# 1. Introduction

## BACKGROUND AND OBJECTIVES

In 2000, the Network of Aquaculture Centres in Asia-Pacific (NACA) and FAO, along with the Thai Department of Fisheries, organized the "Conference on Aquaculture in the Third Millennium" in Bangkok, Thailand. The 2000 Bangkok Millennium Conference reflected on the 25 years of aquaculture development globally and examined the role of aquaculture and its likely role in the overall development context. The conference resulted in a global consensus, "The Bangkok Declaration and Strategy for Aquaculture Development" (Bangkok Declaration), which provided the much needed technical and political vision and guidance for sustainable development of the sector.[1]

A decade after the Bangkok Millennium Conference, FAO, together with NACA and the Government of Thailand, organized the "Global Conference on Aquaculture 2010" (GCA) from 22 to 25 September and the back-to-back meeting of the Fifth Session of the FAO Committee on Fisheries, Sub-Committee on Aquaculture (COFI-AQ) from 27 September to 1 October. The objectives of the GCA were to: review the present status and trends in aquaculture development; evaluate the progress made in the implementation of the Bangkok Declaration; address emerging issues in aquaculture development; assess opportunities and challenges for future aquaculture development; and build consensus on advancing aquaculture as a global, sustainable and competitive food production sector.

As preconference activities, FAO prepared a series of six regional reviews (Asia–Pacific, Europe, Latin America and the Caribbean, Near East and North Africa, North America, and sub-Saharan Africa) and a global synthesis on aquaculture development status and trends. The six regional reviews and the global synthesis were discussed at the workshop on "The Status and Trends of Regional and Global Aquaculture" from 25 to 28 January 2010 at FAO headquarters in Rome. The objectives of the workshop were to: evaluate and improve the contents of the regional reviews and global synthesis and finalize them for presentation at the GCA; and discuss, improve and build consensus on the contents of a preliminary draft document titled "Phuket Consensus and Strategy for Aquaculture Development", to be presented and discussed at the GCA. The workshop participants were the six authors of the regional reviews, the author of the global review, FAO officers and additional experts and resource persons from academia, government agencies, research institutions and producers associations.

Following the contributions made at the workshop, the reviews and the global synthesis were presented at the GCA as main inputs regarding the status and trends of the sector. This *World Aquaculture 2010* document provides a closer look at the state of global aquaculture by 2010, with a prospective view to the sustainable growth of the sector in the next decade and beyond. Regional aquaculture reviews were also prepared in 2005, leading to the preparation of a key FAO publication: *State of World Aquaculture 2006* (FAO, 2006a).

[1] The Bangkok Declaration and Strategy can be found in the document *Aquaculture in the Third Millennium* (Subasinghe *et al*., 2001).

*Seaweed culture in Tanzania offers livelihood support to many women.*

COURTESY OF MATTHIAS HALWART

# 2. General characteristics of the sector

## WORLD PRODUCTION OF FOOD FISH

Aquaculture remains a growing, vibrant and important production sector for high-protein food. The reported global production of food fish from aquaculture, including finfish, crustaceans, molluscs and other aquatic animals for human consumption, reached 52.5 million tonnes in 2008[2] (Table 1). For 2009, the corresponding estimated amount is 55.1 million tonnes, and for 2010 the forecast amount is 57.2 million tonnes. In the period 1970–2008, the production of food fish from aquaculture increased at an average annual growth rate of 8.3 percent, while the world population grew at an average of 1.6 percent per year. The combined result of development in aquaculture worldwide and the expansion in global population is that the average annual per capita supply of food fish from aquaculture for human consumption has increased by ten times, from 0.7 kg in 1970 to 7.8 kg in 2008, at an average rate of 6.6 percent per year. The corresponding estimated amount in 2009 is 8.1 kg, and for 2010 the forecast amount is 8.3 kg.

The contribution of aquaculture to the total production of capture and aquaculture continued to grow from 34.5 percent in 2006 to 36.9 percent in 2008. The contribution is estimated to have increased to 37.9 percent in 2009 and is forecast to further rise to 38.9 percent in 2010.

Globally, aquaculture accounted for 45.6 percent of the world's fish food production for human consumption in 2008, up from 42.7 percent in 2006. In China, the world's

TABLE 1
**World capture fisheries and aquaculture production and consumption**

| | 2008 | 2009 (estimate) | 2010 (forecast) |
|---|---|---|---|
| | | *(Million tonnes)* | |
| **Total production**[1] | **142.3** | **145.1** | **147.0** |
| Capture fisheries | 89.7 | 90.0 | 89.8 |
| Aquaculture | 52.5 | 55.1 | 57.2 |
| **Total utilization** | **142.3** | **145.1** | **147.0** |
| Food | 115.1 | 117.8 | 119.5 |
| Feed | 20.2 | 20.1 | 20.1 |
| Other uses | 7.0 | 7.2 | 7.4 |
| **Aquaculture's contribution (%)** | | | |
| To total production | 36.9 | 37.9 | 38.9 |
| To food fish | 45.6 | 46.8 | 47.9 |
| Per capita food fish consumption (kg/year) | 17.1 | 17.2 | 17.3 |
| From capture fisheries | 9.3 | 9.2 | 9.0 |
| From aquaculture | 7.8 | 8.1 | 8.3 |

*Notes:* In *The State of World Fisheries and Aquaculture 2008* (FAO, 2009a), world aquaculture production, excluding aquatic plants, was reported to be 51.7 million tonnes in 2006, which included originally reported production by China. In 2009, FAO adjusted downward the aquaculture production statistics for 1997–2006 for China, and consequently the world total production was lowered. The adjustment was made according to the results communicated to FAO in 2008 by Chinese authorities following the Second National Agriculture Census carried out by China in 2007 for its national statistical data (including fisheries and aquaculture sectors) for 2006.

*Source:* FAO (2010a, 2010b).

[2] The production analysis is largely taken from *The State of World Fisheries and Aquaculture 2010* (Part 1, Aquaculture) (FAO, 2010a).

largest aquaculture producer, 80.2 percent of food fish consumed by its 1.3 billion people in 2008 was derived from aquaculture, up from 23.6 percent in 1970. Aquaculture production supplied the rest of the world with 26.6 percent of its food fish, up from 4.8 percent in 1970.

Despite the long tradition of aquaculture practices in a few countries over many centuries, aquaculture in the global context is a young food production sector that has grown rapidly in the last 50 years or so. World aquaculture output has increased substantially from less than 1 million tonnes of annual production in 1950 to 52.5 million tonnes in 2008, demonstrating three times the growth rate of world meat production (2.7 percent, from poultry and livestock together) in the same period. In contrast to world capture fishery production, which has almost stopped growing since the mid-1980s, the aquaculture sector maintained an average annual growth rate of 8.3 percent worldwide (or 6.5 percent excluding China) between 1970 and 2008. The annual growth rate in world aquaculture production between 2006 and 2008 was 5.3 percent in volume terms. The growth rate in the rest of the world (6.4 percent) from 2006 to 2008 was been higher than that for China (4.7 percent).

The value of the harvest of world aquaculture, excluding aquatic plants, was estimated at US$98.4 billion in 2008. However, the actual total output value from the entire aquaculture sector should be significantly higher than this figure because the values of aquaculture hatchery and nursery production and the breeding of ornamental fishes have yet to be estimated and included.

If aquatic plants are included, world aquaculture production in 2008 was 68.3 million tonnes, with an estimated value of US$106 billion.

## WORLD PRODUCTION OF AQUATIC PLANTS

Aquaculture produced 15.8 million tonnes (live weight equivalent) of aquatic plants in 2008, with a total estimated value of US$7.4 billion. Of the world total production of aquatic plants in the same year, 93.8 percent came from aquaculture. The culture of aquatic plants has consistently expanded its production since 1970, with an average annual growth rate of 7.7 percent. The production is overwhelmingly dominated by seaweeds (99.6 percent by quantity and 99.3 percent by value in 2008).

Countries in East and Southeast Asia dominate the seaweed culture production (99.8 percent by quantity and 99.5 percent by value in 2008). China alone produced 62.8 percent of the world aquaculture production of seaweeds by quantity. Other major seaweed producers are Indonesia (13.7 percent), the Philippines (10.6 percent), the Republic of Korea (5.9 percent), Japan (2.9 percent) and the Democratic People's Republic of Korea (2.8 percent). In East Asia, almost all cultured seaweed species are for human consumption, although Japanese kelp is also used as raw material in the extraction of iodine and algin. In contrast, seaweed farming in Southeast Asia, with *Eucheuma* seaweeds as the major species, is mainly producing raw material for carrageenan extraction.

Chile is the most important seaweed-culturing country outside Asia, producing 21 700 tonnes in 2008. Africa is also reported to have harvested 14 700 tonnes of farmed seaweeds in 2008, with the United Republic of Tanzania (mainly Zanzibar), South Africa and Madagascar as the leading producers.

## PRODUCTION BY REGION, GROWTH PATTERNS AND TOP PRODUCERS

Asia has retained its dominant position in world aquaculture, producing 88.8 percent of global aquaculture production by quantity and 78.7 percent by value in 2008. China alone accounted for 62.3 percent of world aquaculture production by quantity (Table 2) and 51.4 percent by value in the same year.

The growth patterns in aquaculture production are not uniform among the regions. While China's aquaculture production increased at an average annual rate

TABLE 2
**Aquaculture production by region: quantity (tonnes) and percentage of world production**

| Selected regions and countries | 1970 | 1980 | 1990 | 2000 | 2006 | 2008 |
|---|---|---|---|---|---|---|
| **Africa** | **10 271** | **26 202** | **81 015** | **399 788** | **754 406** | **940 440** |
| | **0.4%** | **0.6%** | **0.6%** | **1.2%** | **1.6%** | **1.8%** |
| Sub-Saharan Africa | 4 243 | 7 048 | 17 184 | 55 802 | 154 905 | 238 877 |
| | 0.2% | 0.1% | 0.1% | 0.2% | 0.3% | 0.5% |
| North Africa | 6 028 | 19 154 | 63 831 | 343 986 | 599 501 | 701 563 |
| | 0.2% | 0.4% | 0.5% | 1.1% | 1.3% | 1.3% |
| **America** | **173 491** | **198 850** | **548 200** | **1 422 637** | **2 367 320** | **2 405 166** |
| | **6.8%** | **4.2%** | **4.2%** | **4.4%** | **5.0%** | **4.6%** |
| Caribbean | 350 | 2 329 | 12 169 | 39 692 | 36 610 | 40 054 |
| | 0.0% | 0.0% | 0.1% | 0.1% | 0.1% | 0.1% |
| Latin America | 869 | 24 590 | 179 367 | 799 235 | 1 640 001 | 1 720 899 |
| | 0.0% | 0.5% | 1.4% | 2.5% | 3.5% | 3.3% |
| North America | 172 272 | 171 931 | 356 664 | 583 710 | 690 709 | 644 213 |
| | 6.7% | 3.7% | 2.7% | 1.8% | 1.5% | 1.2% |
| **Asia** | **1 786 286** | **3 540 960** | **10 786 593** | **28 400 213** | **41 860 117** | **46 662 031** |
| | **69.6%** | **75.2%** | **82.5%** | **87.6%** | **88.4%** | **88.8%** |
| Asia excluding China | 1 021 888 | 2 211 248 | 4 270 587 | 6 821 665 | 11 831 528 | 13 717 947 |
| | 39.8% | 47.0% | 32.7% | 21.0% | 25.0% | 26.1% |
| China | 764 380 | 1 316 278 | 6 482 402 | 21 522 095 | 29 856 841 | 32 735 944 |
| | 29.8% | 28.0% | 49.6% | 66.4% | 63.1% | 62.3% |
| Near East | 18 | 13 434 | 33 604 | 56 453 | 171 748 | 208 140 |
| | 0.0% | 0.3% | 0.3% | 0.2% | 0.4% | 0.4% |
| **Europe** | **510 713** | **770 200** | **1 616 287** | **2 072 160** | **2 209 097** | **2 366 354** |
| | **19.9%** | **16.4%** | **12.4%** | **6.4%** | **4.7%** | **4.5%** |
| Non-European Union countries | 39 431 | 49 985 | 582 305 | 676 685 | 925 664 | 1 088 594 |
| (+ Cyprus and Israel) | 1.5% | 1.1% | 4.5% | 2.1% | 2.0% | 2.1% |
| European Union countries (27) | 471 282 | 720 215 | 1 033 982 | 1 395 475 | 1 283 433 | 1 277 760 |
| | 18.4% | 15.3% | 7.9% | 4.3% | 2.7% | 2.4% |
| **Oceania** | **8 421** | **12 224** | **42 005** | **121 312** | **160 126** | **172 214** |
| | **0.3%** | **0.3%** | **0.3%** | **0.4%** | **0.3%** | **0.3%** |
| **World** | **2 566 882** | **4 705 841** | **13 074 100** | **32 416 110** | **47 351 066** | **52 546 205** |

*Notes:* Data exclude aquatic plants. Data for 2008 contain provisional data of some countries.
*Source:* FAO (2010a).

of 10.4 percent in the period 1970–2008, in the new millennium its growth rate has declined to 5.4 percent, which is significantly lower than in the 1980s (17.3 percent) and 1990s (12.7 percent). The average annual growth in production in Europe and North America since 2000 has also slowed substantially to 1.7 and 1.2 percent, respectively. It is anticipated that, while world aquaculture production will continue to grow, the rate of increase in most of the regions will slow in the forthcoming decade.

In 2008, the top 15 aquaculture-producing countries harvested 92.4 percent of the total world production of food fish from aquaculture (Table 3). Of the 15 countries, 11 were from the Asia–Pacific region.

## PRODUCTION BY ENVIRONMENT AND SPECIES GROUP

Aquaculture production using freshwater contributes 59.9 percent of world aquaculture production by quantity and 56.0 percent by value. Aquaculture using seawater (in the sea and also in ponds) accounts for 32.3 percent of world aquaculture production by quantity and 30.7 percent by value. Aquaculture in seawater produces many high-value finfish, crustaceans and abalone species, but also a large amount of oysters, mussels, clams, cockles and scallops. Although brackish-water production represented only 7.7 percent of world production in 2008, it accounted for 13.3 percent of total value, reflecting the prominence of relatively high-valued crustaceans and finfishes.

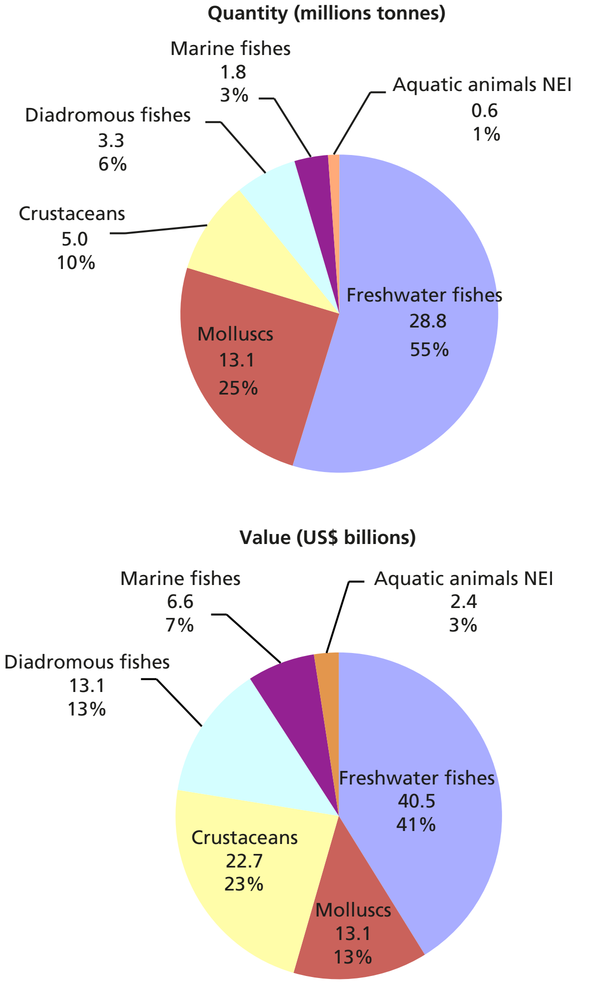
In 2008, freshwater fishes continued to dominate with a production of 28.8 million tonnes (54.7 percent) valued at US$40.5 billion (41.2 percent), followed by molluscs

TABLE 3
**Top 15 aquaculture producers by quantity in 2008 and growth**

| | Production (Thousand tonnes) | | | Average annual rate of growth (Percentage) | | |
|---|---|---|---|---|---|---|
| | *1990* | *2000* | *2008* | *1990–2000* | *2000–2008* | *1990–2008* |
| China | 6 482 | 21 522 | 32 736 | 12.7 | 5.4 | 9.4 |
| India | 1 017 | 1 943 | 3 479 | 6.7 | 7.6 | 7.1 |
| Viet Nam | 160 | 499 | 2 462 | 12.0 | 22.1 | 16.4 |
| Indonesia | 500 | 789 | 1 690 | 4.7 | 10.0 | 7.0 |
| Thailand | 292 | 738 | 1 374 | 9.7 | 8.1 | 9.0 |
| Bangladesh | 193 | 657 | 1 006 | 13.1 | 5.5 | 9.6 |
| Norway | 151 | 491 | 844 | 12.6 | 7.0 | 10.0 |
| Chile | 32 | 392 | 843 | 28.3 | 10.1 | 19.8 |
| Philippines | 380 | 394 | 741 | 0.4 | 8.2 | 3.8 |
| Japan | 804 | 763 | 732 | -0.5 | -0.5 | -0.5 |
| Egypt | 62 | 340 | 694 | 18.6 | 9.3 | 14.4 |
| Myanmar | 7 | 99 | 675 | 30.2 | 27.1 | 28.8 |
| United States of America | 315 | 456 | 500 | 3.8 | 1.2 | 2.6 |
| Republic of Korea | 377 | 293 | 474 | -2.5 | 6.2 | 1.3 |
| Taiwan Province of China | 333 | 244 | 324 | -3.1 | 3.6 | -0.2 |

*Notes:* Data exclude aquatic plants. Data for 2008 contain provisional data of some countries.
*Source:* FAO (2010a).

FIGURE 1
**World aquaculture production: major species groups in 2008**




*Notes:* Data exclude aquatic plants. NEI = not elsewhere included.
*Source:* FAO (2010a).

(13.1 million tonnes), crustaceans (5 million tonnes), diadromous fishes (3.3 million tonnes), marine fishes (1.8 million tonnes) and other aquatic animals (0.62 million tonnes) (Figure 1).

The production of freshwater fishes in 2008 was dominated by carps (Cyprinidae, 20.4 million tonnes or 71.1 percent). A small portion (2.4 percent) of freshwater fishes was cultured in brackish water, including tilapia farmed in brackish water in Egypt. The largest producer of all carps (cyprinids) is China (70.7 percent in 2008), followed by India (15.7 percent). Another 10.2 percent of all carps are produced by Bangladesh, Myanmar, Viet Nam, Indonesia and Pakistan, collectively. The growth in the production of pangas catfish (*Pangasius* spp.) in Viet Nam had been dramatic in recent years, with 1.2 million tonnes produced in 2008.

