformes and Gobiformes). These species are not widely cultured but have a good market price in certain countries. The sand goby production in Asia continues to be almost totally based on on-growing of wild caught fingerlings. The total production of knifefish and gobies was only 698 tonnes in 2008 (840 tonnes in 2006) which, however, is an increase by more than 500 tonnes over 2004 (Lymer, Funge-Smith and Miao, 2010). Much of this increase can be attributed to the Indonesian production of marble goby (*Oxyeleotris marmorata*). Malaysia and Thailand are the other two countries where marble goby is produced although both countries have shown the declining trend in recent years.

The production trend of the freshwater carnivorous species is seen in Figure 13.

2.1.4.2 Marine and brackishwater carnivorous species (i.e. species requiring high input)

The major cultured marine and brackishwater carnivorous species are amberjack, barramundi and Japanese seabass, marine salmonids, grouper, cobia, southern bluefin tuna and seabream (Figure 14).

Amberjack. Japan leads in the culture of amberjacks (*Seriola* spp.), with production of 158 300 tonnes in 2008. It has been stable over the years.

Barramundi and Japanese seabass (families *Centropomidae* and *Percichthyidae*). China reported large production of Japanese seabass (*Lateolabrax japonicus*) starting in 2003 and is now producing 96 000 tonnes. The Republic of Korea is also producing Japanese seabass (2 000 tonnes in 2008). Barramundi (*Lates calcarifer*) production is increasing, with the regional total reaching 44 841 tonnes in 2008, an increase of 42 percent over 2006. Thailand has become the top producer in the region, with a stable production trend since 1998. There are recent increases from Malaysia (11 705 tonnes in 2008, more than double the production in 2006). This species has become popular in supermarkets as a whole table fish.

Salmonids (marine). Culture of salmonids (chinook, coho and Atlantic salmon) in brackish and marine waters is reported from Australia, New Zealand and Japan, and currently the production is 47 000 tonnes. Japanese coho salmon (*Oncorhynchus kisutch*) culture peaked in 1991 and has been declining since. However, in 2008 the production again increased to almost 13 000 tonnes. New Zealand's chinook salmon (*O. tshawytscha*) production has increased in the last two years and is now more than 9 000 tonnes. Over the past ten years, the Australian Atlantic salmon (*Salmo salar*) industry has developed considerably, with 25 000 tonnes being produced in 2008 (21 000 tonnes in 2006).

Grouper (*Serranidae*). Production of grouper has increased from 22 000 tonnes in 2002 to 78 000 tonnes in 2008. This recorded increase is because China started to report on this species in 2003. The major producers include China, Taiwan Province of China, Malaysia, Indonesia, Philippines and Thailand. Viet Nam is producing grouper but has yet to report it separately. There are at least 16 species of grouper that are cultured in many Southeast and East Asian countries as well as other parts of the tropics, in the southeastern United States of America and the Caribbean. Grouper is also cultured in Australia, India, Republic of Korea and Sri Lanka.

Cobia. Cobia (*Rachycentron canadum*) culture has increased from only 13 tonnes in 1996 to 2 400 tonnes in 2002 and to almost 25 000 tonnes in 2008. Chinese production in 2008 was 23 500 tonnes, whereas Taiwan Province of China reported 1 000 tonnes (a decrease of almost 2 000 tonnes from 2006). Culture of this species takes place in other states such as Viet Nam and Thailand, largely as a result of the increasing availability of fingerlings from Taiwan Province of China.

Southern bluefin tuna. The fattening of southern bluefin tuna (*Thunnus maccoyii*) has been a significant industry in Australia in the past ten years, reaching 4 000 tonnes in 2002 and 4 500 tonnes in 2008. The quantity is relatively low compared to other species, but its very high value makes its production a significant economic activity where it is practiced. Data on weight added through fattening are not available.

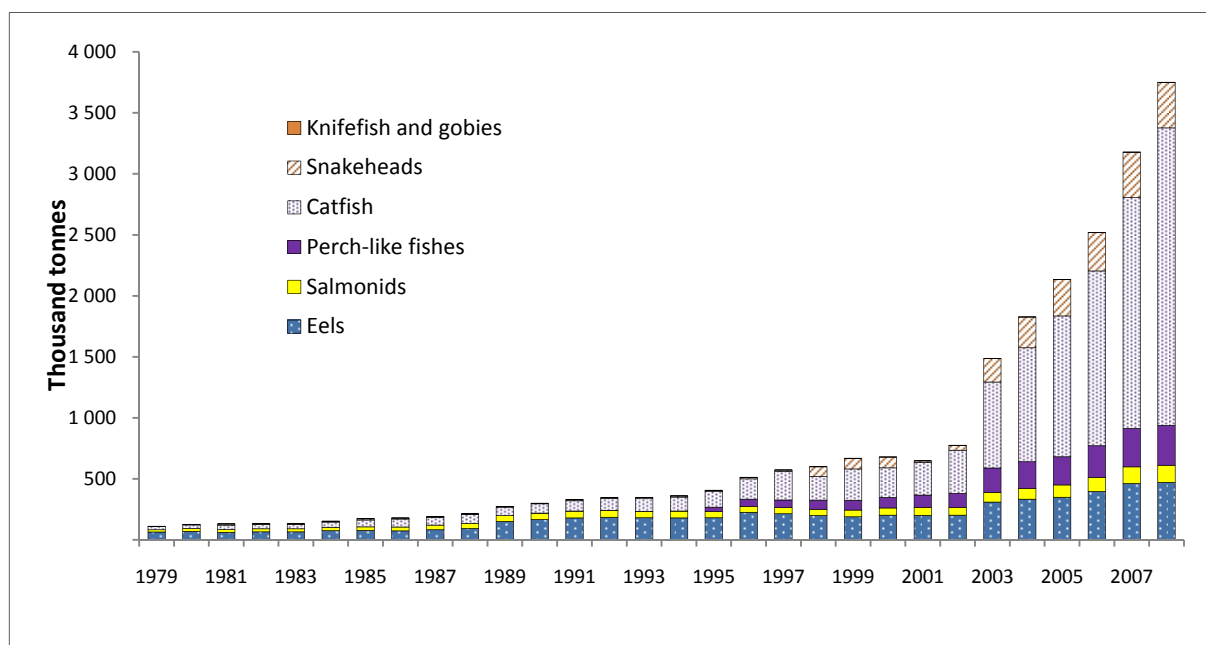


Figure 13: Changes in the production of freshwater carnivorous species in the Asia-Pacific region, 1979–2008.

Source: Lymer, Funge-Smith and Miao (2010).

Seabreams include several species belonging to family Sparidae. Seabreams production is confined to Japan, China, Taiwan Province of China, Republic of Korea and Hong Kong SAR. The Japanese production of seabreams was 71 000 tonnes in 2008. China reported almost 40 000 tonnes from 2003. In 2008, the production was 36 000 tonnes (down from 46 000 tonnes in 2006).

Other important carnivorous species that may contribute significantly to marine finfish culture in the region in the coming years include silver seabream (*Pagrus auratus*) (78 515 tonnes in 2008), lefteye flounder (*Psetta brevirectis*) (78 141 tonnes in 2008), large yellow croaker (*Larimichthys crocea*) (65 977 tonnes in 2008), red drum (*Sciaenops ocellatus*) (50 947 tonnes in 2008), bastard halibut (*Paralichthys olivaceus*) (50 632 tonnes in 2008), porgies and seabream nei (38 753 tonnes) and puffer fish (21 733 tonnes).

2.1.4.3 Finfish requiring low inputs

Most of these species groups are freshwater omnivorous and herbivorous fish. They are an important food fish for developing countries in the Asia-Pacific region. Significant diversification of species used in aquaculture has been observed in many countries in response to diversifying local and international market demands. Below are the important low-input freshwater species cultured in the region:

Tilapia. Production of tilapias has increased steadily over the past two decades, making tilapias the second most important cultured finfish species group after carps. Production reached 2.13 million tonnes in 2008, a 23 percent increase from 2006. This development has been driven by the demand in the international market. In 2008, the top eight producers in the region together produced 2.1 million tonnes of tilapia, a large increase from the 1.7 million tonnes produced in 2006 (Table 5).

Carps and barbs. Finfish aquaculture production from the Asia-Pacific region has long been dominated by carps and barbs. Total production from Asia-Pacific countries in 2008 exceeded 20 million tonnes for the first time. The production of carps and barbs declined in China from 46 percent of the total in 2006 to 44 percent in 2008, whereas regionally the production of carps and barbs in Asia-Pacific countries excluding China increased from 38 percent in 2006 to 41 percent in 2008. The major producers are shown in Table 6.

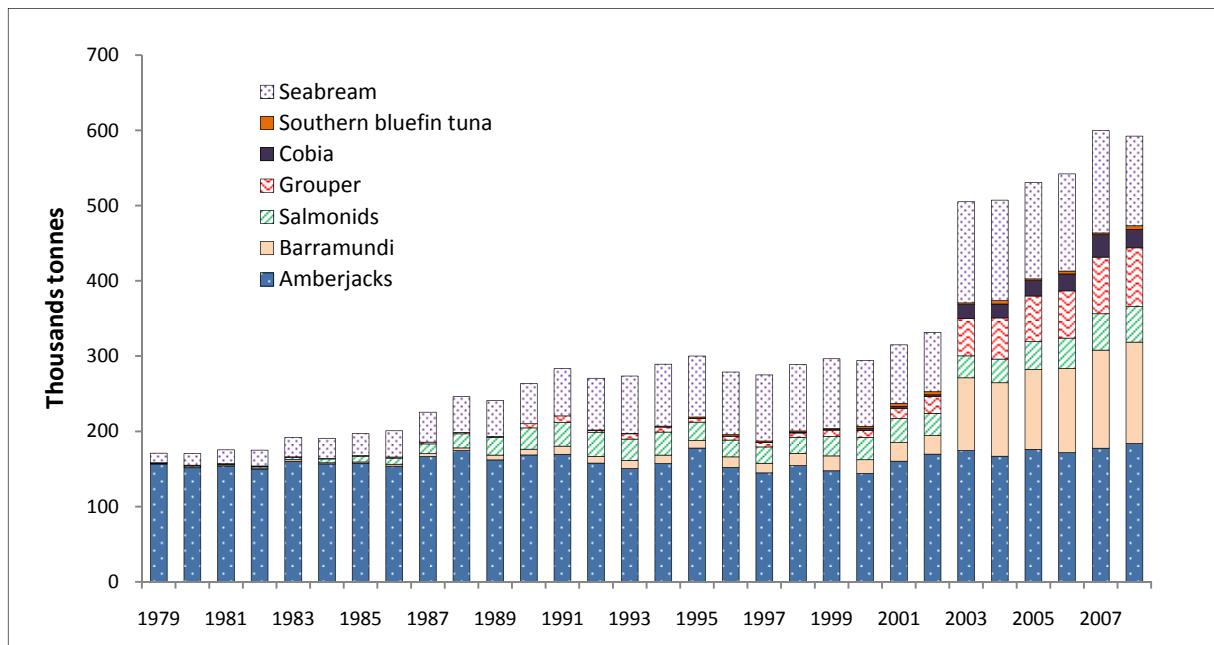


Figure 14: Production of marine and brackishwater species/species-groups in the Asia-Pacific region, 1979–2008.

Source: Lymer, Funge-Smith and Miao (2010).

Table 5: Top-eight tilapia-producing countries in the Asia-Pacific region, 2008.

Country	Production (tonnes)
China	1 110 298
Indonesia	328 831
Philippines	257 133
Thailand	209 945
Taiwan Province of China	81 009
Viet Nam	50 000
Malaysia	34 823
Myanmar	32 794

Source: Lymer, Funge-Smith and Miao (2010).

Table 6: Top-ten producing countries of carps and barbs in the Asia-Pacific region, 2008.

Country	Production (tonnes)
China	14 609 519
India	3 200 621
Bangladesh	696 053
Myanmar	553 101
Viet Nam	415 000
Indonesia	287 877
Pakistan	135 000
Iran (Islamic Rep. of)	87 679
Thailand	63 016
Lao PDR	58 410

Source: Lymer, Funge-Smith and Miao (2010).

Pacus and pirapatinga (*Colossoma* spp. and *Piaractus* spp.). These Latin American species are not reported in detail for most countries, instead they are grouped under “freshwater species nei”. China began reporting production of pirapatinga (*Piaractus brachypomus*) separately in 2003, and there was

a reported 78 000 tonnes produced in 2006 and 77 000 tonnes in 2008. Viet Nam and Myanmar started to report production in 2008, with about 6 000 tonnes each.

Milkfish (*Chanos chanos*) culture is a strong tradition in the Philippines. There are also traditions of milkfish culture in some Pacific Islands (e.g. Guam, Kiribati, Cook Islands, Nauru and Palau). Milkfish have typically been produced in brackishwater ponds and, in the Philippines, also in freshwater pens. There is an increasing trend in Indonesia and the Philippines in the use of marine cages in which fish are fed with either pellets or trash/low-value fish. Indonesia and the Philippines are traditionally the largest producers. Taiwan Province of China is reducing its production, possibly because of increasing attention to higher-value species. Singapore has developed its mariculture of milkfish (Table 7). A small industry is developing in Palau with technology from the Philippines and, as of now, seed from Taiwan Province of China.

Table 7: Top-four producing countries of milkfish (*Chanos chanos*) in the Asia-Pacific region, 2008.

Country	Culture environment	Tonnes
Philippines	Brackish	226 032
	Marine	80 365
	Freshwater	44 439
Indonesia	Brackish	277 002
	Marine	469
Taiwan Province of China	Brackish	27 944
	Freshwater	18 930
Singapore	Marine	917

Source: Lymer, Funge-Smith and Miao (2010).

Mullet (order Mugiliformes). Pond-based brackishwater culture of mullet is typical, but Republic of Korea has been reporting increasing mariculture production since 2000 (over 6 000 tonnes in 2008), and the freshwater culture is almost nil. Indonesia produces the bulk of these species (over 8 000 tonnes), and although its production declined in 1998, it has since shown a stable positive trend (although there was a sharp drop again of nearly 50 percent in 2007). Taiwan Province of China has seen a 50 percent drop in production between 2006 and 2008, and Thailand has reduced its production in recent years. Although not reported as a separate species, China is a producer of mullet (reported as marine finfish nei).

2.1.4.4 Crustaceans

Crustaceans are the species group of highest value in the region. Production has been increasing since the mid-1990s despite problems with disease. Cultured production reached 4.45 million tonnes in 2008, an increase of 19 percent over 2006. The predominant commercial species are two penaeid shrimp, two freshwater prawn and three crab species.

Penaeid shrimp. Marine shrimp continued to dominate crustacean aquaculture. Of the two major species, the whiteleg shrimp, *Litopenaeus vannamei* has overtaken and now greatly exceeds the production of giant tiger prawn, *Penaeus monodon*; in 2008 both accounted for 57 percent of the total crustacean production (down from 62 percent in 2006 because of farming setbacks in some countries and the levelling off of production in 2007 in China). Whiteleg shrimp production in the Asia-Pacific region increased from 2 000 tonnes in 2000 to over 1.0 million tonnes in 2004 and to 1.82 million tonnes in 2008, an 8 percent increase over 2006. China, Thailand, Indonesia and Viet Nam were the major producers of *L. vannamei* in the region (Table 8).

Traditionally, giant tiger prawn has been the most important crustacean cultured in the region. After a continuous decline from 2004 to 2007, production increased by 22 percent to 714 527 tonnes in 2008. This increase was mainly because of the surge of production from Viet Nam (174 000 tonnes) and a limited increase from the Philippines (7 000 tonnes), otherwise a declining trend of production was observed for most other producers in the region.

Whiteleg shrimp ranked first in the region by value at US\$6 485 million, which is almost twice that of 2004. Over the past 20 years, production trends in the region for the major producers have increased. The massive increase in the volume of production of whiteleg shrimp coupled to the similar size ranges produced by all countries has led to depressed prices for whiteleg shrimp. With so many states producing the same species, global prices dropped dramatically during 2002 and 2003. There has been a trend of decreasing prices for a number of years, especially for the smaller-sized whiteleg shrimp. Producers are attempting to overcome the problem of low prices and narrow profit margins through greater intensification. Prices for *P. monodon* remain very high because of a lack of supply, however, until specific pathogen free (SPF) broodstock can be produced, the disease risks for intensive systems remain high.

Table 8: Top-ten producing countries of penaeid shrimp in the Asia-Pacific region, 2008.

Country	Production (tonnes)
China	1 268 074
Thailand	507 500
Indonesia	408 246
Viet Nam	381 300
India	86 600
Bangladesh	67 197
Malaysia	51 047
Myanmar	48 303
Philippines	48 199
Taiwan Province of China	11 761

Source: Lymer, Funge-Smith and Miao (2010).

Giant river prawn (*Macrobrachium rosenbergii*) and **oriental river prawn** (*M. nipponense*) are the major freshwater prawn species cultured in the region. Production of these two species increased by 13 percent during 2006–2008. Oriental river prawn is currently cultured only in China. Giant river prawn is cultured in some 13 countries in the region, with major production from China, Thailand, Bangladesh, India and Taiwan Province of China (Table 9). Total production of the species reached 207 093 tonnes in 2008, with an increase of 13 percent over 2006. Production from China, Thailand and Bangladesh increased significantly during 2006–2008. However, production from India declined by more than half from 30 115 tonnes in 2006 to 12 800 tonnes in 2008. It is not easy to intensify production of freshwater prawns because of their territorial habits and uneven growth rates. Export markets for freshwater prawns are much smaller and less developed than those for marine shrimp, mainly because consumers in general are not as familiar with these species. Freshwater prawns, however, enjoy good domestic markets, especially in South Asia and Southeast Asia.

Crabs. During 2006–2008, cultured crab production continued its increasing trend of the past two decades, the production reaching 759 114 tonnes in 2008, an increase of 25 percent over 2006. Chinese mitten crab (*Eriocheir sinensis*) contributed 68 percent to the total culture crab production in the region in 2008. This species is mainly cultured in China, with a very small amount produced in Republic of Korea. Giant mud crab (*Scylla serrata*) is the most-cultured species in the region; 12 countries reported a combined production in 2008 of 138 000 tonnes, a 29 percent increase over 2006. Production of swimming crabs, nei (Portunidae) from China has increased steadily since it was first reported in 2003, reaching 83 803 tonnes in 2008, an 8 percent increase over 2006.

Table 9: Top-eight producing countries of giant river prawn in the Asia-Pacific region, 2008.

Country	Tonnes
China	345 894
Thailand	28 500
Bangladesh	23 377
India	12 800
Taiwan Province of China	10 058
Myanmar	2 881
Indonesia	942
Malaysia	355

Source: Lymer, Funge-Smith and Miao (2010).

Freshwater crayfish. Production of freshwater crayfish has increased dramatically in recent years because of the rapid increase of production of red swamp crayfish (*Procambarus clarkii*) from China. The production reached 364 619 tonnes in 2008, an increase of 224 percent over 2006. Production of the other three crayfish species (yabby, *Cherax destructor*; red claw, *Cherax quadricarinatus*; and marron, *Cherax tenuimanus*) totalled little more than 200 tonnes.

Lobster. A commodity with very little production volume but very high value, lobster production reached 372 tonnes in 2008, more than ten times the production in 2006. The dominant species cultured is tropical spiny lobster (*Panulirus longipes*). Indonesia is the largest producer, followed by the Philippines. Lobster culture is also practiced in other countries in the region such as Viet Nam, but this is not disaggregated in the reporting to FAO.

2.1.4.5 Molluscs

Mollusc culture is split into low-value species produced in extensive culture systems (e.g. seeded bloodcockle mudflats, mussel and oyster stake culture) and high-value species produced in intensive systems (fed systems and recirculation systems) such as abalone, as well as giant clams, which are cultured for the aquarium trade. Unlike fish culture, the intensification of mollusc culture is not easy and is probably not economically viable. Site availability will likely constrain future development in several states, as can be seen in the leveling off or decline in the production of cultured molluscs in Japan, Republic of Korea and Thailand, where production decreased significantly in 2008. The trend in mollusc culture is more likely to be a shift from lower-value to higher-value species in areas where sites are suitable. Intensive onshore culture operations for high-value molluscs such as abalone and a number of gastropods are increasing. Abalone production in the region increased by 70 percent between 2006 and 2008, reaching 39 046 tonnes.

2.1.4.6 Seaweeds

Seaweed species are classified as to their primary use i.e. as human food or for biopolymer production. The food group includes Japanese kelp, laver (nori), green laver and wakame. The production of these species is confined to East Asian states and is relatively stable. Japanese kelp culture has the largest share of aquatic plant production, with China as the largest producer. Kelp production peaked in 1999 and has since stabilized, which might indicate that the expansion of production area has reached a limit. In 2008, the total production was almost 5 million tonnes.

Seaweeds for biopolymer production consist of *Eucheuma cottonii*, *Kappaphycus alvarezzi*, *Gracilaria* spp. and other red seaweeds. The Philippines has the highest production of these aquatic plants. *Eucheuma cottonii* far exceeds the production of other seaweeds (1.4 million tonnes in 2008). Indonesia reports a large production of *Eucheuma*, almost 2 million tonnes in 2008.

2.1.4.7 Niche species

Niche species, usually not reported, include aquatic invertebrates nei, Japanese sea cucumber, jellyfishes, sea squirts nei, sea urchins nei and sea cucumbers nei. Their combined tonnage was more than 300 000 tonnes in 2008.

2.2 Salient issues

2.2.1 Mariculture and biodiversity

Finfish aquaculture in the Asia-Pacific region accounts for nearly 88 percent of world finfish culture. Within the region, freshwater finfish culture predominates, contributing 92.3 percent to cultured finfish production. On the other hand, marine finfish farming, although not contributing much to total production (e.g. India has a very low mariculture production of finfish relative to its vast coastal

waters) has started to increase in this decade. The growth of this sector would also have a positive impact on biodiversity, as explained below.

Marine fish are primarily sold to the lucrative live food fish restaurant trade (LFFRT) in Hong Kong SAR, Singapore and increasingly to China (Pawiro, 2005). In the past, much of the supply had been from the wild, fished with methods that destroy fragile coral reef habitats (Jones and Steven, 1997; McManus, Reyes and Nanola, 1997). The increasing dependence on farmed fish by the LFFRT and the increasing use of hatchery-bred seed (such as with humpback grouper, *Cromileptes altivelis*) have contributed to the conservation of fragile habitats and reduced concerns regarding the impact of wild seed use on wild populations (Sadovy, 2005). It is thus important to consider this subsector in relation to the capture fisheries production of the same species. The relevant trends are shown in Figure 15.

The sector is growing relatively fast and with sustainable practices, production of these species groups could eventually exceed that from capture. At this point, however, only 15 to 20 percent of the amount consumed each year comes from aquaculture. Culture is constrained by limited and unreliable supply of wild seed and by the difficulty of spawning in captivity, as well as in nursing the fry. Nonetheless, as mentioned earlier the culture of fingerlings in hatcheries has been achieved for some species. Since groupers are difficult to culture in closed systems, full-cycle culture of most species is not yet possible. For this reason, about two-thirds of all grouper culture uses wild seed (Lymer, Funge-Smith and Miao, 2010).

Most mariculture operations are carried out in inshore waters and enclosed bays using small low-technology floating cages. However, there is also a trend to move offshore using larger and more sophisticated cages sited about 1.5 km from shore. In the region, the nations making headway in finfish mariculture are China, Indonesia, Malaysia, Taiwan Province of China, Thailand, Singapore and Viet Nam. There is an emphasis on increasing the use of hatchery-bred seed, seed being one of the major constraints to offshore mariculture expansion.

2.2.2 *Species, culture systems and climate change*

The emergence and eventual huge production of striped catfish culture in Viet Nam was not foreseen. The basic trend in finfish culture by species in the top-ten ranked species from 1990 to 2008 is given in Table 4. Catfish made it into the list in 2008. Before and since there has been no change. While the production of all species has increased significantly, the rank order of the top five species has remained almost unchanged for 17 years. Most importantly, many of the species listed in Table 4 are herbivorous or omnivorous. Such species, together with molluscs and seaweeds, constitute the bulk of Asia-Pacific aquaculture production (Lymer, Funge-Smith and Miao, 2010). This is of importance in relation to the world's concern over climate change, as these species and their production systems account for minimal green house gas emission. Molluscs, which are cultured over wide areas and in large volume throughout the region from Oceania to East Asia, and seaweeds, almost all of which are produced in the Asia-Pacific region, are carbon sequestering (De Silva and Soto, 2009).

2.2.3 *Size of farms, intensity of farming and efficiency*

Around 80 percent of fish farmers in Asia are small-scale, and most small-scale farms are also small in area. An important question is whether small farms are more efficient and thus more productive (i.e. have a higher yield per unit area) than larger farms. This question has been examined for crop and livestock farms (Eastwood, Lipton and Newell, 2004; Fan and Chan-Kang, 2005; Aina, 2007) but has been barely considered for fish farms.

Sufficient data on freshwater ponds were not available for statistical treatment, but small coastal (i.e. brackishwater) farm sizes in Thailand were correlated with their productivity (Kongkeo, 1997). The one-time statistical treatment showed a highly significant ($p < 0.01$) inverse relation between size and yield per unit area (Figure 16). There would be various reasons for this, one being the capacity of the farmer to manage a farm. For example, an early study on intensive shrimp farming in Asia reported

that average sizes of farms were 2.7, 3.2, 7.5 and 12.7 ha in Thailand, Taiwan Province of China, Indonesia and the Philippines, respectively (Kongkeo, 1997) and noted that large shrimp farms with high investment and large overheads were not able to survive “because of insufficient care in farm management”.

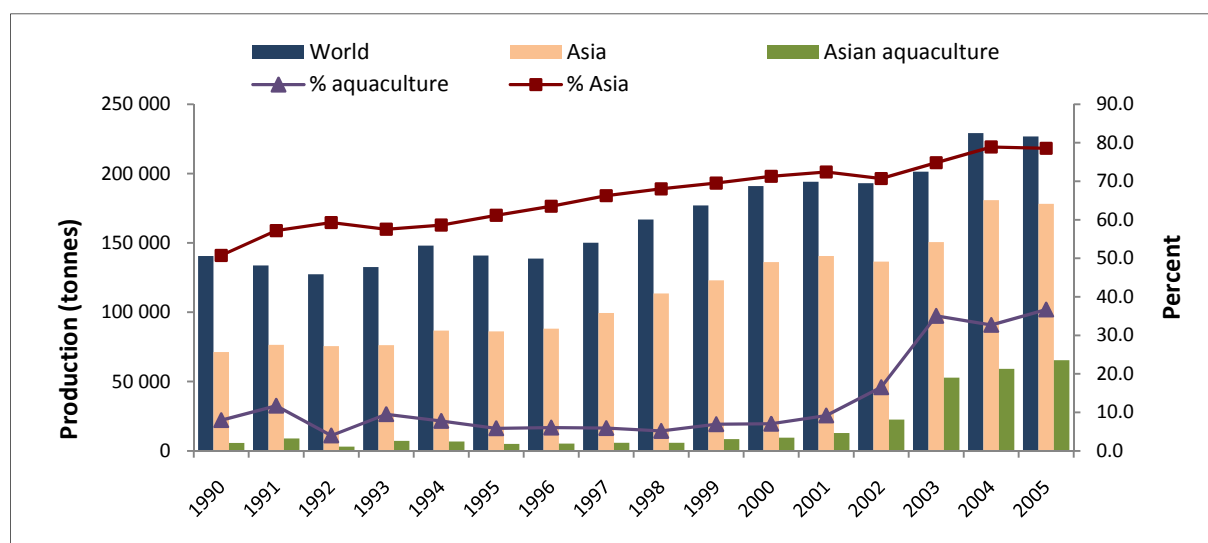


Figure 15: Trends in world and Asian production (capture and culture) of groupers, wrasses and snappers and the percent contribution of Asian aquaculture to the world total.