Mollusc production in 2008 consisted of oysters (31.8 percent), carpet shells and clams (24.6 percent), mussels (12.4 percent) and scallops (10.7 percent). While mollusc production as a whole grew at an average annual rate of 3.7 percent in the period 2000–08, the luxury group of abalones increased in production from 2 800 to 40 800 tonnes in the same period, an annual growth rate of 39.9 percent.

World production of crustaceans was fairly evenly distributed among brackish

COURTESY OF MATHEW BRIGGS

*Pangas catfish farming is a major aquaculture activity in Viet Nam.*

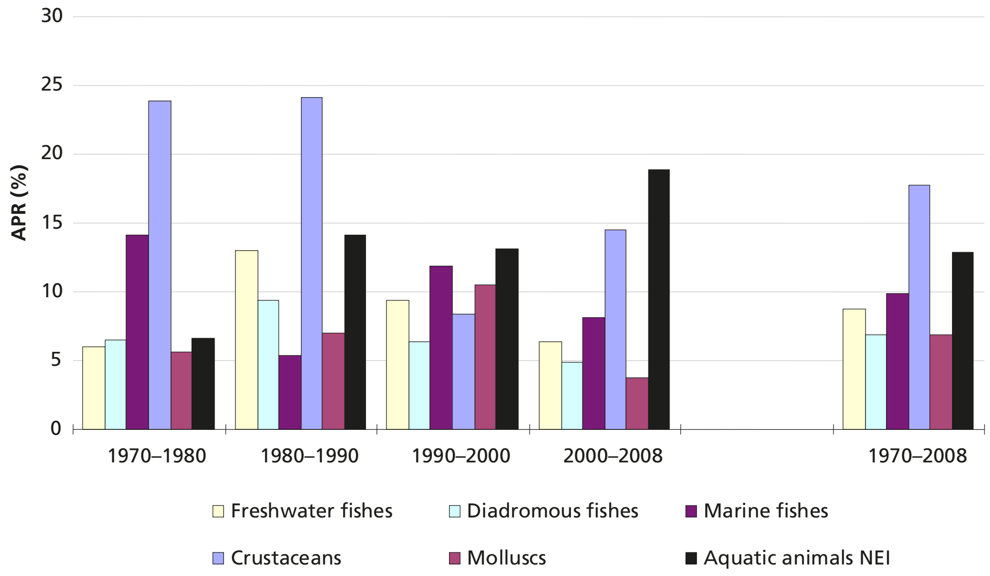
COURTESY OF MICHAEL PHILLIPS

Penaeus monodon *culture is an important post-Tsunami development activity in Ache, Indonesia.*

water (2.4 million tonnes or 47.7 percent) and freshwater (1.9 million tonnes or 38.2 percent), with marine water contributing much less (0.7 million tonnes or 14.1 percent). Crustaceans farmed in freshwater include more than 0.5 million tonnes of marine species; for example, the whiteleg shrimp produced by China, which was previously reported as production from brackish water is in fact largely farmed in inland (freshwater) conditions.

Diadromous fish production in 2008 was dominated by Atlantic salmon (*Salmo salar*) (1.5 million tonnes or 44 percent), milkfish (*Chanos chanos*) (0.68 million

FIGURE 2
**Trends in world aquaculture production: average annual growth rate for major species groups, 1970–2008**



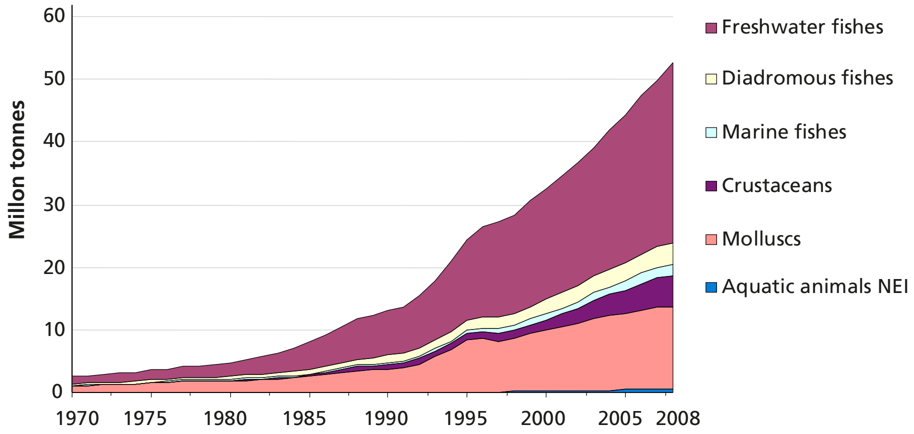

*Note:* APR refers to the average annual percentage rate of growth; NEI refers to not elsewhere included.
*Source:* FAO (2010a).

tonnes or 20.4 percent), rainbow trout (*Oncorhynchus mykiss*) (0.58 million tonnes or 17.4 percent) and eels (Japanese eel, *Anguilla japonica,* and European eel, *A. anguilla,* combined) (0.26 million tonnes or 7.9 percent). Norway and Chile are the world's leading aquaculture producers of salmonids, accounting for 36.4 and 28.0 percent of world production, respectively. However, Atlantic salmon production in Chile was hit hard by a disease outbreak – infectious salmon anaemia (ISA) – in 2009, leading to the loss of half of the production. Other European countries produced another

COURTESY OF KOJI YAMAMOTO

Litopenaeus vannamei *farm in low salinity area (foreground) adjacent to a paddy field (background) in Prachuap Khiri Khan Province, Thailand.*

FIGURE 3
**Trends in world aquaculture production: major species groups, 1970–2008**




*Note:* NEI = not elsewhere included.
*Source:* FAO (2010a).

18.9 percent of total salmonids, while Asia and North America contributed 7.9 and 7.4 percent, respectively.

With regard to marine fishes, flatfish production increased from 26 300 tonnes in 2000 to 148 800 tonnes in 2008, the leading producers being China and Spain. The major species concerned are turbot (*Scophthalmus maximus*), bastard halibut (*Paralichthys olivaceus*), and tongue sole (*Cynoglossus semilaevis*). For Norway, the production of Atlantic cod (*Gadus morhua*) grew significantly in the period 2000–08.

Slightly more than half the volume (0.35 million tonnes or 57 percent) of miscellaneous aquatic animals is produced in freshwater. The most important species are soft-shell turtle followed by frogs. Production in marine water (0.27 million tonnes or 43 percent) includes jellyfishes, Japanese sea cucumber and sea squirts as major species. All major species groups for aquaculture continued to increase in production in the period 2000–08 (Figure 2), although finfish and molluscs production grew at lower rates than in the period 1990–2000. The increased growth rate in the production of aquatic animals NEI (not elsewhere included) reflects the potential relevance of new species, although current production is still very low.

In contrast, crustaceans grew at an average annual rate of close to 15 percent in this period, faster than in the previous decade. The rapid increase in crustacean production was due largely to the dramatic increase in whiteleg shrimp (*Litopenaeus vannamei*) culture in China, Thailand and Indonesia, after the species was successfully introduced from Latin America. Figure 3 illustrates world aquaculture production by major species group in the period 1970–2008.

m aquaculture to the world total production of major species groups has increased markedly since 1950, except for marine fishes. Aquaculture in 2008 accounted for 76.4 percent of global freshwater finfish production, 64.1 percent of molluscs, 68.2 percent of diadromous fishes and 46.4 percent of crustacean production. Although cultured crustaceans still account for less than half of the total global crustacean production, the culture production of penaeid shrimps and prawns in 2008 was 73.3 percent of the total production. While the overall share of aquaculture in total production of marine fishes was as low as 2.6 percent, aquaculture dominates production for some species such as flathead grey mullet (*Mugil cephalus*), gilthead seabream (*Sparus aurata*), silver seabream (*Pagrus aurata*), European seabass (*Dicentrarchus labrax*), turbot (*Scophthalmus maximus*), cobia (*Rachycentron canadum*), red drum (*Sciaenops occelatus*) and bastard halibut (*Paralichthys olivaceus*). For many species now produced through aquaculture, the farmed production is substantially higher than the highest catch ever recorded.

Culture in earthen ponds is the most important farming method in Asia for finfish and crustacean production in freshwater and brackish water. In China, 70.4 percent of aquaculture production in freshwater relied on pond culture in 2008, while the rest of the production came from artificial reservoirs (11.7 percent), natural lakes (7.7 percent), rice paddy fields (5.6 percent), canals (2.7 percent) and others facilities (2.6 percent). The average yield of pond culture in China was 6.8 tonnes per hectare in 2008. Rice-fish culture, often operated at a family scale with renovated paddy fields, has expanded rapidly among rice farmers in China in recent decades; the total area of rice field used for aquaculture was 1.47 million ha in 2008, with an average yield of 0.79 tonnes of food fish per hectare. Rice fields produced 1.2 million tonnes of food fish in 2008, up 15 percent from the 2006 level. Egypt also produced 27 900 tonnes of food fish from rice-fish culture in 2008, accounting for 4 percent of the country's total production.

## PRODUCTION OF INTRODUCED SPECIES

Similar to other agricultural subsectors, the use of introduced species, in addition to indigenous species, has played an important role in increasing aquaculture production and profitability, particularly in Asia. For example, tilapias grown outside Africa reached 2.4 million tonnes in 2008, representing 8 percent of all finfish produced in freshwater and brackish water outside Africa. Whiteleg shrimp (*Litopenaeus vannamei*) introduced to Asia from America, have given rise to a boom in farming of this species in China, Thailand, Indonesia and Viet Nam in the last decade, resulting in an almost complete shift from the native giant tiger prawn (*Penaeus monodon*) to this introduced species. There is a long list of introduced species that have been relocated around the world and provided successful productions. Details of those introduced species are described in *The State of World Fisheries and Aquaculture 2010* (FAO, 2010a).


COURTESY OF TIM PICKERING

*Small-scale tilapia farming in Fiji is on the increase.*

# 3. Resources, services and technologies

## STATUS AND TRENDS

### Land and water

A major challenge to the sustainable development of aquaculture in many countries is the management of conflicts and competition for scarce land and water resources from other sectors, particularly agriculture, shipping, urbanization, tourism and nature protection. When analysed from a country's economic development perspective, the challenge is essentially a case of prioritization of different development activities that compete for use of a finite set of resources, ideally in a sustainable manner, supported by adequate policies, plans and regulatory measures. Many countries have adopted or are in the process of adopting measures to address this challenge through an ecosystem approach to aquaculture (EAA), including multiple or integrated use of water resources, land-use planning and aquaculture zoning.

The nature of conflicts and competition related to the utilization of water for aquaculture is different for freshwater, which originates from both surface water and groundwater sources, and marine water, and therefore warrants situation-specific strategic approaches. In the case of freshwater aquaculture, which accounts for about 60 percent of global aquaculture production, concerns have been raised as to whether aquaculture can continue to use large volumes of freshwater, particularly in open or flow-through systems, for production purposes. Today, agriculture uses more than 70 percent of all water withdrawals, and it is important that this usage is adapted to a future in which water will be reallocated to other users such as aquaculture and human populations (for consumption and other uses). However, the debate is rather complex, as aquaculture in freshwater ponds also contributes to water conservation. Furthermore, closed or recirculating aquaculture systems, which are increasingly used to culture species such as eels, catfish, turbot and tilapia, consume small amounts of water (World Bank, 2006), the bulk of the system water being recycled or reused. However, these account for only a very small percentage of aquaculture production. The bulk of catfishes and tilapias are still grown in open systems. On the other hand, cage culture in freshwater is one of the most water-efficient food production systems, as there is no water use other than that incorporated in fish biomass.

The risk of conflict arises where freshwater is constrained or stressed, as in the case of arid countries, or where freshwater is pumped from groundwater or aquifers. Nonetheless, even in such situations, aquaculture may not be a consumptive user, as effective integration of the water uses with agricultural activities such as farming and perhaps livestock rearing can result in net benefits for competing users (FAO, 2006a). Depending on the situation, water-stressed areas may require more innovative approaches, for example, the use of wastewater and hydroponics. Effluents from aquaculture could be effectively used in agriculture, providing great benefits.

Regarding the use of marine water for aquaculture, the competition is typically not for the quality or volume of water itself, but more often for the use of marine or coastal areas that are claimed for other purposes, such as fisheries, navigation, oil exploration, tourism and urban development. In many countries, effective land-use planning and coastal zoning have promoted healthy competition. Moreover, as land and coastal areas become scarcer, open waters (both near shore and offshore) of the sea


*Rice-fish farming in Guyana.*

are increasingly being considered for aquaculture, although economic, technical, social and environmental factors are often very relevant challenges.

In the global context, there are also differences in the magnitude of conflicts, competition and remedial approaches. Among the regions, Europe continues to seek solutions to reduce the region-wide fish and bird conflict, especially the impact of cormorants on fish farming and capture fisheries. The European Parliament's adoption of the resolution on a pan-European Cormorant Management Plan in December 2008 is an encouraging step in that direction (Váradi *et al*., 2011). In the case of Africa, generally, access to land and water resources by small-scale farmers may be restricted owing to the absence of national plans for land and water use, as well as the absence of zoning for aquaculture (Satia, 2011). In cases where resources are available, other limiting factors include insecurity in land ownership or lease, potential conflicts with other users and inappropriateness of land because of biophysical characteristics. However, to maximize water-use efficiency, integrated irrigation aquaculture is practised and promoted in Africa, particularly in the drought-prone countries of West Africa (Halwart and van Dam, 2006). In the Near East and North Africa region (e.g. Saudi Arabia), irrigation water destined for agriculture is initially used for tilapia farming to avoid contamination from pesticides used on the agricultural crops (FAO, 2006a).

Asia offers good examples of making efficient use of finite land and water resources through the integration of aquaculture into existing agricultural farming systems, particularly rice-fish farming. Indeed, China's experience in rice-fish farming in the last three decades is considered as a "success story in Asian aquaculture" (Miao, 2010). There are also many countries in the Asia region with adequate water resources; an example is Myanmar, which is considered an "aquaculturally emerging country", making substantial contributions to the region's fish production. In addition, India, which is currently the second-largest contributor to global aquaculture production, continues to make concerted efforts to increase production, including the rehabilitation of many thousands of hectares of coastal shrimp ponds that were abandoned in the late 1980s and early 1990s due to disease, through the adoption of better management practices (BMPs) by "small-scale farmer societies" that operate collectively as a unit (FAO/NACA, 2011).

The situation in North America is mixed. The Canadian coastline, which represents 25 percent of the world's coastline, is about 202 000 km long, and the total land mass is about 10 000 000 $km^2$, with a water surface area of about 891 000 $km^2$. In addition, Canada's three million lakes and rivers constitute 16 percent of the world's freshwater. These combined natural resources provide an abundance of potentially suitable sites for supporting both marine and freshwater aquaculture. Unlike Canada, the coastline of the United States of America, comprising 19 924 km, is largely well developed, resulting in competition for space in the coastal and nearshore environment that has the potential to create conflicts with other resource-user groups such as fisheries and tourism (Olin, Smith and Nabi, 2011). Moreover, there are very few areas with unallocated water to support significant new land-based freshwater aquaculture development. As a consequence, both the government and industry are looking towards expansion of the sector in nearshore and offshore waters.

In contrast, the Latin America and the Caribbean region is generally well endowed with freshwater resources, a long coastline and ample territories, features that offer good prospects for aquaculture development. The region contains about 10 percent of the world's population, 14 percent of the world's total land surface and 33 percent of the world's water resources. The annual volume of water resources per person (about 28 000 $m^3$) is much higher than the world average (6 442 $m^3$) (Wurmann, 2011) and, therefore, there is room for expansion of the sector. However, the very high freshwater biodiversity and the existence of broad areas of pristine inland aquatic environment present a challenge and the need for further expansion of the sector to be carefully considered.

**Seed supply and genetic resources**

In general, aquaculture is practised worldwide using a variety of marine and freshwater species, with seed supplied from both wild and hatchery sources. The scale of such practices is difficult to quantify because statistical records do not differentiate between production from capture-based aquaculture (CBA) and other forms of aquaculture in which hatchery-produced seed are used. However, according to one estimate (FAO, 2006b), about 20 percent of marine aquaculture production comes from CBA, representing a value of US$1.7 billion. No corresponding estimate has been made for freshwater CBA production.

The culture of many freshwater species also relies partly or fully on wild seed owing to a number of factors, such as: the supply from hatcheries is not adequate to meet demand; the quality of hatchery-produced seed is perceived to be inferior to wild-caught seed; and seed production technology has yet to be developed or is not yet cost-effective for the species in question. However, the industry continues to benefit greatly from aquaculture biotechnology and genomics research, leading to the closing of the life cycles of many cultured aquatic species; thus hatchery-produced seed is increasingly becoming the standard raw material for aquaculture, a trend that is likely to broaden in the future.

An adequate supply of quality seed is a major step towards establishing the foundation for sustainable global aquaculture production. Conversely, poor-quality seed, caused by factors such as unsatisfactory genetic management of breeders, accidental hybridization and unsatisfactory hatchery and nursery management could undermine the livelihoods of farmers, particularly poor farmers, and the integrity of the production chain. It is therefore important to ensure that hatchery seed production goes hand in hand with appropriate broodstock management plans and selective breeding programmes (FAO/NACA, 2011). Another related point is that the industry needs to practise the planned movement of broodstock, juveniles and seed, both internationally and domestically, to avoid potential impacts on genetic diversity and the translocation of pathogens.

An FAO study (Bondad-Reantaso, 2007) that included 21 country case studies from Africa, Asia and Latin America and three regional syntheses assessed freshwater fish seed resources for aquaculture. The desk study revealed that harvests from freshwater aquaculture will continue to contribute substantially to global aquatic production. The 21 country case studies were unanimous in their findings that the efficient use of freshwater fish seed resources will be necessary to guarantee optimal production from aquaculture. Overall, the study emphasized the importance of production and the supply of quality seed to farmers and reinforced the need to practise seed certification and accreditation as a quality assurance system. The system essentially ensures that certain minimum predetermined quality standards and criteria are met, e.g. genetic purity, appropriate husbandry, high grow-out performance and freedom from major pathogens.

In the study, Mair (2007) emphasized that approaches to genetic improvement using successful research findings (e.g. selective breeding, application of genetic markers, sex control techniques, chromosome set manipulation, crossbreeding and transgenesis) should be integrated with good genetic management during domestication and translocation of aquaculture stocks. In addition, such approaches should be supported by efficient and equitable dissemination and technology transfer strategies coupled with awareness and/or certification programmes. Strengthening awareness and institutional capacity to deal with ecological risks associated with introduced and/or genetically improved fish will be essential. The use of indigenous species and their domestication for freshwater aquaculture production should be promoted. Seed networking among breeders, hatchery and nursery operators, traders, growers and other input/service providers (e.g. water suppliers, transport providers, hormone sellers, nightsoil traders, extension workers) has become an important component of the freshwater aquaculture sector that enables accessibility and delivery of fish seed to areas distant from traditional sources, thus stimulating aquaculture development in marginal and remote rural areas. Seed networking should be promoted and supported with enabling policies and required infrastructure (Little, Nietes-Satapornvanit and Barman, 2007).

To improve the quality of seed, many countries have established regional broodstock management centres that are networked into a national broodstock centre. Examples include Indonesia (tilapia, catfish and common carp) and Viet Nam (four freshwater and three marine centres). The work in these centres has led to improvement of existing strains, for example, the development of a new strain, genetically supermale Indonesian tilapia (GESIT), based on GIFT stocks, and its dissemination to small-scale farmers in Indonesia (FAO/NACA, 2011).

Generally, the application of genetic principles to increase production from aquatic animals lags far behind that of the plant and livestock sectors. It has been estimated that less than 1 percent of the global aquaculture production comes from genetically improved stocks (Acosta and Gupta, 2010). While only a small percentage of farmed aquatic species have been subject to formal genetic improvement, the potential to do so for other species in the future is immense and needs continued research and development (R&D). Ongoing research work on seed improvement focuses on achieving desired attributes for farmed production, such as predictability, homogeneity, reduced seasonal variation, enhanced production parameters (e.g. size, reduced mortality and better feed-conversion ratios [FCRs]). A significant achievement to this end in the past decade has been the development of the GIFT strain of Nile tilapia, which has been hailed as a landmark development in the history of genetic improvement of tropical finfish. The development of the GIFT strain followed a traditional selective breeding programme as the technological approach for genetic enhancement, not the gene technology that leads to a genetically modified organism (Acosta and Gupta, 2010). Details on the GIFT strain are provided in Box 1.

BOX 1

**Food of the masses: the development and impact of genetically improved farmed tilapia (GIFT)**

**Development**

- 1982: Genetic characterization studies reveal introgression of genes of *Oreochromis niloticus* (Asian stocks) with *O. mossambicus.*
- 1987: An international workshop held in Bangkok confirms the poor genetic status of tilapia genetic resources in Asia and Africa.
- 1988: WorldFish Center and partners from the Philippines and Norway start the GIFT project; first direct transfer of pure stocks from Africa occurs.
- 1993: Selectively bred tilapia developed; the International Network on Genetics in Aquaculture (INGA) is established.
- 1994: GIFT strain disseminated and evaluated in five Asian countries with promising results.
- 1997: GIFT project completed; five generations of selection had been undertaken by then; Eknath and Acosta (1998) and Eknath *et al.* (1998) report an accumulated genetic gain of 85 percent over the base population, with 12–17 percent gain per generation. The GIFT Foundation established.
- 1999: The GIFT Foundation forms an alliance with a private-sector company (GenoMar ASA, GenoMar Supreme Tilapia); further improved strain developed and distributed to world's commercial market.
- 2000: GIFT technology transferred for development of national breeding programmes in Asia, Africa and the Pacific; GIFT strain disseminated in 11 countries in the Asia–Pacific region.
- 2004: Improved tilapias developed in most INGA member countries in Asia; dissemination of improved fish to public and private hatcheries initiated; development of a tilapia breeding programme in Africa in progress.
- 2007: WorldFish Center decides (WorldFish Center, 2007) to make GIFT fish available to African governments based on, among others, a clear plan for the management of environmental and biodiversity risks (e.g. introgression with wild Nile tilapia stocks). Introducing GIFT to Africa could improve growth of the current fish stock there by an estimated 64 percent (Ponzoni *et al.*, 2008; Yosef, 2009).
- 2010: In breeding, a private enterprise continues to develop new generations, with generation 21 already in the making. Multiple traits are targeted in the selection programme, such as improved growth and disease resistance. The enterprise uses genetic markers (DNA-based microsatellites) for pedigree information (www.genomar.com/?aid=9077478).

**Key impacts**

- An Asian Development Bank (ADB) impact evaluation study of GIFT involving four Asian countries reported that the introduction and dissemination of GIFT contributed significantly to food security, rural incomes and employment (ADB, 2005). As an example, the study noted that in the Philippines, farmed tilapia is recognized as the most important food fish for poor consumers. In 2003, the President of the Philippines stated that round scad (*Decapterus* spp.) would soon be replaced by tilapia as the "food of the masses". Moreover, as a source of protein in the Philippines, tilapia is generally more affordable than pork, beef and chicken. From 1990 to 2007, average tilapia prices increased by 111 percent, whereas beef prices rose by 148 percent and pork prices by 157 percent. Indeed, tilapia has also been labelled the "aquatic chicken" (Yosef, 2009).

Box 1 – Continued.

- In terms of the contribution of GIFT and GIFT-derived strains to the national supply of tilapia seed, the ADB impact evaluation study found that, in the Philippines, they accounted for 68 percent of the total tilapia seed produced in 2003 (ADB, 2005). In the same period, in Thailand, GIFT contributed to 46 percent of all national tilapia seed production.
- The GIFT technology has been successfully applied for genetic improvement of various carp species in six Asian countries. In India, the improved roho labeo (*Labeo rohita*, Jayanti strain) is considered as the first genetically improved fish of the country (Das Mahapatra *et al*., 2006). In China, the selection experiments with Wuchang bream (*Megalobrama amblycephala*) indicated that the fifth generation of selected strain increased 30 percent relative to the control group. Consequently, in 2002, the Chinese Ministry of Agriculture certified the fifth generation of selected bream as a good breed for aquaculture development (Li, 2002).
- GenoMar reported that, by applying its state-of-the-art breeding technology, it has demonstrated increased genetic gain per year of 35 percent when compared with conventional breeding programmes. It now produces a new generation every nine months, with genetic gain of more than 10 percent in growth (www.genomar.com/?aid=9082291).

*Source:* Adapted from Gupta and Acosta (2004) and Acosta and Gupta (2010).

Bartley *et al.* (2009) reviewed the use and exchange of aquatic genetic resources in aquaculture, particularly addressing the information relevant to access and benefit sharing on aquatic genetic resources.

The most recent technological breakthrough in the advancement of aquaculture is the closing of the life cycle of southern bluefin tuna (*Thunnus maccoyii*) in southern Australia. This achievement was ranked second of all the 50 best inventions in 2009 by *TIME* magazine (Kruger, 2009). The successful spawning of southern bluefin

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*Post larvae culture tanks of* Penaeus monodon *and* Litopenaeus vannamei *in a large scale hatchery using imported SPS broodstock from overseas, in Bac Lieu Province, Viet Nam.*

tuna in captivity, initiated by Kinki University in Japan[3] and mastered in Australia, is considered timely as, globally, tuna stocks are in dramatic decline, with the numbers of southern bluefin tuna down by almost 90 percent in many areas. Encouraging advances have also been achieved in the spawning of Atlantic bluefin tuna (*Thunnus thynnus*) in captivity. In an experiment conducted in cages off the coast of Croatia in the Adriatic Sea, gametogenesis was achieved and the eggs were spawned without hormones or human assistance (Jalbuena, 2009).

Progress has also been made in life cycle manipulations (photoperiod regimes) in trout and salmon that prepare fish for spawning throughout most of the year. Thus, the salmon industry has been transformed from a highly seasonal industry with only wild species available almost exclusively from July/August to November of each year, to one that can supply good quality fish to the market on a year-round basis, thereby meeting the ever-growing demand for fish in the United States of America, European markets and elsewhere.

Furthermore, genetic work on common carp in carp-producing countries of Europe is contributing not only to a better seed supply to European producers but also to carp-breeding programmes in Asia (Jeney and Zhu, 2009).

There have also been impressive developments in the breeding and domestication of shrimp, the largest single internationally traded fishery product. Specific pathogen free and specific pathogen resistant domesticated stocks of whiteleg shrimp (*Litopenaeus vannamei*) have been widely developed and commercialized. Globally, shrimp farming using domesticated *L. vannamei* expanded from only 10 percent of total shrimp production in 1998 to 75 percent of total world shrimp production in 2006 (Wyban, 2007). In addition, work on the domestication of *Penaeus monodon*, the most widely used species in Asia before the outbreak of white spot disease that caused substantial economic losses to the industry, has been going on since the 1970s under several programmes conducted by research institutes and private companies in Australia, Belgium, France, Madagascar, Malaysia, the Philippines, Tahiti (French Polynesia), Thailand and the United States of America (Hoa, 2009). These domestication developments will eventually reduce dependence on wild-caught postlarvae, which have a high risk of introducing pathogens into the culture environment and also result in substantial bycatch losses of other aquatic organisms.

At the global level, the Commission on Genetic Resources for Food and Agriculture, the only permanent forum for governments to discuss and negotiate matters relevant to biological diversity for food and agriculture, considered the issue of managing aquatic genetic diversity for the first time in 2007. As a first step toward compiling the first "State of the World's Aquatic Genetic Resources" for 2013, the commission has launched a review of existing information systems, and plans to develop a more streamlined reporting system for national and international organizations. With the number of farmed fish strains, hybrids and other genetic resources increasing in aquaculture, the commission's review will be useful to identify and determine their relative contributions to farmed fish production.[4]

### Feed

Aquafeeds and feeding practices vary significantly according to farming system, species under culture and stocking intensity. Species that are primarily dependent on aquafeed include carnivorous fish and shrimps (e.g. marine finfish, salmonids, eels, marine shrimps and freshwater prawns) and herbivorous and omnivorous fish (e.g. most of the non-filter-feeding carps, tilapia, catfish and milkfish). Filter-feeding finfish (e.g. silver carp [*Hypophthalmichthys molitrix*] and bighead carp [*H. nobilis*]) can derive

[3] See: www.kindai.ac.jp/english/research/aquaculture.html
[4] See: www.fao.org/nr/cgrfa/cthemes/aqua/en/

their dietary requirements from phytoplankton and zooplankton and thus do not necessarily need supplementary feed.

It was estimated that in 2008 about 31.5 million tonnes or 46.1 percent of global aquaculture production (including aquatic plants) was dependent on the direct use of feed, either as farm-made or home-made formulated aquafeed or industrially manufactured compound aquafeed (Tacon, Hasan and Metian, forthcoming). In terms of quantity, the major consumers of aquafeed are herbivorous and omnivorous fish. In 2008, an estimated 28.8 million tonnes of compound aquafeed were produced, of which about 31 percent was consumed by carps. On the other hand, while carnivorous fish and shrimps consume relatively less feed, they cannot thrive without fish or other marine proteins as a major component of their diet. Broadly, there are three methods of using fish as fish feed: in raw unprocessed form, mixed with agricultural products and fish by-products, and in the form of fishmeal and fish oil, mainly derived from the reduction of small pelagic fish.

A study (Hasan *et al*., 2007) on the status and trends concerning the use of aquaculture feeds and nutrients in 20 countries covering three regions (Asia, Latin America and sub-Saharan Africa) reports that there are notable differences between the regions with regard to the production and use of aquafeeds, with each region having its own set of priorities for development of the aquafeed sector. Aquaculture in Asia is primarily rural and pond-based semi-intensive farming of species that feed low on the food chain and depend mainly on farm-made feeds. A good case in point is the large-scale carp farming systems in Andhra Pradesh, India, which are almost totally dependent on feed based on mixes of agricultural by-products (FAO/NACA, 2011). However, intensification of farming practices involving shrimp and some freshwater and marine carnivorous species is driving the growth of the industrially manufactured aquafeed sector.

The Asia region has seen an increase in the number of small-scale producers engaged in making customized feeds according to required specifications, a process that has lead to greater feed efficacy, reduction in feed costs and improved feed quality. It is predicted that by 2013 farm-made feed usage in Asia will increase to 30.7 million tonnes, representing a growth of 60 percent from the levels of 2003–04. The study by Hasan *et al*. (2007), however, emphasizes the need to further improve farm-made feeds through research and development programmes focusing on factors such as ingredient quality, seasonal variability, marketing and storage, and improvements in processing technology. The R&D efforts need to be supported by improved extension services (De Silva and Hasan, 2007).

In Latin America, given the semi-intensive and intensive nature of most farming systems, with salmonids, shrimps and tilapia accounting for the bulk of production, the aquaculture sector is mainly dependent on industrially manufactured feeds, which are readily available in most countries. The region is also generally self-sufficient in fishmeal and fish oil, with Peru and Chile contributing almost half of the world's fishmeal production. In contrast, many Asian and sub-Saharan African countries are net importers. Farm-made feeds are rarely used in Latin America, except in localized areas in some countries such as Brazil and Cuba, where a small number of small-scale farmers occasionally use agricultural by-products to replace or complement formulated complete diets. However, to stimulate rural aquaculture, the knowledge and capacity of small-scale farmers need to be enhanced to produce low-cost, farm-made aquafeeds based on the wide range of locally available ingredients in the region (Flores-Nava, 2007).

In sub-Saharan Africa, more than 70 percent of the total regional production is produced on semi-intensive and intensive commercial farms (e.g. tilapia, catfish, shrimp and abalone) by less than 20 percent of the farmers (Hecht, 2007). The remaining less than 30 percent is produced by small-scale subsistence farmers, who comprise over 80 percent of all farmers. Thus, large-scale commercial aquaculture


*Feed distribution using automatic feeder for cage cultured Atlantic salmon near Bodo, Norway.*

is primarily dependent on industrially manufactured feeds. It is expected that the domestic aquafeed industry will grow with the expansion of commercial aquaculture enterprises. Availability of farm-made aquafeeds produced by small-scale commercial feed producers is also likely to increase and play a pivotal role in the expansion of rural commercial aquaculture. For improved utilization of feed resources in the region, the study's recommendations include: developing appropriate manufacturing machinery and bulk storage facilities; developing country-specific farm-made feed formulations; ensuring effective dissemination of information, such as availability of ingredients and formulations; and developing country-specific animal feed standards and reviewing pertinent legislation to ensure stability, quality and food safety.

In summary, there are a few feed-related issues that the aquaculture industry in the three regions needs to address. They are: (i) reducing dependence on fishmeal and fish oil; (ii) ensuring national quality standards for raw materials, feed additives and feeds; (iii) facilitating safe and appropriate use of aquafeeds produced by small-scale manufacturers; and (iv) building the capacity of small-scale farmers to make more effective farm-made feeds.

The financial viability of aquaculture investments is highly dependent on the total price paid for aquafeeds, which generally account for 50–70 percent of production cost. Generally, the impact of increased feed price, as in the case of the recent increase in global food prices, will vary between countries and regions and depend on the trends in species used and levels of intensification of farming systems (Rana, Siriwardena and Hasan, 2009). Thus, in contrast to salmonid culture in Europe, an increase in fishmeal and fish-oil prices may not have a significant impact on tilapia, catfish and carp farming in most of the Asian and sub-Saharan African countries, as the proportion of fishmeal and fish oil in the diets of such species is relatively low, typically 2–7 percent for fishmeal and 1 percent for fish oil. In contrast, the high price of other ingredients (e.g. cereal and cereal by-products, the usual sources of carbohydrate in most of the aquafeeds) may have a profound impact (also see Chapter 7).

In the past decade, policy-makers, research institutes and private-sector feed manufacturers have been paying increased attention to the sustainable use of fish as feed in aquaculture, primarily the use of fishmeal and fish oil (Box 2).

BOX 2

**Fishmeal and fish oil: trends in use and prices**

Fishmeal and fish oil are preferred components in the feed of many land-farm animals, including swine, poultry and dairy cattle. In 2002, aquaculture used 45 percent of the total global annual fishmeal production, and by 2006 its share increased to 57 percent. This growth was the result of a reduction in the share of fishmeal used for land-farm animals, rather than an increase in the pelagic fish catch that is used for fishmeal. In particular, poultry's share registered a sharp decline from 22 percent to 14 percent over the four-year period. In the case of fish oil, aquaculture's share was about 87 percent of the total global annual production in 2006, with the remaining 13 percent used for a variety of purposes, including direct human consumption and land-farm animal feed. It has been estimated that, by 2012, 60 percent of world fishmeal production and 88 percent of world fish oil production will be used by aquaculture (Huntington and Hasan, 2009).

Global production of fishmeal and fish oil has stabilized at 6–7 million tonnes and 1 million tonnes, respectively, resulting in increased competition for a limited supply of resource between the expanding aquaculture and livestock sectors (FAO, 2006a). It has been argued that the growing demand for fishmeal and fish oil will continue to drive the price upwards and that the price could reach a level where the use of fishmeal and fish oil may no longer be financially viable. The European Feed Manufacturers Federation has accordingly suggested that the fish feed industry reduce the inclusion of fishmeal and fish oil by 5–10 percent per year between 2007 and 2010 in order to support a sustainable aquaculture development (Váradi *et al*., 2011).

Analysing the trends in prices of fishmeal and fish oil and their alternative ingredients, soymeal and rapeseed oil, respectively, over the past decade, including the last couple of years that saw significant increases in global food prices, Jackson (2010) points out that despite the fact that fishmeal and fish oil production is not increasing, their prices are remaining stable against alternative ingredients. Moreover, for the last few years, the amount of fishmeal and fish oil has remained static, while output from aquaculture has continued to increase. He therefore stresses that the higher prices of fishmeal and fish oil alone are not limiting the growth of aquaculture, rather that the higher prices of all feed ingredients could have an impact on the pace of aquaculture growth.

The continuing concerns about the use of fish as feed and the rising prices of fishmeal and fish oil have led to considerable investments in research to find alternative sources of affordable and high-quality plant and animal-based feed ingredients. Fishmeal could be replaced by vegetable protein concentrates, including genetically modified derived feed materials (i.e. soybean meal, rapeseed meal). However, such replacement results in increased costs in the form of enzymes to remove antinutritional factors and amino acids to improve the nutritional profile. The replacement of fish oil appears to be a challenge because of the difficulty in finding alternative sources of omega-3 fatty acids.

Among the ongoing research activities, Researching Alternatives to Fish Oils in Aquaculture, coordinated by the University of Stirling, the United Kingdom, and Perspectives of Plant Protein Use in Aquaculture, coordinated by the Institut National de la Recherche Agronomique, France, focus on targeted reduction of dependence on fishmeal and fish oil. As an example, salmon's current inclusion of fishmeal of between 35 and 47 percent is expected to be reduced to 12–16 percent (Rana, Siriwardena and Hasan, 2009). Moreover, as a positive impact of research, the FCRs of salmons and trouts are about 1.3 and are likely to remain at this level over the next few years, while FCRs of other fish and crustaceans are expected to be reduced over the next ten years. Among others, FCRs for selected species are: carps: 1.8–1.6, catfish: 1.5–1.3, milkfish: 2.0–1.6, and shrimps: 1.6–1.4 (Tacon, Hasan and Metian, forthcoming).

Box 2 – Continued.

Nonetheless, further research in aquaculture nutrition will continue to find better substitutes that could partially replace and supplement fishmeal and fish oil. In doing so, consideration should be given to environmental factors and consumers' perceptions with regard to risks and benefits of substitutes.