Source: FAO (2007).

Note: The apparent sudden increase in production in 2003 and subsequent years is caused by the desegregation of marine finfish production data by China. Before that, grouper production was aggregated into marine finfish data.

A related issue is technical efficiency, regardless of farm size. An extensive study of the determinants of farm-level technical efficiency in freshwater pond polyculture systems in China, India, Thailand and Viet Nam found that yield, input level and technical efficiency tend to increase with intensity level (Dey *et al.*, 2005). Estimates of technical efficiencies ranged from 42 percent among extensive farms in Viet Nam to 93 percent among intensive farms in China. The study pointed out that low-intensity farms could raise their technical efficiency by “increasing human capital”, in other words, by improving skills of workers through training and extension. This would be enhanced by provision of basic infrastructure, easier access to seed supply, and security of tenure or a well-defined system of land-use rights. Among intensive farms, technical efficiency could be increased by the “continuous development of new technology and cross country technology transfer”.

While some smaller farms could be made more productive or technically efficient by good management and better technical support, the usual drawback seen for small farms is their lower economy of scale than large commercial farms. To gain economy of scale, the principal recommendation from a number of recent initiatives on small aquaculture farmer development is to encourage farmers to organize themselves into clusters or formal associations (Umesh *et al.*, 2010).

A third issue with some link to farm size is the fragmented structure of the aquaculture production sector (WB, 2007) which prevails in most of Asia-Pacific, except in Central Asia where their vast state farms have been privatized. The sector in the developing countries comprises numerous small farms that are operating independently, some commercial, some subsistence, many remotely located, some owner operated, others leased, a few communally operated and some unregistered. This structure complicates the management and servicing of the sector and suggests the urgent need to strengthen the capacity of local regulatory authorities and providers of extension services. Again, it underlines even more the need for farmer associations.

2.2.4 Farming systems

The farming systems in Asia are diverse, and many systems are for a single group of commodities, such as finfish culture in earthen or lined ponds, cages, pens and raceways, depending on the species and the water availability. Pond culture is the dominate production system for finfish.

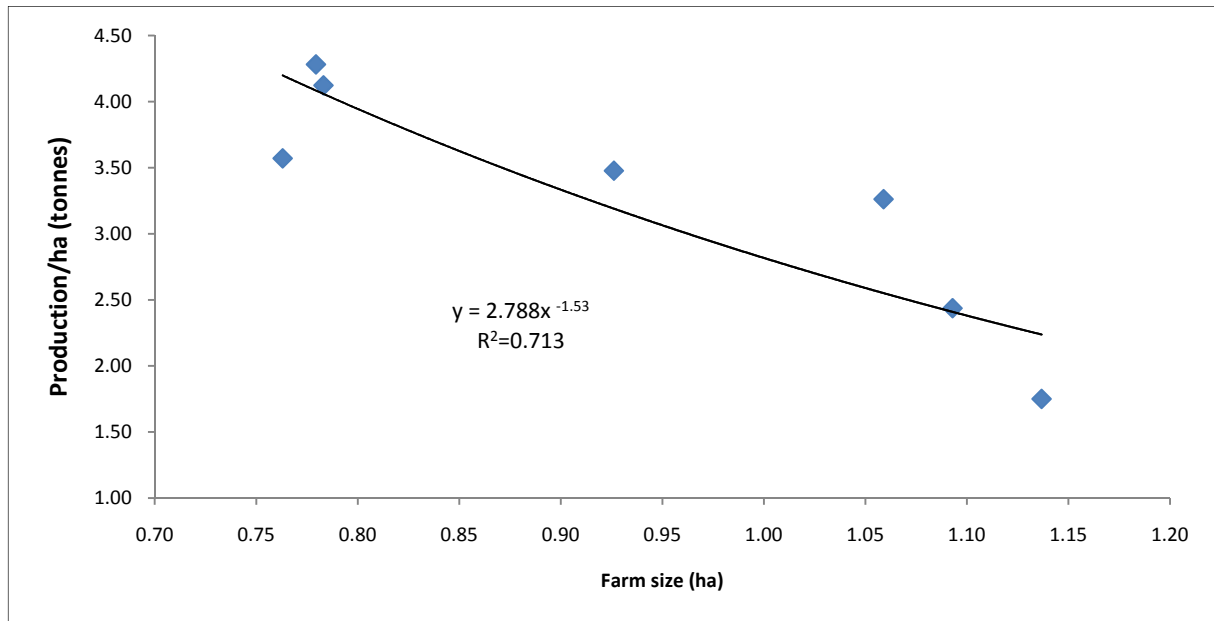


Figure 16: The relationship of mean average production per year (each data point, 2000 to 2006) to farm size of coastal pond culture in Thailand.

Source: Kongkeo (1997).

The biggest technological introduction has been the use of large circular cages for offshore (1 to 1.5 km from the shore line) fish culture. However, this system is confined to a very few species and countries, the main constraints being seed stock supply, the large capital investment required and the difficult servicing of such facilities. The main species that is currently cultured in offshore cages in the region is cobia (*Rachycentrum canadum*). Offshore cage farming is unlikely to become widespread in Asia, as its development is hampered by availability of capital and the hydrography of the surrounding seas, which does not allow the technology to be easily transferred (De Silva and Phillips, 2007).

Two major shifts in China have been the growth of monoculture systems of higher-value species and the huge increase in tilapia production. More monoculture has slowed down the growth of the aquaculture of carps in integrated agriculture-aquaculture systems. Monoculture has occurred in pond systems and marine cages. Nonetheless, the multitrophic system in coastal areas that includes *Laminaria* seaweed, molluscs (abalone and scallops), seacucumber and other species continues to be practiced in extensive coastal areas of the Yellow and Bohai seas. Heightened interest in its further development and sustainability, as well as adaptation in other countries has been induced by the potential value of the system as an adaptation measure to climate change impacts and its potential contribution to greenhouse gas mitigation.

The small, highly productive, integrated systems in Viet Nam called VAC (integrated garden [V], fishpond [A] and livestock [C] system [VAC in Vietnamese is *vuon, ao, chuong*, which means garden, pond and livestock] continue to be operated by small farm households. These are important for household and community food security and family income. In the PICTs, some countries like Samoa, Fiji and Papua New Guinea (PNG) have VAC-like systems using tilapia, carps or both species integrated with the staple root crop taro, vegetables and chickens or pigs; in Vanuatu, it is taro and freshwater prawn. The potential role of the integrated agriculture-aquaculture systems in small Pacific Island countries to food security is amplified by the fact that the farms supply some of the food needs of extended families and clans (FAO/SAP and SPC, 2010).

2.3 The way forward

2.3.1 *Improving efficiency and productivity*

The 2006 global review of the status of global aquaculture (FAO, 2006) identified the decreasing availability of land and freshwater resources for aquaculture as a constraint to expansion and growth, and intensification as the option. This would generally apply to Southeast, South and East Asia and is a given for the PICTS. The Central Asian region, however, has vast inland water resources relative to the CAR states' population size and current production, so that the way forward for CARS to increase production is the improvement of the productivity of aquaculture and the waterbodies. In the PICTs, as far as the foodfish species and freshwater and marine prawns are concerned, the immediate needs are the development of domestic feeds and a more reliable supply of seed. Local markets are not large except, in a relative sense, for the lower-value food fish such as tilapia, carps and milkfish in Fiji and PNG. The culture of other species is geared mostly for export.

As to size of farms and scale of farming systems, the linked options for Asian aquaculture remain improvements in the economy of scale and the effectiveness of servicing small farmers through their being associated (consolidation of small farms by large industrial firms would not be a politically or socially attractive alternative for raising technical and economic efficiencies with so many small farms providing livelihoods for millions of rural households and food to the thousands of rural communities). More efficient and productive use of inputs could be attained by integrated farming, as well as with business models such as cluster, satellite and contract farming that increase efficiencies. In the Pacific Island countries where all land-based farms are small, integrated farming (in Fiji, Kiribati, Papua New Guinea, Samoa, and possibly Solomon Islands and Vanuatu) would increase overall productivity of the farm. Fiji is also exploring the suitability of cluster or satellite farming to promote commercial farming. In Central Asia, where pond farms are large (having been state collective farms that are now privatized), the basic issue is improvement of productivity through improved seed and better feed management, improvement of technical efficiency with reliable seed and feed quality and supply, and better farm management skills.

2.3.2 *Research and development (R&D) and regulatory support to facilitate adoption*

The development of aquaculture in the region has been aided by, firstly, introductions of new species, the notable examples being tilapia and for a brief period in the 1990s in Southeast Asia and Bangladesh, the African catfish (or the hybrid of *Clarias macrocephalus* x *C. gariepinus* developed in Thailand), and more recently, the whiteleg shrimp (*Litopenaeus vannamei*) and cobia (*Rachycentrum canadum*); secondly, by intensification and thirdly, by the development of indigenous species for aquaculture. As the FAO/RAP/APFIC review (Lymer, Funge-Smith and Miao, 2010) notes, the region has seen an increasing number of species or species groups being cultured. The major driver of diversification in Asia (especially in Southeast Asia and China) is usually the market. As the 2005 review (FAO, 2006) had noted, as soon as farmers hear of a promising species, they would adopt it in a farming scale that invariably skips the trial stage. Farmers seldom wait for research results or advice from government R&D institutions, which leaves government having to do a catch-up job in providing technical advice as well as setting up regulatory measures. This phenomenon had often occurred for higher-value species such as marine crustaceans and finfish and for a few freshwater species such as freshwater prawn, mandarin fish and recently, pangasiid catfish in Viet Nam.

2.3.3 *Focus on fewer species of regional priority*

Central Asian aquaculture and the stocking of freshwater bodies is likewise predominantly based on the use of introduced species, particularly cyprinids from China and Europe and snakeheads from China and probably Southeast Asia, but also on the development of the silurid catfish and perch species which are native to the region. The region has more than 60 cultured species or species groups (the average is 39 species per country) including sturgeon; however, carps are the dominant species in all CAR states, cultured in ponds and stocked in lakes and reservoirs, mainly as food for local

populations. Other than food security, foreign exchange earning through export of the higher-value species or products other than caviar remains a goal of the CAR countries (FAO/SEC/FIEL, 2009).

The PICTs has had 48 species or species groups tried for culture in successive periods of development since the 1930s. Many of the species were introduced from outside the region, others are indigenous in some PICTs and moved around the region, and some (such as giant clam, trochus, seacucumber, milkfish and carageenophytes [i.e. *Eucheuma*]) are native to the region. Culture trials were mostly geared towards commercial feasibility, but only a handful of species – shrimp, giant clams and marine pearl oysters – became commercially viable. Eventually, the region focused only on 11 species, two of which are for food security (tilapia and milkfish) and the others for livelihood generation and/or export (FAO/SAP and SPC, 2010).

2.3.4 *Cage culture to turn a potential problem into an opportunity*

Another option, driven by competition over land and lately, the prospect of rising sea levels, is cage culture. The outlook for all forms of cage farming looks relatively bright for Asia (De Silva and Phillips, 2007). However, it is unlikely that the large-scale, capital-intensive, vertically integrated marine cage-farming practices seen in northern Europe (e.g. Norway) and South America (e.g. Chile) would occur in Asia. Instead, clusters of small farms generating synergies, acting in unison and thereby attaining a high level of efficiency is seen as the way to go. Examples would be the mariculture parks in the Philippines and the highly concentrated cage culture facilities in southern China and in Halong Bay, Viet Nam. The southern bluefin tuna cage operations in Australia are not small, but they do provide an example of clusters of farms “acting in unison and generating synergy.”

3. RESOURCES, SERVICES AND TECHNOLOGIES

3.1 Status and trends

3.1.1 Land and water resources

The land and freshwater resources available for aquaculture in most of the countries in the Asia-Pacific are becoming scarce due to the expansion of aquaculture itself and the demands of other sectors. Freshwater resources are also suffering from deteriorating quality, and even the lagoons in some Pacific Island countries are beginning to be impacted by domestic effluent. Intensive pearl culture had also triggered outbreaks of vibriosis (a bacterial disease) in the lagoons where pearl oyster farms are sited in the northern Cook Islands. Central Asian states generally have ample water resources relative to their populations and their current level of aquaculture production: 43 000 km² of lakes and reservoirs, 26 000 ha of ponds and other inland waterbodies for fish culture, and 154 000 km of rivers (FAO/SEC/FIEL, 2009). A threat to aquaculture in this region, however, is the pesticide runoff from vast croplands and recently, the rising domestic effluent levels discharged into rivers. Furthermore, aquaculture has lower priority than crop irrigation in the allocation and use of water resources.

3.1.2 Seed

Farmers in the Asia-Pacific region are now enjoying a reliable supply of hatchery-bred seed of finfish, except freshwater eel (*Anguilla* spp.), southern bluefin tuna and some grouper species, as well as wrasse. A number of grouper species, however, have been domesticated and their hatchery seed production commercialized (Nguyen *et al.*, 2009). For example, the culture of the humpback grouper (*Cromileptes altivelis*), one of the highest valued groupers (US\$46–48 per kg live in the Hong Kong SAR market), is now entirely based on hatchery-produced seed.

On the other hand, although the life cycles of giant mud crab (*Scylla serrata*) and lobster species have been closed experimentally, commercialization of the hatchery production of these could take a few more years. Mangrove crab seed production on a commercial scale has taken a long stride with the technology on breeding developed and transferred through the regional training and outreach activities of the South East Asian Fisheries Development Center Aquaculture Department (SEAFDEC-AQD) based in the Philippines. Commercial hatcheries, however, do not yet exist.

Mollusc culture is still largely dependent on wild spat collection, and very little genetic work is being done on any of the important species, so that the important issues are the management of the resource and protection of its habitat from degradation. In the Pacific Island countries, however, the technology for the hatchery production of giant clam (*Tridacna* and *Hippopus*) is now widespread, initially spurred by the need to produce seed for restocking of depleted natural populations and later for the on-growing of aquarium-size clams for an expanding global trade in ornamental species.

One notable development in the production of abalone seed has been driven by a disease problem that infects spat of the major culture species *Haliotis diversicolor* in the temperate growing areas (Japan, Republic of Korea and Taiwan Province of China). This prompted the shift in the production of seed to hatcheries in tropical zones, particularly Thailand. Local Thai seed growers produce and ship abalone spat grown to a size that is less vulnerable to the disease to growers in Taiwan Province of China. Meanwhile, Thai farmers have also begun on-growing *H. diversicolor*, gradually replacing the smaller local species, *H. asinina*.

3.1.3 Genetic improvement

The first genetic improvement in cultured tropical species was on the Nile tilapia (*Oreochromis niloticus*). A massive, systematic and well-invested breeding programme developed the genetically improved farmed tilapia (GIFT). This resulted in significant production gains that boosted yields of

small-scale farmers (Eknath and Hulata, 2009; Acosta and Gupta, 2010). It was followed by the development of genetic improvement technologies to produce all-male tilapias. The genetic manipulation approach fostered the culture of all-male tilapia stocks and reduced the practice of using sex steroids for sex reversal of tilapia hatchlings into phenotypically male fish. The use of hormone for sex reversal in the major producing countries (e.g. China, Indonesia, Thailand and the Philippines) is now being replaced by this technology. It has been suggested that the YY/GMT (Genetically Male Tilapia) technology in *O. niloticus* is the only genetic technology adopted by the aquaculture industry for the production of all males (Beardmore, Mair and Lewis, 2001), although this is now being done on giant freshwater prawn (*Macrobrachium rosenbergii*) on a limited scale in Thailand and India following its development by Thai geneticists. The pros and cons of using GMT and the proliferation of the use of the technique by small-scale hatcheries are discussed by Mair *et al.* (2002).

Genetic work on marine shrimp to develop SPF stocks is being conducted for *P. monodon* in Thailand and in Malaysia and has expanded to include the production of SPF seed for *L. vannamei*, which is now the dominant aquaculture species. At present, much of the SPF seed of *L. vannamei* still comes from Hawaii. Work on bivalve molluscs, particularly edible oyster, continues to focus on polyploidy to improve growth.

3.1.4 Animal health management

Many disease problems and the occasional severe epizootic – such as the epizootic ulcerative syndrome (EUS) and koi herpes virus disease (KHVD) in freshwater fish (Sunarto, Rukyani and Itami, 2005; Sunarto *et al.*, 2005), viral nervous necrosis (VNN) in marine fish, white spot disease (WSD) and Taura syndrome (TS) in penaeid shrimp, white tail disease (WTD) in *M. rosenbergii* and infectious myonecrosis virus (IMNV) in *L. vannamei* – have time and again exposed the vulnerability of aquaculture systems to pathogens and to the factors that make them virulent and cause their spread. The increasing globalization and volume of trade in aquaculture products that include live species has opened new pathways for pathogens to spread.

Asian countries began to implement national aquatic animal health management strategies in the early 1990s; this was catalysed by an FAO-NACA-OIE regional programme. This and the development and adoption in 1999–2001 of the Asia Regional Technical Guidelines for the Responsible Movement of Live Aquatic Animals by 21 Asia-Pacific governments were major outcomes. The implementation of key elements of the regional programme remains the focus of the Network of Aquaculture Centres in Asia-Pacific's (NACA) regional aquatic animal health programme under a continuing partnership with FAO and (the World Organisation for Animal Health (OIE). In the Association of Southeast Asian Nations (ASEAN) region, SEAFDEC-AQD also initiated and continues to operate a regional capacity-building programme on fish health management.

The commitment of governments in the region to aquatic animal disease surveillance and disease reporting has been strong. The quarterly aquatic animal disease (QAAD) reporting system is a testimony to this progress. The QAAD reporting system in the Asia-Pacific region, a joint activity of NACA, FAO and the OIE Regional Representation (Tokyo), has been going on since 1998. Twenty-one countries in the region take part in the reporting system. The data generated through this reporting system provide up-to-date information on important diseases in the Asia-Pacific region and serve to alert the region on emerging diseases.

The trained human capacity for disease diagnosis and the laboratory facilities for working on some of the key diseases of concern to the region have increased substantially in the last decade. Some of the laboratories from the region are now recognized as OIE reference laboratories for some key diseases like EUS, WTD and WSD.

The application of modern diagnostic methods for servicing the aquaculture sector is increasing, driven by food safety concerns and trade. The use of polymerase chain reaction (PCR) technology to service the shrimp farming sector has progressed considerably. Government and private PCR service-

providing laboratories in several countries (e.g. India, Indonesia, the Philippines, Thailand, Viet Nam) are screening samples of shrimp broodstock and postlarvae to provide hatcheries and farmers a technical basis for their decisions. Use of virus-free broodstock and seed has minimized the impact of some of the serious shrimp viral pathogens in the region. Epidemiological approaches have been increasingly used to identify risk factors for key disease outbreaks and later develop interventions in the form of better management practices (BMPs). Application of BMPs in shrimp farming has helped the sector to minimize the impact of serious viral pathogens and has enabled farmers to live with the viruses and sustain production.

From a regional perspective, governments have increased their investments in aquatic animal health management. The awareness of and capacity for disease management has progressed considerably over the past decade. There is increasing evidence of governments taking steps to build capacity to deal with aquatic animal diseases and meet international standards. Import risk analysis (IRA) is increasingly used by countries to make decisions on introductions of live aquatic animals.

Another key support to aquatic animal health management is the Asia Regional Advisory Group (AG) on aquatic animal health. The 10-member high-level group whose membership includes experts from some governments and with FAO, OIE, SEAFDEC and a multinational veterinary company as institutional members was constituted by the Governing Council of NACA in 2001 to advise NACA and Asian governments on aquatic animal health management. It meets yearly to review the Asian disease situation, consider regional and international developments, develop and communicate specialist advice to governments on aquatic animal health management matters and promote the role of the region in influencing international standard setting processes and trade policies.

3.1.5 Feeds

Asia is the largest user of farm-made and industrially produced aquafeeds (De Silva and Hasan, 2007; Hasan *et al.*, 2007; Rana, Siriwardena and Hasan, 2009). There are many controversies associated with feeds, primarily regarding the use of fishmeal and fish oil in aquaculture. Asian aquaculture has its share of these, given its large and increasing utilization of fishmeal and trash fish/low-value fish. China is the biggest user of fishmeal and used 1.6 million tonnes in 2004, of which 1.2 million tonnes were imported. Approximately 75 percent of the total usage was for aquafeed production. With its expanding mariculture, Vietnamese aquaculture uses 62 500 tonnes of fishmeal per year. Other significant users are Indonesia, the Philippines and Thailand.

The low and high predictions for fishmeal usage in Asia in the year 2010 are 2.0 and 2.2 million tonnes, respectively (equivalent to 8.4 and 12.8 million or 7.3 and 11.2 million tonnes of raw material, based on fishmeal conversion rates of 4.0 and 3.5, respectively (Hasan and Halwart, 2009).

A persistent issue relates to feeding trash or low-value fish to high-value marine finfish such as grouper, wrasse and cobia. As their production is expanding, so is the use of low-value fish which has been traditionally used as the main feed, sourced through traditional fishing practices and industrial fishing. Marine finfish culture in the region utilized 1.6 to 2.8 million tonnes of low-valued fish in 2004 and was projected to require 913 000 to 1 663 000 tonnes in 2010, depending on the extent of growth of the sector (De Silva and Turchini, 2009). To address this issue, an FAO regional Technical Cooperation Programme (TCP) project on substituting low-value fish with pellet feed indicates that the substitution with formulated feeds can be profitable and improve management (Lymer, Funge-Smith and Miao, 2010).

In the Pacific Island countries, the high cost of feed as well as feed ingredients, which have to be imported, is considered a major constraint to the mostly small-scale finfish and crustacean farmers. As feed is largely imported, a local feed manufacturing venture would help reduce costs, but the small volume of culture creates a demand that is hardly attractive to prospective investors in feed manufacture. Meanwhile, some governments provide farmers with feed, which they formulate and produce in barely sufficient amounts.

3.1.6 Credit and insurance

Aquaculture insurance in Asia started more than 20 years ago, but while fisheries insurance soared, aquaculture insurance showed mixed results and has generally had a limited growth (van Anrooy *et al.*, 2006). The reasons for this include the specific difficulties involved in aquaculture insurance and the limited profitability of aquaculture insurance pilot schemes. In the past, general insurance companies in Asia were sometimes ordered to provide aquaculture insurance services by law or decree, although knowledge of the sector was minimal, as was the interest shown by the companies in setting up nationwide coverage. As a result, many aquaculture insurance schemes in Asian countries did not go beyond the pilot scale. In the latter part of this decade, however, a series of aquaculture insurance-focused workshops developed schemes for small-scale aquaculture and further increased awareness among government agencies and financing institutions. A hybrid insurance scheme was articulated, the essential feature of which is that the state provides compensation for catastrophic damage and other damages that private insurers would not insure, whereas private insurers would insure farms for the usually insurable perils. A special feature of the scheme is to use insurance to encourage the adoption of BMPs (Secretan *et al.*, 2007).

3.2 Salient issues

3.2.1 Seed

In seed production, the increasing advocacy of popularizing the culture of indigenous species (Welcomme and Chavalit, 2003) induced the development of hypophysation techniques for species such as the mahseers (*Tor spp.*). This was inevitably followed by the commercialization of hatchery production (Ingram *et al.*, 2005, 2007). Similarly, almost all marine shrimp culture and that of the giant river prawn (*M. rosenbergii*) is based on hatchery-produced seed stock. Advances in the artificial breeding of many species have reduced pressure on wild resources, an important concern with shrimp (especially in the Sundarbans in Bangladesh), as well as with groupers, especially in the Philippines, the East Malaysian state of Sabah, Indonesia and Viet Nam. Selective breeding programmes for important cultured species and broodstock management plans using genetic tools have been initiated over the last decade (Sang *et al.*, 2007; Aung *et al.*, 2010). Countries have set up broodstock management centers. In Indonesia, centers have been established for tilapia, North African catfish and common carp and networked into a National Broodstock Centre. Work in these centers has led to the improvement of existing strains; a genetically supermale Indonesian tilapia (GSIT), based on GIFT stocks has been developed and is being disseminated to farmers. In Viet Nam four freshwater and three marine broodstock centers have been established. However, a regional approach and rationalization of genetic improvement of cultured stocks could have produced quicker results that would have been rapidly promoted, as with GIFT tilapia (Acosta and Gupta, 2010).

Hatchery production of most commercially cultured species in the region is done in small-scale operations. Seed production has gone hand in hand with the introduction of appropriate broodstock management plans and selective breeding programmes for the cultured species. A linked issue is the unplanned movement of broodstock, juveniles and seed across borders with little consideration of potential impacts on genetic diversity (Nguyen *et al.*, 2009) and the translocation of pathogens.

Timely and adequate supply of quality seed has been a precondition to scaling up production or entry into aquaculture. Networks of private producers and traders dominate the supply of seed to farmers in Asia and are important promoters of production, although poor-quality seed, caused by poor genetic management of breeders and accidental hybridization, is a common constraint. The poor-quality seed undermines the livelihoods of poor farmers and the integrity of the production chain and entire aquaculture economy. For example, in the Yangtze River basin, inbreeding has slowed down the growth rate of farmed Chinese carps by 20–30 percent compared with wild counterparts, causing a 15 percent drop in revenue (WB, 2007). Inbred fish pose a genetic risk to wild counterparts if they escaped to rivers in large numbers, which may result in the loss of pure stock. In some areas, cross-breeding of silver and bighead carps that have a similar appearance has eliminated pure stocks, so that

the efficiency and capacity of silver carp to feed on phytoplankton has plummeted, reducing growth and compromising the value of polyculture of different carp species (WB, 2007).

3.2.2 *Aquatic animal health management*

Countries in the region are at different stages of development of their national aquatic animal health strategies and action plans. Good progress has been made in disease diagnosis, aquatic animal health certification and quarantine, disease surveillance and reporting, and farm-level health management. However, there is need to improve capacity for contingency planning, zoning and import risk analysis.

The use of veterinary products, especially antibiotics, and other substances in hatchery and culture has diminished but remains a problem linked to food safety (and thus to trade), as well as to direct impacts (e.g. of antibiotic use) on human health and the environment.