The use of trash/low-value fish in aquaculture is another important issue that is being considered by policy-makers. It is estimated that some 5–6 million tonnes of trash/low-value fish are used as direct feed in aquaculture worldwide (Tacon, Hasan and Subasinghe, 2006), particularly for marine carnivorous fish species (e.g. in China, Indonesia, Thailand and Viet Nam), marine crustaceans (lobsters and crabs) and certain freshwater fish species (Hasan and Halwart, 2009). Based on production estimates of commodities in 2004 that rely on trash fish/low-value fish as the main feed source, one estimate (De Silva and Turchini, 2009) placed the Asian use of trash fish as fish feed at between 2.465 and 3.882 million tonnes per year. Moreover, it has been estimated that by 2013 aquaculture in Viet Nam and China may require about 1 million tonnes and 4 million tonnes of trash/low-value fish, respectively (Hasan *et al.*, 2007). Hence, the demand for trash/low-value fish is likely to continue unless viable alternatives become available. There are, however, growing concerns that the continued use of trash/low-value fish may result in adverse environmental effects and biosecurity risks. In addition, there are mounting claims that the so-called "trash fish" could be used as human food, an issue that has been addressed in a recent study (Hasan and Halwart, 2009). The industry urgently needs to reduce its dependence on trash/low-value fish through the development of suitable dry pellet feeds and must convince farmers of the benefits of using such feeds (De Silva and Hasan, 2007).

To address the issue, successful farm trials in four countries (China, Indonesia, Thailand and Viet Nam) under an ongoing FAO-supported Technical Cooperation Programme have demonstrated the technical and economic feasibility of using pellet feeds to displace direct use of trash/low-value fish in marine finfish culture (Miao and Funge-Smith, 2010; FAO/NACA, 2011).

A recent global study (Huntington and Hasan, 2009) has recommended a set of measures on sustainable sourcing of raw materials for aquafeed for consideration by policy-makers and other stakeholders. In summary, the study emphasizes improving the management of feed fisheries, including the piloting of innovative approaches such as the certification of responsibly managed fisheries; adopting feed fisheries sustainability criteria and the branding of aquafeeds produced using sustainable raw materials; continuing further development of plant and other substitutes for fishmeal and fish oil; and developing economically competitive food products for direct human consumption from species that are currently reduced to fishmeal and fish oil.

It is encouraging that the private sector has already initiated steps to implement some of the above global study recommendations. To facilitate the aquaculture industry to continue its growth in a sustainable way, the International Fishmeal and Fish Oil Organisation, assisted by the Global Aquaculture Alliance and other stakeholders, has been developing a Global Scheme for Responsible Supply. The scheme is a third-party audited set of standards that enables fishmeal and fish oil producers to demonstrate that their raw materials come from fisheries managed according to FAO's Code of Conduct for Responsible Fisheries (Jackson, 2010).

## Farming technologies

Farming technologies used in aquaculture depend mostly on the species farmed, the levels of inputs used and production targeted, the state of the production environment and the profile of the producer. Over the past decade, technological advances have


*Bang-hak farmer club in Chonburi Province, Thailand formulates their own floating tilapia feeds using small milling machinery provided by the Thai Department of Fisheries.*

COURTESY OF KOJI YAMAMOTO

COURTESY OF MOHAMMAD R. HASAN

*Preparation of trash fish/low-value fish for feeding of mouse grouper in a cage farm, Lampung bay, Lampung, Indonesia.*

contributed substantially to aquaculture production throughout the world, and further development of technology and management systems will be essential to enable the aquaculture sector to meet the ever-growing demand for safe and quality products. Essentially, new technologies will be required to make more efficient use of natural resources (e.g. water, land, energy and feed ingredients) and improve the productivity and overall economic efficiency of aquaculture farms.

Overall, significant improvements have been achieved in the areas of: aquatic animal health management and disease control; feed management (e.g. the development of underwater surveillance systems to manage feeding and biomass (especially in salmon cage culture), reduction in fishmeal usage and FCRs); the environmental performance of aquaculture systems (including more efficient recirculatory systems); energy and labour-efficient cage systems; human health and safety; and the quality of aquaculture products. These improvements have led to a more positive public perception of the sector.

The development of new and improved farming systems, particularly cages and innovative enclosure systems for fish culture in offshore and high-energy coastal and ocean environments, has taken place in many parts of the world, particularly in Europe and North America (Halwart, Soto and Arthur 2007). Asia is benefiting from these developments, and the modern technologies are being adopted. For example, the Norwegian salmon industry now produces more than 1 100 tonnes of salmon in 60 000 $m^3$ cages, a biomass corresponding to 2 200 cows on land (Subasinghe, Soto and Jia, 2009). The environmental impacts of these systems are minimal, as they are fully researched, tested and closely monitored during operations to ensure sustainability. However, for such systems to be successful in Asia, they need to be efficiently operated and closely monitored so that they receive broad public acceptance.

Further improvements in aquatic animal health management and disease control will enable aquaculture development in all regions and across all scales of enterprise from small to industrial scale. The recent production of specific pathogen free and specific pathogen resistant shrimp broodstocks is considered a major technological breakthrough. To address the strict food safety and quality requirements of importing countries, there is an increasing use of microbial inoculants and probiotics instead of antibiotics and chemicals. The former are intended to improve the water and soil quality, minimize the risk of bacterial infection through exclusion or improve feed utilization. There is also an increasing use of nutraceuticals, including herbal products, to replace chemical therapeutants. The use of molecular techniques for pathogen screening and identification is providing significant insights into pathogenesis (disease development), showing strong potential for application in disease control and prevention programmes, as well as for treatment of diseases (e.g. DNA vaccines). Development of vaccines for the industrial-scale salmon industry in Europe and Latin America and, more generally, for freshwater and marine fish culture, will enable development of marine and freshwater fish culture across all commercial scales.

Technology development through nutritional research will be an important enabling factor leading to improved quality and cost-effectiveness of aquaculture feeds that will utilize new protein and fat sources as feed ingredients, eventually reducing reliance on marine protein sources (Subasinghe, 2009). Significant improvements in weight gains in salmonids have been achieved through genetic research. Further genetic improvement by selection against disease and for improved growth and other desirable traits, as in the case of tilapia (GIFT), will benefit aquaculture development across regions. Seed production for new marine species will also become a critical factor enabling aquaculture in the next decade.

Technology development will also enable improvements in the environmental performance of aquaculture systems, improve the safety and quality of aquaculture products and, combined with effective education and information, lead to a more positive public perception of the sector.

Globalization and the increased flow of new technologies between countries will minimize differences between established and newly emerging industries and, in the process, help the small-scale sector as well. Investment by the private sector will most probably be oriented towards larger-scale industrial aquaculture or towards aquaculture commodities with significant value. The R&D basis for the small-scale sector may need more targeted government interventions to ensure a balance with industrial-scale development. However, this R&D effort will only provide sustainable solutions to poverty and livelihood improvement if it leads to competitive small-scale aquaculture (Subasinghe, 2009).

### Aquatic animal health support services

In the recent past, major aquatic animal disease outbreaks in various parts of the world have disrupted aquaculture production with severe consequences in terms of financial losses incurred by both large and small-scale farmers. As preventive measures, it is, therefore, important that countries develop their human capacity and physical facilities for the diagnosis of aquatic animal diseases and the timely treatment of affected animals with safe drugs. (Chapter 4 provides supplementary information on a comprehensive or holistic aquatic animal health management plan.) While the regions and the countries within the regions are at different stages of development with regard to animal health services, Europe, particularly European Union (EU) member countries, and North America are relatively well advanced. In the last decade, there have also been substantial developments in Asia and in some countries in Africa and in Latin America and the Caribbean.

In Europe, aquatic animal health support services, supported by research, contribute to the development of new medicines and treatment methods. The private sector's contribution to addressing aquatic animal health risks extends beyond the region, as

European pharmaceutical companies produce a large variety of veterinary medicines for the world market. However, one of the major problems for the aquaculture industry in Europe and also one that concerns the global aquaculture industry is the limited availability of licensed or authorized veterinary medicinal products for aquatic animal health (Váradi *et al.*, 2011). For example, the severe shortage of drugs for minor use minor species, which includes fish except salmonids, has been globally recognized as a critical issue in aquaculture development.

Other related global issues that need to be considered by the aquaculture sector include improving and strengthening the fisheries–veterinarian dialogue and cooperation and promoting certification of aquatic animal health service providers (Bondad-Reantaso and Subasinghe, 2008). As part of the initiative to improve the fisheries–veterinarian dialogue, a restructuring of the veterinary curricula to include aquatic species will be of central importance. Similarly, fishery biologists will have to embrace veterinary knowledge. With regard to certification, it is expected that certified providers will provide confidence to importers and consumers regarding product quality and safety.

The Federation of European Aquaculture Producers (FEAP) identified a number of factors (e.g. cost and time of licensing process, non-transferability of licences, and domination of the pharmaceutical market by a small number of international companies) leading to the limited availability of licensed products to treat diseases and parasites in farmed fish (FEAP, 2004). The FEAP also identified a number of actions to address this issue, namely: authorized products should be licensed for salmonids or finfish rather than for a single species, the time frame for a newly licensed product should be extended to 15 years and generic products should be made widely available.

Special measures have been introduced in Norway and in some EU countries, including the United Kingdom, to address the issue of drug shortage. The United Kingdom now permits registration of a veterinary medicine product within two days provided that the drug is well defined and manufactured and licensed within the EU. In the case of Norway, vaccines, even in a preliminary development stage, can be imported to address

COURTESY OF MATTHEW BRIGGS

*Fully equipped PCR laboratories are common in most major shrimp producing countries in the world.*

major diseases provided that the drug demonstrates safety for the aquatic animals and has some basic efficacy data (Váradi *et al*., 2011). Generally, there has been a reduction in the use of antimicrobials and a preference for development and use of vaccines.

With regard to the status of aquatic animal health support services in North America, following the outbreak of infectious diseases in the early 2000s, both the Canadian and the United States Governments have accorded treatment of diseases a high priority, resulting in increased collaboration between research institutes and the private sector in developing effective and safe drugs. In Canada, a multistakeholder national working group on fish health management in aquaculture recently identified sea lice, bacterial kidney disease and other bacterial pathogens as issues of greatest concern (Olin, Smith and Nabi, 2011).

In the Asia–Pacific region, the capacity of professionals, both at the public- and private-sector levels, to undertake disease diagnosis and the availability of laboratory facilities to analyse diseases of concern to the region have increased substantially in the last decade (FAO/NACA, 2011). Indeed some of the laboratories from the region are now recognized as World Organisation for Animal Health (OIE) reference laboratories for some of the major diseases, such as epizootic ulcerative syndrome, white tail disease and white spot disease. Moreover, there is an increasing trend in the region to apply modern disease diagnostic methods such as the use of polymerase chain reaction (PCR) technology to service the shrimp farming sector. In many countries (e.g. India, Indonesia, Thailand and Viet Nam), government and private PCR service-providing laboratories are screening samples of shrimp broodstock and seed (postlarvae), thus enabling hatchery operators and farmers to make science-based decisions that eventually assist them in securing a higher return on investment. The region as a whole also stands to gain, as economic losses are avoided due to the use of virus-free broodstock and seed.

In the case of Latin America and the Caribbean, a challenging issue is to strengthen the capacity of some countries, particularly countries other than, for example, Chile and Ecuador, which are relatively well developed, to take preventive actions with regard to aquatic animal disease outbreaks. Another constraint is that the region does not have a sufficient number of trained staff to deal with disease-related issues. It has been suggested that the region consider seeking technical support from international institutions such as FAO (Wurmann, 2011).

In Africa, very few countries (e.g. Egypt, Nigeria and South Africa) have specific aquatic health support services. Many countries, including those with fish and fishery products export industries, depend on services provided by the veterinary or public health services (Satia, 2011).

## Aquaculture capital

Aquaculture capital is broadly defined as funds provided by lenders and investors to private entrepreneurs, both large-scale and small-scale, for the purpose of starting new aquaculture-related businesses or scaling up of existing businesses. Funds could come from a variety of lending sources: informal (e.g. moneylenders, intermediaries or input suppliers, friends and relatives), semi-formal (e.g. non-governmental organizations [NGOs]) and formal sources (i.e. public- and private-sector financial institutions). However, owing to the absence of systematic recording and collating of data by funding sources at the regional and country levels, it is difficult to quantify the total amount of such funds channelled to the aquaculture sector and, hence, the proportion of lending by each source. Nonetheless, this section provides an overview of the characteristics of the aquaculture financial markets. Moreover, the definition of aquaculture capital is extended to cover financial assistance to national aquaculture sectors (governments and the private sector) by multilateral and bilateral international development agencies.

***Funds to private entrepreneurs***

It is important to note that access to timely, affordable and adequate financial capital is a precondition for the successful operation of aquaculture businesses. However, financial institutions in all the regions are generally cautious in extending loan facilities to aquaculture producers because of the inherent risks involved, such as outbreaks of disease that could totally eliminate stocks, the long production cycle needed for repayment and the lack of adequate collateral to cover risks, in most cases by small-scale producers.

However, in the developed countries of North America and Europe and in some countries of Latin America and the Caribbean, producers generally have relatively better access to capital from a variety of sources, including support from governments. These sources include, for example: the European Fisheries Fund, which is cofinanced by member states; the United States Department of Agriculture Farm Service Agency, which provides farm ownership and operating loans to those who are unable to obtain commercial credit from banks; the Chilean Economic Development Agency (Corporación de Fomento de la Producción); financial support provided to salmon farmers by three multinational feed producers in Chile that account for over 80 percent of the market; and venture capital investment and stock market funds (e.g. the Greek and Norwegian stock exchange markets).

In the case of Africa, few examples of formal credit facilities extended to small farmers exist. In some countries (e.g. Kenya, Malawi and Nigeria), soft credit lines for aquaculture projects are provided by agricultural development banks and commercial banks. In Malawi, the "Malawi Gold Standard" (a programme funded by the United States Agency for International Development) supports lending to emerging small-scale commercial farmers. Abban *et al.* (2009) reported that only 12 percent of aquaculture producers in Ghana are able to obtain loans from either agricultural or commercial banks. Thus, access to finance by small farmers remains one of the major constraints to expand and intensify production. The access issue mainly arises owing to the absence of collateral, as small-scale farmers typically do not own land or have


*Small-scale commercial aquaculture is promoted in Africa through development projects.*

water rights. Moreover, high interest rates, lack of famers' capacity to prepare viable and bankable projects, and local banks' lack of expertise to evaluate aquaculture loans add to the problem.

Owing to the difficulties of obtaining loans from formal sources in Africa, some producers, particularly non-commercial farmers, finance their activities with funds provided by friends and relatives. Commercial farmers, on the other hand, often have access to loans from their producers associations and input suppliers and traders. The latter usually require farmers to sell their harvest to them. In general, notwithstanding the problems indicated, overall access to finance, be it through formal or informal sources, appears to have improved, particularly in North and West African countries and in Kenya and Uganda (Poynton, 2006; Ngugi and Manyala, 2009; Abban *et al.*, 2009). Furthermore, large commercial farms with support provided by foreign investors do not seem to have had capital and liquidity problems, but this situation could change owing to the impact of the global economic crisis.

The pattern in Asian (e.g. in Bangladesh and India) aquaculture financial capital markets is generally similar to Africa. In particular, small-farmers, including subsistence farmers' credit needs are largely obtained from informal and semi-formal (e.g. NGOs) sources. India offers a good model, which is being replicated in some countries in the region, for effectively providing financial and other aquaculture support services to small-scale producers through adoption of BMPs and formation of "aquaclubs/societies" and clusters (Box 3). Cluster organizations reduce transaction costs, offer economies of scale and improve access to financial services and the ability to manage funds.

Currently, in India, most of the farmers belonging to such societies purchase feed (60–70 percent of total expenses) on credit from feed suppliers and repay after harvest. The balance of the expenses is borne by the farmers. The BMP programme management is currently negotiating with banks and insurance companies to obtain credit and premium insurance coverage for farmers (Box 3). Another important development with regard to credit in Asia is the Government of Viet Nam's direct support to realize the potential of striped catfish (*Pangasianodon hypophthalmus*) within the context of the country's aquaculture development. In addition to research and trade promotion support, the Government has arranged support for bank loans to both producers and processors (Thanh Phuong and Oanh, 2010).

***Funds to national governments***

Aquaculture capital provided by bilateral and multilateral development institutions has been useful in the development of aquaculture, particularly in the areas of capacity building, applied research, development of codes of practice and capital for investment in the production chain. Between 1988 and 1995, the total value of development aid for aquaculture development was US$995 million, of which the three major international development banks (World Bank, Asian Development Bank [ADB] and Inter-American Development Bank) financed 69 percent. From 1974 to 2006, the World Bank's investment in aquaculture-related projects was just over US$1 billion. However, its portfolio was skewed in terms of geographic distribution, with Asian countries receiving 91.4 percent of loans by value, followed by Latin America (3.2 percent) and Africa (1.4 percent). In terms of quality of loans, of the 21 completed projects, only two were rated unsatisfactory (World Bank, 2006). From a country perspective, Bangladesh, one of the largest recipients of funding to aquaculture-related activities, received US$264.1 million between 1985 and 2005. Of the total amount, the World Bank and the ADB contributed about 50 percent, the balance being contributed by eight other donors, including 15 percent by the Department for International Development (DFID) (WorldFish Center, 2005).

BOX 3

**Successful adoption of better management practices (BMPs) in India (2002–09)**

In the area of aquaculture support services, a major success story in Asia is the adoption of better management practices (BMPs) in India by small-scale shrimp farmers who are organized into "aquaclubs/societies" and clusters. The BMP model is a good example to the rest of the world for supporting sustainable small-scale aquaculture development and management.

Under a collaborative project between the Marine Development Authority, India, and the Network of Aquaculture Centres in Asia-Pacific (NACA), supported by FAO, shrimp farmers collectively implemented BMPs to reduce disease-related losses, improve yields and produce safe and quality shrimp. In 2006, the project was implemented in five coastal states. The BMPs were promoted in 28 clusters (aquaclubs) comprising 730 farmers (compared with five clusters in 2002) with 1 370 ponds. The production of BMP shrimp increased from 4 tonnes in 2002 to 870 tonnes in 2006. The prevalence of shrimp disease was reduced from 82 percent in 2003 to 17 percent in 2006. Farmers also had higher profitability and lower cost of production. In the demonstration ponds, for every US$25 invested by a farmer, around US$13 was earned as profit in 2006, compared with US$6 by non-demonstration farmers. The project also improved the farmers' ability: to articulate demands and to interact with markets and market forces; to access financial services; and to improve their farming skills, technical knowledge and awareness on pollution.

The Government has been a driving force behind the success of the BMP model. To consolidate and expand the BMP activities after project closure, in 2007 the Government established the National Centre for Sustainable Aquaculture (NaCSA) under the administrative control of the Marine Products Export Development Authority. In 2008–09, this centre extended support to 251 societies covering 6 486 farmers in five coastal states. Ongoing activities include: continued use of hatchery-supplied seed and the pilot testing of specific pathogen free *Penaeus monodon* seed in society farms; discouraging the use of unnecessary chemicals and encouraging no use of antibiotics; use of a digitalized database supported by geographic information systems (GISs) as part of the traceability programme; pilot testing of World Wide Fund for Nature (WWF) shrimp dialogue standards by societies; and working with banks and insurance companies to obtain credit and premium insurance coverage. Outside India, the BMP approach has been adopted by several countries in the Asia region (e.g. Indonesia and Viet Nam) and is expected to spread to countries in other regions.

*Note:* The concept of BMPs is based on International Principles for Responsible Shrimp Farming, which was developed by FAO, NACA, the United Nations Environment Programme Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, the World Bank and the WWF Consortium on Shrimp Farming and the Environment. On 8 November 2006, the consortium programme received a World Bank Green Award for its efforts towards responsible shrimp farming.

*Source:* Umesh *et al.* (2010).

## Aquaculture insurance

The worldwide aquaculture insurance sector is at a preliminary stage, despite the increase in demand for insurance to share the risks associated with the rapidly changing production processes. Although there has been a considerable increase in premiums, which have grown from about US$100 000 in 1974 to US$50 million in 2002 and to US$100 million at present, these represent only a miniscule proportion of the value of the world's farmed fish stock (van Anrooy *et al*., 2006; Váradi *et al*., 2011).

A global review of the aquaculture insurance sector by FAO (van Anrooy *et al*., 2006) reported that a conservative estimate of the total number of aquaculture policies in force would be between 7 500 and 8 000, with some 5 000 policies in the Asia region, indicating that less than 1 percent of the estimated 11 million farmers are insured. Aquaculture insurance policies differ according to species, culture system and identified risks. The aquaculture insurance market structure is dominated by a small number of international and national underwriters and reinsurance companies. The global review's recommendations included joint efforts by stakeholders to raise awareness through education and outreach and the development of legal and policy environments at the national level in support of aquaculture insurance.

In terms of insurance coverage of aquaculture stock by region, Europe, North America and Oceania are generally better served. Europe, in fact, is the best-served region in the world. A large number of the major insurance businesses have their headquarters located in Europe. The main insured species in Europe are salmon, seabass and seabream, tuna, trout and turbot. In 2007, in terms of value, the top five causes of industry losses were weather, diseases, algal blooms, water quality and cage damage. Globally, the largest losses came from the Mediterranean tuna-ranching sector.

In North America, aquaculture insurance has been available to producers in both Canada and the United States of America since the mid-1970s. However, in the case of the United States of America, the insurance programme for catfish has largely failed as a result of variable production levels and disease problems. Producers did not find the subsequent insurance terms and conditions satisfactory and instead have lobbied to have aquaculture covered under the Agricultural Risk Protection Act. Oceania is well served by the international insurance market. In Australia, insurance brokers provide the necessary linkages between international insurers and aquaculture producers.

Some other regions (Africa and Asia) are poorly covered by aquaculture insurance. Aquaculture in these regions is mainly practised by small-scale farmers who often lack access to extension and financial services. Subsidiaries of multinational aquaculture enterprises and the largest domestic enterprises are generally served by aquaculture underwriters. Similarly, small-scale farmers in Latin America and the Caribbean have little or no access to insurance, while the export-oriented, more industrialized sector (e.g. salmon and shrimp) is somewhat better covered.

As a follow-up to the FAO global review of aquaculture insurance, a regional workshop held in Bali on the promotion of aquaculture insurance for small-scale farmers in the Asian region suggested the development of a layered risk management system, called the "hybrid approach" (Bueno and van Anrooy, 2007; Secretan *et al.*, 2007). Broadly, at the bottom of the layered system is improved on-farm management based on adoption of BMPs by groups or clusters of farmers. Next is the development of mutual insurance schemes among groups of farmers and their associations, which constitutes the first level of insurable risks. The next level includes the participation of national and international insurance and reinsurance companies. Finally, the top level consists of well-managed government emergency disaster relief systems and improved extension services.

At a subsequent workshop held in September 2009 in Bangkok that was conducted jointly by the Thai Department of Fisheries and FAO, it was agreed that the shrimp farming sector of Thailand, which includes around 13 000 farms (of which 85 percent are small-scale operations), would constitute an ideal group for the application of the hybrid approach and that formation of a mutual insurance company to be owned and operated by the shrimp farmers themselves would be the best way forward. It was also recognized that the Government would be required to provide an enabling environment through a policy and legal framework that would allow the establishment of a mutual insurance scheme. The workshop further recommended that a committee be formed to report on the social, legal and financial feasibility of establishing a mutual insurance company for the Thai shrimp farmers (FAO, 2010c).

## SALIENT ISSUES AND SUCCESS STORIES

### Salient issues

The salient issues influencing further development of the global aquaculture sector are:

- developing, updating and implementing policies, plans and strategies, as appropriate, by countries to address increasing competition for land and water resources from other economic development activities (e.g. shipping, urbanization, agriculture, tourism and nature protection) and to provide access to suitable sites;
- decreasing further reliance on finite supplies of fishmeal and fish oil by further developing cost-effective and socially and environmentally acceptable alternate feed ingredients;
- building the capacity of small-scale farmers to make more effective farm-made feeds;
- providing greater access to affordable veterinary services and medicinal products;
- providing greater access to affordable finance and insurance facilities to aquaculture producers, in particular to small-scale producers;
- gaining competence/enhanced skills; professionalization; efficiency and integration.

### Success stories

In the past decade, a number of innovations in the aquaculture sector have contributed to: increased productivity; reduced production and marketing costs; and better understanding and appreciation of environmental, social and animal welfare issues. The innovations have been in the fields of vaccination, selective breeding, life cycle manipulations, genetic manipulation, fishmeal and fish oil substitutes, quality feeds, harvesting and processing, packaging and retailing. There have also been many innovations and improvements at the levels of farm operation and production management. It is clear that farmers, producers and many others in the value chain are continuously improving their skills and competence and applying these to their daily work routines.

In summary, while there are a number of specific remarkable success stories to report, a few are highlighted, namely the explosive growth of striped catfish culture in Viet Nam, the development of the GIFT strain of tilapia, the closing of the life cycle of the whiteleg shrimp and its introduction to Asia for aquaculture development, the closing of the life cycle of southern bluefin tuna, the spawning of Atlantic bluefin tuna in captivity, and the successful adoption of BMPs in many countries.

## THE WAY FORWARD

In 2008, the world consumed 115.1 million tonnes of fish, including 52.5 million tonnes originating from aquaculture. The earth's population is forecast to reach 8.31 billion in 2030. If capture fisheries production (89.7 million tonnes in 2008) and the non-food uses of fish (27.2 million tonnes in 2008) remain constant, aquaculture needs to produce 79.1 million tonnes by 2030 in order to maintain the current (2008) annual per capita consumption of 17.1 kg. Thus, 24 years from now, aquaculture will need to produce 28.8 million tonnes more per year than current annual production. In meeting this daunting task, in the coming years, the aquaculture sector is expected to contribute more effectively to global food security, nutritional well-being, poverty reduction and economic development.

The responsible use of natural resources and the protection of the environment will remain major challenges in the future development of aquaculture technology and systems. New technologies focusing on offshore systems and inland recirculation systems will probably be in place. It seems likely that the future use of new aquaculture species and culture technologies will follow the successful salmon culture model. In addition, governments are expected to address the issue of conflicts and competition over land and water resources through the adoption of balanced land-use policies and zoning programmes.

In the future, the sector will be increasingly dependent on the availability of high-quality seed and feed and will take into further consideration consumers' concerns about animal welfare and health issues. Veterinary services and supplies are likely to contribute significantly to aquaculture development through the application of new research developments in the fields of therapeutics and vaccines, disease gene mapping and early identification systems. As further aquaculture development takes place, there will be an increasing need for financial and insurance services, particularly by small-scale farmers, that is expected to be met by governments and large industry producers such as feed and seed producers.

COURTESY OF ROHANA SUBASINGHE

*Marine fish cages in Ha Long Bay, Viet Nam.*

# 4. Aquaculture and environment

## STATUS AND TRENDS

### General environmental conditions

Aquaculture practices rely upon the use of natural resources such as land and water that are parts of the overall environment shared by other living beings. While responsible aquaculture can provide substantial environmental benefits, such as recovery of depleted wild stocks, preservation of wetlands, desalinization of sodic lands, pest control, weed control, and agricultural and human waste treatment, there have been cases of adverse environmental impacts as well (World Bank, 2006). The most common negative environmental impacts that have been associated with aquaculture include: discharge of aquaculture effluent leading to degraded water quality; alteration or destruction of natural habitats; competing demands for the use of the finite fishmeal and fish oil resources; introduction and transmission of aquatic animal diseases through poorly regulated translocations; and the negative impact of escaped farmed fish on populations, communities and genetic diversity (FAO, 2006a).

As a result of strong public scrutiny on the environmental impacts of some forms of inconsiderate aquaculture development, starting about a decade ago and gathering considerable momentum over the past five years, significant progress in addressing many of the key concerns in the environmental management of aquaculture has been made. Continued public pressure and commercial necessity have led the aquaculture sector to make great efforts to reduce and mitigate its environmental impacts and governments to increasingly recognize that aquaculture, when well planned and well managed, can yield broad societal benefits without concomitant environmental degradation.

COURTESY OF KOJI YAMAMOTO

*Coral trout* (Plectropomus leopardus) *is a marine species categorised as near threatened in the IUCN Red List. This highly priced fish is now bred in captivity at the Krabi Coastal Fisheries Research and Development Centre in Thailand.*

As a consequence, many countries in the regions have put in place policies, strategies and regulations governing environmental sustainability focusing on compliance with more stringent environmental mitigation and protection measures. In several countries, these changes have been initiated by the private sector, resulting in reduced environmental impacts and improved efficiency and profitability. In particular, the private sector has made tremendous advances and contributions towards responsible and sustainable management of the aquaculture sector through adoption of corporate social responsibility, self-regulation and BMPs, and application of environmental certification, either individually or in a coordinated manner, to demonstrate credibly that its production practices are non-polluting, non-disease transmitting and/or non-ecologically threatening.

In the North America region, both Canada and the United States of America have stringent environmental regulations associated with the aquaculture sector. The region has made significant progress in mitigating environmental impacts, for example in the challenging area of water quality problems originating with excess nutrients and organic enrichment (Olin, Smith and Nabi, 2011). In Africa too, several countries are taking steps to mitigate environmental impacts by providing effective environmental stewardship. Producers are required to undertake environmental impact assessments (EIAs), which are followed up by confidential farm audits (Satia, 2011). In the Asia–Pacific region, there is increasing evidence that aquaculture of marine species, particularly those for the live food fish restaurant trade (LFFRT) of grouper species for which the life cycle has been closed, is indirectly assisting biodiversity conservation (FAO/NACA, 2011). In the past, the LFFRT was predominantly dependent on wild-caught fish, often using destructive fishing methods that affected the conservation of fragile habitats such as coral reefs (Nguyen *et al*., 2009).

Despite substantial progress towards environmental conservation, there is no room for complacency. Continuing improvements, interventions and investments are required to ensure a higher degree of environmental sustainability and economic viability in the sector as pressures on the natural resource base and public awareness of environmental issues reach unprecedented levels (Subasinghe, 2009).

### Aquatic animal health management

Disease outbreaks and serious mortalities stemming from exotic disease incursions are negative consequences of the expansion and diversification of the aquaculture sector associated with globalization, increased international trade and the irresponsible movement of live aquatic animals and their products across and beyond national borders (Bondad-Reantaso *et al*., 2005). Thus, managing aquatic animal health has become a high priority for the global aquaculture sector, as major disease outbreaks in various parts of the world have disrupted aquaculture production, often with severe socio-economic and ecological consequences, including irreversible damage to aquatic animal populations and substantial loss of biodiversity. Monetary losses could range from national-level estimates as low as US$17.5 million (white spot disease of shrimp in India in 1994) to as high as US$650 million (for yellowhead virus and white spot disease in Thailand in 1994) to a global estimate of US$3.2 billion (Israngkura and Sae-Hae, 2002; FAO, 2007).

Development and implementation of a comprehensive national aquatic animal health management plan that is strategic and in harmony with regional and international plans is an important function that countries should consistently carry out in order to prevent, control and eliminate diseases in a timely manner and respond to consumers' increasing concerns for food safety, ecosystems integrity and animal welfare.

In the last decade, significant developments have taken place in many counties with regard to managing aquatic animal health, such as: increased development of national strategies and frameworks for regional programmes on aquatic animal health; increased compliance with international standards relating to aquatic animal health (e.g. the World Trade Organization's sanitary and phytosanitary measures [WTO, 1994]; OIE's Aquatic Animal Health Code [OIE, 2010]; and the Convention on Biological Diversity [CBD, 1992]); increased application of risk management strategies (e.g. border controls, quarantine, inspection and health certification); increased awareness on biosecurity (e.g. transboundary diseases/pathogens and aquatic invasives); increased awareness on climate change implications with respect to transboundary aquatic animal diseases; and increased use of BMPs. Nonetheless, in many countries, including member countries of the Regional Commission for Fisheries (RECOFI) in the Near East and North Africa region, more capacity-building support is needed in areas such as basic fish health management, legislation and import risk analysis.

In North America, both Canada and the United States of America follow a comprehensive or holistic approach to aquatic animal health management. Canada's approach focuses on management decisions that could affect the sustainable use of oceans and freshwater systems. Further, Canada's National Aquatic Animal Health Program is being implemented in line with standards set by OIE. However, regulatory amendments have recently been initiated to address the issue of this programme being currently regulated under the Health of Animals Act, which has more direct relevance to terrestrial animals than to aquatic animals.

In the United States of America, the guiding principle is ecosystem-based management that considers the ecosystem-based effects of aquaculture operations and management. In both countries, environmental assessments, monitoring and surveillance activities are a fundamental part of any treatment plan. In the United States of America, a comprehensive national aquatic animal health plan has been developed and is now being implemented. A major goal of the plan is to protect the nation's farmed and wild aquatic resources from the introduction and spread of devastating infectious diseases.

In Europe, within the EU, the health of aquatic animals and their products is governed by legislation that emphasizes a comprehensive, risk-based approach to disease surveillance. The legislation requires aquaculture entrepreneurs to prepare a fish health management plan. However, the capacities of countries that were part of the former Soviet Union (e.g. Latvia) and the former Yugoslavia (e.g. Bosnia and Herzegovina) are being strengthened with technical assistance provided by FAO, the EU and other donor agencies.

Aquatic animal welfare is another area of common concern to European consumers, policy-makers, and producers for both future acceptance of aquaculture products and ethical reasons. Some of the recent areas of progress in addressing this issue include: a new cage design to maintain an adequate swimming volume for fish; new legislation, known as the "Slaughterhouse Act", in Norway; a total ban on use of carbon dioxide as a sedative from 2010; and percussive stunning. Moreover, such concerns have also been addressed under the EU-funded CONSENSUS programme, in which all stakeholders, including European consumer associations, have developed a set of "sustainability indicators" that are applicable at the farm level.

Many countries in the Asia–Pacific region have also made considerable progress in aquatic animal health management. In particular, progress has been made in the areas of disease diagnosis, aquatic animal health certification and quarantine, disease surveillance and reporting, and farm-level health management. However, limited progress has been made with regard to contingency planning, zoning and import risk analysis.

A significant achievement of the region is the development and adoption of the Asia Regional Technical Guidelines for the Responsible Movement of Live Aquatic Animals (FAO/NACA, 2000), which were developed through an FAO Technical Cooperation Programme and adopted by the 21 participating Asia–Pacific countries. The technical guidelines serve as a useful reference document for development of national aquatic


*On farm diagnosis of fish for diseases and pathogens is a common practice in aquaculture.*

animal health strategies. Moreover, the governments remain committed to improving aquatic animal disease surveillance and disease reporting. All 21 countries participate in the FAO/NACA/OIE Quarterly Aquatic Animal Disease reporting system, which provides current information on important diseases in the region and serves as an early warning system for emerging diseases. Another key area of progress in the region is the functioning of the ten-member high-level Asia Regional Advisory Group on aquatic animal health, which provides advice to NACA and Asian governments on aquatic animal health management (FAO/NACA, 2011).

In Africa, with the recent spread of aquaculture development in many countries, there is a need to build and strengthen capacity for aquatic animal health management. The recent spread of epizootic ulcerative syndrome (EUS) in the Zambezi River Valley, which is threatening the food security and livelihoods of rural populations in an area shared by seven countries, underscores the urgency of promoting this type of capacity-building support. Since 2007, FAO has been helping the countries to build capacities in EUS diagnosis, targeted EUS surveillance and basic aquatic animal health management. In addition, FAO, in cooperation with OIE, is helping to develop and implement an aquatic biosecurity framework for the Southern Africa region based on appropriate policies and regulations (FAO, 2009b).

In the case of the Near East and North Africa region, the eight RECOFI member countries have identified aquatic animal health management as an important tool for sustainable aquaculture development and have recognized the need for technical support to improve their current level of capacity. Accordingly, RECOFI has endorsed a long-term (May 2009–May 2011) capacity-building programme at the national and regional levels, focusing on a number of areas, including disease diagnostics and aquatic biosecurity (Lovatelli, 2009).

### Introduced species

While some of the introduced species for aquaculture have brought about negative impacts or loss of biodiversity, at the same time, introduced species have led to significant development of new aquaculture industries in many countries without apparent negative impacts. It has been reported that losses have been due to competition for food and space with indigenous species, alteration of habitats, transmission of pathogenic organisms, and genetic interactions such as hybridization and introgression (FAO/NACA, 2011). As a measure to reduce potential negative impacts stemming from introduced species for aquaculture, it is recommended that a science-based full risk assessment be conducted prior to deciding on an introduction.

Experience with regard to the translocation of introduced species in Africa confirms some of the concerns expressed above. For example, the introduction of the Nile tilapia resulted in hybridization with indigenous species in Kenya, South Africa, Zambia and the United Republic of Tanzania, and irreversible changes in species and catch compositions of major inland fisheries in lakes, rivers and wetlands in several countries (Pitcher and Hart, 1995; Satia and Bartley, 1998; Satia, 2011). However, it has been stressed that, in almost all cases, the introductions were made without following internationally acceptable procedures and protocols. Subsequently, conscious of the adverse impacts, African countries adopted (in 2002) the Nairobi Declaration on Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien[5] Species for Aquaculture in Africa, which, along with other international codes such as the FAO Code of Conduct for Responsible Fisheries, is used as a guideline to address such issues (Satia, 2011).

In the Asia–Pacific region, there is little explicit evidence to demonstrate the serious negative impacts of introduced species on biodiversity. In fact, the wide and sustained use of introduced species in China's inland aquaculture is cited as a success story in

BOX 4

**Towards the sustainable use of introduced aquatic species in China: major findings and lessons learned**

Diversification of cultured species is a major goal of China's aquaculture development programme. Efforts to achieve this goal have been generally satisfactory, resulting in the introduction of 129 aquatic species, of which three finfish species/species groups (tilapia, sturgeon and catfish) and two crustacean species (red swamp crayfish and whiteleg shrimp) stand out in terms of production and socio-economic contributions. The total production of introduced species increased from 780 000 tonnes in 1998 to 2.5 million tonnes in 2006, representing 5.9 and 11.7 percent of total inland aquaculture production, respectively.