3.2.3 *Putting the feed issue in perspective*

The issues surrounding the use of fishmeal are discussed elsewhere (see Hasan *et al.*, 2007; De Silva and Turchini, 2009; Huntington and Hasan, 2009; Rana, Siriwardena and Hasan, 2009, among others). A feature of aquaculture development in the region that needs reiterating is that the major commodities cultured in the region feed low in the trophic chain, and therefore Asia's demand on fishmeal and fish oil for feed manufacture is low relative to the enormous volume of food fish it produces. Related to this fact is the large number of small-scale farming activities that depend on farm-made feeds. A good example is the large-scale carp farming industry in Andhra Pradesh, India, which almost totally depends on mixes of agricultural by-products as feed that include bran-oil cake (Hasan *et al.*, 2007). The increasing cost of formulated feed, even for species that require a low protein level, has made Andhra Pradesh farmers continue to use farm-made mixes.

3.2.4 *Credit and insurance*

Aquaculture operations in Asia have not enjoyed easy access to capital or to crop insurance, mainly because of the perceived high risks in aquaculture. Credit and insurance worthiness are closely linked. While small-scale aquaculturists in Bangladesh, India, Indonesia and the Philippines have increasing access to micro finance, they do not have similar easy access to insurance. It appears that it is the commercial credit and insurance providers that are risk averse, rather than the farmers, because the grouper and shrimp farmers, in particular, but also the tilapia, catfish, and mollusc farmers have not been deterred from farming – notwithstanding the numerous risks – by poor access to credit and insurance. Their lack of access to institutional credit and commercial insurance usually compels them to borrow from non-formal sources or resort to non-market strategies for crop loss mitigation, which for poor small farmers, diminishes their capacity to invest into more farm assets and adopt BMPs.

3.3 **The way forward**

3.3.1 *Seed*

Several approaches ranging from institutional to farmer managed decision-making tools have been adopted by countries and farmers to assure fish seed quality (Bondad-Reantaso, 2007). The multi-country review found that strategy has shifted from centralized to decentralized seed production, which offers opportunities for poor farmers to enter into the fish seed business. Decentralized fish seed production should be supported by appropriate breeding strategies to maintain the genetic quality of broodstock. Building support services at the local level is crucial to expanding fish seed supply. With basic technologies for small-scale fish breeding and fry nursing largely in place, future support should focus on extension of knowledge and building of institutional support for rural households where there is potential for fish breeding and fry nursing. Information sharing mechanisms on hatchery breeding and fry/fingerling production as an agribusiness will also help enhance capacities in countries where these technologies are still not well developed.

Aquaculture can be used to address the limited supply of seed for the culture of indigenous species. A programme in Lao PDR by the Living Aquatic Resources Research Centre (LARReC) and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), uses wild breeders to produce seed in hatchery. The scheme is as follows: breeders of target species are collected from the wild, stocked in ponds to develop new broodstock, transferred to hatcheries to spawn, and released into the wild after spawning. Some of the fingerlings are released into the wild, the rest are sold. This scheme diversifies the number of species cultured, improves hatchery and nursery technique, reduces the use of alien species, possibly protects the wild breeders, and contributes to biodiversity conservation. The species in the LARREC CIRAD programme are isok barb (*Probarbus jullieni*), *Pangasius krempfi* and striped catfish (CC, 2009).

In the PICTs, there are examples of commercial operations such as a *Macrobrachium* hatchery in Fiji, a tilapia cage culture farm in Vanuatu, shrimp hatcheries in New Caledonia, giant clam hatcheries in Kiribati and the Marshall Islands, and a milkfish farm in Palau which could take over or supplement seed production from government stations given the right incentives and technical support. Government could maintain or develop broodstock, as in Fiji, and regulate private seed producers so that improper introductions are avoided. Once this is initiated, government should gradually withdraw from seed production (FAO/SAP and SPC, 2010).

In Central Asia, the improvement of facilities for breeding and hatchery production is an urgent task. Scientific and technical capacity for genetic work is strong, a legacy from the Soviet era. In most countries, seed production has been done by both government and private commercial enterprises. In keeping with the transition to a market economy, to avoid competing with the private seed producers, government should begin to concentrate on genetic research for broodstock development, while providing technical and economic incentives to hatchery operators and grow-out farmers (FAO/SEC/FIEL, 2009).

3.3.2 Feed

Except in the PICTs, feeds and availability of ingredients are not seen as constraints to aquaculture development in the region. However, it is expected that improvements to feed management and increased efficacy in feed manufacture, both small and large scale, will lead to a further improvement in feed availability, feed utilization efficacy and profitability, as well as reduce environmental impact (FAO, 2010). Research continues on alternative sources of dietary protein and oil, especially vegetable oil (including palm oil) (Hasan *et al.*, 2007; Rana, Siriwardena and Hasan, 2009). Some limited commercial applications with carnivorous freshwater species such as clariid catfish (in Thailand) and snakehead (in Cambodia) have been initiated.

3.3.3 Biosecurity

The national and institutional capacities in aquatic animal health management have improved considerably during the past decade. The new strategy is to integrate the various management strategies to protect the sector from biological risks into a broader programme on biosecurity. This move would give more focus to the risk analysis and management capacities of governments and the private sector to deal with a broader range of risks, including the biological, technical, environmental, economic and social risks.

For the PICTs, biosecurity is crucial because of the relatively pristine natural environment and rich biodiversity of the region. In Central Asia, capacity building would be useful at the more fundamental level: development of national policies and regional strategy along with the strengthening of institutional and manpower capacities. The risk of spread or introduction of pathogens in Central Asian Republics is amplified by the long river systems that cross many borders.

3.3.4 Credit and insurance

The use of insurance to encourage adoption of BMPs, group insurance for small farmers organized into clusters and pilot testing of the hybrid insurance scheme developed in the Regional Workshop on the Promotion of Aquaculture Insurance in Asia⁸ are attractive options to explore. The linkages are as follows (Secretan, *et al.*, 2007): Organized farmers can successfully manage certain risks to crop loss through the adoption of BMPs; yields and profitability, product quality and environmental performance are improved with BMPs. The result can be described as follows: *Crop success becomes more predictable, which makes farmers credit worthy. Credit worthiness and BMP adoption are thus mutually reinforcing. In turn access to credit leads to increased investments in farm assets and likely expansion of operations, which further improves farmers' management capabilities. The end result is small farmers become insurance worthy.*

⁸ Held in Bali, Indonesia, 30 April–2 May 2007.

4. AQUACULTURE AND THE ENVIRONMENT

4.1 Status and trends

4.1.1 *Environmental performance of the sector*

Aquaculture in the Asia-Pacific region has generally become more environmentally friendly, a result of two decades of increasing awareness and publicity of the adverse impacts and perceived impacts of aquaculture on the natural resources and the backlash of bad practices on the productivity and sustainability of farms. Farmers have learned that being environmentally friendly makes good business sense. Regulations have been instituted or tightened, but the most important development has been the increasing uptake of BMPs, codes of conduct or practices, and certification schemes. These have been driven by a number of forces that include food safety and health considerations and the growing consumer awareness of the environmental and social responsibilities of aquaculture. A key requirement and tool for sustainability, however, needs stronger enforcement: environmental impact assessment (EIA) (Soto, Aguilar-Manjarrez and Irde, 2009).

Because of their fragile island ecosystems, several countries in the PICTs have a strictly enforced EIA regulation of any development, including aquaculture. The environmental regulations, especially in Palau, Marshall Islands and the Federated States of Micronesia, are extensively based on the United States' Environmental Protection Authority (EPA) regulatory framework, likely because of their continuing close economic, scientific and political ties with the United States of America.

According to De Silva and Davy (2010), the effect of the rapid expansion of aquaculture is tighter policing of the sector. They suggest that the reason for this is that aquaculture emerged as a significant food production sector only in the last three decades in the midst of a heightened public and global awareness of environmental issues. An expert workshop concurs with this reason, elaborates on it, and adds another (Bartley *et al.*, 2007). Because aquaculture is relatively new and growing rapidly, its growth impinges on uses of land and water (such as hotels, farms, housing developments, industry, etc.) that may already be established near waterbodies where aquaculture is proposed or being developed. These previously established activities have been accepted by society, so that adding aquaculture to the picture invites additional scrutiny and criticism. The second reason is that farming and other terrestrial development often uses private land with well-defined boundaries and access rights, whereas the aquaculture ventures that are most often criticized or heavily regulated are marine and coastal operations located on common property where boundaries and access rights are less well defined and impacts more difficult to contain. The workshop pointed out there may also be misconceptions regarding the science on which regulations are based, so that the industry may feel that regulation does not always address the real causes of environmental perturbations. A bright spot is that environmental effects have been more clearly identified for all food-producing sectors to address more efficiently. Industry needs to be aware that the cost of avoiding hazards can be lower than the penalties for non-compliance or the cost of cleanup or rehabilitation.

Experience from Asia has also demonstrated the importance of non-governmental organizations (NGOs) and trade in promoting environmentally sustainable aquaculture, which reverts to farmers and national authorities in the form of promoting and adopting better practices that reduce or avoid the use of drugs, and advocating water recycling or treatment before discharge, efficient feeding regimes, the use of healthy seeds and clean ponds. Ultimately, it is the returns to the farmer that influence production decisions. Farmers have learned that environmental responsibility makes good business sense and that pollution leads to outbreaks of disease; they have begun to recognize and understand the link between disease and the environment (WB, 2007).

4.2 Salient issues

4.2.1 Impacts from nutrient loading

Negative environmental impacts from aquaculture occur in many ways and forms, one of the most visible being the discharge of nutrients to the aquatic environment, the impacts being more severe on inland systems. This is comparable to leaching of fertilizer and other inputs in terrestrial farming systems. In the Asia-Pacific region, specific instances of such impacts have been demonstrated in isolated cases where intense farming activities occur in enclosed waterbodies. Over time, nutrients accumulate to a point that the concentration triggers fish kills in cultured and naturally recruited stocks, when upwelling of deeper deoxygenated water occurs under certain weather conditions (Haert, van Dok and Djuangsih, 2002; Abery *et al.*, 2005). An attempt to determine the nutrient discharge levels (particularly of nitrogen (N) and phosphorus (P)) from catfish farming in the Mekong Delta was made by De Silva *et al.* (2010) using available massbalance models and data from an extensive survey previously carried out by Vietnamese workers (Box 1). The findings suggest that the striped catfish farming system in the Mekong Delta, aside from its obvious economic benefits to the people, would in the long run aid in sequestering carbon dioxide in significant quantities. There would be adverse impacts of excessive nutrient discharge on coastal waters, but this example – showing the discharge is far less than is made out to be for lack of evidence – is cited to demonstrate the importance of scientific evidence in providing a balanced perspective to aquaculture.

Box 1. Organic effluent from catfish farms in the Mekong Delta, Viet Nam.

The estimated quantity of discharge from catfish farming was much less than the potential run-off from fertilizer used in rice farming in the Mekong Delta, which is applied at 170 to 182 kg per sown acre of paddy, totalling 7.48 million ha in 2000 (Truong, 2003). In effect, the organic effluent from catfish farms in the delta is minor relative to that from other sources, particularly rice farming. Catfish farming along the Mekong River and its tributaries occurs within 60 km of the river mouth. The Mekong River has the tenth highest flushing rate of all rivers in the world; in other words, the nutrient discharge is carried fairly rapidly to the South China Sea, enriching the immediate waters. In this connection, studies on the Amazon River have demonstrated that nutrient discharge from rivers, through increased diazotrophy could enhance CO₂ sequestration (Cooley *et al.*, 2007; Subramaniam *et al.*, 2008).

4.2.2 Biodiversity and alien species

The diversity of the major groups of organisms tends to be greater in aquatic environments; the number of known marine and freshwater fish species is around 25 000, indicative of a very high biological diversity at the species and ecosystem levels. At the genetic level, unique populations of the same species are more common in freshwaters than in marine.

Of earth's water resources, 97.5 percent is salty. Oceans cover 71 percent of the world's surface, and marine biodiversity includes fish and a wide variety of invertebrates, plants and microscopic life. In contrast, earth has only around 35 million km³ of freshwater or 2.5 percent of all water resources, of which only 23.5 percent is habitable (Shiklomanov, 1993, 1998; Smith, 1998). Thus less than 0.5 percent of the earth's waters are available to support life. Inland waters, which account for 25 percent of all aquatic species and have the highest vertebrate diversity of all ecosystems, are among the world's most threatened ecosystems (Groombridge, 1992). It has also been suggested that global freshwater biodiversity is declining faster than even the most affected terrestrial ecosystems (Ricciardi and Rasmussen, 1999). In the above context, and considering that the bulk of Asia-Pacific aquaculture production is derived from freshwater systems, developments in aquaculture have to conserve biodiversity.

Alien species have played a significant role in the development of the aquaculture sector in the Asia-Pacific region (De Silva *et al.*, 2009). In inland aquaculture, the tilapias, catfishes, and the common,

Chinese and Indian major carps play a major role; in 2005, alien species accounted for nearly 12 percent of the cultured finfish production (2.6 million tonnes), valued at US\$2.59 billion (De Silva *et al.*, 2006). This contribution exceeds 40 percent when China is excluded. In some Asian nations such as Indonesia and the Philippines, inland aquaculture is dominated by alien species, and in Bangladesh and India the contribution from alien species has been increasing steadily (De Silva *et al.*, 2006). Likewise, in the last decade there has been an increase in alien species culture in China. According to Liu and Li (2009), the production of exotics in China increased from 780 000 tonnes in 1998 to 2.5 million tonnes in 2006, accounting for 5.9 and 11.7 percent of the total, respectively. Some exotic species have come to play an important role in aquaculture production and the economy, such as the channel catfish, tilapia, red swamp crayfish, sturgeons and whiteleg shrimp.

Often, the use of alien species in aquaculture is claimed to have brought about negative impacts or loss of biodiversity, particularly in freshwater bodies. It has been suggested that such effects on biodiversity have mostly resulted from competition for food and space with indigenous species (Barel *et al.*, 1985; Moyle and Leidy, 1992), alteration of habitats (Kottelat and Whitten, 1996; Collares-Pereira and Cowx, 2004) and the transmission of pathogenic organisms (Dobson and May, 1986), as well as through genetic interactions such as hybridization and introgression (Dowling and Childs, 1992; Allendorf and Leary, 1998; Araguas *et al.*, 2004), and other indirect genetic effects (Waples, 1991). On the other hand, it has been pointed out that in the Asia-Pacific region explicit evidence is lacking to demonstrate that any of the introductions or translocations through aquaculture has affected biodiversity, such as, for example, in the case of tilapias, which is one of the most widely distributed and cultured species groups in the region (De Silva *et al.*, 2004). Table 10 gives an indication of the adverse, beneficial and unknown impacts of various tilapia species; apart from the Mozambique tilapia (*O. mossambicus*), which was introduced in the early 1950s, there are more beneficial than adverse impacts from the rest (FAO, 2007).

Table 10: Number of instances of introduction of 17 species of tilapine fishes and their ecological and socio-economic impacts. Ad – adverse effects; Bf – beneficial effects; Un – unknown. Where relevant, the percentages are given in parentheses.

Species	No.	Ecological effects			Socio-economic effects		
		Ad	Bf	Un	Ad	Bf	Un
<i>Oreochromis aureus</i>	13	0	1	42	0	7	36
<i>O. macrochir</i>	21	0	0	21	0	1	20
<i>O. mossambicus</i>	91	7	5	79	4	19	68
<i>O. niloticus</i>	79	2	6	71	0	28	51
<i>O. urolepis honorum</i>	22	0	0	22	0	1	21
<i>Tilapia rendalli</i>	32	2	0	30	2	2	28
<i>T. zilli</i>	30	2	0	28	0	1	29
Other tilapine spp.	31	4	1	26	0	0	31
Total	349	17	13	319	6	59	284
(percent)		(4.9)	(3.7)	(91.4)	(1.7)	(16.9)	(81.4)

Source: FAO (2007).

4.2.3 Positive environmental impacts of mariculture

Mariculture is the fastest growing aquaculture subsector in the Asia-Pacific region. The growth of this subsector has gone hand in hand with development of artificial propagation of key species and a consequent decrease in the use of wild seed resources for most species. There is evidence that aquaculture of marine species in the Asia-Pacific, in particular those destined for the live food fish restaurant trade (LFFRT) of grouper species, etc., is indirectly assisting biodiversity conservation. The LFFRT had been predominantly dependent on high-valued fish that are often caught using destructive fishing practices, which has impacted on the fragile habitats such as coral reefs (see Nguyen *et al.*, 2009). The increasing production of cultured marine finfish and the corresponding dissuasion of the public on the consumption of wild-caught groupers has increased the dependence of the trade on cultured species whose life cycle have been closed. These changes are contributing, however modestly for now, to the preservation of the fragile habitats and therefore biodiversity, although hard quantitative data to support this claim are lacking. It is expected that in the foreseeable future, with the closing of the life cycle of many of the species used by the LFFRT, such as the production of

humpback grouper (now entirely based on hatchery reared seed), the positive impacts on biodiversity from aquaculture will be enhanced. It may even lead to the recovery of some of the most endangered finfish species of the region, such as the Napoleon wrasse (*Cheilinus undulatus*).

The suggestion that aquaculture reduces food security through its use of fish to feed fish persists (Edwards, 1997). The debate is even more heated in the mariculture of finfish because almost all of the species cultured in cages are carnivorous. Research has been going on to try to reduce the use of fishmeal and low-value fish for cultured species, and extension efforts have intensified to demonstrate to small-scale cage culturists (in China, Indonesia, the Philippines, Thailand and Viet Nam) that replacing low-value fish with formulated feed can be profitable and improve management (Lymer, Funge-Smith and Miao, 2010; Hasan, 2011).

This controversy, the core issue of which is food security, should not detract from the above-cited good impacts of mariculture on biodiversity and the fact that there are other systems that benefit the environment. These include culture-based fisheries and rice-fish culture, which essentially conform to an ecosystem approach to aquaculture (EAA), thus favouring biodiversity conservation and minimizing long-term environmental impacts. As to mariculture species, the molluscs, which are filter feeders, and the seaweeds, which strip the water of nutrients, help improve the quality of coastal waters, thus reducing the likelihood of eutrophication. Molluscs lock CO₂ in their shells and seaweeds break down CO₂ through photosynthesis, abilities that give them an added utility. The coastal integrated system in China has demonstrated the positive impact of *Laminaria* seaweeds and molluscs (scallop, abalone, etc.) on the coastal environment. In Fiji, some farmers are becoming interested in growing *Eucheuma* seaweed around their pearl farms, both for its commercial potential and for its biological value to the pearl oysters.

4.3 The way forward

4.3.1 Stakeholders' influences on responsible farming

Pressures on the sector from the public, conveyed through governments and civil society, have induced less environmentally perturbing practices. For example, these have abated or greatly diminished mangrove destruction for aquaculture purposes, as well as led to the recovery or increase in area through replanting. They have also induced better health management practices, particularly the prudent or non-use of veterinary drugs. Overall, these have encouraged responsible farming.

4.3.2 Policy and technical guidelines

Countries have introduced legislative measures to prevent mangrove destruction, and BMPs have been promoted that include mangrove conservation and replanting. The shrimp consortium of FAO, NACA, the World Bank, and the United Nations Environment Programme (UNEP) contributed to the global effort to develop policy, regulations and guidelines for codes of industry practice and BMPs. Most of the farming sector itself has realized that a code of practice that is transparent and adhered to by organized farmer groups can be effective evidence of responsible farming to counter allegations that are sometimes biased or without scientific merit.

4.3.3 Market-based incentives

Related to stakeholders' positive influence is the power of the market to induce responsible behaviour. The market has increasingly played a major role in the adoption of better farming practices. The market mechanism, i.e. market-based incentive, should be increasingly relied on to promote environmentally friendly aquaculture. This would lessen the cost of surveillance and enforcement and increase the efficiency of the use of public funds.

5. MARKETS AND TRADE

5.1 Status and trends

5.1.1 Major markets and trade characteristics of important species

The major species in Asia traded in the international market in this decade have been marine shrimp, tilapia and pangasiid catfish. Other commodities with sizable trade volume are seaweed and marine fish, especially reef species such as groupers and wrasses which are shipped live to the Hong Kong SAR and southern China markets. The internationally traded seaweed is the carageenan-yielding species *Eucheuma*, almost all of it originating from the Philippines and Indonesia. A very tiny volume comes from the PICTs, mainly from Kiribati and the Solomon Islands. Dried seaweed is traded regionally, and China has increased its import of the material from the Philippines in this decade; this has induced the establishment of more seaweed farms but also created concerns among local processors about the shortage of material as a result of China's increasing demand; dried raw seaweed is tariff-free in China, while processed products have a high import duty (Ricohermoso, 2008). Carp is generally not exported, although Myanmar exports Indian carps, targeting South Asian communities in destination countries, including those in the Middle East and Europe. Milkfish in small but increasing volume is exported also to countries with sizeable Filipino expatriate populations. Giant clams for the aquarium trade and cultured pearls (mainly *Pinctada margaritifera* and in much lower quantity, *Pteria penguin* or "mabe", which means "half pearl" in Japanese) are the major products exported by the PICTs. Live rock and corals, the latter cultured in land-based facility or harvested from the reefs, are also exported by Pacific Island countries. Cultured aquarium fish are gaining more importance in Asia (e.g. in India, Indonesia, Malaysia, the Philippines, Thailand and Sri Lanka) and are beginning to be explored for commercial purposes in the Pacific Island countries.

FAO Globefish commodity reports in 2009 and 2010 are the source of the status and trends, summarized below.⁹

Marine shrimp. The major markets for shrimp remain the United States of America, Japan and the European Union (EU). Russia is emerging to be a significant importer of Asian shrimp. The export volumes and prices of the major traded commodities (which include shrimp) suffered a slump in 2008 with the global economic downturn but have shown recovery in early 2010. Export volume also went down because of production problems in supplier countries, but this also raised prices of the commodity in importing countries. Shrimp prices in the United States of America were boosted by the Gulf of Mexico oil spill. In early 2010, supermarkets in Japan were the major buyers of head-on giant tiger prawn. The share of prepared and processed shrimp dropped to 25.4 percent from 26.5 percent in 2009, although imports of "sushi shrimp on rice", mostly supplied by Thailand, surged significantly.

Some major producers of cultured shrimp, including Bangladesh, China, Indonesia and Viet Nam reported declining production in 2010 for various reasons but mainly adverse weather in Viet Nam and China, poor management in Bangladesh and disease in Indonesia. In the overall climate of low aquaculture production, Thailand was the only main player with a good production outlook (see Box 2). With a 68 percent market share, China, Indonesia, Thailand and Viet Nam were the top shrimp suppliers to the Japanese market. Compared with the same period in last year, overall supply from Thailand also increased significantly to 17 600 tonnes (31.5 percent increase), followed by Viet Nam at 9 900 tonnes (7.4 percent increase), but imports from Indonesia and China fell. United States of America shrimp imports declined by 4 percent in the first quarter of 2010, mainly owing to limited production in the main supplying countries. Thailand, however, managed to expand its exports to the United States of America market by 7 percent, representing 35 percent of total United States shrimp imports. In contrast, Indonesian shrimp exports declined by 30 percent as a result of disease problems.

⁹ www.globefish.org/homepage.html; accessed 30 December 2010.

Box 2: Stockpiling of shrimp in times of low world prices – an example from Thailand.

The decline in 2009 in global shrimp price prompted the Government of Thailand to intervene in this large sector, which earns approximately US\$4 billion annually in foreign exchange and employs thousands in farming and ancillary activities. The government had agreed to stockpile 10 000 tonnes of shrimp (*Litopenaeus vannamei*) valued at 1.4 billion THB (equivalent to US\$412 million) to tide the industry over the low export prices (Bangkok Post, 2009).

Tilapia. Asia contributes about three quarters of the world's tilapia production. China alone produces 1.2 million tonnes (in 2009), while the rest of Asia contributes 0.9 million tonnes. Production in Indonesia and the Philippines increased during the past decade to over 300 000 tonnes each. In these three countries, tilapia production is mainly for the domestic market. Africa, mainly Egypt, is important, with 430 000 tonnes of cultured tilapia production, while Latin America accounts for 280 000 tonnes. Globally, tilapia production involves mainly the culture of Nile tilapia (*Oreochromis niloticus*); in 2008, about three quarters of world tilapia production was Nile tilapia.

Exports of tilapia from China to the United States and the Mexican markets were substantial, while exports to the EU were slow but expected to pick up once the economic crisis was over. In the first nine months of 2009, Chinese tilapia exports were 176 500 tonnes, 10 percent more than in the same period of 2008. Total earnings from export were US\$490 million, roughly on a par with the 2008 figure. The main importing country was again the United States of America, with 91 600 tonnes, or 15 percent more than the previous year. Mexico, the second major importer of Chinese tilapia, reported lower imports in 2009. Russian imports of Chinese tilapia expanded strongly in 2009 to reach 19 000 tonnes. Russian traders thus replaced pangasiid catfish from Viet Nam with Nile tilapia from China. Other significant exporters of tilapia are Indonesia, the Philippines, Taiwan Province of China and Thailand. The product form that is most preferred by importers is, surprisingly, frozen whole rather than fillet.

Pangasiid catfish. The supply of farmed catfish in Viet Nam was lower in 2009 than in 2008 because of poor demand and lower prices. However, by the end of 2009, processors had managed to turn the situation around: the total value of exports almost reached the 2008 level. Total Vietnamese catfish exports were 607 700 tonnes in 2009, a 5 percent decline from the record high 2008 figure. The value declined by 7 percent during the same period to US\$1 342 million.

The United States of America greatly increased imports of pangasiid catfish in the first ten months of 2009 compared to the same period in 2008. Despite several difficulties, such as import tariffs and the issue of whether or not to call pangasiid “catfish” again, exports to the United States of America reached 34 500 tonnes, an increase of 72 percent compared with the same period last year. The United States of America is now Viet Nam’s fourth largest market. Viet Nam is the main supplier of catfish to the United States market, accounting for 65 percent of total imports. Catfish from China, which is subject to a rigorous control process by United States control bodies, declined sharply in 2009.

Other markets were less attractive for Vietnamese catfish producers, and production was reduced in Viet Nam by 30 percent, as the economic situation was not very positive. Russia, which was the largest market for Vietnamese catfish in 2008, was closed to Vietnamese products in the opening months of 2009, which resulted in a 66 percent reduction of imports in 2009. Likewise Ukraine, the second largest market, cut imports by 49 percent as a result of the difficult economic situation in the country. The Russian market recovered somewhat in the closing months of 2009, but Ukraine showed no sign of improvement.

Western European markets were more encouraging for Vietnamese catfish, as its low price was well accepted in the present economic situation. Spain and Germany became the top two importers of Vietnamese catfish, expanding their imports by 7 and 4 percent, respectively during 2009. Overall EU imports of pangasiid catfish in 2009 were on a par with the 2008 imports. The average unit value of Vietnamese pangasiid catfish exports over the whole year was US\$2.20/kg. The United States market

offers the highest value for exports, where US\$3.20/kg is paid, while values are lowest in the Russian and Ukrainian markets, with US\$1.65/kg. The United States market buys value-added products such as breaded fillets, while the former USSR countries import fillets with little value addition.