The introduced species that have been successful are essentially tropical and/or subtropical, and are in high demand in both domestic and international markets. It has been noted that few or no introduced species have been invasive or had an adverse impact on biodiversity.

A major lesson learned from the introductions is the importance of suitable adaptation of each species to culture conditions in China, supported by research and technology development and dissemination of findings. For example, in the case of channel catfish (*Ictalurus punctatus*), initial work focused on: reproductive aspects and fry rearing; development of suitable diets based on nutritional research; most effective feeding regimes; and common diseases and treatments, including Chinese herbal treatments. The next step involved development of suitable culture techniques and management regimes.

While there are a number of laws and regulations related to control of introduced species, it is considered desirable to have specific laws and regulations for introduced species. It is also suggested to have a single authority to deal with introduced species and their impacts. China recognizes the complexities of introductions and is committed to adopting further measures that would ensure responsible use of introduced species.

*Source:* Adapted from Liu and Li (2010).

[5] Introduced species, rather than alien species, is the preferred term.

Asian aquaculture (Box 4). Moreover, it has been reported that the development and dissemination of GIFT, GIFT-derived and other Nile tilapia strains has not caused any significant adverse impacts on biodiversity in the Asia–Pacific region (Acosta and Gupta, 2010). Nonetheless, it is important that appropriate risk management measures are taken to avoid any negative impacts on highly fragile and pristine environments, in particular in the Pacific region.

North America's experience with introduced species tends to reinforce Asia–Pacific's position. Accordingly, it has been argued that the use of the introduced Atlantic salmon in British Columbia presents less risk to native Pacific salmon than would culture of chinook (*Oncorhynchus tyschawytscha*) or coho (*O. kisutch*) salmon (Olin, Smith and Nabi, 2011). In North America, fish escaping from cages are an important concern. However, to support the industry's "zero escape" strategy, a variety of regulatory, monitoring and scientific research tools are used.

In Europe, native species represent the major share of aquaculture production, with introduced species accounting for a non-negligible part. A major concern in this region relates to the potential negative impacts of escaped farmed species that are native in the region, such as *Salmo salar*. Escapes of this species have been blamed for significantly affecting the genetic diversity of the wild stocks in several countries in the region (Thorstad *et al*., 2008). The region gives importance to the endangering of indigenous species though other human practices, such as the transfer of live organisms between regions and ballast water release from ships.

In Latin America and the Caribbean, a recent significant development in Chile is the modification of the country's General Law of Fisheries and Aquaculture that aims to prevent farmed salmon escapes, an issue resulting in large part due to weak regulations. According to preliminary industry estimates, the modification is likely to require more than US$500 million of investments within the salmon industry.[6] However, the escapes of salmon species from aquaculture in southern Chile contribute to local fisheries and livelihoods, even though deliberately allowing fish to escape is an illegal practice. An interesting case is that of the growing wild populations of chinook salmon in this country that have originated from aquaculture escapes and possibly from ranching. Such populations are beginning to support a recreational fishery that provides important revenues for local people, thus generating a mixed reaction within society (Soto *et al*., 2007). The reflection here is that societal perception of aquaculture escapes can vary depending on the overall primary objectives, which could range from environmental conservation (as is the case in some European countries) to food security (as in many countries in Asia or Latin America). The balance between these two depends on societal choices, and there is an increasing interest in promoting such balance through an ecosystem approach.

### The ecosystem approach to aquaculture

Aquaculture needs an enabling policy environment in order to grow in a sustainable manner and to be integrated into agro-ecosystems (where appropriate) or to other coastal zone uses. Also, the interactions between aquaculture and the larger system in which it occurs, in particular, the influence of the surrounding natural and social environment on aquaculture, must be taken into consideration (Subasinghe, 2009). The EAA (Box 5) is a recommended approach to achieve the above goal. It is "a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems" (Soto, Aguilar-Manjarrez and Hishamunda, 2008; FAO, 2010d).

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[6] See: www.thefishsite.com/fishnews/11915/prevention-and-punishment-of-salmon-escapes

To ensure that aquaculture contributes positively to sustainable development, the EAA is guided by three interlinked principles:

1. Aquaculture development and management should take account of the full range of ecosystem functions and services and should not threaten the sustained delivery of these to society.
2. Aquaculture should improve human well-being and equity for all relevant stakeholders.
3. Aquaculture should be developed within the context of other sectors, policies and goals.

Aquaculture development affects and is affected by other human activities, such as fisheries, agriculture, irrigation and industry, as well as increasing urbanization, which could lead to conflicts and environmental degradation. To address this issue, Principle 3 of the EAA emphasizes the importance of adopting integrated planning and management systems, as has been applied in many countries through integrated coastal zone management and integrated watershed management. In essence, there is a need for the sectoral integration of various activities, especially where mutual benefits are likely to arise (Box 6).

Tools have been developed and are being improved to deal with sectoral integration, including better planning of aquaculture siting based on zoning of areas (FAO, 2010d; Aguilar-Manjarrez, Kapetsky and Soto, 2010) and integrated aquaculture practices, such as rice-fish farming, which is practiced widely in Asia and particularly in China (Miao, 2010), and integrated aquasilviculture using mangroves as biofilters (Soto, 2009).

In this regard, the development of integrated multitrophic aquaculture (IMTA)

BOX 5

**The core ideas underlying the ecosystem approach**

The ecosystem approach recognizes that:

- Humans are an integral part of important ecosystems, and people should be at the centre of biodiversity management. This implies the need for an integrated, participatory approach in the identification of issues and in "ecosystem" management.
- Ecosystems provide services that underpin most human activity, and thus it is necessary to ensure that the sustained delivery of these services is not threatened through damage to ecosystem functions.
- Given the level of ignorance of the functioning of these highly complex systems, there is a need for a precautionary and adaptive approach.
- Some activities threaten or reduce the quality of ecosystem services available to society at large and, therefore, represent a cost that should be accounted or internalized.
- Waste products from one activity or sector may serve as inputs to another, thus enhancing productivity and reducing pressure on ecosystem functions and services.
- Ecosystems function at a range of scales from highly local to global, and, therefore, a "nested" approach is required with different approaches to management according to scale.
- There is a need for analysis and understanding of the broader social, economic and environmental implications of meeting targets and for transparency of decision-making in relation to trade-offs between social, economic and environmental objectives.

*Sources:* Hambrey, Edwards and Belton (2008); FAO (2010d).

BOX 6

**Various types of sectoral integration**

- Policy (institutional) integration: minimizing intersectoral conflict and coordinating policy and management measures to ensure consistency and a situation that is fair for all.
- Operational (or enterprise-level) integration: ensuring that the various activities pursued by a particular enterprise are coordinated and mutually reinforcing. This may include recycling of wastes.
- Waterbody integration: promoting a balance between different activities or sectors within an aquatic system in order to maximize the reuse of nutrients or other materials, thereby increasing efficiency and reducing pressure on the environment.
- Provision of "green infrastructure": maximizing the delivery of ecosystem services, including waste assimilation, by ensuring that areas or corridors of a range of habitat types are conserved or re-created and managed appropriately.

*Sources:* Hambrey, Edwards and Belton (2008); FAO (2010d).

systems is a welcome opportunity, especially in the western hemisphere. The IMTA process involves combining the cultivation of artificially fed aquaculture species (e.g. finfish/shrimp) with organic-extractive aquaculture species (e.g. shellfish/herbivorous fish) and inorganic-extractive aquaculture species (e.g. seaweed). The IMTA approach is expected to create balanced systems for environmental sustainability (biomitigation), economic stability (product diversification and risk reduction) and social acceptability (BMPs) (Soto, 2009; Váradi *et al*., 2011).

In North America, integrated aquaculture is in its early developmental stage in Canada, whereas it is not practised in the United States of America. However, the region is studying the potential of IMTA on a pilot basis. Integrated multitrophic

COURTESY OF RTHIERRY CHOPIN

*Salmon (left), mussels (right foreground) and seaweeds (right background) integrated multi-trophic aquaculture (IMTA) in the Bay of Fundy, Canada.*

aquaculture has also generated considerable interest in the Europe and the Latin America and the Caribbean regions and elsewhere.

### User conflicts

With weak or improper regulations for allocation and use of natural resources, there is always a tendency for conflicts to emerge among resource users. In the process, less influential and disadvantaged stakeholders are invariably denied access to these resources. Unregulated or improperly regulated aquaculture development also encourages practices that exploit the resources beyond their carrying capacity.

In the case of aquaculture, water and land are essential for its practice, but equitable and easy access to these resources is becoming increasingly complex owing to demand for the same resources by other competing economic activities (e.g. traditional fisheries, agriculture, urban development, and tourism), often triggering conflicts with potential users (also see Chapter 3).

In Europe, one of the major conflicts relates to the use of rural or coastal marine sites, especially in areas where tourism or nature conservation activities are now increasingly in demand, replacing the earlier declining traditional economic activities. In North America, there have been cases of conflicts between aquaculture and traditional fisheries, where commercial salmon fishers hold aquaculture responsible for environmental pollution leading to a decline in wild salmon stocks. However, the other view held is that the decline in stocks, except in Alaska, had occurred long before salmon aquaculture appeared. Moreover, salmon fishers are against installation of any aquaculture gear that might interfere with traditional fishing activities (Olin, Smith and Nabi, 2011). In the Asia–Pacific region, there are instances of conflicts between aquaculture producers and agricultural farmers in areas suitable for shrimp culture and in floodplains or common-property areas suitable for culture-based fisheries.

To address conflict-related issues, there is a need for more effective land-use planning, aquaculture zoning and efficient use of water resources based on frameworks for the management of multiple or integrated use of resources and their environmental assessment.

### Public perception

While some cases of unplanned management and improper practices of aquaculture in some parts of the world have triggered environmental, health and social concerns, on many occasions the significant benefits of adopting responsible and sustainable aquaculture practices, particularly aquaculture's contributions to poverty alleviation through employment creation, income generation, food security and protein supplementation, and foreign exchange earnings, tend to be overshadowed. The negative image perception concerns all countries and regions, particularly those engaged in production of high-value commercial aquatic commodities. Nonetheless, irrespective of the correctness, authenticity and biases of the various arguments, it is incumbent on the aquaculture sector to take notice of the public's concerns and act in a manner to gain their trust and confidence (De Silva and Davy, 2010).

To demonstrate to the public that aquaculture development is sustainable and could proceed in a socially and environmentally responsible manner, it is essential that the aquaculture sector continuously project the correct image through such activities as engaging civil society, media and other stakeholders in constructive dialogues and sharing information and data with them, including best practice cases, in a transparent manner. The development of sustainability indicators under the EU-funded CONSENSUS programme is a good example of how to address the image problem.

In essence, the important message that the aquaculture sector needs to convey convincingly to the public is that it has not remained complacent; rather it continues to make efforts to enhance its credibility based on the application of internationally accepted principles of responsible aquaculture practices. FAO's recent work on the development of international guidelines on aquaculture certification, based on extensive consultations with stakeholders, is a step in the right direction. The guidelines, which are non-binding, cover a range of issues: animal health and welfare, food safety, environmental integrity, and social-economic aspects relating to aquaculture workers. The guidelines were approved at the Twenty-ninth Session of the Committee on Fisheries (COFI) in early 2011. It is expected that, if the guidelines are followed in full by the aquaculture sector, the perceived negative image of the sector could to a large extent be reversed. For example, certification will enable consumers to know whether the shrimp they are considering buying were raised without damaging a coastal mangrove swamp, whether the fish farm worker was paid a fair wage and whether the shellfish is free of contamination.[7]

## SALIENT ISSUES AND SUCCESS STORIES

### Salient issues

The salient issues relate to:

- addressing value-based environmental concerns as compared with science-based concerns, such as water quality, escapes and disease outbreaks, that can be assessed and acted upon;
- developing comprehensive and effective zoning and coastal spatial planning that takes into consideration the concerns of the aquaculture industry;
- making continuous efforts to address the negative image perception by enhancing the sector's credibility based on the application of internationally accepted principles of responsible aquaculture practices;
- addressing the need to increase aquaculture's production capacity without exceeding the ecosystem's assimilative capacity by providing support to countries that lack the technical capacity to prepare and implement the EAA.

### Success stories

Several success stories are highlighted: environmental management in aquaculture (in particular, in mariculture); new developments related to integrated aquaculture in the form of IMTA; engagement of consumers in the development of sustainability indicators; and the adoption of environmentally sustainable practices (Box 7).

Indeed, it is now increasingly recognized that aquaculture can make positive contributions to the environment by helping reduce the negative impacts of other industries and activities. There are aquaculture systems that contribute to environmental

BOX 7

**Sustainable aquaculture practices**

In the United States of America, the case of pond culture of catfish provides a good example of an industry developing water management and reuse strategies to improve environmental quality. In fact, following creation of increased awareness on environmentally sustainable practices by the industry, farmed catfish, which had earlier been placed in a precautionary category by the Monterey Bay Aquarium's Seafood Watch Program, graduated to the Best Choice category.

*Source:* Olin, Smith and Nabi (2011).

[7] See: www.globefish.org/first-global-guidelines-for-aquaculture-certification-finalized.html

rehabilitation or that mitigate the impacts of effluents from other agricultural and even industrial operations. Integrated farming systems (e.g. rice-fish farming) and the rehabilitation of endangered populations through stocking are well known. The use of mollusc culture to improve carbon sequestration and seaweed culture in coastal areas to reduce aquatic nutrients loading are also good examples of where aquaculture practices can serve as environmental improvements and at the same time contribute to socio-economic development.

## THE WAY FORWARD

In general, the aquaculture sector needs to continue to improve environmental performance, which so far has been the result of a combination of legislation, technological innovations and management practices. To achieve sustainable aquaculture development (environmentally, economically and socially), countries are advised to mainstream the EAA into their aquaculture policy, strategy and planning and, where required, be provided with technical guidance and assistance in developing and implementing a plan. Moreover, as part of the EAA, to deal with environmental issues, countries need to promote adoption of BMPs and the use of EIAs and biosecurity frameworks. In addition, to achieve benefits, countries need to promote the integration of aquaculture with other sectors.

*When carefully planned and practiced, aquaculture can have an appealing look. Salmon cages in Chile.*

COURTESY OF DORIS SOTO

# 5. Markets and trade

## STATUS AND TRENDS

### Main markets and trade characteristics

Markets for fish and fishery products are varied in terms of location, ranging from domestic to regional (both intraregional and inter-regional) to international markets. In the past decade, in line with the increased growth of global aquaculture production, there has been an impressive development of trade in many aquaculture products based on both low- and high-value species, at all levels of market. In addition, consumers' tastes and preferences for aquaculture products also vary, with markets catering to demand for live aquatic animals to a variety of processed products. While the demand for aquaculture products continues to increase, there is a growing recognition of quality and safe products by consumers. In response to such concerns, issues such as food safety, traceability, certification and ecolabelling are becoming increasingly important and are thus considered a high priority by countries engaged in aquaculture.

Globally, fish is a valuable traded commodity, representing a significant source of foreign exchange earnings, in addition to its important contributions to employment creation, income generation and food security.[8] In 2008, about 39 percent (live weight equivalent) of world fish and fishery products was internationally traded as various food and feed products, compared with 25 percent in 1976 (FAO, 2010a). In general,


COURTESY OF ALESSANDRO LOVATELLI

*Fish market with a variety of shellfish on display in Italy.*

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[8] The extent of global trade in aquaculture products is difficult to analyse, as FAO statistics on international trade in fish and fishery products do not distinguish commodities as being of wild or farmed origin. However, based on the species traded (mainly shrimp, prawns, salmon, seabass, seabream, molluscs, tilapia and catfish), it is clear that much of the trade in fish and fishery products involves commodities originating from aquaculture.

this increase in volume is a reflection of the sector's growing degree of openness to, and integration in, international trade. Some of the specific factors that have contributed to this rise are: growing globalization of the fisheries and aquaculture value chain; outsourcing of processing to countries where comparatively low wages and production costs provide a competitive advantage; increasing consumption of fishery commodities; favourable trade liberalization policies; and technological innovations, including improvements in processing, packaging, transportation and changes in distribution and marketing that have significantly changed the way fishery products are prepared, marketed and delivered to consumers.

In 2008, world exports of fish and fishery products reached a record value of US$102.0 billion, which was 9 percent higher than in 2007 and nearly double the corresponding value in 1998 (FAO, 2010a). Trade in fish and fishery products was affected by the financial crisis that began in late 2007 and erupted into a full-blown economic crisis in late September 2008. Preliminary estimates indicate that fish trade declined by 7 percent in 2009 compared with 2008. However, there have been increasing signs that in 2010 fish trade began to recover in many countries and the long-term forecast remains positive (Box 8).

The top-ten exporters of fish and fishery products in 1998 and 2008 are shown in Table 4. China, Norway and Thailand are the top three exporters, with China alone contributing almost 10 percent, or about US$10.1 billion. A growing share of China's fishery exports consists of reprocessed raw material. China's fishery imports have registered a significant increase, up from US$1 billion in 1998 to US$5.1 billion in 2008, when it was the sixth-largest importer. Viet Nam, the sixth-largest exporter of fish and fishery products in the world, has also experienced significant growth, up from US$0.8 billion in 1998 to US$4.6 billion in 2008. Viet Nam's export growth has been triggered by its flourishing aquaculture industry, in particular in the production of striped catfish and of both marine and freshwater shrimp and prawns. Developing countries, including China, Thailand and Viet Nam, accounted for 50 percent (US$50.8 billion) of world exports of fish and fishery products in value terms and 61 percent (33.8 million tonnes in live weight equivalent) in terms of quantity.

Net exports of fish and fishery products (i.e. the total value of fish exports less the total value of fish imports) by developing countries are higher than those of several other agricultural commodities, such as rice, meat, sugar, coffee and tobacco. Net

BOX 8

**Fishery export and import trends in 2010**

For the period January–July 2010, fishery exports from China, the number one supplier, grew by an impressive 26.8 percent, and exports from Thailand were 7.8 percent higher than in the same period in 2009. Similarly, import values also registered increases by varying degrees in 2010. For the period January–June 2010, as compared with the same period in 2009, imports by the United States of America increased 16 percent, the imports figure for European Union was up 5.5 percent in terms of extra-community trade, Japan increased its imports be 5 percent and Australia, the largest seafood market in the Pacific, reported a 20 percent growth in imports. This rising trend was even more pronounced in developing countries. Brazil, China, Hong Kong SAR, Republic of Korea, Malaysia and Mexico all experienced double-digit growth in fishery import values. Strong national currencies relative to the US dollar and rapid economic growth in Brazil, China, India, Indonesia and Malaysia boosted domestic purchases of fishery products and prices of exported fishery commodities throughout 2010.

*Source:* Adapted from FAO (2010b).