5.1.2 *Food safety requirements*

At the start of the decade, the major issues facing traded food fish and shrimp in Asia were food safety, anti-dumping and the environmental impact of farming, in other words, non-tariff barriers to trade (NTBT). These drove the intensified effort of governments and the private sector, usually with technical assistance from regional (ASEAN, NACA, SEAFDEC) and international organizations (FAO, Deutsche Gesellschaft für Internationale Zusammenarbeit (GTZ), WB, World Wide Fund for Nature (WWF)) to help with policies and regulations and industry groups (e.g. Global Aquaculture Alliance, GAA) as well as private certification groups (such as Naturland, Aquaculture Certification Council (ACC)) to also help with the development of CoCs, codes of practices, BMPs, and certification schemes for food safety, organic labelling and in a few cases, the beginnings of social labelling. The net effect of these market-driven initiatives has been more responsible farming and better market access. While the certification standards were geared at first to export commodities, the modern multinational retail chains (supermarkets) have begun to introduce their own certification standards for products they source from local producers and sell in domestic markets (Reardon, Timmer and Minten, 2010).

Risk assessment and traceability became more widely adopted by exporting countries, especially the major shrimp producers, as a fundamental requirement for domestic and export marketing. Risk analysis was introduced and the capacity for this management tool began to be strengthened through workshops, training activities and seminars.

Organically grown products, including cultured aquatic products (particularly fish and shrimp) were thought to remain as niche products. However, the increasing concerns for healthy food coupled with the rising purchasing power of younger consumers and the higher educational attainment of household heads, who usually make the purchasing decisions, have raised the demand for food with health and safety attributes. This has been boosted by the increasing role of modern retail outlets and specialty stores, especially the larger chains with their own certification standards and auditing backed by a powerful purchasing mechanism. Organic certification applies mainly to cultured aquatic products, ecolabelling to captured products as well as farmed molluscs. Organic farmed products in the Asia-Pacific region include shrimp in Bangladesh, India, Indonesia and Thailand; salmon in Australia; and mussels in New Zealand (H. Josupeit, Products, Trade and Marketing Service, FAO Fisheries and Aquaculture Department, Rome, Italy. Personal communication, 2007).

5.1.3 *Social organizations and clusters in market development*

There are models of marketing that have shown the important role of organized farmers in market development. An example is the highly successful e-choupals¹⁰ in India assisted by the Indian Tobacco Corporation, which are becoming widespread. A second case is the Network of Aquaculture Centres in Asia-Pacific-Marine Products Export Development Authority (NACA-MPEDA) project (which has been institutionalized into the National Centre for Sustainable Aquaculture, NaCSA) on small-scale shrimp development in India that promoted the formation of farmer clusters and farmer societies, initially to improve the adoption of BMPs, but subsequently expanding into product certification to obtain premium price and have a better access to markets. The latest initiative was to develop linkages

¹⁰ The Indian Tobacco Corporation e-choupal (“e” for electronic or ICT facilitated, “choupal” is literally a kiosk or a place to gather for a common activity) experience shows how agriculture farmers with facilitated access to the Internet and market and technical information concerning commodities can increase their income by 5 to 10 percent. Farmers can decide when and how much to sell based on their understanding of the likely price movements for their products. Modern technology not only allows them to realize better prices but also to improve their logistics. The aggregation of food grains allows for efficiencies for both farmer and buyer.

– through contracts – with buyers in the United States of America and Japan. This approach was adapted in Viet Nam and in Aceh, Indonesia as part of the post-tsunami rehabilitation programme in Aceh with the collaboration of NACA, FAO, American Red Cross, International Finance Corporation of the WB and other organizations. A key element of a recent FAO Department of Fisheries and Aquaculture certification (focused on food safety) initiative in Thailand for shrimp aquaculture is the formation of farmer clusters. Three advantages of being organized for marketing have been demonstrated by these cases: reduced costs of transaction, greater leverage by organized small farmers with buyers and overcoming the disadvantage caused by asymmetry of information between producers and buyers.

5.1.4 *Potential for an increase in the demand for aquaculture products*

Three factors will increase the demand for aquaculture products in the Asia-Pacific region: (i) increasing population, (ii) decreasing or stagnating supply from wild fishery and (iii) the rising awareness of the health benefits from consuming fish. These will be abetted by the increasing role of supermarkets. Another factor that Globefish has noted is that during the recent global economic crisis, tilapia became a preferred food fish in Europe and the United States of America because of its “attractive price-value ratio”; in other words, it is a good, inexpensive fish. This could apply as well to the pangasiid catfish.

5.2 **Salient issues**

5.2.1 *Export of not so high value freshwater fishes*

The markets that cater to cultured commodities are wide ranging and even contrasting. For example, the production of nearly 0.5 million tonnes of major carps (rohu, *Labeo rohita*) and mrigal, *Cirrhinus cirrhosus*) in the Kolleru Lake area of the eastern state of Andhra Pradesh, India is almost exclusively marketed within the country (Table 7), but outside the state, fish are being transported by land over a distance of 1 000 to 1 400 km. In contrast, the same species cultured in the Irrawaddy Delta area of Myanmar is exported to neighbouring Bangladesh and the Middle East, while almost all of the pangasiid catfish cultured in the Mekong Delta is exported to nearly 100 countries. Culture of low-valued finfish for export could impact on local food fish supply and prices and hence affordability to the poor. The current developments to meet export niche markets do not appear to have such a negative impact, but governments should be alert to this possibility and plan adaptive actions. Importantly, the development and expansion of culture practices for export will create more livelihood opportunities, particularly in the processing sector, and such income generation would enhance the purchasing power within communities. In spite of the above advantages, production for an export market does not necessarily ensure the economic viability of culture practices, as discussed earlier. In effect, the vulnerability of such practices to economic risk is greater than that of those catering to the local market.

Only two cultured low-value finfish species cater, in significant quantities, to the export market. However, with globalization, liberalized trade and large concentrations of ethnic communities overseas, there are possibilities for the number of species to increase to cater to the culinary preferences of such communities. This is already evident in the small quantities of wild-caught freshwater species that are being exported by Myanmar to niche markets. It is unlikely that wild catch could fulfil the demand of an expanded export market, so that an opportunity exists to develop them for culture to supply niche markets.

Overall, the export of freshwater finfish that are mostly considered as less high-valued commodities is assuming an increasing importance in Asia. New markets are being developed for these, as in the case of rohu from Myanmar. The development of exports makes it necessary to develop the processing sector. Processing in developing countries in Asia is labour intensive, providing significant employment opportunities, particularly in densely populated urban areas where most processing plants are located. In most instances, the majority of the employees are women. It is expected that the export

of cultured freshwater commodities will increase gradually. There are other commodities with good export potential, notably the giant river prawn, which has received little attention as an export commodity. However, this is likely to change in the foreseeable future. It would then benefit from improved processing and development of new markets.

5.2.2 *Non-tariff trade barriers*

The export commodities from the Asia-Pacific have met market non-tariff trade barriers. For example, pangasiid catfish (primarily striped catfish) exports to the United States of America were banned when legislative steps were taken by the United States Congress restricting the use of the word “catfish” to only those fish of the family *Ictaluridae*, which is widely farmed in America’s southern states. In addition, antidumping measures were also issued by the United States of America in 2003, leading to tariffs ranging from 44.66 to 63.88 percent levied on frozen fillet catfish from Viet Nam. A recent analysis (Duc, 2010) of the issues has shown that the antidumping tariff raised the United States domestic price of processed catfish and lowered the Vietnamese export price, but this lowering caused by the United States tariff raised market demand outside the United States of America and consequently boosted the Vietnamese export volume of catfish. Apart from non-tariff trade barriers, the tra catfish exports are faced by adverse publicity about the product quality.

5.2.3 *Benefits from the value chain*

A study of the market chains for a number of low-valued cultured commodities in the region (De Silva, 2008) showed that the production systems and target clientele of each differ greatly between each other and between countries. For example, the carp farming system in Central Highland Region of Viet Nam occurs in three phases, physically separated by long distances. In each stage (production of hatchlings, fry to fingerling rearing and grow-out), the market chains that operate are distinct from each other. The profit margins retained at each stage of transaction are relatively low, often less than 15 percent per unit weight, but the operations remain economically viable because of the large turn over. It also helps that the size of individual operations is small, which requires very low capital outlay.

The same study examined the relatively lower-value farmed carnivorous freshwater fish species in Asia, which fall mainly into two groups, catfishes and snakeheads. In Viet Nam, catfish farming has grown to a very large industry. The structure of this subsector is characterized by small-scale independent units, mostly pond-based farms that are very intensive. Catfish farming and processing have become the major employment providers in the delta, by-passing all other primary production sectors.

Catfish and snakehead market chains in Thailand are geared to keeping the fish alive until it reaches the consumer. This already is a form of value adding, but other methods are carried out by households, such as drying or smoking small quantities of fish that are sold from street stalls.¹¹

The study found that, in all cases, profit margin at each stage of the value chain was 10 to 12 percent on average, except at the retail point in the importing country. For example, rohu exported at approximately US\$1.2 to 1.3 per kg costs the consumer in Rome, Italy, US\$8 to 9 per kg. Cultured freshwater fish species that are of low value can thus be a significant export commodity. The export value has exceeded US\$1 billion per year, with three species groups (catfish, tilapias and carps) accounting for most of it. Most importantly, export of these commodities has induced the establishment of ancillary services and the creation of jobs in the handling, transport and processing sectors.

¹¹ Another example is the deboning of milkfish – sold fresh, filleted or processed – in the Philippines, which has expanded from a small-scale activity to an export-oriented industrial operation (see Alsons Aquaculture Corporation [www.alibaba.com/member/geeme68/aboutus]). The technique has been introduced through FAO projects in Palau and Kiribati, which have small but growing milkfish culture sectors.

5.2.4 Commodity prices

Food commodity prices have increased over the years, sometimes spiking during certain years, unsurprisingly triggering intense concern and public debate (Alston, Beddlow and Pardey, 2009). On the other hand, the prices of cultured aquatic organisms have remained static and in some cases declined in real terms (Figure 12). For example, the average unit price of marine shrimp has declined significantly over the years, and that of other commodities has remained static or declined perceptibly. This has occurred in the midst of increasing costs of fuel and other inputs, especially feed. Declining prices would impact on the sector in a number of ways, not the least on its growth, but a positive offshoot would be the drive towards improving the cost-efficiency of production or adopting strategies that enable the farmer to get a premium price, add value to the product or lower the cost of marketing. An example of the former is the adoption of a package of improvements that consists of healthy and certified seed, more efficient feed and feeding, good health management of the stock, and proper handling at harvest and postharvest. An example of the latter would be the adoption of BMPs and certification, preferably cluster certification to reduce its cost. Adding value would include some on-farm processing such as drying, smoking or depuration. Being organized for economy of scale reduces transaction costs for farmers, a strategy that is increasingly promoted in the region, beginning with forming farmer clusters to organizing and registering them as formal associations.

5.2.5 Market share of producers

Notwithstanding the measures described above, the farm-gate price for farmed products remains a major issue. The very low farm-gate price relative to the retail price is exemplified by the striped catfish value chain. Figures 17 and 18 show the distribution of the proceeds along the value chain. These schematic presentations reflect, among others, the problem of market inefficiency, including the asymmetry of information possessed by farmers and buyers, as has been noted in a study by NACA and the ASEAN Foundation on the sustainability and competitiveness of small farmers in some ASEAN countries (www.enaca.org/bmp projects).

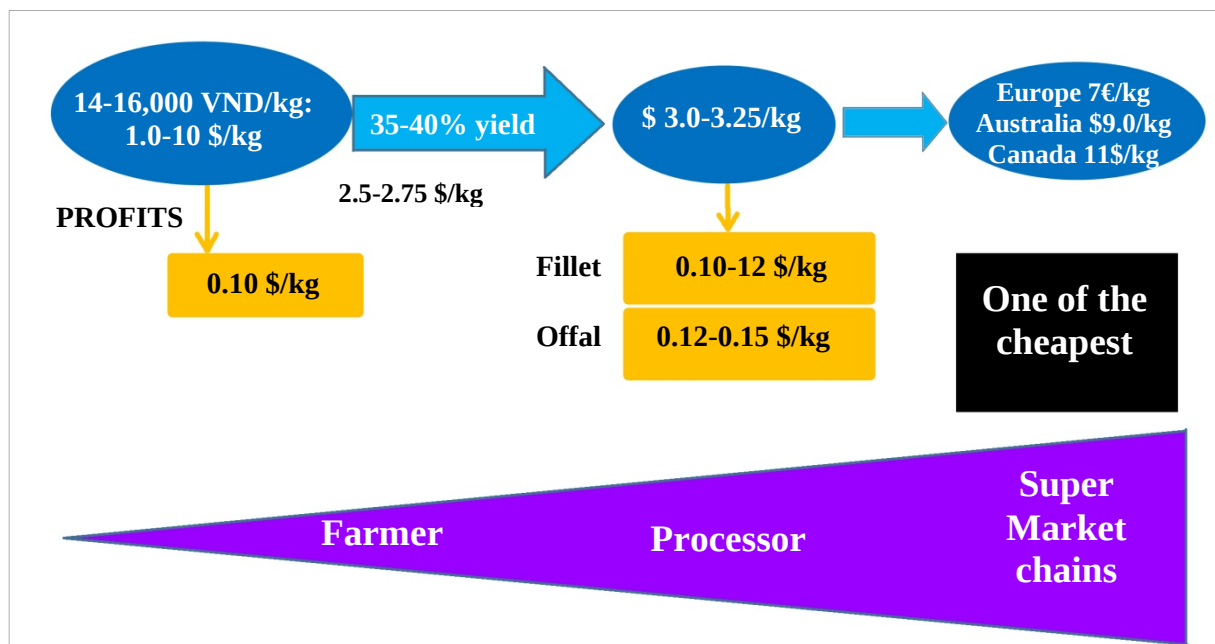


Figure 17: A schematic representation of the price of pangasiid catfish at each stage in the value chain in the Mekong Delta, Viet Nam (VND 17 500= US\$1.00).

Source: Compiled by authors based on observations of Sena S. De Silva, 2010.

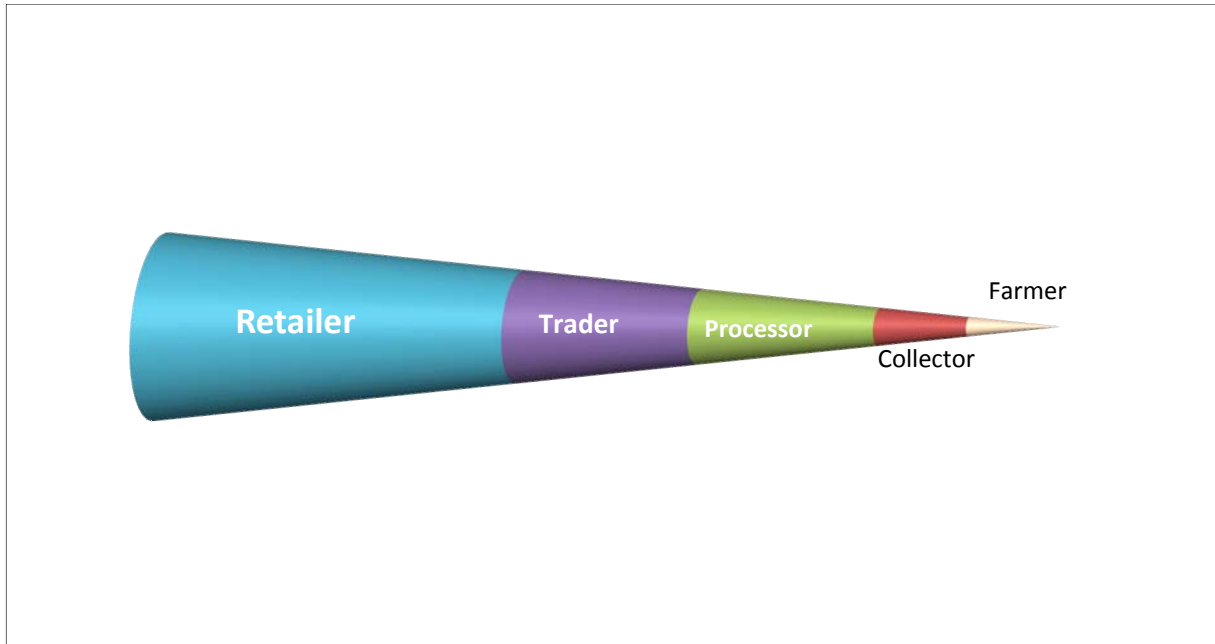


Figure 18: Share of costs of catfish (usual retail price US\$8.5/kg) purchased by the consumer.

Source: Globefish (July, 2009).

5.2.6 Price spreads and viability of farms

The farm-gate price, which is actually the share of the farmer in the ultimate value of the product, is crucial to the economic viability and sustainability of farms, big and small, in the Asia-Pacific region, even more so with the rising cost of inputs and the additional cost of complying with an increasing number of requirements for market access.

Global food prices have increased 83 percent over the last three years, and the predictions are even gloomier in the wake of an increased food need of 50 percent of the current production by year 2030 (Evans, 2008). On the other hand, the trends in farm-gate price of the commonly cultured five species groups of freshwater finfish over the last 28 years indicate that in effect, the farm-gate price has remained static or even declined slightly over the years (Figure 19). None of these five, two of which (carps and tilapia) are among the world's top-ten ranked cultured groups, fetches a price that is more than US\$1.50 per kg on average (the exception is the snakeheads, which are highly preferred species in Cambodia, Viet Nam and Thailand but mostly sold locally; the quantity, however, is small compared to the production of tilapia, carps and catfish). This in effect puts the bulk of aquaculture produce in the category of low-value products. Cultured low-value finfish and molluscs constitute a significant component of the food basket of poor, rural communities, often providing the main source of animal protein (Dey and Garcia, 2007). Furthermore much of the low-value freshwater finfish (as well as the green mussels) are cultured with low input requirements and under environmentally benign conditions.

The above suggests that farms producing lower-value and generally freshwater species have difficulty becoming economically viable. While inroads into the export market by some of these, particularly pangasiids and rohu, have been a bright spot, the question remains as to whether the farmers can stay viable. To illustrate, the predicted cash flow in pangasiid catfish farming indicates that the current break-even point for the producer is VND15 000 to 16 500 or around US\$1. An approximate comparison of the farm-gate prices of these fish and their retail prices in developed countries (e.g. Australia, 9 to 11 AU\$/kg; Italy, 7 €/kg) indicates that between both ends of the market chain there is a four to five-fold price difference. This rather wide difference would be the result of an increasingly higher logistical cost of bringing a perishable product from the farm to a foreign market, which would have a higher labour cost as well. This raises the issue as to how the farmer may be able to capture a higher share of the retail price.

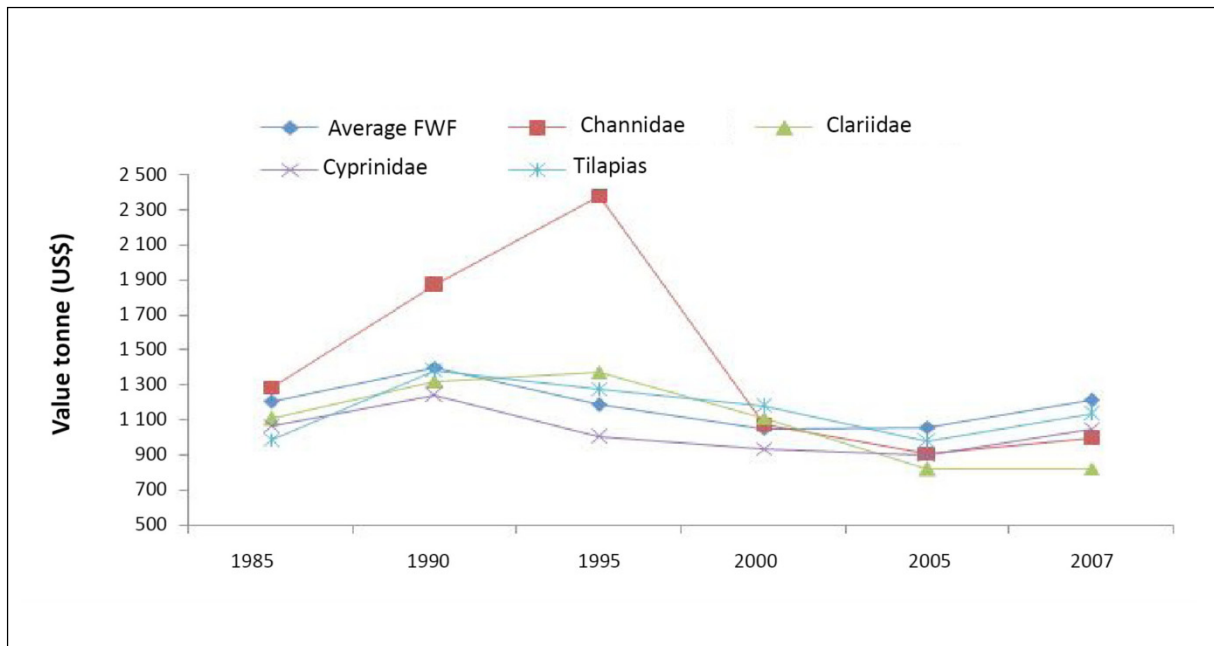


Figure 19: Trends in the average farm gate price of cultured freshwater species and selected species groups over the years.

Source: Compiled by authors

FWF = Farm gate price of freshwater fishes.

5.3 The way forward

5.3.1 Improving efficiencies along the value chain

The issues discussed above appear complex; the core issue is the economic viability of a farm, and the broader issue is that unless a farm remains viable it cannot continue to provide benefits to the farmer and his family and to society. Along the value chain are opportunities to meet both objectives. These include improving technical and economic efficiencies, achieving economy of scale (especially for small farms), producing a diversity of products from the farm, deriving more value from the farm product and improving market access. These opportunities and the ways and means to achieve them are described in Section 7.2.

5.3.2 Consolidating the fragmented marketing system

A related strategy is to find a way to consolidate the fragmented marketing system, which is characteristic of most of Asia, and integrating the small producers into the modern market chain. This fragmented nature is an inevitable effect of having many small independent farms but also because of the poor market infrastructure and market information system in rural areas. The "aquachoupal scheme" in India provides a model for organizing producers and using the new information technology to integrate the producers into the market. The rise of modern supermarkets (Reardon, Timmer and Minten, 2010) with their extensive purchasing systems would eventually drive small independent farmers to better organize for marketing. Farmers would also need to comply with the quality and food safety standards imposed by the modern retail chains. These are reasons for government and the supermarkets to provide technical and management assistance in production and product marketing to organized farmers.

6. CONTRIBUTION OF AQUACULTURE TO FOOD SECURITY, SOCIAL AND ECONOMIC DEVELOPMENT

This subject is broadly covered in Section 1, which provides a macro-level perspective of the three major contributions of aquaculture to the regional economies, namely, to GDP, employment, and food security and nutrition.

6.1 Status and trends

A review in 2007 by the World Bank (WB, 2007) describes the impacts of aquaculture on poverty and livelihoods, with emphasis in Asia. These remain valid and are summarized herewith.

6.1.1 Income and employment

Aquaculture generates income for the rural poor through direct sales of aquaculture products and employment in fish production and services, especially in processing. In Southeast Asian countries, for example, fish farmers generally earn higher household incomes than other farmers. In China, aquaculture has been an integral part of rural strategy, absorbing surplus rural labour that was released following agricultural reform. More than 3 million Chinese have found employment in aquaculture since 1974.

6.1.2 Food security

In many countries, the average market price of fish is lower than that of meat and poultry. The low product prices can make cultured fish highly accessible to even the poorest segments of the population. In landlocked countries such as Nepal and Lao PDR, the poor largely depend on freshwater aquaculture for their animal protein intake. Furthermore, aquaculture production may reduce fish prices, increasing access to fish by poor households.

6.1.3 Women in aquaculture

In Bangladesh and Viet Nam, more than 50 percent of workers in fish depots and processing plants are women, and although salaries of these workers are low, they are higher than wages earned from agricultural activities. Shrimp seed collection and fish marketing are important sources of employment for rural women. Aquaculture in the Mekong Delta has contributed to a decrease in urban migration by young women and prevented women from going into the sex trade, also reducing the risk of spreading human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS). Projects that targeted women and poor households have provided access to land, water, credit and extension that otherwise would not be affordable; however, in a number of cases, the poor lost control of the land and water resources after withdrawal of project support.

6.1.4 Creating and distributing wealth

Aquaculture can have an important role to play in poverty reduction, and the robust growth of aquaculture suggests that it can be a major rural growth sector. The landless can find an entry point through rehabilitation of unused sodic lands or lease of public waters. Moreover, those lacking entrepreneurship can benefit through employment creation. Some studies indicate that poorer households may benefit more, in relative terms, than richer ones. Given the trend toward consolidation and vertical integration, changing markets, and conditions of trade, smallholders face an array of challenges. Experiences in Asia indicate that well-organized and well-informed smallholder producers can thrive, and that the establishment of a critical mass of self-sustaining smallholder aquaculture requires sustained nurturing and public support linked to progressive rural and agricultural development policies. Low-value food fish production can be a viable strategy where favourable circumstances exist, as described elsewhere in this review. In many areas, it is a mainstay of local economies. Under conditions in which land, water and labour have limited alternative uses, extensive

culture requiring modest capital and knowledge (e.g. culture of carps and other omnivores) can be an attractive pro-poor production model. A counterargument can also be made for poor producers to grow high-value species such as groupers in small cage-culture operations. This may require less capital and generate higher returns – but only where there is access to the markets for such species and risks are manageable. Thus, coherence of these twin objectives – production of cheap food fish and reduction of poverty through rural fish farming – requires an astute balance of policies and incentives. Gradual intensification taking full advantage of natural productivity could increase supplies, while moderate production costs keep fish prices affordable to the poor.

6.2 Salient issues

6.2.1 *Small-scale farms and their contribution to rural development*

The recently completed FAO studies on assessing the contribution of small-scale aquaculture to sustainable rural development have yielded some useful indications: small-scale aquaculture is not a panacea to poverty or social ills, but some of its attributes can help alleviate rural poverty and mitigate social problems (Bondad-Reantaso and Prein, 2009). Gleaned from seven case studies, the contributions include, among many others: (i) alternative employment opportunity for underemployed or otherwise idle rural labour (Vietnamese shrimp farming), (ii) additional community livelihood (seaweed farming in the Philippines), (iii) fallback employment to displaced labour from the commercial and industrial sector (Thailand inland integrated farms), and (iv) magnet for investments from government and private sector into the rural community (shrimp farming in Viet Nam, tilapia cage culture and seaweed culture in the Philippines).