TABLE 4
**Top ten exporters and importers of fish and fishery products**

| | 1998 | 2008 | APR |
|---|---|---|---|
| | *(US$ millions)* | | *(Percentage)* |
| **Exporters** | | | |
| China | 2 656 | 10 114 | 14.3 |
| Norway | 3 661 | 6 937 | 6.6 |
| Thailand | 4 031 | 6 532 | 4.9 |
| Denmark | 2 898 | 4 601 | 4.7 |
| Viet Nam | 821 | 4 550 | 18.7 |
| United States of America | 2 400 | 4 463 | 6.4 |
| Chile | 1 598 | 3 931 | 9.4 |
| Canada | 2 266 | 3 706 | 5.0 |
| Spain | 1 529 | 3 465 | 8.5 |
| Netherlands | 1 365 | 3 394 | 9.5 |
| TOP TEN SUBTOTAL | 23 225 | 51 695 | 8.3 |
| REST OF WORLD TOTAL | 28 226 | 50 289 | 5.9 |
| **WORLD TOTAL** | **51 451** | **101 983** | **7.1** |
| **Importers** | | | |
| Japan | 12 827 | 14 947 | 1.5 |
| United States of America | 8 576 | 14 135 | 5.1 |
| Spain | 3 546 | 7 101 | 7.2 |
| France | 3 505 | 5 836 | 5.2 |
| Italy | 2 809 | 5 453 | 6.9 |
| China | 991 | 5 143 | 17.9 |
| Germany | 2 624 | 4 502 | 5.5 |
| United Kingdom | 2 384 | 4 220 | 5.9 |
| Denmark | 1 704 | 3 111 | 6.2 |
| Republic of Korea | 569 | 2 928 | 17.8 |
| TOP TEN SUBTOTAL | 39 534 | 67 377 | 5.5 |
| REST OF WORLD TOTAL | 15 517 | 39 750 | 9.9 |
| **WORLD TOTAL** | **55 051** | **107 128** | **6.9** |

*Note:* APR refers to the average annual percentage rate of growth for 1998–2008.
*Source:* FAO (2010a).

exports increased significantly from US$9.8 billion in 1988 to US$17.4 billion in 1998 to US$27.2 billion in 2008. In 2008, world imports also reached a new record of US$107.1 billion, up 9 percent on the previous year and up 95 percent with respect to 1998. Japan, the United States of America and the EU are the major markets, accounting for about 69 percent of world imports in 2008. Developed countries as a whole are responsible for about 78 percent of all imports by value and 58 percent by volume, indicating the higher unit value of commodities imported. About 50 percent of the import value of developed countries originated from developing countries.

An increasing trend in global fisheries trade is the emergence of new markets for some of the relatively low-value species. While the focus of trade in global markets is mainly on high-value species such as shrimp, salmon, tuna, seabass and seabream, a number of high-volume but relatively low-value species such as tilapia and catfish are also traded in large quantities, not only nationally and within major producing areas (such as Asia and South America), but also at the international level. Many of these species are farmed (FAO, 2009a). The striped catfish industry in Viet Nam provides an interesting story of the successful development of a market for such a species (Box 9). On the other hand, demand for high-value farmed species such as salmon is also increasing and opening up new markets in both developed, transition and developing countries. The increase in demand for farmed salmon, as in the case of other farmed species, is facilitated by the expansion of modern retail channels and supermarkets and by the availability of product throughout the year in various processed forms (e.g. fillets or loins).

In the past two decades, the growth of supermarkets in the developing world, especially in several countries in Asia and Latin America, has been considered a

BOX 9

**The catfish industry in Viet Nam**

Aquaculture of striped catfish, *Pangasianodon hypophthalmus*, locally known as "ca tra" and also commonly referred to as river catfish and sutchi catfish, in Viet Nam, is one of the largest single species-based farming systems within a relatively small geographical area, the Mekong Delta, popularly known as the food basket of Viet Nam (Phan *et al.*, 2009). Striped catfish constitutes about 95–97 percent of the total catfish production in Viet Nam, with the Mekong catfish (*Pangasius bocourti*) accounting for the balance (Thanh Phuong and Oanh, 2010). In 2008, the total production was about 1.4 million tonnes, which resulted in about 640 800 tonnes in volume of processed fish valued at about US$1.5 billion. The fish was exported globally to more than 100 markets. In the western world, striped catfish is considered as an affordable and acceptable substitute for "white fish" such as Atlantic cod (*Gadus morhua*).

The sector has reached its current status within a decade or less, surpassing any form of aquaculture development in the world, production increasing from a mere 10 000 tonnes in 1996 to 1.4 million tonnes in 2008. Being a relatively new and fast-developing sector, it has affected the socio-economic aspects of the region to a great extent, with the striped catfish being labelled as the "princess in Vietnamese aquaculture" (Thanh Phuong and Oanh, 2010). Most farms are small-scale and farmer owned, managed and operated. Although a quantitative assessment of these socio-economic aspects has yet to be made, one of the most significant impacts of the industry has been on increased land prices. In addition, as almost all the production is exported, the sector also supports a large processing sector where 90 percent of the employees are women. It is predicted that, in 2015, the labour requirement will be 42 000 people in catfish farming and 210 000 people in the processing sector (Sub-Institute for Fisheries Economics and Planning in Southern Vietnam, 2009). The catfish farming sector has also stimulated a number of subsidiary service sectors, such as the feed manufacturing and fresh-fish transportation sectors (by boat). It has been estimated that these subsidiary sectors provide about 10 percent of the total livelihood opportunities to those living in the Mekong Delta.

Since the 1980s, Viet Nam's fisheries sector has had a thriving export subsector. Seafood now ranks fourth among the foreign currency earners for the country, behind crude oil, garments and textiles, and footwear. Export earnings from fish and fishery products increased from US$0.8 billion in 1998 to US$4.6 billion in 2008, when Viet Nam became the fifth-largest exporter in the world. The export value of catfish exceeded US$1.4 billion in 2008, accounting for about one-third of the total value of Vietnamese fisheries exports.

While production is still increasing, the farmgate price of catfish has fallen to about US$0.80 per kilogram. Continued farming by small-scale farmers has thus become a challenge. The small-scale farming sector needs significant attention and effort, including continued and wider promotion and the application of BMPs to enable it to remain competitive in the international market. Catfish farming in Viet Nam is considered to have few environmental impacts and large social benefits. However, the Mekong Delta is considered likely to be significantly affected within the next decade or so by climate change, principally through sea-level rise and corresponding seawater intrusion and reduced river flow rate (White, Melville and Sammut, 1996). To ensure sustainability of catfish farming in the delta, there is a need for advanced suitable adaptive measures, the foremost of these being the development of salinity-tolerant strains of striped catfish, and the associated changes in hatchery production (De Silva and Soto, 2009).

"supermarket revolution", targeting not only higher-income consumers but also lower- and middle-income consumers. Indeed, the rapid growth in the early 2000s in China, Indonesia, Malaysia and Thailand has continued, and the "newcomers" – India and Viet Nam – have grown even faster (FAO, 2010a; Reardon, Timmer and Minten, 2010). Supermarkets offer consumers a wider choice, reduced seasonal fluctuation in availability and, often, safer food.

In order to gain wider access to export markets, there is a clear need for aquaculture farmers to improve the quality and safety of their products. However, it also needs to be emphasized that, alongside quality and safety issues, supermarkets and retailers around the world, largely in developed and importing countries, are demanding, on behalf of their customers, increasingly detailed requirements based on environmental and ethical criteria. With the more stringent requirements of export markets, small-scale farmers are facing difficulties in producing for export. As they strive to meet such consumer requirements, they may become uncompetitive owing to the high cost of compliance. This lack of competitiveness could lead to their marginalization or exclusion from markets. Thus, empowering small farmers to become competitive in global trade is becoming urgent and, perhaps, a significant corporate social responsibility.

As a consequence, there is a need for policy-makers to emphasize these aspects when improving governance of the trade sector. They must be aware that policies can be much more effective if producers participate in decision-making and regulatory processes. Such recognition has already led many governments to build national capacities to assist producers and processors in complying with mandatory food safety regulations, while empowering farmers and their associations for greater self-regulation. This move is contributing to improving the management of the sector at the farm level, typically through the promotion of BMPs and "codes of practice" of well-organized associated producers, as well as collaboration between producers, government agencies and expert (R&D) institutions. In this regard, several approaches are being tried to link small farmers to supermarkets, for example, by establishing collection centres and forming farmer companies.

In the past decade, with the entry of China into the World Trade Organization (WTO) in 2001 and that of Viet Nam in 2007, all major fishing or fish-farming countries, other than the Russian Federation (which is at an advanced stage of negotiations to join the WTO), are now members of the organization. Along with the growing membership of the WTO, both bilateral and multilateral trade agreements have played an increasingly important role in international trade in aquaculture products. Notwithstanding WTO rules and regulations that are meant to level the international trading field, an issue of growing concern to the global aquaculture export market is the use of different trade barriers to protect local markets from foreign competition. Cases cited as an example refer to the United States of America's application of antidumping tariffs on exports of striped catfish from Viet Nam, salmon from Chile and Norway, and shrimp from Brazil and Ecuador (FAO, 2006c; FAO/NACA, 2011; Olin, Smith and Nabi, 2011; Wurmann, 2011). However, a recent impact assessment (Duc, 2010) of antidumping measures on the export of catfish from Viet Nam has shown that the 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.[9] The study concluded that the antidumping measures were not favourable to United States consumers and in fact harmed the United States catfish industry.

[9] Vietnamese catfish was marketed to the United States of America under the name "catfish". However, to protect the domestic catfish sector, the United States Congress passed a labelling law in November 2002 restricting the use of the word "catfish" to only those fish belonging to the family Ictaluridae, which is farmed popularly in the southeast of the United States of America. A consequent action by the United States of America was to declare that Viet Nam was dumping products on the United States market, leading to imposition of antidumping tariffs ranging from 44.6 to 63.9 percent.

In all regions except Western Europe and North America, the lack of adequate and quality infrastructure support remains a constraint on further development of both domestic and international markets for aquaculture products. This type of support broadly falls into two categories: support that is internal to the sector, such as establishment of quarantine facilities; and support that is external to the sector but benefits the sector as well, such as transportation and power facilities. For domestic markets, a network of quality roads that connects rural producers, particularly small-scale producers, to urban and peri-urban market centres is essential to increase profitability and competitiveness of business and to stimulate aquaculture growth.

### Harvest and post-harvest services

An important feature of the global fish-processing industry is that there is enormous diversity within and between the regions in terms of species processed, product forms supplied and processing techniques used (Box 10). Fish is one of the most versatile food commodities and can be utilized in a variety of ways and product forms. It is generally distributed as live, fresh, chilled, frozen, heat-treated, fermented, dried, smoked, salted, pickled, boiled, fried, freeze-dried, minced, powdered or canned, or a combination of two or more of these forms (FAO, 2009a). In the past decade, fuelled by changing consumer tastes and concerns for food quality and safety, there have been significant advances in technology (e.g. refrigeration, ice making and other fish-processing equipment), packaging and logistics, making the processing sector more efficient in terms of higher yields and financial returns.

In developed countries, sophisticated production equipment and methods are used and the focus is on convenience foods such as ready and/or portion-controlled, uniform-quality meals. In many developing countries, there is a trend towards increased processing, ranging from simple gutting, heading or slicing to more advanced value-addition, such as breading, cooking and freezing, depending on the commodity and market value. Some of these developments are driven by increasing demand in the domestic retail industry or by a shift in cultured species, for example, the introduction of *Litopenaeus vannamei* in Asia.

BOX 10

**Fish utilization**

In 2008, about 81 percent (115 million tonnes) of world fish production was used for direct human consumption. The remaining 19 percent (27 million tonnes) was destined for non-food purposes, of which about 76 percent (20.8 million tonnes) was used for the manufacture of fishmeal and fish oil. The remaining 6.4 million tonnes was comprised of fish that were utilized mainly for ornamental purposes, for culture (fingerlings and fry), for bait and for pharmaceutical uses, as well as for raw material for direct feeding in aquaculture, livestock farming and the rearing of fur-bearing animals. While separate statistics on fish processing from aquaculture sources are not readily available, the overall data provide a good reflection, given that aquaculture accounted for about half of total food fish production.

Of the total fish destined for human consumption, 49.1 percent was in live and fresh form, which is often the most preferred and highly priced product form, followed by frozen fish (25.4 percent), prepared or preserved fish (15.0 percent) and cured fish (10.6 percent). Live and fresh fish increased in quantity from 45.4 million tonnes in 1998 to 56.5 million tonnes in 2008 (live weight equivalent).

*Source:* Adapted from FAO (2010a).


*Modern shrimp farm in Baja California.*

There has been an increasing globalization of the fisheries value chain, with more and more processors in developing countries being contracted by firms that are mostly located in developed countries. The increasing practice of outsourcing processing depends on the species, product form, and cost of labour and transportation. There are many cases where processors in developed countries are facing reduced margins because of increased competition from low-cost processors in developing countries. Another parallel development is the integration of processing and producing activities. For example, large producers of farmed salmon, catfish and shrimp in developing countries have established advanced processing plants to improve the product mix, obtain higher yields and respond to evolving quality and safety requirements in importing countries.

At the regional level, in the EU, the value of processed fishery products was about €18 billion a year, almost twice the value of landings and aquaculture production combined (Váradi *et al*., 2011). The processed products include preparations and canned fish (€6.7 billion), followed by fresh, chilled, frozen, smoked or dried fish (€5.2 billion). According to an EU resolution, the main challenges the processing sector faces are: growing competition regarding final products because of the general WTO policy of reducing tariff barriers; and unfair competition owing to a lack of instruments to ensure the traceability of imported fish. In terms of employment, more than 135 000 people are engaged in the processing sector, many of whom work in firms with 20 employees or fewer. There has, however, been a decreasing trend in employment owing to closures of inefficient small firms or the merger of small firms with large firms.

In the Asia–Pacific region, the processing sector is largely labour-intensive and consequently provides significant employment opportunities, contributing to food security and general well-being. The processing sector is also contributing to the empowerment of women as, in most instances, the majority of the employees are females. The spectacular development of export markets for three freshwater finfish species groups (catfish, tilapias and carps) has created ancillary developments in the processing sector as well. Another major development in Asia has been the practice of outsourcing processing of fish. For example, whole fish from European and North American markets are sent to Asia (China in particular, but also India and Viet Nam) for filleting and packaging, and are then re-imported.

A study of the market chains for a number of low-value cultured aquatic commodities (catfish, snakehead and roho labeo) in the Asia region (De Silva, 2008) found that, in all cases, the profit margin at each stage of the value chain was 10–12 percent on average, except at the retail point in the importing country. For example, roho labeo exported at approximately US$1.2–1.3 per kilogram costs the consumer in Rome, Italy, US$8–9 per kilogram. The wide difference in margins raises the issue as to how farmers, particularly small-scale farmers, could obtain higher farmgate price, in other words a higher share of the retail price. In this regard, FAO and the Norwegian Agency for Development Cooperation (NORAD) have initiated a comprehensive value-chain analysis of the international fish trade and food security, with a focus on arriving at policies that will safeguard the interests of small-scale producers. Case studies covering small-scale sectors in ten developing and two developed countries will analyse the factors that determine prices and margins throughout the value-chain, as well as the distribution of benefits among the various stakeholders.[10]

In Latin America and the Caribbean, larger producers often process their own products, as in the case of salmon, and transfer them to "brokers", even in the country of destination. For larger outputs, products are sent to the nearest cities that have cold storage facilities and processing plants.

In the African context, the scale of processing, both in technical and value terms, is significantly smaller. In response to the preference of urban consumers for more standardized produce and "easy/ready to prepare" commodities, there has been a growth in artisanal-type fish dressing industries at farmgates and markets. There are also instances of wholesale sellers handling produce in coolers and minivans for sale in distant markets. In some cases, to add value to their products, sellers, essentially women, sell larger pieces of smoked or dried fish. Post-harvest handling and packaging are limited to molluscs and crustaceans that are exported.

#### Food safety requirements

An encouraging trend is that governments, along with the private sector, are paying greater attention to consumers' and other stakeholders' growing concerns about fish food safety (e.g. antimicrobial residues and harmful micro-organisms). Consequently, compliance with international food safety standards has improved. There is, however, a need for support to further capacity building in many developing countries to meet the increasingly stringent requirements for export.

Exporting countries recognize that such continuous capacity-building support is critical as, based on past experience, the economic impact of the presence of human health hazards in aquaculture products can be devastating. Cases of detentions or rejections of consignments of aquaculture products under the EU alert system for food and feed highlight the magnitude of such impact. For example, in 2005, 177 consignments were detained or rejected, representing 48 percent of the total and an estimated cost of US$9.3 million. The main causes of detentions/rejections were microbial hazards (38 percent), nitrofuran (27 percent), malachite green (20 percent), sulphites (13 percent) and other residues (3 percent) (Subasinghe and Ababouch, 2009).

In terms of regional status and performance with regard to food safety issues, a core objective of the 2002 European strategy for sustainable aquaculture development – to "assure the availability to consumers of products that are healthy, safe and of good quality, as well as promoting high animal health and welfare standards" – is generally being successfully implemented. In North America, the Canadian Food Inspection Agency (CFIA) regulates food safety and food quality of fish and seafood exported from and imported into Canada. Processors engaged in exports are required to register with the CFIA and should have an in-plant Quality Management Program.

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[10] See: www.globefish.org/a-value-chain-analysis-of-international-fish-trade-and-food-security-with-an-impact-assessment-of-the-small-scale-sector.html

For inspection of imports, which consists of risk-based sampling and management, the CFIA also uses the services of other countries having reliable inspection systems. The regulatory arrangement in the United States of America is similar, with the responsibility shared between the Food and Drug Administration and the National Oceanic and Atmospheric Administration (NOAA).

Most Latin American and Caribbean countries have plant certification programmes run by their health authorities, two of which stand out – the Standard Sanitary Operation Procedure (SSOP) and the Hazard Analysis and Critical Control Point (HACCP) system – and are applied for exports, including those to the United States of America and the EU markets. Institutions in some countries also have the capacity to carry out residue control programmes in aquaculture operations and in plants through traceability, and their certification guarantees the quality of aquaculture products (FAO, 2006c).

The Asia–Pacific region, having a number of leading exporters and importers, also attaches great importance to food safety issues and compliance with international standards. For example, in China, the recent report of unacceptable levels of drug residues occurring in some exported products has received the highest attention of policy-makers. Some of the measures taken to strengthen the "quality and safety" management work include improvements in the Quality and Safety Standard System and the Examination and Test and Certification System, and improvements in the related laws and regulations. The Government's commitment to address quality and safety issues is further reflected in the Ministry of Agriculture's Action Plan on Transformation Growth Mode of Aquaculture, which aims to promote the transition from the "high productivity" mode to the "quantity and quality" and "profit and ecology" mode of aquaculture development (Zhou, 2007).