In another context, in the Pacific Island countries some medium-scale enterprises have worked out a business model in the culture and trade of giant clams that relies on mutual trust between the hatchery operator-exporter and the grow-out farmers. In Kiribati for instance, a private farm produces and distributes giant clam to households in a nearby atoll community for them to grow into aquarium-size clams. The farm also provides the cages and dispenses technical advice. It then buys back the market-size clams from the ongrowers, paying cash on the spot. The small on-growers in turn, with the farm's technical advice, assure that the farm is buying back healthy clams of the desired size. The farm provides certified F2 seed and the farmer-ongrowers are under a strict obligation not to mix poached clams with the harvest because of EU as well as CITES rules (although Kiribati is not a member of CITES or OIE). The clams are exported to Germany. The business relationship between the farm and the small farmer-ongrowers is thus proving to be a sustainable and economically viable arrangement.¹²

6.3 The way forward

6.3.1 *Women-oriented aquaculture*

An aquaculture project in Nepal that was started in 2000 has shown that small-scale aquaculture meets the fundamental objective of empowering poor rural women so that they can move out of poverty (Jharendu Pant, Aquaculture and Genetic Improvement, WorldFish Center, Penang, Malaysia – personal communication, 2010). The project enabled a mix of positive social impacts that included enabling the women to earn more, improving their and their family's health, enabling children to have a better opportunity to attend school longer, motivating the women farmers to take a more active part in community affairs and strengthening community institutions.

¹² This is among the provisional findings of the project RAS/TCP/3301 "Lessons learned from past and ongoing aquaculture initiatives in selected Pacific Island countries", which started on 18 May 2010.

7. EXTERNAL PRESSURES ON THE SECTOR

7.1 Status and trends

7.1.1 Hazards

Natural, biological and economic hazards have increased in intensity and frequency in this decade. The Asia-Pacific region has reeled from natural hazards that have included the tsunami of 2004, cyclones, flooding, drought, the severe acute respiratory syndrome (SARS) and avian flu pandemics, and the global financial crisis. The Pacific Island countries have also had a tsunami, heavy flooding, drought and the repeated impacts of powerful cyclones. A very severe winter in 2007 in Tajikistan extensively destroyed crops and livestock and set back aquaculture by killing broodstock. The Central Asian region has the classical case of the destruction of fisheries and severe impacts on present and future aquaculture development by a factor external to the sector, the fate of the Aral Sea. Red and green tides and eutrophication have occasionally affected coastal aquaculture in China, Hong Kong SAR, Japan, East Malaysia, the Philippines and Thailand.

7.1.2 Impacts of natural and biological disasters on aquaculture

The immediate effect of these natural and biological disasters on aquaculture is destruction of physical facilities, natural resources and crops; damage to crops or reduction in value of harvests; and loss of capital investments. They have not led to the abandonment of farms but have set back growth. In the Pacific Island countries, the repeated impacts of cyclones or a single severe natural event have aborted promising pilot projects and caused the abandonment of a number of pilot-scale or early commercial ventures (FAO/SAP and SPC, 2010).

Government compensation is usually granted for damage to crops and infrastructure from catastrophic events (van Anrooy *et al.*, 2006; Secretan *et al.*, 2007), but market-based insurance has not been a significant instrument of risk mitigation and coping in most of Asia except Japan and to a certain level, China.

A positive effect of biological hazards, especially the bird flu pandemic, is the increase in demand for and price of fish, as in Viet Nam and Thailand. While not quite a positive impact, small farmers operating integrated farming systems in central Thailand whose chicken enterprises were decimated by the bird flu decided to concentrate on and expand the fish component of the system to recover and try to repay loans (Pongthanapanich, Bueno and Sungkhao, 2011). The same study noted another positive contribution of aquaculture during times of economic crisis: farm family members who had been laid off or terminated from their jobs in the manufacturing and service sectors during the global economic downturn had found fall-back employment in the family fish farm.

7.1.3 Impacts of urbanization

Creeping urbanization is another phenomenon that is not a hazard by definition but is affecting aquaculture in various ways. This has raised land prices in farming areas that are on the path of urban creep. But it has also diversified the opportunity for employment of farm family members in the manufacturing and service sectors. The impacts have been the conversion of aquaculture land, whose market price has appreciated, to other uses, abandonment of leased aquaculture land because rents have been raised, and the growing scarcity and rising cost of farm labour because rural workers are finding employment in the urban sector. Aging of farmers and the outmigration of farm family members for employment in towns are not exogenous factors, but the combination is starting to show adverse effects on the growth of aquaculture and could eventually have a deeper impact. Scarce and expensive farm labour is one. Abandonment of farms is a real possibility. On the other hand, higher wages from non-farm employment are improving the farm household welfare; and farmers can relocate to areas where land is cheaper.

7.2 Salient issues

7.2.1 Resilience and adaptive capacity

As the hazards described above are exogenous factors, the only salient issue relates to the twin attributes of resilience and adaptation. Many lessons have been learned and disseminated from the recovery and rehabilitation measures after natural disasters, the most significant one in recent times being the 2004 Indian Ocean tsunami. A general lesson is that sustaining the five livelihood capitals endows better resilience to a farming household and a farming community. A second lesson is that a strong social capital enables a community whose physical, natural and financial capitals have been diminished by a disaster to recover better and faster. Preparedness is essential, thus early warning systems and contingency measures are extremely important. Overall, the aquaculture sector in Asia has shown remarkable resilience. Adaptation measures to the repeated impacts of natural hazards have also provided a degree of resilience and adaptive capacity to the expected severe impacts of climate change.

7.3 The way forward

7.3.1 The ecosystem approach to aquaculture (EAA) and risk management

Economic and ecological resilience go together. This could be attained with the application of the ecosystem approach to aquaculture (EAA) management. Incorporating EEA and risk management strategies into policy and development programmes; improving the capacities of institutions at the national, local and community levels for EEA application and risk management; and integrating the efforts of government, farmer groups, business and industry would increase collective resilience and likely provide ideas to find opportunities in the risks. These would give the aquaculture sector a much better ability to face external pressures.

7.3.2 The implications of climate change

The FAO/RAP-APFIC review (Lymer, Funge-Smith and Miao, 2010) describes the impacts of climate change on fisheries including aquaculture in Asia-Pacific region, the broad implications on governance and the specific implications on mitigation and adaptation. These are mostly based on various analyses that have been done of the sector in the past three years (i.e. FAO, 2007; De Silva and Soto, 2009). To summarize the highlights, especially those that apply to aquaculture:

- *Good governance is essential for effective adaptation.* Tackling existing incentive structures that make bad practices lucrative may be an important component of governance.
- *Flexibility and adaptability in governance and management are important components of good governance that need to be operationalized.* Emphasis should be on building the adaptive capacity of communities and industries to be able to cope with unpredictable changes and events.
- *Cross-sectoral governance should be supported.* This represents best practice that should be pursued irrespective of climate change. However, the challenges that climate change pose in constraining resources heighten the need to improve cross-sectoral coordination. Integrating disaster management into the fisheries sector, and vice versa, will be important given the high vulnerability of the sector to extreme events.

The suggested actions for adaptation and mitigation are as follows:

- Ensure that the fisheries sector is clearly incorporated into mainstream climate change strategies and vice versa.
- Ensure that the opportunities and threats presented by climate change are understood and supported as part of adaptation measures for the sector.
- Identify and support high-risk countries and locations.

- Build supportive economic and trade policies.
- Pursue appropriate technologies.
- Pursue mitigation actions in a manner that supports the sector more broadly.

8. THE ROLE OF SHARED INFORMATION: RESEARCH, TRAINING, EXTENSION AND NETWORKING

8.1 Status and trends

8.1.1 *Training and information*

The status review of aquaculture in the Asia Pacific region carried out in 2005 (FAO, 2006) lists the research and training institutions in the region. There have not been major changes in that list, which contains the names and programmes of institutions in mainland Asia, Oceania and Iran (Islamic Republic of). In 2005, Iran established the coldwater fish research center, which became a lead centre of NACA in 2006. Not mentioned in the 2005 review is the premier regional institution in the Pacific, the University of the South Pacific, whose main campus is in Suva, Fiji. Its Institute of Marine Resources includes aquaculture in its mandate, with an academic (undergraduate and graduate), training and research programme (FAO/SAP and SPC, 2010).

In Southeast Asia, Viet Nam in 2000 had only two faculties dedicated to aquaculture but by 2010, the number has increased to eight, with a potential output of over 700 graduates per year. This development coincides with the rapid growth of Vietnamese aquaculture, which echoes the same development in Thailand in the 1990s when aquaculture, particularly shrimp farming but also marine finfish and tilapia cage culture, were growing fast.

In the later part of this decade, Central Asia has embarked on a rebuilding of the national capacities for education, training and research. It has a legacy from the former USSR of strong education and research in the basic and engineering sciences that support fisheries development, but the R&D infrastructure and programmes along with manpower development have deteriorated from lack of support after independence in 1991. A number of training and research activities as institutional capacity building projects are being supported by FAO and the Government of Turkey. Training programmes for CAR personnel are also offered by Turkey in its schools and training institutes.

This section continues the treatment of China as a subregion of the Asia-Pacific region. China's research system consists mainly of national and local fisheries research institutions and universities. There are more than 200 fisheries research institutes in China. National research institutions and universities, most of which are engaged in basic and applied research, are the major power for aquaculture research and technological development. National research institutions are under the direct administration of the Chinese Academy of Fishery Sciences in the Ministry of Agriculture. Universities fall under the administration of the Ministry of Education or the provincial governments. Local institutions focus on solving the technical problems that affect local aquaculture development. They are more producer-oriented and sometimes quicker to respond to farmers' needs than the other two categories. They are often a step ahead of national institutions and universities in terms of practical technological advances and are funded mainly by provincial and/or municipal governments. Non-fisheries private commercial companies sponsor aquaculture research, especially in the areas of aquaculture feeds, chemicals (for the control of fish diseases) and breeding and culture technologies of high-value species (www.fao.org/fi/fishery and aquaculture factsheets, accessed 23 December 2010).

Aquaculture training, specifically in aspects of integrated fish farming, continues to be conducted for a global clientele by the Freshwater Fisheries Research Centre in Wuxi, which is NACA's Lead Centre in China.

The 2005 review of the Asia-Pacific region (FAO, 2006) did not cover the Japanese R&D infrastructure and programmes, which have generally played a major influence in research and have continuously provided academic and short-term specialized training to researchers, technologists and scientists from a number of Asian countries, particularly the members of the SEAFDEC, which consists of the ASEAN members and Japan. Research in Japan is carried out by three sets of institutions. In 2001, the national research institutes were reorganized into the Fisheries Research

Agency, composed of nine research institutes and two departments. The second group are the prefectural fisheries experimental stations operated by prefectural governments for locally specific and applied research. Thirdly, research programmes are carried out in universities. More than 18 faculties or departments in universities are conducting fisheries research and education in Japan (www.fao.org/fi/fisheries and aquaculture factsheets, accessed 23 December 2010).

Overall, the level of aquaculture education in the region has increased, with more people undertaking undergraduate and postgraduate training in aquaculture and related fields. Regional, inter-regional and national training in specific areas in aquaculture has increased significantly. Regional organizations and institutions such as NACA, SEAFDEC, the Asian Institute of Technology (AIT) and the University of the South Pacific (USP) have played a major role over the last decade. New groups of stakeholders were included in their programmes. NACA, for example, has been providing or facilitating regional and inter-regional training through short courses and study visits. A specific example is an inter-country training for private-sector personnel after the Indian Government decided to permit whiteleg shrimp culture. The study programme was designed for Indian private-sector personnel to learn through a study visit to Thailand, Viet Nam and China. Similarly, specialized training programmes have been conducted on emerging areas of aquaculture in the participants' countries, primarily grouper culture for a variety of groups, including personnel of some Pacific Island countries (i.e. New Caledonia) who were starting or planning to start grouper culture enterprises.

The governments in the region have sought training programmes on specialized issues relating to import risk analysis (e.g. Malaysia) and development of national aquatic animal health strategy (e.g. Hong Kong SAR), in addition to an increased trend in exchange visits facilitated through organizations such as NACA. FAO, as well as the Secretariat of the Pacific Community (SPC) have also provided training in aquatic animal health management and in risk analysis related to introduction and movement of aquatic species to personnel in the Pacific Island countries. This is expected to be a growing trend in the region and will help capacity building and better awareness of international regulations in specific areas that relate to aquaculture and trade.

The interregional technical cooperation programme advocated by the Bangkok Declaration and Strategy of 2000 has been carried out between Asia and Africa, usually under the framework of FAO-NACA collaboration. Through this broad arrangement, NACA has facilitated 12 exchange visits, since 2002, of farmers, scientists and administrators from a number of Sub-Saharan countries. This enables African counterparts to obtain insights on the viability of small-scale farming operations in the Asia-Pacific region and the technological and management aspects associated with the development of the sector.

An important step taken recently is to facilitate farmer-farmer interactions between countries. A case in point is a recent interaction between Indian shrimp farmers and Vietnamese catfish farmers to show the latter the advantages and mechanics of organizing farmer clusters in India. The region has also taken steps to train trainers in selected commodities, such as shrimp culture, seaweed culture, mollusc culture, etc., with the focal point being a country that is considered to be performing relatively well in the specific activity. The primary objective of this programme is to strengthen the capacity of small-holder farmers for competitive and sustainable aquaculture. For example, the Philippines is considered to be a leading nation for seaweed farming, and the in-country expertise of its trainers is used to train the trainers from other countries in the region and prepare information material based on small-scale farming experiences. A key outcome of this arrangement is to encourage the adoption of BMPs and the formation of clusters (www.enaca.org/modules/bmpprojects). A key feature of the aquaculture training activities occurring in the region is the use of in-country expertise for training and technical advice.

8.1.2 *Research*

This is one area whose impacts on aquaculture development in the region, with the exception of the GIFT Tilapia, have not been quantified. In effect, this aspect needs a dedicated study. The general

notion is that overall research output has increased significantly along with the increased funds available for research. Some countries such as Thailand and Viet Nam have increased the amount of funding for aquaculture research. It is also worthwhile to mention the existence of interregional research cooperation, apart from those activities supported under donor-funded projects, between regional organizations such as NACA and the Network of Aquaculture Centres of Central and Eastern Europe (NACEE) on the sharing of information on the genetic resources of finfish species.

Research has generally been focused on solving biological, technical and economic problems, mostly in production but also in postharvest handling, food safety, marketing and biosecurity related to the introduction and transfer of live aquatic animals. Recently, research to inform policy-making has been increasing, induced by the need to comply with international agreements and protocols such as the Code of Conduct for Responsible Fisheries (CCRF) and the Convention on Biological Diversity (CBD), and to develop policy guidelines for the implementation of the recently articulated and now widely promoted ecosystems approach to management.

The problems of Japanese aquaculture and how these were addressed generally reflect the aquaculture research issues in many countries in the region, especially those whose aquaculture sectors are expanding and intensifying (Box 3).

The Japanese research (and regulatory) response highlights an important shift in aquaculture research in Asia as a whole: research focus has broadened from productivity to one that encompasses the environment and food safety. Although not widespread, research has been carried out beyond adaptive research (the type of research that adjusts technology to a particular situation) to product development.

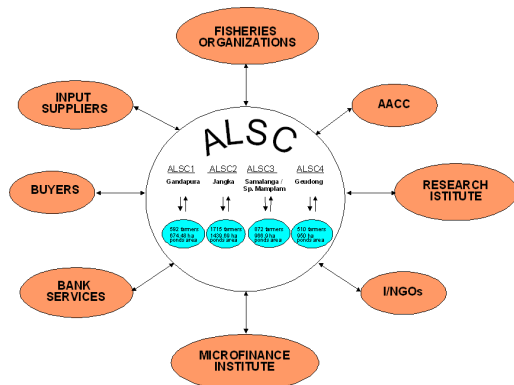
Box 3. Japanese research and regulatory responses to some aquaculture issues.

The issues and the research as well as regulatory responses in Japan have included the following:

- Overcrowded farming and excessive feeding have led to the environmental deterioration of aquaculture sites and appear to have become a major cause of eutrophication, red tides and fish disease. To reduce the pollution caused by aquaculture operations, improvement in feed practices from use of live feed to dried pellets, and the development of automatic feeding machines which can limit feed residues in water by using optical sensors have been under way. (In response to growing environmental awareness, the Law to Ensure Sustainable Aquaculture Production was enacted in 1999).
- In addition to these efforts to reduce organic loads, an integrated utilization/conservation system of coastal zones was established from the viewpoint of the material circulation function of natural ecosystems.
- Viral diseases, possibly carried by imported seed have struck, causing significant damage. For example, in 2003 and late 2004, koi herpes virus disease (KHVD) occurred. But there was no specific cure for it, so that to deal with this and other new diseases, genetic research was accelerated in the development of strains which are resistant or tolerant to specific pathogens. The new strains, however, raised concerns about their genetic impact on native fishes.
- Another issue is a decline in fish prices due to overproduction, increased fish imports and decreased per capita fish consumption in Japan. To cope with the overproduction and intense competition, farmers tried to create branded products identified by producing area and methods. Production traceability systems via Internet were developed to differentiate products and add credibility for food safety. Fishermen's organizations and the government promoted the traditional Japanese food culture and seafood consumption, as well as the creation of new seafood products or cooking recipes suitable for the modern cuisine. (National Aquaculture Sector Overview (NASO), Japan [[www.fao.org/fi/fact sheets](http://www.fao.org/fi/fact%20sheets) accessed 23 December 2010]).

Box 4. Aquaculture Livelihood Service Centers, Aceh, Indonesia.

In the region, the importance of the new information technology for small-scale farmers is seen as a very effective dissemination tool. Rural farmers with proper training can use information and communication technology (ICT) effectively. For example, in Aceh, the general operational model adopted in the use of ICT is for the farmer to go to the Livelihood Service Center in her or his community and then communicate with the Aceh Aquaculture Communication Centre to consult with experts there or to discuss immediate problems.



8.2 Salient issues

8.2.1 Information technology

Small farmers are beginning to use ICTs. The "aquachoupals" in India, as part of the broader "e-choupal" marketing assistance for crop, livestock and fish producers, have been using ICT for more than a decade to obtain the best price for products of the participating farmers.

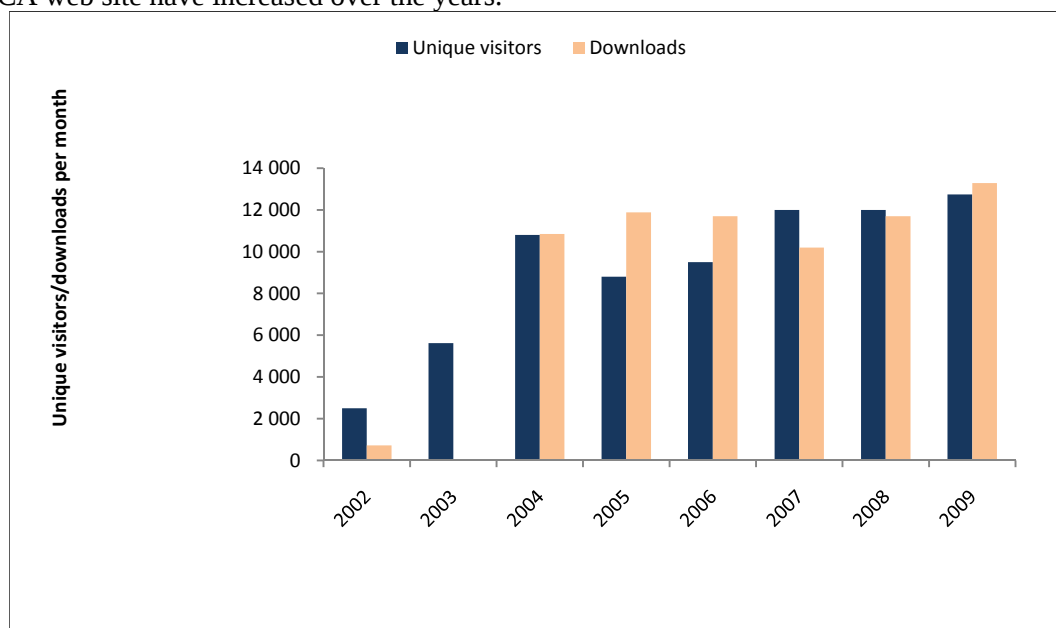
Another example is seaweed farmers in the Philippines using the mobile phone to keep tab of seaweed prices. This increasing use of ICT for marketing will reduce the information asymmetry between traders and producers to the benefit of the latter. In Aceh, Indonesia, Aquaculture Livelihood Centers equipped with ICTs have been established at the community level and farmers trained in their use (Box 4). The purpose is to enable them to find solutions to technical problems as well as source suitable markets (Ravikumar and Yamamoto, 2009).

There has been an overall increase in the use of the new communication tools to access information by many stakeholder groups. This is exemplified by the trend in access to information and downloading of material from the NACA Website (www.enaca.org), which is dedicated to aquaculture R&D in the region (Box 5).

A recent initiative in farmer training is the Application of Business Management Principles in Small Scale Aquaculture programme jointly conducted by NACA, NhaTrang University and the United Nations University Fisheries Training Program (UNU-FTP). This programme brought together and trained a collection of farmers who have had a tertiary education. They are expected to spread the message in their farming communities to bring about an effective application of business management principles to improve economic viability and environmental sustainability.

Box 5: Access to and downloads from the Network of Aquaculture Centres in Asia-Pacific (NACA) Web site.

The trends in access (average number of hits per month) and the downloads of material of the NACA web site have increased over the years.



8.3 The way forward

8.3.1 Quantifying research impact

Although done in agriculture in general and for certain commodities like corn, no serious attempt to quantify the impact of research in fisheries or aquaculture in the region has been made except on the R&D investments to develop and promote GIFT tilapia. Studies that can show returns on investment on aquaculture research at the national level would provide a persuasive argument to justify requests for increased R&D funding for aquaculture. The old qualitative justification based on the fact that aquaculture has been increasing faster than any other food production sector probably has some mileage left, but a quantitative, science-based evidence of research impact would give it greater persuasive power. This research area would provide policy guidance for public resource allocation among different aquaculture commodities and serve as an investment guide for the private sector.

8.3.2 Lessons in regional cooperation

In Asia, new fish culture technologies had spread through regional cooperation fostered initially and largely by external assistance and then taken up by self-sustaining regional indigenous organizations, including NACA, SEAFDEC, SPC and others. This cooperation was marked by resource pooling, results sharing, and cooperation and trust. Each initiative built on another, which ensured uptake and continuity after project assistance ended (WB, 2007). This regional sharing of technology and information as well as capacity building is cost effective and needs to be sustained.

8.3.3 Producer organizations and knowledge transfer models

Developing effective producer organizations is another cost-effective approach to increasing knowledge, achieving economies of scale, capturing value and promoting better practices, and gaining access to credit and markets. Knowledge dissemination models such as the "e-choupal" in India, the

Aquaculture Livelihood Service Centers pioneered in Aceh, Indonesia, and the One-stop Aqua Shop piloted in India, Pakistan and Viet Nam have shown success or bright prospects.

8.3.4 Public-private partnerships and alliances

The experience in Asia shows that the corporate world was again a key to acquiring intangible capital. Companies and producer groups invested not only in training of their staff but also in research and innovation. Private demand for technical and scientific skills complemented external support for capacity building. With public support, formal, vocational and informal training built human capacity. Links were established with external centers of expertise and trainers received needed instruction. Development of social capital through civil society dialogue, community-based approaches and co-management of natural resources benefited from sustained support (WB, 2007)

8.3.5 Opportunities from regional cooperation arrangements

A regional cooperation arrangement in the form of a regional fisheries commission has been established in the Central Asia and Caucasus region (known as Central Asian and Caucasus Regional Fisheries and Aquaculture Commission); Turkey and Russia are included as members and China is an active observer providing donor assistance. The mode of cooperation and its work programme were designed for a networking arrangement based on technical cooperation among members. The Pacific Island countries, while represented in NACA with the associate membership of SPC, also sees regional cooperation through a networking arrangement as a way to achieve the benefits of technical cooperation. Regional cooperation among the members of the network could eventually include the active participation of the farmers who themselves are associated in their own countries, as well as industry players. A business to business cooperation through joint ventures could be facilitated by the regional organization.

8.3.6 Consultative meeting among donor and development assistance agencies

A consultation among regional indigenous organizations (i.e. NACA, SEAFDEC, Bay of Bengal Programme (BOBP), SPC, AIT, FAO, WorldFish Center, development banks (Asian Development Bank (ADB) and WB) and donor agencies operating in the region (including the Pacific Island countries and the Central Asian Republics) could be organized in the next decade. Its purpose would be to establish development assistance priorities in line with the Paris Declaration of 2005 (available online at www.oecd.org/dataoecd/11/41/34428351.pdf). The consultation could use the findings and recommendations of the Global Conference on Aquaculture 2010 (available online at www.aqua-conference2010.org/) as a basis for a priority and strategy setting.

9. GOVERNANCE AND MANAGEMENT OF THE SECTOR

9.1 Status and trends

9.1.1 *Stages in the establishment of governance mechanisms for aquaculture and where the region stands*

Aquaculture, as an infant economic sector, has been seen as an orphan or a distant cousin of capture fisheries. What this implied was that the various elements of its governance and management resided in different government authorities, and there was no specific policy and regulatory framework for aquaculture. As aquaculture matured towards the end of the last millennium, this situation has improved in the region. Governments have promulgated policy and regulations for aquaculture, harmonized various laws and regulations heretofore under enforcement by separate government authorities into a coherent set of regulations that apply to aquaculture, and formulated aquaculture development strategies and plans to implement policy and achieve development goals. This is generally true in most of Asia. The Pacific Island countries have lately followed the same pathway, although some are still in the process of finalizing through stakeholder consultations their draft policy frameworks. This phase of improving the governance of the aquaculture sector has been assisted by regional organizations such as NACA, SPC, the Asia-Pacific Fisheries Commission, BOBP and FAO, as well as other organizations including the WorldFish Center, WB, ADB and various donor agencies. The Central Asian Republics and some Caucasus countries are being assisted by the FAO and the Government of Turkey, which have provided technical and funding assistance to the process of establishing and now operating a regional fisheries commission for Central Asia and the Caucasus.

Following this stage was the promotion of a second set of sectoral governance and management instruments: the international and regional agreements, protocols, and codes of conduct that were accompanied by or soon followed with technical guidelines. The major instrument was the Code of Conduct for Responsible Fisheries (CCRF). SEAFDEC “regionalized” the code for ASEAN.

The third stage was the development of national and industry codes of practices, good aquaculture practice (GAqP) guidelines and better management practices (BMPs). Along with this stage was the development of voluntary certification schemes and standards geared towards food safety and the environmental and social responsibility of aquaculture production as well as trade.

Capacity building for institutions and workers, industry and farmer groups was built into each stage. Training activities were held and systems and facilities modernized to improve capacities for surveillance and enforcement of legally mandated and voluntary standards, to conduct EIA and audit environmental performance, and later, to apply the new tools of management, including risk assessment and EEA. A parallel effort to improve the ability of the sector to comply with an increasing number and stringency of guidelines for responsible aquaculture was the organization of farmers. Some organizations included farmers and other players in the value chain, such as the suppliers of inputs, processors and traders.

To track the effects of policy measures and to improve effectiveness of action plans for the sector’s development, the information capability of governments was strengthened. This is an ongoing effort region-wise, as many governments, especially those in the Pacific Island countries and the Central Asian regions, have yet to establish or need to strengthen information and statistical services dedicated to aquaculture.

The Asia-Pacific region has gone through the three stages with moderate success. A broad indication of the effect of these governance frameworks is the reduction of conflicts over resources, less incidence of environmental impacts from and on aquaculture, the reduction in the conversion of mangroves for coastal aquaculture, improved trade flows and volumes from compliance with food safety standards, and a generally more orderly growth and development.

In sum, the governance of the sector has been strengthened by the following steps undertaken by governments and the private sector: policies and regulations that are in line with international agreements (especially the CCRF) have been enacted, formulated or realigned; environmental regulations and standards have been instituted or their enforcement strengthened; certification schemes on food safety, environmental and social responsibility of farms and hatcheries and in processing and trading are becoming more widespread; environmental and social codes of practices and BMPs have been widely promoted; and the organization of farmers into clusters and associations has gained regional attention and strong consideration by governments and producers.

These gains need to be sustained because of the continuing pressure to be more responsible from various segments of the public based on actual faults or perceived sins. Continuing awareness raising and capacity building for responsible aquaculture complemented by science-based evidence to influence public perceptions would be helpful.

9.1.2 Overall perspective on the management of the sector

This section focuses on a few key elements thought to have impacted on aquaculture in the Asia-Pacific region and to have significant influence on its future development.

A. Institutional aspects

Overall, improvement in governance of the sector has occurred, but this is not evenly spread. The shrimp exporting countries have generally led in adopting and improving capacity to implement CoCs, BMPs and certification standards. They include Thailand, China, Bangladesh, Indonesia, the Philippines, Malaysia and India. Australia and New Zealand have strong capacities for biosecurity, and Australia has contributed resources, including scientific, technical and financial assistance, to the development of BMPs and the regional programme for aquatic animal health management.

Improvements in sector governance included strengthening of government and semi-government institutions. Two notable examples are the establishment of the National Centre for Sustainable Aquaculture (NaCSA) under the Ministry of Commerce and Trade and the National Fisheries Development Board (see www.nfdb.ap.nic.in/), in India, under the Ministry of Agriculture. NaCSA began with a research-based project to solve the specific problem of shrimp disease, progressed into the development of BMPs for shrimp culture and the organization of farmers into clusters and clusters into farmer societies, and expanded to addressing the issues of market access and the rehabilitation of abandoned shrimp ponds (Umesh *et al.*, 2010).

In Thailand, the government uses dedicated teams for each of the major commodities to interact with the farmers to bring about improvements in the farming methods and source markets and to advise on day to day problems in relation to diseases and farm management. In Viet Nam, the establishment of the Vietnam Association for Sea Food Exports (VASEP), a semi-governmental authority, has facilitated the marketing of cultured shrimp and catfish. It has also taken over the responsibility of fighting the legal battles for the sector.

An indirect indicator of improved support to governance is the extensive range of aquaculture statistical data that are being collated and reported by many countries, such as China, Indonesia, Malaysia, the Philippines, Myanmar and Thailand, and made available to the public. Most of these countries have created web-accessible fisheries and aquaculture information sites and data bases.

There is an increasing trend in the region to comply with farm registration, thereby resolving issues related to ownership, which is a key factor related to certification and compliance with standards for individual commodities. Indeed, the region has witnessed the removal of aquaculture facilities in compliance with legal rulings, influenced by social and environmental considerations. Two of the most notable in this regard are the ruling of the Indian Supreme Court on shrimp farming and the

removal of aquaculture activities in Kolleru Lake, Andhra Pradesh (Ramakrishna, 2007; Roy *et al.*, 2008).

In emerging aquaculture activities such as culture-based fisheries, there is a move towards co-management, including profit sharing on an agreed basis by the community, factors that lead to overall sustainability and economic viability (Saphakdy *et al.*, 2009).

Regulations to maintain environmental integrity are increasingly enforced on aquaculture operations in the region. Most notable is the moratorium on the expansion of cage culture activities in enclosed bays in China and the associated encouragement to move operations offshore (1 to 1.5 km from shoreline) using newly developed circular cages (Kongkeo *et al.*, 2010). In a similar fashion, the extent of cage culture operations permitted in static inland waterbodies (e.g. reservoirs) is restricted to four percent of the total water surface area.

B. Certification

The Asia-Pacific region, through the Consortium of Shrimp Aquaculture and the Environment has played a major role in the attempts to develop guidelines for certification procedures that are globally applicable (www.enaca.org/aquaculture_certification). Some countries in the region have embarked on the development of their own certification procedures, within the framework of the global certification guidelines, and standards for cultured commodities and feeds.

Certifications for food safety and environmental responsibility are becoming widely adopted, but those that address social responsibility (i.e. social labels) have been more difficult. An initiative has been started by FAO to look into the governance of employment in aquaculture, which could lead to the development of a guideline on which a social certification scheme could be based.

C. Zonation

In some countries in the region, the governance mechanisms in place impart some degree of zonation of aquaculture activities. This trend will continue to be a significant factor as aquaculture development proceeds. Two factors that will come into play in zonation will be social and environmental in nature: social, to avoid displacement or exclusion of disadvantaged groups, and environmental, to impose limits on the farm densities and intensity of operations in a given area and waterbody. It is expected that water allocation and use will be better managed and holistic, taking into account climatic change scenarios, user needs, and water availability and discharge.

Early use of zoning as a development, regulatory and servicing mechanism included the establishment of aquaculture investment zones in Malaysia to encourage investors and facilitate servicing and management of the farms set up in the zone; the estate aquaculture farms in Indonesia, which are in fact a component of a massive government programme to relocate large numbers of people; the shrimp and carp industrial parks in Iran constructed by the government, complete with power, road, and water intake and discharge facilities to encourage farmers and those planning to invest in farming to locate their farms in these parks; and the mariculture parks in the Philippines.

Unplanned operations will be minimized with better planning, and suitable mitigation strategies will be introduced to restore the culture environment to an acceptable quality. A case in point is co-management and stock enhancement with filter-feeding species, both measures meant to resolve conflicts between cage culture operators and open-water fishers in reservoirs in the Cirata catchment in West Java (Abery *et al.*, 2005).

9.2 Salient issues

Among the voluntary governance instruments, social certification has not gained much headway. That said, national labour codes are invariably inspired by the principles of social justice and human rights

and geared to the pragmatic objectives of economic development and higher productivity. The labour code provisions, regulations and implementing mechanisms are comprehensive and detailed. The need, however, is widely seen as better enforcement, but most developing countries need more resources and better capacity building. It is for this reason that voluntary certification schemes and codes of industry practice are very important. Compliance by farmers would reduce the cost of surveillance, monitoring and enforcement of regulations. Most of the voluntary certification schemes carry a market incentive such as better access to market and premium price, which usually increases motivation for compliance and enables the surpassing of legally enforced standards.

9.3 The way forward

Sustaining the gains in governance is crucial. It is also important to remove obstacles as well as facilitate the achievement of sustainability objectives. The following measures are suggested by the above discussion:

The ecosystem approach to aquaculture (EAA) concept presents a comprehensive mechanism for managing aquaculture development in a sustainable and responsible manner. The need at this point is capacity building for concerned government institutions.

A technical guideline on governance and a regional project to promote awareness and its adoption followed by strengthening the capacity of governments to implement the guidelines would be useful.

The development of codes of industry practices that address social issues could start with the commercial and industrial-scale operations, as well as the aquaculture products processing sector.

The increasing number and stringency of codes, BMPs and other instruments have increased costs of compliance to farmers. Assessing the cost and benefit of compliance and searching for ways to reduce costs and complexity would likely increase the rate of compliance.

10. IMPLEMENTATION OF THE BANGKOK DECLARATION

10.1 Compliance: an overview

At this point in most of Asia, aquaculture has become a robust and well established sector, so that the challenge to its governance and development has shifted from providing a favourable investment climate and enabling environment for the private sector (this is still needed in Central Asian and most of the Pacific Island countries) to ensure equity, maintain environmental sustainability and facilitate trade. The road map for sustainable aquaculture is built on three main pillars (WB, 2007): (i) good governance, including establishment of an enabling environment for aquaculture investment through policies and practices, facilitating equitable access to water, land, resources and markets; (ii) commitment to environmentally sustainable and healthy aquaculture; and (iii) creation of the human and institutional capacity and knowledge required for management, innovation and building of aquaculture infrastructure.

Collectively, the 17 action recommendations of the Bangkok Declaration and Strategy (BDS) would strengthen these three pillars. The presence of NACA had facilitated regional implementation of the BDS recommendations. At the subregional levels, SEAFDEC boosted and complemented the adoption of many of these in the ASEAN. SPC did the same in the Pacific Island countries. SPC, representing 21 PICT governments, became an associate member of NACA shortly after the Aquaculture Millennium Conference in 2000. Thus in the Asian region, investments in research and manpower development expanded and as with other economic activities, aquaculture took advantage of the advances in information technology to facilitate the dissemination and utilization of knowledge and technology and the sharing of lessons and best practices, the latest product being the compilation and publication of a book on selected cases of successful aquaculture initiatives in Asia (De Silva and Davy, 2010). The processes and uptake of the results were made more effective by the institutional framework for regional cooperation provided by NACA as well as by SEAFDEC and SPC. This cooperative framework also served to facilitate collaborative activities that provided technical assistance or donor funding from international organizations and donor agencies.

NACA's participation in the consortium on shrimp aquaculture and the environment catalyzed numerous regional and national activities that resulted in the development and adoption of policy and better practices. Its collaborative programme with FAO and OIE has considerably boosted aquatic animal health, as well as environmental provisions of the BDS. Regional activities that included the collaboration and/or support of the Asia-Pacific Economic Cooperation Council (APEC), ASEAN, WorldFish Center, the United States Department of State and other organizations such as the Australian Centre for International Agricultural Research (ACIAR), as well as the private industry sector providing animal health care and products were organized.

Policies, capacity building and regional and national programmes for the development of livelihoods of the poor people based on aquaculture and aquatic resources were the focus of a dedicated programme created in NACA with multi-institutional cooperation.

The recommendations on marketing and trade were followed up with a regional workshop and seminar on aquaculture marketing and trade (NACA, 2003) aimed at awareness raising and capacity building that involved several countries and national institutions in Asia, traders, processors, farmers associations and NGOs, the Intergovernmental Organization for Marketing Information and Technical Advisory Services for Fishery Products in the Asia and Pacific Region (INFOFISH), FAO, World Trade Organization (WTO), WorldFish Center, WWF, GAA, Aquaculture Certification Council, SEAFDEC and United Nations Development Programme (UNDP) Viet Nam. Trade issues and agreements were discussed and a regional strategy was adopted that became the basis of a regional programme that encompassed aquaculture production and market access in NACA.

In line with the BDS, a genetic and biodiversity programme was also established that initiated regional research, training and information activities.

Interregional technical cooperation, already being conducted by NACA even before the BDS was intensified. SPC became a member, a genetic research and information exchange programme was carried out with NACEE, Technical Cooperation among Developing Countries (TCDC) activities in training were conducted for personnel in Africa and the Pacific, and experiences were shared with the aquaculture networks then being formed in Latin America and Africa through FAO and, with Latin America, through APEC and FAO. Experiences and lessons from NACA have been shared with the Central Asian region through FAO. The 17 action recommendations of the BDS were carried out mostly on a regional scale in the Asia-Pacific region, marked by collaboration among various organizations.

10.2 The way forward

10.2.1 Challenges and opportunities

The sector will have to aim at achieving production increases while maintaining environmental integrity, and do so with social responsibility. This will improve access to markets, an important ability in the face of increasing competition.

The trend to utilize modern communication techniques in accessing markets, even from remote production areas is likely to be further enhanced. This will increasingly enable small-scale farmer clusters to access markets, be competitive and thereby become or remain economically viable.

The producers in the region, the majority of whom are small-scale farmers, will come to understand the stringent guidelines that are being imposed by buyers and consumers and will be more effective in meeting these challenges by being organized, operating through cluster systems. There will be an increasing emphasis and a higher degree of adoption of BMPs that are being developed for most major commodities and particular farming systems.

As particular subsectors develop, the tendency is to put in place suitable mechanisms for their proper governance. Improved governance will facilitate the emerging small-scale farming sectors to comply with the increasing demands of the market for traceability, food quality and safety and other product attributes, and of the public for environmental and social responsibility of farming practices. Increasingly, standards will be adopted that will allow farmers to measurably prove that their operations are environmentally sustainable and socially responsible.

The development that could have the greatest impact on production is in mariculture, particularly of high-value marine finfish for the Live Food Fish Restaurant Trade. However, it is envisaged that such developments will follow different paths and along the lines witnessed in the last decade. For example, in countries such as Indonesia, Thailand and Viet Nam, production will continue to come from small to medium-scale cage culture operations (Kongkeo *et al.*, 2010), whereas in China it will increasingly come from offshore mariculture – farther ashore than where China's floating cages are currently located – using more advanced cage technology.

The global demand for products from seaweeds has been rising. Equally important is that seaweed culture is a low investment venture, which makes it compatible with the livelihood resources and strategies of small rural households in remote coastal communities. The colloid has numerous industrial and commercial uses, as well as healthcare and food applications. These attributes and the long stretches of coastal waters suitable for seaweed cultivation will push the growth in seaweed production, particularly in countries such as Indonesia and the Philippines. The Pacific Island countries have a vast natural resource for seaweed production, but marketing has stunted its farming in the region. Without a processing plant in the Pacific, the cost of transporting the raw material of a low-value commodity for processing in a distant factory will continue to be a disincentive to governments and the private sector.

The sector has to be sensitive and responsive to public perceptions, which on balance have not been positive, notwithstanding the strides made towards responsible farming. In this regard, it is important to showcase the impacts of the sector on conserving biodiversity, enhancing natural stocks through stock enhancement (which conserves depleted stocks and revives fishing livelihoods), and its being an effective secondary user of water. Public perception has a strong influence on policy, and policies conducive to investment and growth will be key to more private investment and faster development.

In the region, the sector will increasingly adopt a more responsible attitude toward the use and sharing of genetic resources, a crucial element related to biodiversity conservation and to ensuring that the best potential of available genetic resources are used responsibly (Bartley *et al.*, 2009). Nations will need guidelines. In this regard, the transfer of genetic material (i.e. eggs, hatchlings, seedstocks and broodstock) across national borders and beyond natural ranges of distribution will cease to be haphazard. Science-based broodstock management strategies will be put in place for the major cultured species.

Any development plan has to take into account the potential impacts of climate change on aquaculture (De Silva and Soto, 2009) and the various options to adapt to changes, mitigate risks, manage impacts and exploit opportunities presented by the changes. The initiatives that have been taken to prepare for the impacts will need to be intensified and broadened to include other sectors and integrate the various risk management strategies.

Overall, the sector has become more socially responsible and moving towards achieving environmental integrity. One fact that is impinging on economic viability is that, excluding the shrimp farming and the growing marine finfish farming sectors, the region is primarily a low-value commodity producer. The difference in the price of these low-value commodities at farm gate and at the retail outlet is wide. Accordingly, players in the world marketplace have the responsibility to work towards equity at all levels. These two goals for the farmers – economic viability and equity – are essential to their sustainability and therefore that of the sector.

10.2.2 Foreseeable major trends in the sector in the Asia-Pacific region

The stagnation in the capture fisheries sector will continue to place a heavy responsibility on aquaculture to meet the increasing food fish needs of the region. These are the likely pathways to increasing production in a sustainable way:

Increased culture area

There are many countries in the region that still have adequate freshwater resources, such as Myanmar and the states of the Central Asian Republic, and thus have room for further expansion in culture area. Big countries such as India are making a concerted effort to raise aquaculture production. India has been considering a more rapid expansion in mariculture in its vast, hardly tapped coastal waters.

Rehabilitation of abandoned ponds

In India and elsewhere in the region, there are vast areas of abandoned shrimp ponds. For example, in Andhra Pradesh, a single district, Krishna, had 29 845 ha of abandoned ponds (NaCSA, 2009). With the implementation of BMPs and a better market access, these ponds could be rehabilitated, bringing back the livelihoods of many thousands of poor households. This is not unique to India. In the coming decade, a concerted effort will be made by countries to rehabilitate abandoned ponds or sustain the productivity of active ponds, with the application of BMPs and better servicing of the sector.

Secondary use of water bodies

Asia accounts for over 40 percent of the global acreage of reservoirs exceeding 0.1 km³ capacity. Reservoirs are rarely impounded for fishery purpose. Potential fishery activities in these resources receive scant attention even at the planning stage, with exceptions in a few countries such as China (De Silva and Amarasinghe, 2009). Reservoir construction often raises controversy but once impounded,

they can be utilized for capture fisheries and aquaculture, in particular, cage culture and culture-based fisheries. Fishery-related activities provide livelihood opportunities to displaced persons.

These developments are not evenly widespread in the region. For example, in Indonesia, where the development of cage culture activities in three reservoirs (Cirata, Jatilnuhur and Saguling) of the Ciratum watershed was started as a means of providing alternative livelihoods to displaced persons, an average production of nearly 40 000–50 000 tonnes/year is obtained, or nearly 2 to 2.3 tonnes/ha/year (Abery *et al.*, 2005). These intensive cage culture developments have had problems related to management, ownership and environmental impacts which are being addressed in order to bring about environmental integrity and sustainability of the system.

China has a vast reservoir resource, estimated to be 31 percent (2 302 million ha) of inland water resources. This resource, apart from being developed for culture-based fisheries, is also used extensively for cage culture of relatively high-valued species (Miao, 2009). On the other hand, India has medium and large-sized reservoirs of nearly 2 million ha in total area, but this resource is currently unused or underutilized for aquaculture (Vass and Sugunan, 2009). It is expected that there will be an increase in culture-based fisheries and aquaculture in countries with reservoir resources. India has taken steps to develop cage culture in reservoirs.

Culture-based fisheries (CBF)

CBF is considered a fishery activity in the CCRF, but when practiced in small waterbodies with ownership of the stock, it is aquaculture (De Silva, 2003). In Asia, CBF generally uses non-perennial waters, primarily impounded for downstream rice cultivation, for community-based aquaculture development. This is a farmer-based activity that is often located in rural areas, and an excellent example of an EAA, where the only external input is seed stock, making it an eco-friendly, low-cost input activity with major societal benefits (Hasan, Bala and De Silva, 1999; De Silva, 2003). It has been estimated that the area of waterbodies classified as small-scale irrigation schemes available in developing nations in Asia is 66 710 052 ha (FAO, 1999). A significant proportion of this area is suitable for CBF development provided the seed inputs, social organization and legislative support for such activities are available.

In the past decade, great strides have been made in CBF. These developments taking place in Asian nations such as Bangladesh, Lao PDR, Sri Lanka and Viet Nam have been considered as a success in Asian aquaculture (Middendorp, Hasan and Apu, 1996; De Silva, 2003). It is expected that this activity will become widespread, bringing about significant increases in food fish availability to rural communities (Amarasinghe and Nguyen, 2010). Using 15 percent of the water acreage for CBF would produce 2.5 million tonnes more of fish a year (De Silva, 2003).

The effective use of CBF practices in small waterbodies can be illustrated by a case in Sri Lanka. In 2006–2007, in nine administrative districts nearly 0.25 million tonnes of fish was produced. Apart from improving rural people's nutrition, this generated supplementary income to communities not previously engaged in fishery-related activities. CBF as an aquaculture activity also brings social harmony (Saphakdy *et al.*, 2009).

Mariculture

Mariculture is the fastest growing subsector in the Asia-Pacific region. The total production of cultured marine/brackish carnivorous fish species in the Asia-Pacific region has increased considerably in the last four years, reaching some 650 000 tonnes in 2008, an increase of 23 percent over 2004 (Lymer, Funge-Smith and Miao, 2010). This trend will continue, with an increasing reliance on hatchery-bred seed. The artificial breeding technology for some important species is being developed and commercialized and could subsequently be applied to the other species. This will have significant impacts on biodiversity conservation, not only of the species cultured but more importantly, on the fragile habitats of such species, primarily the coral reefs, which are encountering other negative impacts such as from climate change (Hughes *et al.*, 2003).

Seaweed species cultivated for food, such as Japanese kelp, laver (nori), green laver and wakame have had a relatively stable production. The production of Japanese kelp peaked in 1999 and since then has stabilized, which might indicate that the rapid expansion of production area had reached a limit and further sites are no longer available. On the other hand, the production of seaweeds for biopolymers that include the red seaweeds *Eucheuma cottonii*, *Kappaphycus alvarezzi*, *Gracilaria* spp. and others has been expanding and will continue to do so because of the increasing demand for the colloid for various industrial, commercial and health product applications. The Philippines and Indonesia are the largest producers. New areas are being investigated for the expansion of seaweed production, since global demand for carrageenan and alginates is expected to continue to rise. Expansion will be carried out in poorer coastal communities, as the investment and technology are low. A further value from seaweed farming is carbon dioxide absorption (Lymer, Funge-Smith and Miao, 2010).

Unlike fish culture, the intensification of mollusc culture is quite difficult and probably not economically viable (Lymer, Funge-Smith and Miao, 2010). The issue of site availability is likely to constrain future development of mollusc culture in several states (for instance, production from both Japan and Republic of Korea decreased significantly in 2008 from 2006 levels). The trend in mollusc culture is more likely to be a shift from lower-value species to higher-value species in areas where sites are suitable. A further dimension is the development of intensive onshore culture operations such as those for abalone and a number of other gastropod species. Abalone production in the region increased 70 percent between 2006 and 2008, reaching 39 046 tonnes.

Finfish mariculture will continue to be confronted with issues related to feeds. In this regard, the currently available scientific evidence is scanty and not explicit, in spite of many claims to be so (WWF, 2005). With the controversies surrounding the use of fish for fishmeal and fish oil production rather than for direct use for human consumption (Aldhous, 2004), the issue to address is the primary resource availability. Another issue would be the overall carbon emission from the culture of a unit weight of marine species.

Emerging species

The rapid growth in the tra catfish farming sector in Viet Nam was not predicted, nor was the development of rohu, another low-value finfish, into an export commodity. It is not difficult to envisage the similar emergence of some other species in the coming decade. In particular, several members of the family Epinephalidae (groupers) have the potential. Increasing living standards in the region are likely to shift preferences to relatively expensive seafood, such as groupers. An indication of its potential for an even more rapid growth in the next decade is the jump in the total reported grouper production in 2002 from 22 000 tonnes to 78 000 tonnes in 2008 (Lymer, Funge-Smith and Miao, 2010). As of now, much of the production comes from small cage farms in nearshore areas. The establishment of large offshore cages, although likely to be slow and limited to a few areas, would add to this output.

The adoption of BMPs will enable the sector to continue to comply with or better meet food quality standards, improve productivity and ensure economic viability. In order to bring about management improvements in small-scale farms, there will be the need to increase farmer – extension services interactions, enabling sharing of knowledge, seeking solutions to problems encountered in daily culture practices, as well as enabling organized farmers to seek and make good use of market information. Innovative arrangements in information flow and access, facilitated by ICT, could be used, as had been successfully implemented in Aceh, Indonesia (Coutts, De Silva and Mohan, 2009; Kumar and Yamamoto, 2009).

There will be major strides in feed management. Feed cost is the highest recurring cost in semi-intensive and intensive culture systems. It is expected that there would be improvements in commercial feeds as well as in farm-made feeds in their quality, ingredient usage, digestibility and efficacy (FAO, 2010). However, feeds for tropical finfish culture will not be able to match the protein reduction attained for temperate salmonids (achieved by increasing the lipid content in feed, which makes feed less costly and more effective). On the other hand, what could be expected are simple

improvements to feed management that reduce costs without reduction in yield and lowering of flesh quality. Adoption of BMPs and an increasing cluster approach in farming systems will drive the process.

More attention on indigenous species

There is an increasing effort to develop the culture of suitable indigenous species which have a good market in the respective countries. For example, mahseer or *Tor* spp. such as *T. tutipora* and *T. tambroides* is an important group of food fishes as well as of cultural value for some nations. The culture of these species is being developed based on hatchery-produced seed (Ingram *et al.*, 2005, 2007). The wild populations of some of these indigenous species are much depleted due to overfishing and habitat degradation, so that a boost in the aquaculture of such species will also enhance the conservation and rehabilitation of wild populations. A fish like mahseer could facilitate the growth of new economic activities in rural areas such as eco-tourism and recreational fishery (Nguyen *et al.*, 2009).

Public-private sector partnerships in R&D

Public-private partnership in R&D needs to expand into strategic areas; it has been limited to hatchery production and a few research projects. Investments in research by governments of developing countries is limited, with the exception of China, India and Thailand, for all agricultural research (Echeverria, 2006). The internationally funded collaborative research projects have yielded good returns on investment. One of the best known examples is the development of improved strains of Nile tilapia. The internal rate of return (IRR) for the period 1988–2010 was estimated to be US\$368 million in 2001 prices (ADB, 2005). The GIFT strain (Genetically Improved Farmed Tilapia) has enabled tilapia aquaculture to progress rapidly (Eknath and Hulata, 2009; Acosta and Gupta, 2010). In 2009, more than 1.5 million tonnes was produced by China, Indonesia, Malaysia, the Philippines and Thailand. However, the genetic potential of most other commonly cultured species has not been realized to the same extent as that of tilapia or salmon, which more investments in genetic research could achieve. Limited government resources for research could be complemented by public-private partnerships. This strategy would harness and pool the intellectual and physical resources of the partners. Just as important, it would also find a middle ground between research results as a public good (because of government participation) and as a private property solely for the private sector's commercial interest. An example of public-private partnership is the collaboration in Thailand between government, industry and academia to develop specific pathogen free (SPF) broodstock and postlarvae of *Litopenaeus vannamei* and *Penaeus monodon*. Research to develop a product such as improved seed of a high-value species could be solely of interest to the private sector, but research to develop products and procedures for, say, aquatic health management or to reduce the environmental impacts of farming would need public-private support.

Box 6. Southern bluefin tuna cage culture in Australia: TIME Magazine award as second best invention of 2009.

The closing of the life cycle of the southern bluefin tuna was nominated the second-ranked best invention for 2009 by the TIME magazine. Such breakthroughs in artificial propagation and closure of the life cycle of many more important species are to be expected in the ensuing decade, some of which, such as, for example, Napoleon wrasse (*Cheilinus undulatus*) will have immense aquacultural and conservational value, and will enable aquaculture to be appreciated not only for its value in food fish production but also for its contributions to biodiversity conservation.

Technological advances and applications

The food crises in the 1960s and 1970s were primarily overcome with the development of high yielding varieties (HYVs) of rice and wheat, a technological advance essentially on seed. The adoption of the HYVs was enabled by nationally coordinated high priority programmes of applied and adaptive research, extension and input provision to farmers and product marketing.

Could the huge strides in aquaculture be similarly attributed to such a technological advance? In aquaculture, the genetic potential of farmed organisms has been fully realized only for salmon and to some extent for Nile tilapia. However, the overall gains in aquaculture production over the last two decades cannot be attributed to the contribution of these two species. None-the-less, the application of genetic technology to produce improved strains, the use of biotechnological procedures such as polymerase chain reaction (PCR) and products such as vaccines to improve aquatic health management, and the application of breeding technologies to produce SPF broodstock and seed in shrimp have in various ways contributed to increases in production. Downstream research and development led to the improvement in water quality, health and feed management, efficient and quality feeds, and the hypophysation technique and its application to emerging species. Then, at the design stage, more efficient devices and systems were developed and manufactured, such as paddle wheels and aerators, water recirculation systems, feeding systems, and systems for monitoring the status of a hatchery or farm. All these were subsequently packaged for application in aquaculture with remarkable effects. One outcome was the intensification of farming systems. On the other hand, one single innovation – the closing of the life cycle of southern bluefin tuna (*Thunnus maccoyii*) – made such a huge impact on farming of the species that it was ranked second of the 50 best inventions in 2009 by TIME Magazine (Kruger, 2009) (Box 6). All these suggest that the most useful attribute of a package or, as with the bluefin tuna award, an outstanding piece of technology is its impact on the productivity and sustainability of the sector; better yet if it improves public perception. Ultimately, the application of technology will need to be facilitated by a suitable policy framework enabled by a focused and well-supported action programme. These – policy, action programme and a technology package wrapped around genetically improved seed – were the basic ingredients of the Green Revolution.

10.2.3 Noteworthy developments in the Asia-Pacific region

This review closes with a summary of successful cases and notable developments in the region selected for the range of factors that have contributed to their success and the variety of attributes that characterize their success. The list includes: (i) the shift from giant tiger prawn (*Penaeus monodon*) to whiteleg shrimp (*Litopenaeus vannamei*), (ii) striped catfish (*Pangasianodon hypophthalmus*) culture in the Mekong Delta, Viet Nam; (iii) rohu (*Labeo rohita*) culture in Myanmar; (iv) improvements in rice-fish farming; and (v) the development and adoption of BMPs. These appear as Annexes.

11. REFERENCES

- Abery, N.W., Sukadi, F., Budhiman, A.A., Kartamihardja, E.S., Koeshendrajana, S., Buddhiman & De Silva, S.S. 2005. Fisheries and cage culture of three reservoirs in west Java, Indonesia; a case study of ambitious developments and resulting interactions. *Fisheries Management and Ecology*, 12: 315–330.
- Acosta, B.O. & Gupta, M.V. 2010. The genetic improvement of farmed tilapias project: impact and lessons learned. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 149–171. Dordrecht, Springer.
- ADB. 2005. *An impact evaluation on the development of genetically improved farmed tilapia and their dissemination in selected countries*. Manila, Asian Development Bank. 124 pp. (available at: www.adb.org/publications).
- Ahmed, N. 2011. On-farm feed management practices for freshwater prawn farming in southwest Bangladesh. In: M.R. Hasan and T. Shipton (eds.). *On-farm feeding and feed management in aquaculture*. FAO Fisheries and Aquaculture Technical Paper Rome, FAO. (in press).
- Ahmed, N., Allison, E.H. & Muir, J.F. 2009. Rice fields to prawn farms: a blue revolution in southwest Bangladesh? *Aquaculture International*, 18: 555–574.
- Aina, L.O. 2007. *Globalisation and small-scale farming in Africa: what role for information centres?* World Library and Information Congress: seventy-third IFLA General Conference and Council, 19–23 August 2007, Durban, South Africa. 6 pp. (available at: archive.ifla.org/IV/ifla73/papers/120-Aina-en.pdf).
- Aldhous, P. 2004. Fish farms still ravage the sea. Sustainable aquaculture takes one step forward, two steps back. *Nature online*, 17 February 2004; doi: 10.1038/news040216-10. (available at: www.nature.com/news/2004/040217/full/news040216-10.html).
- Allendorf, F.W. & Leary R.F. 1998. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. *Conservation Biology*, 2: 170–184.
- Alston, J.M., Beddow, J.M. & Pardey, P.G. 2009. Agricultural research, productivity, and food prices in the long run. *Science*, 325 (September 4, 2009): 1209–1210.
- Amarasinghe, U.S. & Nguyen, T.T.T. 2010. Enhancing rural farmer income through fish production: secondary use of water resources in Sri Lanka and elsewhere. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 103–130. Dordrecht, Springer.
- Araguas, R.M., Sanz, N., Pla, C. & Garcia-Martin, J.L. 2004. Breakdown of the brown trout evolutionary history due to hybridisation between native and cultivated fish. *Journal of Fish Biology*, 65 (Supplement A): 28–37.
- Aung, O., Nguyen, T.T.T., Poompuang, S. & Kamonrat, W. 2010. Microsatellite DNA markers revealed genetic population structure among captive stocks and wild populations of mrigal, *Cirrhinus cirrhosus* in Myanmar. *Aquaculture*, 299: 37–43.
- Aye, K.M., Lay, K.K., Win, H. & De Silva, S.S. 2007. A new freshwater aquaculture practice that has successfully targeted niche markets with major positive societal impacts: Myanmar. *Aquaculture Asia*, 14: 22–26.
- Bangkok Post. 2009. B 1.4bn plan approved to buy shrimp. 3rd July 2009, B3.
- Barel, C.D.N., Dorit, R., Greenwood, P.H., Fryer, G., Hughes, N., Jackson, P.B.N., Kawanabe, H., Lowe-McConnell, R.H., Nagoshi, M., Ribbink, A.J., Trewavas, E., Witte, F. & Yamoka, K. 1985. Destruction of fisheries in Africa's lakes. *Nature*, 315: 19–20.
- Bartley, D.M., Brugère, C., Soto, D., Gerber, P. & Harvey, B. (eds.) 2007. *Comparative assessment of the environmental costs of aquaculture and other food production sectors: methods for meaningful comparisons*. FAO/WFT Expert Workshop. 24–28 April 2006, Vancouver, Canada. FAO Fisheries Proceedings No. 10. Rome, FAO. 241 pp.
- Bartley, D., Nguyen, T.T.T., Halwart, M. & De Silva, S.S. (eds.) 2009. Special issue on use and exchange of genetic resources of cultured aquatic organisms. *Reviews in Aquaculture*, 1: 157–280.
- Beardmore, J.A., Mair, G.C. & Lewis, R.I. 2001. Monosex male production in finfish as exemplified by tilapia: applications, problems, and prospects. *Aquaculture*, 197: 283–301.
- Bondad-Reantaso, M.G. (eds.) 2007. *Assessment of freshwater fish seed resources for sustainable aquaculture*. FAO Fisheries Technical Paper No. 501. Rome, FAO. 628 pp.

- Bondad-Reantaso M.B. & Prein, M.** (eds.) 2009. *Measuring the contribution of small-scale aquaculture: an assessment*. FAO Fisheries and Aquaculture Technical Paper No. 534. Rome, FAO. 179 pp.
- CC (Catch and Culture).** 2009. Why raise native fishes if it's easier to farm alien species already introduced? *Catch and Culture*, 15 (2): 20-24. (also available at www.apfic.org/publications).
- Collares-Pereira, M.J. & Cowx, I.G.** 2004. The role of catchment scale environmental management in freshwater fish conservation. *Fisheries Management and Ecology*, 11: 303–312.
- Cooley, S.R., Coles, V.J., Subramaniam, A. & Yager, P.L.** 2007. Seasonal variations in the Amazon plume-related atmospheric carbon sink. *Global Biogeochemical Cycles*, 21, GB3014, doi:10.1029/2006GB002831.
- Coutts, R., De Silva, S. & Mohan, C.V.** 2009. Boosting aquaculture livelihoods in post-disaster Aceh, Indonesia. ADB Knowledge Showcase, Disaster Risk Management Indonesia, 22 November 2009, 2 pp.
- De Silva, S.S.** 2003. Culture-based fisheries: an underutilized opportunity in aquaculture. *Aquaculture*, 221: 221–243.
- De Silva, S.S.** 2008. *Market chains of non-high value cultured aquatic commodities: case studies from Asia*. FAO Fisheries and Aquaculture Circular No. 1032. Rome, FAO. 46 pp.
- De Silva, S.S. & Amarasinghe, U.S.** (eds.) 2009. *Status of reservoir fisheries in five Asian countries*. NACA Monograph No. 2. Bangkok, Network of Aquaculture Centres in Asia-Pacific. 116 pp. (available at: www.enaca.org/modules/wfdownloads/singlefile.php?cid=12&lid=981)
- De Silva, S.S. & Davy, F.B.** 2010. Aquaculture successes in Asia, contributing to sustained development and poverty alleviation. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 1–14. Dordrecht, Springer.
- De Silva, S.S. & Hasan, M.R.** 2007. Feeds and fertilizers: the key to long-term sustainability of Asian aquaculture. In M.R. Hasan, T. Hecht, S.S. De Silva & A.G.J. Tacon, eds. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*, pp. 19–47. FAO Fisheries Technical Paper No. 497. Rome, FAO. 510 pp.
- De Silva, S.S. & Phillips, M.J.** 2007. A review of cage aquaculture: Asia (excluding China). In M. Halwart, D. Soto & J.R. Arthur, eds. *Cage aquaculture – Regional reviews and global overview*, pp. 18–48. FAO Fisheries Technical Paper No. 498. Rome, FAO. 241 pp.
- De Silva, S.S. & Soto, D.** 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto & T. Bahri, eds. *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge*, pp. 151–212. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome, FAO. 212 pp.
- De Silva, S.S., Subasinghe, R.P., Bartley, D.M. & Lowther, A.** 2004. *Tilapias as alien aquatics in Asia and the Pacific: a review*. FAO Fisheries Technical Paper No. 453. Rome, FAO. 65 pp.
- De Silva, S.S. & Turchini, G.M.** 2009. Use of wild fish and other aquatic organisms as feed in aquaculture – a review of practices and implications in the Asia-Pacific. In M.R. Hasan & M. Halwart, eds. *Fish as feed inputs for aquaculture: practices, sustainability and implications*, pp. 63–127. FAO Fisheries and Aquaculture Technical Paper No. 518. Rome, FAO. 407 pp.
- De Silva, S.S., Mohan, C.V. & Phillips, M.J.** 2007. A different form of dumping: the need for a precautionary approach for yet another new species for shrimp farming in Asia. *Aquaculture Asia*, 12 (October–December 2007): 4–8.
- De Silva, S.S., Nguyen, T.T.T., Abery, N.W. & Amarasinghe, U.S.** 2006. An evaluation of the role and impacts of alien finfish in Asian inland aquaculture. *Aquaculture Research*, 37: 1–17.
- De Silva, S.S., Nguyen, T.T.T., Turchini G.M., Amarasinghe U.S. & Abery N.W.** 2009. Alien species in aquaculture and biodiversity: a paradox in food production. *Ambio*, 38: 24–28.
- De Silva, S.S., Ingram, B.A., Nguyen, P.T., Bui, T.M., Gooley, G.J. & Turchini, G.M.** 2010. Estimation of nitrogen and phosphorus in effluent from the striped catfish farming sector in the Mekong Delta, Vietnam. *Ambio*, 39: 504–514.
- Dey, M.M. & Garcia, Y.T.** 2007. Demand for fish in Asia: a cross-country analysis. In B. Johnston, ed. *Economics and market analysis of the live reef-fish trade in the Asia-Pacific region*, pp. 13-42. ACIAR Working Paper 64. Canberra, Australian Center for International Agricultural Research.

- Dey M.M., Paraguas, F.J., Srichantuk. N., Xinhua, Y, Bhatta, R. & Dung, L.T.C.** 2005. Technical efficiency of freshwater pond polyculture production in selected Asian countries: estimation and implication. *Journal of Aquaculture Economics and Management*, 9(1–2): 39–63.
- Dobson, A.P. & May, R.M.** 1986. Disease and conservation. In M. Sonlé, ed. *Conservation biology: the science of scarcity & diversity*, pp. 345–365. Sunderland, MA, Sinauer Associates Inc.
- Dowling, T.E. & Childs, M.R.** 1992. Impact of hybridisation on a threatened trout of the southwestern United States. *Conservation Biology*, 6: 355–364.
- Duc, N.M.** 2010. Application of econometric models for price impact assessment of antidumping measures and labelling laws on global markets: a case study of Vietnamese striped catfish. *Reviews in Aquaculture*, 2: 1–16.
- Eastwood, R., Lipton, M. & Newell, A.** 2010. Farm size. In P. Pingali & R. Evenson, eds. *Handbook of agricultural economics*, Vol. 4, pp. 3323–3397. Amsterdam, Elsevier B.V.
- Echeverria, R.G.** 2006. Mobilizing financial resources and improving their allocation. In *Reorienting agricultural research to meet the millennium development goals*. Proceedings of the GFAR 2006 Triennial Conference, 8–11 November 2001, New Delhi. GFAR Secretariat, c/o FAO Rome. 239 p.
- Edwards, P.** 1997. Sustainable food production through aquaculture. *Aquaculture Asia*, 2(1): 4–7.
- Eknath, A.E. & Hulata, G.** 2009. Use and exchange of genetic resources of Nile tilapia (*Oreochromis niloticus*). *Reviews in Aquaculture*, 1: 197–211.
- Evans, A.** 2008. *Rising food prices; drivers and implications for development*. A Briefing Paper. London, Chatham House, Royal Institute of International Affairs. 11 pp. (available at: www.chathamhouse.org.uk).
- Fan, S. & Chan-Kang, C.** 2005. Is small beautiful? Farm size, productivity and poverty in Asian agriculture. *Agricultural Economics*, 32 (s1): 135–146
- FAO.** 1999. *Irrigation in Asia in figures*. Water Reports 18. FAO, Rome. 228 pp.
- FAO.** 2006. State of world aquaculture 2006. *FAO Fisheries Technical Paper* No. 500. Rome, FAO. 134 pp.
- FAO.** 2006. *Regional review on aquaculture development. 3. Asia and the Pacific – 2005*. FAO Fisheries Circular No. 1017/3. Rome. FAO. 97 pp.
- FAO.** 2007. *Database on introductions of aquatic species (DIAS)*. Data and Statistics Unit of the Fisheries and Aquaculture Department, Rome, FAO. (available at: www.fao.org/fishery/dias/en).
- FAO.** 2009a. *Fishstat Plus: universal software for fishery statistical time series*. *Aquaculture production: quantities 1950–2007; Aquaculture production: values 1984–2007; Capture production: 1950–2007; Commodities production and trade: 1950–2007; Total production: 1970–2007*, Vers. 2.30. FAO Fisheries and Aquaculture Department, Fishery Information, Data and Statistics Unit. (available at: www.fao.org/fi/statist/FISOFT/FISHPLUS.asp)
- FAO.** 2009b. *The State of World Fisheries and Aquaculture 2008*. FAO Fisheries and Aquaculture Department. Rome, FAO. 176 pp.
- FAO.** 2010. *Report of the FAO Expert Workshop on On-farm feeding and feed management in aquaculture, Manila, the Philippines, 13–15 September 2010*. FAO Fisheries and Aquaculture Report No. 949. Rome, FAO, 37 pp.
- FAO/SAP and SPC.** 2010. *Building on progress: aquaculture in the Pacific*. A note prepared for an informal meeting on Pacific Aquaculture, 23 September 2010, Phuket, Thailand. 16 pp.
- FAO/SEC/FIEL.** 2009. *Regional synthesis: the fisheries and aquaculture status and prospects for development in Central Asian and Caucasus countries*. Report of the regional intergovernmental meeting to initiate the establishment of a Central Asian fisheries organization. Dushanbe, Tajikistan, 10–12 November 2008. FAO Fisheries and Aquaculture Report No. 887. 173 pp.
- FAO/NACA/UNEP/WB/WWF.** 2006. *International principles for responsible shrimp farming*. Bangkok, Network of Aquaculture Centres in Asia-Pacific. 20 pp.
- Globefish.** 2009–2010. Reports on production and global trade in shrimp, tilapia, pangasius 2009 and 2010. (available at: www.globefish.org)
- Groombridge, B. (ed.)** 1992. *Global biodiversity: status of the earth's living resources*. London, Chapman and Hall. 450 pp.

- Haert, B.T., van Dok, W. & Djuangsih, N.** 2002. Nutrient budget for Saguling Reservoir, West Java. *Water Research*, 36(8): 2152–2160.
- Hasan, M.R.** 2011. FAO Regional Technical Cooperation Project “Reducing the dependence on the utilization of trash fish/low-value fish as feed for aquaculture of marine finfish in the Asian region”. *FAO Aquaculture Newsletter*, 47: 26-27.
- Hasan, M.R., Bala, N. & De Silva, S.S.** 1999. Stocking strategy for culture-based fisheries: A case study from Oxbow Lakes Fisheries Project. In H.A.J. Middelndorp, P. Thompson & R.S. Pomeroy, eds. *Sustainable inland fisheries management in Bangladesh*, pp. 157–162. ICLARM Conference Proceedings No. 58, Manila, International Center for Living Aquatic Resources Management.
- Hasan, M.R. & Halwart, M.** (eds.) 2009. *Fish as feed inputs for aquaculture: practices, sustainability and implications*. FAO Fisheries and Aquaculture Technical Paper No. 518. Rome, FAO. 407 pp.
- Hasan, M.R., Hecht, T., De Silva, S.S. & Tacon, A.G.J.** (eds.) 2007. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*. FAO Fisheries Technical Paper No. 497. Rome, FAO. 510 pp.
- Hishamunda, N., Cai, J. & Leung, P.** 2009. *Commercial aquaculture and economic growth, poverty alleviation and food security: assessment framework*. FAO Fisheries and Aquaculture Technical Paper No. 512. Rome, FAO. 58 pp.
- Hortle, K.G.** 2007. *Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin*. MRC Technical Paper No 16. Vientiane, Lao PDR, Mekong River Commission. 87 pp.
- Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Conolly, S.R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J.B.C., Kleypas, J., Lough, J.M., Marshall, P., Nyström, M., Palumbi, S.R., Pandolfi, J.M., Rosen, B. & Roughgarden, J.** 2003. Climate change, human impacts, and the resilience of coral reefs. *Science*, 301(5635): 929–933.
- Huntington, T.C. & Hasan, M.R.** 2009. Fish as feed inputs for aquaculture – practices, sustainability and implications: a global synthesis. In M.R. Hasan & M. Halwart, eds. *Fish as feed inputs for aquaculture: practices, sustainability and implications*, pp. 1–61. FAO Fisheries and Aquaculture Technical Paper No. 518. Rome, FAO. 407 pp.
- Ingram, B., Sungan, S., Gooley, G., Sim S.Y., Tinggi, D. & De Silva S.S.** 2005. Induced spawning, larval development and rearing of two indigenous Malaysian mahseer, *Tor tambroides* and *T. douronensis*. *Aquaculture Research*, 36: 1001–1014.
- Ingram, B., Sungan, S., Tinggi, D., Sim, S.Y. & De Silva, S.S.** 2007. Breeding performance of Malaysian mahseer, *Tor tambroides* and *T. douronensis* broodfish in captivity. *Aquaculture Research*, 38: 809–818.
- Jones, R.J. & Steven, A.L.** 1997. Effect of cyanide on corals in relation to cyanide fishing on reefs. *Marine and Freshwater Research*, 48: 517–522.
- Kongkeo, H.** 1997. Comparison of intensive shrimp farming systems in Indonesia, Philippines, Taiwan and Thailand. *Aquaculture Research*, 28(10): 789–796
- Kongkeo, H. & Davy, F.B.** 2010. Backyard hatcheries and small-scale shrimp and prawn farming in Thailand. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 67–83. Dordrecht, Springer.
- Kongkeo, H., Wayne, C., Murdjani, M., Bunliptanon, P. & Chien, T.** 2010. Current practices of marine finfish cage culture in China, Indonesia, Thailand and Vietnam. *Aquaculture Asia*, 15 (2): 32–40.
- Kottelat, M. & Whitten, T.** 1996. Freshwater biodiversity in Asia with special reference to fish. *World Bank Technical Paper* No. 343, 59 pp.
- Kruger, J.** 2009. The best inventions of the year. *TIME*, November 23, 2009, pp.16–60.
- Kumar, B.R. & Yamamoto, K.** 2009. Aquaculture livelihoods service centres in Aceh, Indonesia: a novel approach to improving the livelihoods of small-scale fish farmers. *Aquaculture Asia*, 14(4): 16–22.
- Liu, J. & Li, Z.** 2010. The role of exotics in Chinese inland aquaculture. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 173–185. Dordrecht, Springer.

- Lymer, D., Funge-Smith, S. & Miao, W.** 2010. *Status and potential of fisheries and aquaculture in Asia and the Pacific 2010*. RAP Publication 2010/17. Bangkok, FAO Regional Office for Asia and the Pacific. 85 pp. (also available at www.apfic.org/publications).
- Mair, G.C., Clarke, G.J.C., Morales, E.J. & Sevilleja, R.C.** 2002. Genetic technologies focussed on poverty? A case study of genetically improved tilapia (GMT) in the Philippines. In P. Edwards, D.C. Little & H. Demaine, eds. *Rural aquaculture*, pp. 197–225. Oxford, CABI Publishing.
- McManus, J.W., Reyes, R.B.J. & Nanola, C.L.J.** 1997. Effects of some destructive fishing methods on coral cover and potential rates of recovery. *Environmental Management*, 21: 69–78.
- Miao, W.** 2009. Development of reservoir fisheries in China. In S.S. De Silva & U.S. Amarasinghe, eds. *Status of reservoir fisheries in five Asian countries*, pp. 3–17. NACA Monograph No. 2. Bangkok, Network of Aquaculture Centres in Asia-Pacific. 116 pp (available at: www.enaca.org/modules/wfdownloads/singlefile.php?cid=12&lid=981).
- Miao, W.** 2010. Recent developments in rice-fish culture in China: a holistic approach for livelihood improvement in rural areas. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 15–40. Dordrecht, Springer.
- Middendorp, H.A.J., Hasan, M.R. and Apu, N.A.** 1996. Communal fisheries management of freshwater lakes in Bangladesh. *ICLARM Quarterly Naga*, 19: 4–8.
- Middendorp, H.A.J., Thompson, P. & Pomeroy, R.S.** 1999. (eds.). *Sustainable inland fisheries management in Bangladesh*, pp. 171–175. ICLARM Conference Proceedings No. 58, Manila, International Center for Living Aquatic Resources Management.
- Moyle, P.B. & Leidy, R.A.** 1992. Loss of biodiversity in aquatic ecosystems; evidence from fish faunas. In P.L. Fielder & S.K. Jain, eds. *Conservation biology: the theory and practice of nature conservation*, pp. 129–161. New York, Chapman and Hall.
- NACA.** 2003. *AquaMarkets 2003: report of the seminar consultation on accessing and fulfilling market requirements of aquatic products*. Manila, 2–6 June 2003. Bangkok, Network of Aquaculture Centres in Asia-Pacific, 337 pp.
- NaCSA.** 2009. *Proposal under the “Plan for revival of abandoned shrimp ponds in Krishna District, Andhra Pradesh. Kakinada, Andhra Pradesh*. Kakinada, India, National Centre for Sustainable Aquaculture. 5 pp.
- Nguyen, T.T.T., Davy, F.B., Rimmer, M. & De Silva, S.S.** 2009. Use and exchange of genetic resources of emerging species for aquaculture and other purposes. *Reviews in Aquaculture*, 1: 260–274.
- Pawiro, S.** 2005. Trends in major Asian markets for live grouper. *INFOFISH International* 4/ 99: 20–24.
- Phan, L.T., Bui, T.M., Nguyen, T.T.T., Gooley, G.J., Ingram, B.A., Nguyen, H.V., Nguyen, P.T. & De Silva, S.S.** 2009. Current status of farming practices of striped catfish, *Pangasianodon hypophthalmus* in the Mekong Delta, Vietnam. *Aquaculture*, 296: 227–236.
- Phuong, N.T. & Oanh, D.T.H.** 2010. Striped catfish aquaculture in Vietnam: a decade of unprecedented development. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 131–147. Dordrecht, Springer.
- Pongthanapanich, T., Bueno, P. & Sungkhao, J.** 2011. Pilot testing of indicators for measuring the contribution of small-scale aquaculture to sustainable rural development: Thailand case study. In M.G. Bondad-Reantaso, P. Bueno & T. Pongthanapanich, eds. *Indicator system for assessing the contribution of small-scale aquaculture to sustainable rural development: outcomes of pilot tests*. FAO Fisheries and Aquaculture Technical Paper No. 545. Rome, FAO. (in preparation).
- Ramakrishna, R.** 2007. Kolleru carp culture in India: an aquaplosion and an explosion. *Aquaculture Asia*, 12(4): 16–21.
- Rana, K.J., Siriwardena, S. & Hasan, M.R.** 2009. *Impact of rising feed prices on aquafeeds and aquaculture production*. FAO Fisheries and Aquaculture Technical Paper No. 541. Rome, FAO. 63 pp.
- RAP.** 2003. *Myanmar aquaculture and inland fisheries*. RAP Publication 2003/18. Bangkok, FAO Regional Office for Asia and the Pacific. 62 pp.

- RAP.** 2007. Selected indicators of food and agriculture development in the Asia-Pacific region 1996–2006. RAP Publication 2007/15. Bangkok, FAO Regional Office for Asia and the Pacific. 230 pp.
- Ravikumar, B. & Yamamoto, K.** 2009. Aquaculture livelihoods service centres in Aceh, Indonesia: a novel approach to improving the livelihoods of small-scale fish farmers. *Aquaculture Asia*, 14(4): 16–21.
- Reardon, T., Timmer, C.P. & Minten, B.** 2010. *Supermarket revolution in Asia and emerging development strategies to include small farmers*. International Food Policy Research Institute, Pusa, New Delhi 110012, India P. Pingali, ed. Seattle, Bill and Melinda Gates Foundation, 6 pp. (available at: www.pnas.org/content/early/2010/12/01/1003160108.abstract).
- Ricohermoso, M.** 2008. *Report of the inception workshop on the project Sustainability and Competitiveness of Small-scale Farmers in selected ASEAN Countries*. NACA-ASEAN Foundation. 28 pp. (available at: library.enaca.org/inland/reports/asean_project_workshop.pdf).
- Ricciardi, A. and Rasmussen, J. B.** 1999. Extinction rates of North American freshwater fauna. *Conservation Biology*, 13: 1220–1222.
- Ridler, N. & Hishamunda, N.** 2001. *Promotion of sustainable commercial aquaculture in sub-Saharan Africa*. Volume 1. Policy framework. Rome, FAO. 67 pp.
- Roy A.K., Saha, G.S., Kumaraiah, P. & Sarangi, N.** 2008. Growth of forward and backward industries linked with aquaculture in Kolleru Lake area, Andhra Pradesh, India. *Aquaculture Asia*, 13 (October–December): 11–15.
- Sadovy, Y.** 2005. Trouble on the reef: the imperative for managing vulnerable and valuable fisheries. *Fish and Fisheries*, 6: 167–185.
- Sang, N.V., Hao, N.V., Hung, D., Khoi, P.D., Ha, B.T.L., Dinh, V.H., & Dien, N.** 2007. Selective breeding for growth and fillet yield of river catfish *Pangasianodon hypophthalmus* in the Mekong Delta, Vietnam. *Aquaculture Asia*, 12(2): 26–27.
- Saphakdy, B., Phomsouvanh, A. Davy, B., Nguyen, T.T.T & De Silva, S.S.** 2009. Contrasting community management and revenue sharing practices of culture-based fisheries in Lao People's Democratic Republic. *Aquaculture Asia*, 14 (3): 3–8.
- Secretan, P.A.D., Bueno, P.B., van Anrooy, R., Siar, S.V., Olofsson, Å., Bondad-Reantaso, M.G. & Funge-Smith, S.** 2007. *Guidelines to meet insurance and other risk management needs in developing aquaculture in Asia*. FAO Fisheries Technical Paper No. 496. Rome, FAO. 148 pp.
- Shiklomanov, I.A.** 1993. World freshwater resources. In P.H. Gleick, ed. *Water in crisis: a guide to the world's fresh water resources*, pp. 13–24. New York, Oxford University Press.
- Shiklomanov, I.A.** 1998. *Archive of world water resources and world water use*. Global Water Data Files: State Hydrological Institute. Data archive on CD-ROM from State Hydrological Institute, St. Petersburg, Russia.
- Soto, D., Aguilar-Manjarrez, J. & Irde, E.** 2009. Countries implementation of environmental impact assessment in aquaculture according to information reported to and collected by FAO. In *Environmental impact assessment and monitoring of aquaculture*, pp. 553–562. FAO Fisheries and Aquaculture Technical Paper No. 527. Rome, FAO.
- Smith, D.I.** 1998. *Water in Australia*. Oxford, Oxford University Press. 384 pp.
- SPC.** 2007. *Aquaculture action plan*. Noumea, Secretariat of the Pacific Community. 31 pp.
- Subramaniam, A., Yager, P.L., Carpenter, E.J., Mahaffey, C., Björkman, K., Cooley, S., Kustka, A.B., Montoya, J.P., Sañudo-Wilhelmy, S.A., Shipe, R. & Capone, D.G.** 2008. Amazon River enhances diazotrophy and carbon sequestration in the tropical North Atlantic Ocean. *Proceedings of the National Academy of Sciences of the United States*, 105: 10460–10465.
- Sunarto, A., Rukyani, A. & Itami, T.** 2005. Indonesian experience on the outbreak of koi herpesvirus in koi and carp (*Cyprinus carpio*). *Bulletin of the Fisheries Research Agency*, Supplement No. 2, pp. 15–21.
- Sunarto, A., Taukhid, Rukyani, A., Koesharyani, I., Supriyadi, H., Gardenia, L., Huminto, H., Agungpriyoni, D.R., Pasaribu, F.H., Widodo, Herdikiawan, D., Rukmono, D. & Prajitno, B.** 2005. Field investigations on a serious disease outbreak among koi and common carp (*Cyprinus carpio*) in Indonesia. In P. Walker, R. Lester & M. Bondad-Reantaso, eds.

- Diseases in Asian aquaculture V*, pp. 125–135. Manila, Fish Health Section, Asian Fisheries Society.
- Truong, V.T.** 2003. *A draft inception report on integrated assessment of trade liberalization in rice sector, Vietnam*. Hanoi, United Nations Environment Programme. 28 pp.
- Umesh N.R., Chandra Mohan, A.B., Ravibabu, G., Padiyar, P.A., Phillips, M.J., Mohan, C.V. & Vishnu, B.** 2010. Shrimp farmers in India: empowering small-scale farmers through a cluster-based approach. In S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture*, pp. 41–66. Dordrecht, Springer.
- UN.** 2009. *World population prospects. The 2008 revision*. Population Division of the Department of Social Affairs, United Nations Secretariat. (available at: esa.un.org/unpp).
- Valderrama, D., Hishamunda, N. & Zhou, X.** 2010. Estimating employment in world aquaculture. *FAO Aquaculture Newsletter* No. 45, August 2010, pp. 24–25.
- van Anrooy, R., Secretan, P.A.D., Lou, Y., Roberts, R. & Upare, M.** 2006. *Review of the current state of world aquaculture insurance*. FAO Fisheries Technical Paper No. 493. Rome, FAO. 92 pp.
- Vass, K.K. & Sugunan, V.V.** 2009. Status of reservoir fisheries in India. In S.S. De Silva & U.S. Amarasinghe, eds. *Status of reservoir fisheries in five Asian countries*, pp. 31–55. NACA Monograph No. 2. Bangkok, Network of Aquaculture Centres in Asia-Pacific. (available at: www.enaca.org/modules/wfdownloads/singlefile.php?cid=12&lid=981).
- Waples R.S.** 1991. Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. *Canadian Journal of Fisheries and Aquatic Sciences*, 48: 124–133.
- Welcomme, R.L. & Chavalit, N.** 2003. *The impacts of introductions and stocking of exotic species in the Mekong Basin and policies for their control*. MRC Technical Report No. 9. Vientiane, Mekong River Commission. 35 pp.
- WB.** 2007. *Changing the face of the waters: the promise and challenge of sustainable aquaculture*. Washington DC, The World Bank. 188 pp.
- WWF (World Wide Fund for Nature).** 2005. *Risk on local fish populations and ecosystems posed by the use of imported feed fish by the tuna farming industry in the Mediterranean*. WWF Mediterranean Programme. 12 pp.

Noteworthy aquaculture developments in the Asia-Pacific region in the decade 2000–2009

These five cases illustrate the following characteristics of aquaculture development in the region: the resourcefulness, resilience and adaptability of small-scale farmers; and the innovative production and marketing strategies that have increased productivity, profitability and employment opportunities.

Shift from giant tiger prawn (*Penaeus monodon*) to whiteleg shrimp (*Litopenaeus vannamei*)

In the early years of development of shrimp aquaculture, the global shrimp aquaculture sector was dominated by the giant tiger prawn, a species indigenous to the region. In Asia, it had accounted for more than 80 percent of cultured shrimp production. However, viral diseases began to devastate shrimp aquaculture, initially yellowhead disease in 1990, followed by white spot disease in 1994 (Kongkeo and Davy, 2010). These viruses decimated the sector in most shrimp-producing nations, and there was no further significant increase in tiger prawn production (Figure 1).

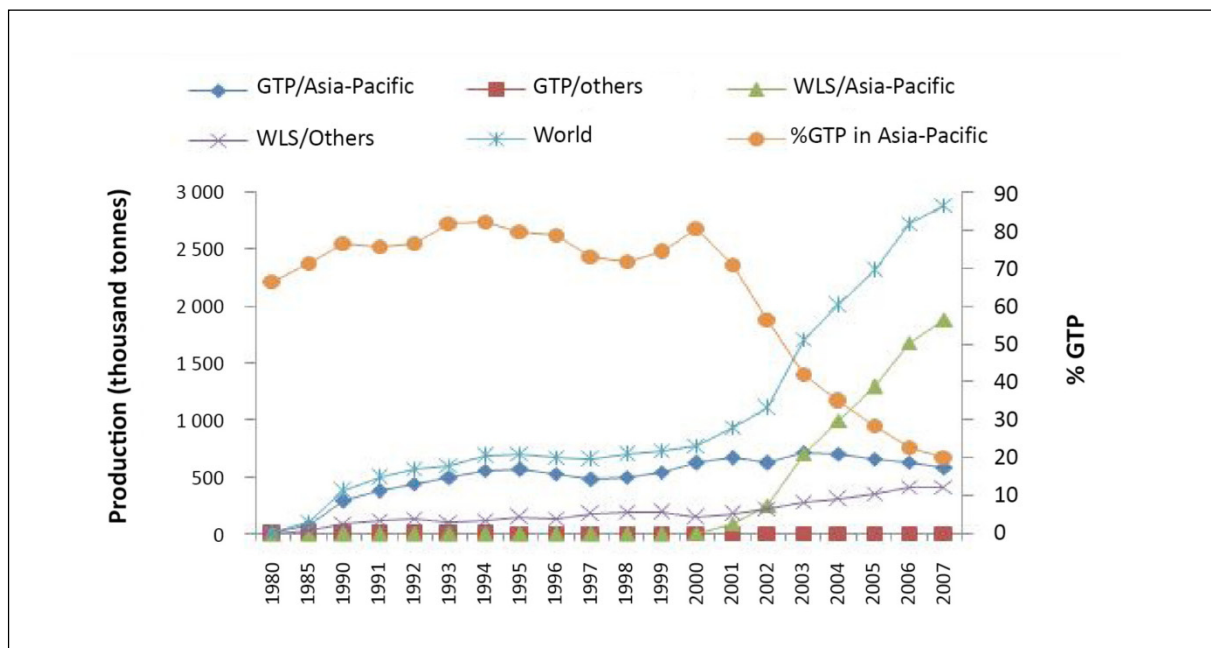


Figure A1: Trends in production of giant tiger prawn (GTP) in the Asia-Pacific region and elsewhere and the percent contribution from the region and elsewhere to world production, and the percent of GTP of all (including whiteleg shrimp, WLS) shrimp production in the Asia-Pacific region.

Source: Kongkeo and Davy (2010).

In order to revive the sector and to maintain livelihoods and foreign exchange earnings, some countries introduced the exotic whiteleg shrimp (*Litopenaeus vannamei*), notably China and Thailand. This decision and the adaptive capacity of the small-scale farmers increased shrimp production levels rapidly since 2000. The success of *L. vannamei* culture in the Asia-Pacific region was also boosted by the availability of specific pathogen free (SPF) broodstock and postlarvae. The shift to whiteleg shrimp culture by some countries enabled the region to continue its dominance in global shrimp culture. The associated issues of livelihoods and technical developments are considered in detail by Kongkeo and Davy (2010).

The introduction of *L. vannamei* to the region faced controversies, one of which was its impact on biodiversity (De Silva, Mohan and Phillips, 2007). While it is now known that this introduction has been responsible for the entry of two exotic viruses, Taura syndrome virus and infectious myonecrosis virus, its impact on genetic biodiversity is yet to be established.

Striped catfish (*Pangasianodon hypophthalmus*) culture in the Mekong Delta, Viet Nam

The farming of striped catfish, a relatively old tradition in Viet Nam, has intensified greatly in this decade (Phuong and Oanh, 2010; Phan *et al.*, 2009). In only seven to eight years, the sector has reached a status where it contributes nearly 30 percent of the Vietnamese aquaculture production, and it reached 837 000 tonnes in the first seven months of 2008 (Figure 2).

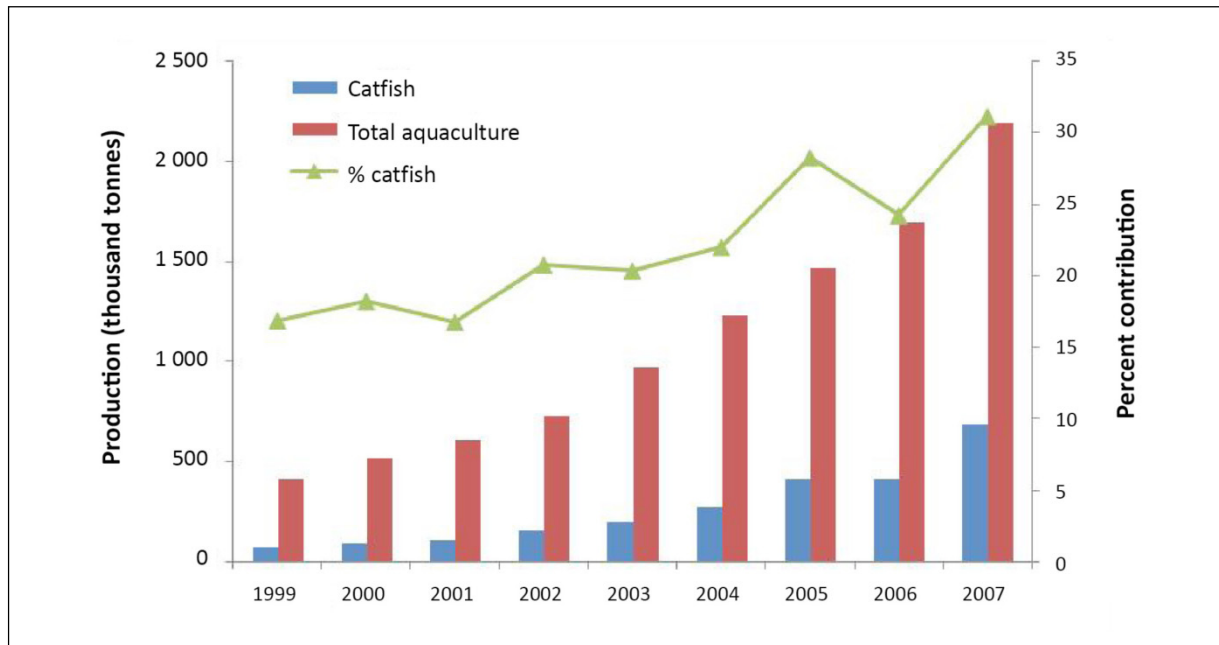


Figure A2: Trends in striped catfish production in the Mekong Delta, total aquaculture production and the contribution of the former to the total.

Source: Phan *et al.* (2009).

Importantly, being an acceptable substitute for “white fish”, it has become an export commodity (Figure 3), earning nearly US\$1 billion in 2007 (Phan *et al.*, 2009). Most of all, the sector employs some 150 000 to 170 000 workers, mostly women, in the processing sector.

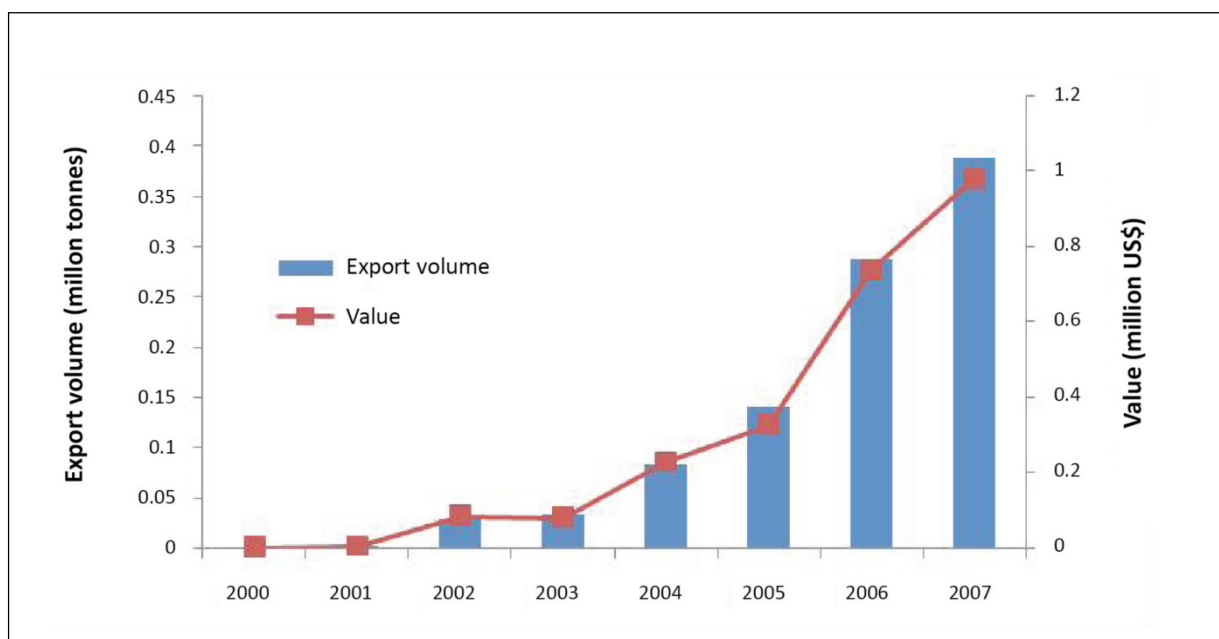


Figure A3: Export volume of striped catfish fillets and value of exports.

Source: Modified after Phan *et al.* (2009).

The median productivity attained by the sector ranges from an incredible 350 to 450 tonnes/ha/crop (Phan *et al.*, 2009), far exceeding that of any primary food production sector in the world. As described by Phuong and Oanh (2010), there are many reasons that have enabled the striped catfish farming sector to be unique in aquaculture development. Striped catfish farming in the Mekong Delta is practiced in 4 to 4.5 m deep ponds (Phan *et al.*, 2009) with regular water exchange, and the sector is horizontally integrated, with hatchery production, fry to fingerling rearing and grow-out operations being practiced as distinct entities, even with a geographical division within the delta.

The striped catfish farming sector demonstrates the innovativeness of farmers in the region: a traditional low-yielding culture system has adopted improved technology in artificial propagation, feed and nutrition, and husbandry to achieve huge production levels. The farming sector, working with the government was able to exploit the market for “white fish” in the west with an acceptable and relatively low-cost species.

Needless to say, the catfish farming sector has met with many obstacles, including trade embargoes (see Duc, 2010) and unfounded criticisms of environmentally unfriendly practices and the quality of the product, particularly through the Internet. In fact, the sector is moving towards developing better management practices (BMPs) for catfish farming and providing evidence from scientific studies that the catfish farming sector is not as environmentally degrading as suggested (De Silva *et al.*, 2010).

Rohu (*Labeo rohita*) culture in Myanmar

Myanmar, with vast and relatively pristine water resources, can be considered as an aquaculturally emerging nation (RAP, 2003; Aye *et al.*, 2007). Aquaculture contribution has increased from 5 to almost 22 percent of the total fish production in only a decade. This increase has not been solely the result of an increase in culture area, but is due to an almost doubling in yield per unit area, to nearly 4 500 kg/ha within ten years (Figure 4).

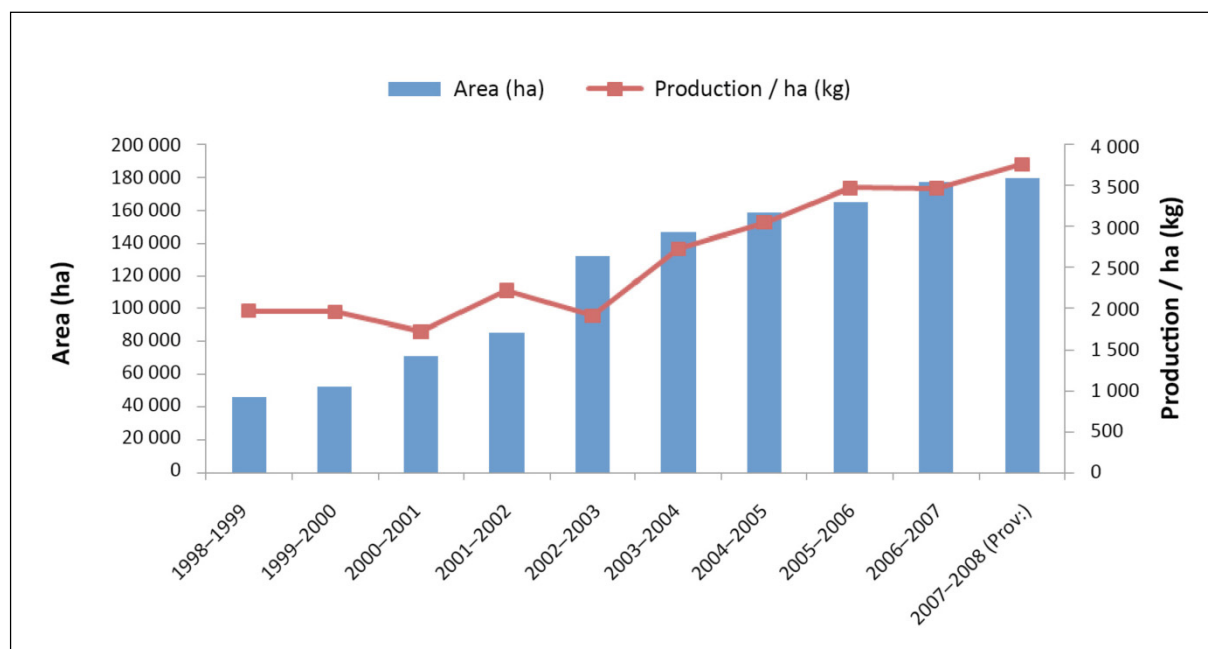


Figure A4: Trends in the aquaculture area and productivity per unit area in Myanmar.

Source: Data from Department of Fisheries, Ministry of Livestock and Fisheries, Yangon, Myanmar. Personal communication (2008).

Rohu is indigenous to Myanmar and found in all of its river systems. It has been cultured in ponds using traditional methods for the local market. Entrepreneurs, recognizing the demand for this species by Indian and Bangladeshi communities in the Middle East and Europe, began to supply this niche market, initially through Bangladesh and later directly. A processing sector developed along with the

trade, employing mostly women, even as the culture practices improved (Aye *et al.*, 2007). Rohu farming has created many livelihood opportunities for the poor, contributed to food security and most of all, ensured that the local availability of this preferred species to the people of Myanmar was not jeopardized by its export (Aye *et al.*, 2007). This development shows that there are niche markets for relatively low-value species.

Improvements in rice-fish farming

Rice-fish farming is one of the oldest traditional aquacultural practices and is thought to have originated in China. The region has an area of 137.5 million ha under rice cultivation (90 percent of the world's cultivated area; RAP, 2007), so that improvements in rice-fish farming to suit the modern consumer needs for food fish will be of huge significance. China has made important strides in rice-fish farming in the last three decades, and these developments have been considered a success story in Asian aquaculture (Miao, 2010). In China, the yield and area under rice-paddy culture have increased significantly over the years (Figure 5).

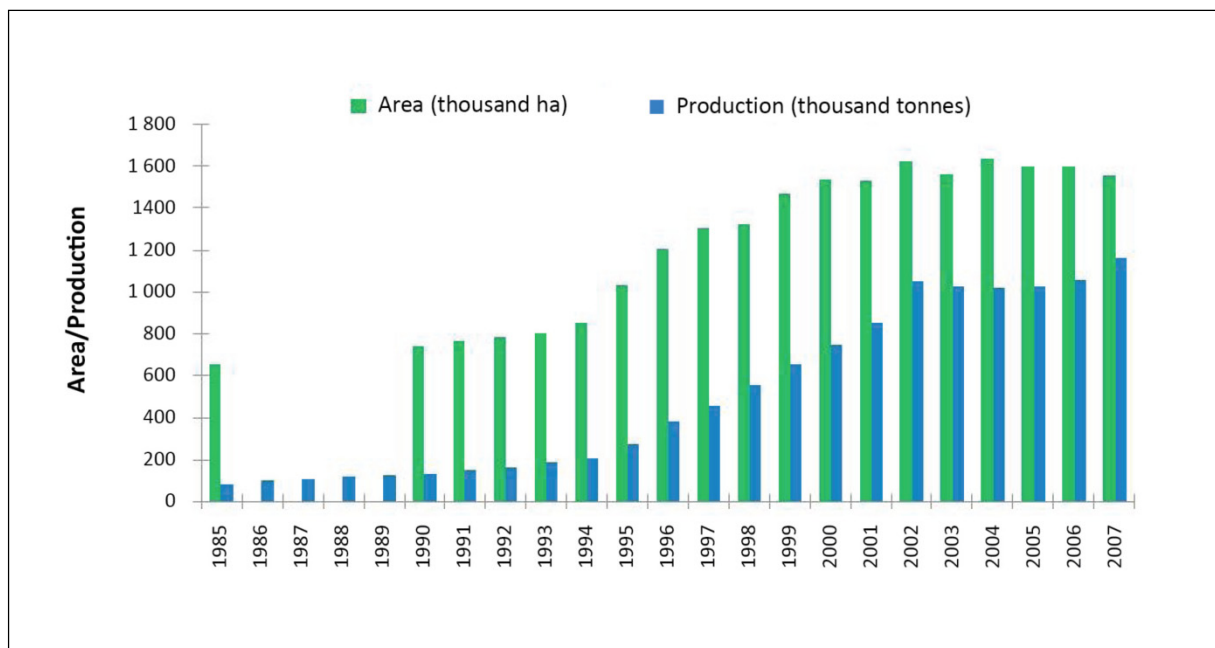


Figure A5: The rice paddy area and fish production from rice-fish culture in China, 1985–2007.
Source: Miao (2010).

In China's 1.55 million ha of paddy-field fish culture, 16 million tonnes of fish are produced, in addition to 11 million tonnes of paddy. Rice yield has increased 13-fold during the last two decades, so that the rice-fish system is now considered one of the most important food production systems in China. Improvements in the system, including use of higher-value species and better management have enabled rice farmers to gain an income of US\$2 000 – 4 000/ha, two to four times higher than rice alone. It has increased the income of some 2–3 million rural households in China (Miao, 2010).

A comparable development has occurred in Bangladesh, where "gher"¹ design potentially provides good opportunities for diversified production of prawn, fish, rice and dike crops. In these multiple crop systems, average annual yields of prawn, fish and rice were estimated at 467 986 and 2 257 kg/ha, respectively. This increase in productivity and profitability has raised living standards (Ahmed, Allison and Muir, 2009).

¹ In Bangladesh, the term "gher" means an enclosure made for prawn cultivation by modifying existing rice fields and building higher dikes, and excavating a canal several feet deep inside the periphery to retain water during the dry season (Ahmed, 2011).

Development and adoption of better management practices (BMPs)

The application of BMPs had its beginnings in Asian aquaculture, when answers were sought to revive the disease-stricken shrimp farming industry in Andhra Pradesh. The concept was articulated in the International Principles for Responsible Shrimp Farming (FAO/NACA/UNEP/WB/WWF, 2006). The adoption of BMPs goes hand in hand with the organization of small-scale farmers into clusters or associations. By being organized, the farm management and common property resource use are conducted as a single communal unit. The success of adoption of BMPs has been demonstrated in small-scale shrimp farming in India. This has been extended to other states to rehabilitate vast areas of abandoned shrimp ponds and as a tool for reaching niche markets (Umesh *et al.*, 2010). The implementation of BMPs is a success story in aquaculture development in Asia.

BMPs are being developed for many other major commodities cultured in the region, such as for the tra catfish farming system in the Mekong Delta, Viet Nam (Phan *et al.*, 2009). The adoption of BMPs for the major cultured commodities in the coming decade would be a key to attaining sustainability, improving the livelihoods of small-scale farmers, attaining food safety and meeting ever-increasing and stringent market demands.

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