Thailand and Viet Nam, two of the other top-ten exporters of fish and fishery products in the world, have also taken initiatives with regard to compliance with food safety standards (FAO, 2006c). In 2003, Thailand launched a comprehensive food safety and quality ("farm to plate") programme, and declared 2004 as "Food Safety Year" to increase awareness and improve systems for safe aquaculture production. In 2004, Viet Nam also intensified its efforts towards improving the food safety and quality of its products, particularly those for export, through a wide-ranging programme including farmers' education. Based on experience gained over the years, the countries continue to build on these initiatives.

In Africa, food safety is an issue that is receiving increased attention from many countries, including those that are working to meet EU regulations on safety and quality control, which will be a requirement for their emerging export sector (Satia, 2011). While several countries in the region have adopted SSOP and HACCP programmes in the context of capture fisheries, few countries have aquaculture-specific facilities. The countries are, however, taking measures to address this shortcoming, including significant capacity building and training of producers, exporters and other stakeholders, often with technical assistance provided by FAO. While this approach to enhance export capacity is no doubt desirable, governments simultaneously need to develop strategies to safeguard small-scale producers from the impacts of compliance with stringent international trading standards.

### Certification and organic aquaculture

Driven by concerns that some forms of aquaculture are environmentally unsustainable and socially inequitable, there have been various attempts in recent years to respond to the consequent public perceptions and market requirements. Policy and regulations governing environmental sustainability have been put in place in many countries, requiring aquaculture producers to comply with more stringent environmental mitigation and protection measures. Food safety standards have been raised and international trade regulations tightened. In some countries, these changes were initiated by the aquaculture sector itself, usually within the more organized private industry sector to ensure its sustainability and protect operations from poorly managed activities. Both government and the private sector in all regions have made significant advances in the management of aquaculture, and there are many examples of improved and better management that have reduced environmental impacts and improved efficiency, including profitability.

The need to respond to environmental and consumer concerns on aquaculture production and the drive to secure better market access have led to increasing interest in certification of aquaculture production systems, practices, processes and products. For example, recent legislation in both Europe and the United States of America requires mandatory certification to identify whether aquatic products are produced from aquaculture or are wild caught. These markets increasingly recognize that some form of certification is a way of assuring buyers, retailers and consumers that fishery products are safe to consume and originate from aquaculture farms adopting responsible management practices. FAO's programme to provide capacity-building support in the area of food safety to developing countries is focused on food standards linked to the Codex Alimentarius and developed in close collaboration with the World Health Organization. The Codex Alimentarius includes standards for all principal foods (whether processed, semi-processed or raw) for distribution to the consumer, with provisions related to food hygiene, food additives, pesticide residues, contaminants, labelling, presentation, methods of analysis and sampling. The Codex Secretariat, housed in the FAO Nutrition and Consumer Protection Division, has primary responsibility for normative work on food safety.

There is, however, a need for harmonization of product quality and safety standards within aquaculture, implying increased development and wider use of internationally accepted, scientifically based standards. The principles of achieving harmonization of standards and equivalence in food control systems and the use of scientifically based standards are embodied in two binding agreements of the WTO: the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) and the Agreement on Technical Barriers to Trade (TBT Agreement). The SPS Agreement confirms the right of WTO member countries to apply measures necessary to protect human, animal and plant life and health. The objective of the TBT Agreement is to prevent the use of national or regional technical requirements or standards in general as unjustified technical barriers to trade.

In several countries, aquaculture producers are introducing environmental certification of aquaculture products, either individually or in a coordinated manner, in order to demonstrate credibly that their production practices are non-polluting, non-disease transmitting and/or non-ecologically threatening (FAO, 2006a). The success of these certification schemes, however, is yet to be demonstrated. Some countries are attempting to introduce State-mediated certification procedures to certify that aquaculture products are safe to consume and farmed in accordance with certain environmental standards (Subasinghe and Phillips, 2007). However, most of the work done on improved management leading to better production practices and products has been on salmon and shrimp, mainly because of their high commodity value, cost absorption capacity and the importance attached to them as the most internationally traded products.

Socially responsible aquaculture is also high on the agenda in certain markets, and certification is one way to verify the effort put into working towards a more socially sustainable aquaculture sector. It is now widely accepted that aquaculture should be conducted in a socially responsible manner, within national rules and regulations that benefit the workers, small-scale farmers, local communities, investors and the country, and in a way that contributes effectively to rural development, poverty alleviation and

COURTESY OF MATHEW BRIGGS

*Live grouper is on display in a restaurant in China.*

food security and delivers benefits to the local community and surrounding resource users.

Another important issue in aquaculture certification is animal health and welfare. In essence, aquaculture should be conducted in a manner that assures the health and welfare of farmed aquatic animals by minimizing stress, optimizing health, reducing aquatic animal disease risks and maintaining a healthy environment at all phases of the culture cycle.

At the global level, there have been two significant developments in the area of aquaculture certification. The first is FAO's work on the development of international guidelines on aquaculture certification (Chapter 4). The second is the ongoing initiative of the World Wide Fund for Nature (WWF) to develop global standards for the responsible aquaculture of 12 species (shrimp, salmon, abalone, clams, mussels, scallops, oysters, *Pangasius*, tilapia, trout, *Seriola* and cobia) that have the highest market value and/or the heaviest trading in the world market. The standards, which are expected to be finalized in 2011, focus on minimizing or eliminating the key negative environmental and social impacts. It is expected that the certification process for these standards will be overseen by a new organization, the Aquaculture Stewardship Council (WWF, 2010).

In support of the environment, some producers in the food sector in general have been promoting the sale of organic products and, in the process, earning a premium by differentiating themselves from other producers. Organic aquaculture is relatively new and limited to relatively few countries and species. In Europe, there were initial obstacles related to its introduction, one of which was the lack of common standards for the markets of the EU and the United States of America. Globally, there are about 30 non-governmental certifiers, 18 of them in the EU. Salmon and trout are the main organic species in the EU (Váradi *et al*., 2011). In North America, there is at present no legal definition of what constitutes organic aquaculture (Olin, Smith and Nabi, 2011). The National Organic Standards Board established an Aquatic Task

Force and Aquaculture Working Group in 2000 to examine issues and formulate recommendations, and the work is progressing well. In Canada, there is currently only one company that holds ecocertification – the company certifies Atlantic salmon. Another company practises organic farming, raising only chinook salmon. In 2008, the industry initiated the Canadian Aquaculture Standards Forum to promote common understanding and capacity building with regard to standards and certification.

**Role of producer associations**

From the aquaculture self-help groups, including women's groups in developing countries, to the more formal regional and international producer associations (PAs) in developed countries, PAs have been playing a major role in the development of markets and trade. At a special session on PAs at the second meeting of the COFI-AQ, the Sub-Committee acknowledged PA contributions towards aquaculture development and suggested that they (particularly small-scale farmers associations) be provided with appropriate support to strengthen their capacity.

While there are varying degrees of accomplishment among the PAs, some of the common ones are: shaping and influencing policy and regulations; facilitating access to markets; and developing and promoting codes of conduct, certification schemes, BMPs and self-regulatory practices. In the case of countries with market distortions and weak governance, there is emphasis on "getting organized to resist exploitation by middlemen and local pressure groups" and on mobilizing credit (Hough and Bueno, 2003).

Generally, in developed regions, PAs are not actively engaged in product marketing and supply; they are more involved in improving farm-level practices and in representing industry in national and international fora on policy and technical areas. However, there are exceptions, as in North America, where two associations (The United States of America Catfish Institute and the Mussel Industry Council of North America) are engaged in promoting and marketing of the species they represent.

In the Asia–Pacific region, there are best practice cases of involvement in marketing activities by small-scale farmers associations, clusters or self-help groups that are often supported by NGOs and operate as a single unit following BMPs (Box 3). In Africa, fish farmer associations representing particular species function in a number of countries at the regional, national and local levels. Overall, these associations have been useful in the advancement of aquaculture in the region, including contributing to setting regional and national aquaculture policy agenda, as was evident in their participation at the New Partnership for Africa's Development (NEPAD) Fish for All Summit in Nigeria in 2005. Operationally, the associations are engaged in a range of activities, such as providing extension and marketing support, facilitating input supply and serving as a conduit for obtaining assistance from government and financial institutions.

**Potential for increase in demand**

World aquaculture production is dominated by species at the lower end of the food chain. Carp and shellfish account for a significant share (more than 70 percent by volume) of species cultivated in developing countries for human consumption. However, in response to a ready market for these species in both developed and developing countries, the production of species at the higher end of the food chain (in particular, carnivorous species) has, in recent years, been growing rapidly compared with that of species at the lower end of the food chain.

The demand for fish as a healthy and nutritious food commodity is increasing, even in the developing world, particularly in China, India and Indonesia, i.e. countries with


*Cultured red snappers fetch good prices in the market.*

a large population and increasing disposable income.

The demand for low-value species for national consumption is currently met primarily through national production; however, this may not be the case in the coming decades. In regions and countries where the cost of production is low and production conditions are better, low-value fish may be farmed and shifted for local consumption, while nationally produced high-value fish may enter the global market.

## SALIENT ISSUES AND SUCCESS STORIES

### Salient issues

As the global aquaculture industry expands and caters to the diversified food preferences of consumers, it is essential that the issue of tariffs to protect local markets is addressed in line with WTO rules and regulations that are intended to level the global trading field. It is also suggested that FAO's technical guidelines for responsible fish trade (FAO, 2009c) be considered by concerned countries.

To facilitate access to both domestic and international markets, governments need to provide adequate infrastructure development support to the industry (e.g. electricity and rural road networks). However, as providing exclusive infrastructure development support that is outside the sector (e.g. access to well-functioning seaports and airports, regular supply of energy and efficient information and communication technology services critical for exports) is neither practical nor financially viable, it is important that such support be considered within a comprehensive national infrastructure development framework that also recognizes the special needs of the aquaculture sector.

As countries develop their capacity to comply with stringent international trading standards, governments need to develop strategies and programmes that will safeguard small-scale farmers, who might be marginalized or excluded from markets. To allow small-scale farmers to take advantage of economies of scale and to enable them to comply with trade requirements in a cost-effective and responsible manner, governments need to facilitate the continuation of development of small-scale farmers into producers associations, "cluster groups" or "self-help groups" through capacity building on better management and marketing practices, including compliance with certification guidelines, and other technical measures. Moreover, FAO's and NORAD's value-chain analysis of international fish trade is expected to recommend policy measures that would not only enable small-scale farmers to better access international markets but also to obtain prices and margins that would let them achieve long-term sustainability from an economic, social and biological resource perspective.[11]

### Success stories

The unprecedented development of the striped catfish sector in the Mekong Delta is considered an aquaculture success story, not only in Viet Nam, but also globally. This success can be attributed to, among others, supportive government policies in the areas of research, infrastructure development and exports, and the innovativeness of farmers in adapting research findings, particularly in the areas of artificial propagation, feeds and nutrition, and husbandry (Box 9).

## THE WAY FORWARD

Through trade, globalization is playing an increasingly important role in aquaculture development. Its requirements are twofold: (i) strengthening of international, national and interprovincial or interstate biosecurity and food safety measures; and (ii) enhancing the ability of governments and producers to comply with trade and market access requirements for safe and quality products through training, legislation, codes of practice, certification and traceability schemes. These requirements are creating a considerable drive for importing and exporting countries to harmonize standards collectively as well as to address issues such as the certification of products and processes. Further global cooperation and harmonization of standards for aquaculture production and trade will be important in order to support the increasingly globalized aquaculture sector.

As a consequence, there is a need for policy-makers to consider these aspects when improving governance of the trade sector. They must continue to recognize that policies can be much more effective if producers participate in decision-making and regulation processes. Such recognition has already led many governments to build national capacities to assist producers and processors in complying with mandatory food safety regulations, while empowering farmers and their associations for greater self-regulation. This move is contributing to improving the management of the sector at the farm level, typically through the promotion of BMPs and codes of practice of well-organized associated producers.

[11] See: www.globefish.org/a-value-chain-analysis-of-international-fish-trade-and-food-security-with-an-impact-assessment-of-the-small-scale-sector.html

# 6. Contribution of aquaculture to food security and to social and economic development

## STATUS AND TRENDS

Hunger and malnutrition remain among the most devastating problems facing the world's poor. A considerable portion of the global population is currently suffering from one or more forms of nutrient deficiency. The deteriorating trend in the global food security situation reached an alarming level in 2009. For the first time in human history, more than one billion people suffered from hunger or were undernourished. In 2009, an additional 105 million went hungry as the global economic slowdown, reinforced by the food and fuel crisis, reduced incomes and employment opportunities of the poor and significantly diminished their access to food. The crisis is also reported to be stalking the small-scale farms and rural areas of the world, where 70 percent of the world's hungry live and work. While the number of people who live in chronic hunger and malnutrition registered a modest decline in 2010 – to 925 million – primarily because of brighter economic prospects and lower food prices, it remains unacceptably high (FAO, 2010e, 2010f).

The recent spike in food insecurity underlines the urgency to adopt substantial and sustained remedial actions that would ensure achievement of the 1996 World Food Summit target of reducing the number of people who suffer from hunger and malnutrition by half to no more than 420 million by 2015 (FAO 2010e). The Declaration of the 2009 World Summit on Food Security reiterated the need for urgent action to eradicate hunger from the world (Box 11). Aquaculture also has an important

BOX 11

**World Summit on Food Security: five principles for sustainable global security**

Principle 1: Invest in country-owned plans, aimed at channelling resources to well-designed and results-based programmes and partnerships.
Principle 2: Foster strategic coordination at the national, regional and global level to improve governance, promote better allocation of resources, avoid duplication of efforts and identify response-gaps.
Principle 3: Strive for a comprehensive twin-track approach to food security that consists of: 1) direct action to immediately tackle hunger for the most vulnerable and 2) medium- and long-term sustainable agricultural, food security, nutrition and rural development programmes to eliminate the root causes of hunger and poverty, including through the progressive realization of the right to adequate food.
Principle 4: Ensure a strong role for the multilateral system by sustained improvements in efficiency, responsiveness, coordination and effectiveness of multilateral institutions.
Principle 5: Ensure sustained and substantial commitment by all partners to investment in agriculture and food security and nutrition, with provision of necessary resources in a timely and reliable fashion, aimed at multi-year plans and programmes.

*Note*: In the declaration, the term agriculture comprises crops, livestock, forestry and fisheries, including aquaculture.

*Source:* Declaration of the World Summit on Food Security. WSFS 2009/2. 16–18 November 2009. FAO, Rome.

and increasing role to play in addressing food insecurity by enhancing the supply and consumption of fish and other marine and freshwater products, which are commonly rich sources of protein, essential fatty acids, vitamins and minerals, by generating higher incomes and employment opportunities and by enhancing trade, thereby reducing poverty and promoting social and economic development.

Despite the widely accepted importance of aquaculture's contributions to food security, employment creation, income generation and the empowerment of women, it is also recognized that a more systematic and quantitative evaluation of the impact of aquaculture is needed to measure clearly the contributions and to use these results to formulate suitable policies and secure adequate funding. To address such shortcomings in impact evaluation, a number of initiatives have been taken or are under way, such as FAO's recently completed work on development of systematic conceptual and operational empirical frameworks for the assessment of commercial aquaculture's direct and indirect impacts on economic growth, poverty alleviation and food security, and ongoing work on the preparation of technical guidelines on enhancing the contribution of small-scale aquaculture (Cai, Leung and Hishamunda, 2009; Bondad-Reantaso and Prein, 2009).

Although carrying out impact analysis at a global level is an issue, it can, however, be safely stated that, based on the regions where aquaculture is practised, the aquaculture industry plays an important role in providing food security and in promoting social and economic development. The following section provides a broad review of aquaculture's contributions in some of the countries where it is practised.

### Contribution to food security

Fish originating from both culture and capture fisheries sources can make significant contributions to improve and diversify dietary intakes and promote nutritional well-being among most population groups. Fish have a highly desirable nutrient profile and provide an excellent source of high-quality animal protein that is easily digestible and of high biological value. Fatty fish, in particular, are an extremely rich source of essential fatty acids, including omega-3 polyunsaturated fatty acids that are crucial for normal growth and mental development, especially during pregnancy and early childhood (FAO, 2003). Fish are also rich in vitamins (fat-soluble vitamins A, D and E, and water-soluble vitamins, B complex) and minerals (especially calcium, phosphorus, iron, selenium and iodine in marine products). Therefore, fish can provide an important source of nutrients, particularly for those whose diets are lacking in other animal-source foods.

Globally, slightly more than half (54 percent) of the total food fish supply is obtained from marine and inland capture fisheries, the remaining (46 percent) of supply being derived from aquaculture (Table 1). The contribution of capture fisheries to per capita food supply stabilized at 10–11 kg per capita in the period 1970–2000, and then declined to 9.3 kg per capita in 2008. Recent increases in per capita availability have been obtained from aquaculture production. Globally, aquaculture's contribution to per capita food availability grew from 0.7 kg in 1970 to 7.8 kg in 2008.

More food fish is being consumed globally on a per capita basis, with annual consumption increasing from an average of 12.6 kg in the 1980s to 14.4 kg in the 1990s and reaching 17.0 kg in 2007 (Table 5). According to preliminary estimates, the annual per capita apparent fish consumption grew to 17.1 kg in 2008 and is forecast to have increased further to 17.3 kg in 2010. However, the increase has not been uniform across and within countries and regions, reflecting different eating habits, availability of fish and other foods, prices and socio-economic levels. In fact, annual per capita fish consumption can vary from less than 1 kg in one country to more than 100 kg in another. The most substantial increases in annual per capita fish consumption have occurred in East Asia (from 10.8 kg in 1961 to 30.1 kg in 2007), Southeast Asia (from 12.7 kg in 1961 to 29.8 kg in 2007) and North Africa (from 2.8 kg in 1961 to 10.1 kg in 2007). China, in particular, has experienced dramatic growth in its per capita fish

TABLE 5
**Total and per capita apparent food fish supply by continent in 2007**

| | Total food fish supply | Per capita food fish supply |
|---|---|---|
| | *(Million tonnes, live weight equivalent)* | *(kg/year)* |
| World | 113.1 | 17.0 |
| World (excluding China) | 78.2 | 14.6 |
| Africa | 8.2 | 8.5 |
| Asia | 74.5 | 18.5 |
| Europe | 16.2 | 22.2 |
| Latin America and the Caribbean | 5.2 | 9.2 |
| North America | 8.2 | 24.0 |
| Oceania | 0.9 | 25.2 |

*Source:* FAO (2010a).

consumption, with an average growth rate of 5.7 percent per year in the period 1961–2007, mainly owing to the substantial growth from aquaculture.

In 2007, fish contributed 15.7 percent to the global population's intake of animal protein and 6.1 percent of all protein consumed. There are, however, many countries where fish contributes more than or close to 50 percent of total animal protein intake (e.g. Bangladesh, Cambodia, the Congo, Equatorial Guinea, the Gambia, Ghana, Guinea, Indonesia, the Philippines, Sierra Leone, Sri Lanka, and Togo). Indeed, the International Conference on the Sustainable Contribution of Fisheries to Food Security, held in Kyoto (Japan) in 1995, recognized that aquatic products contribute meaningfully to the maintenance of good nutrition. It is interesting to note that farmed aquatic meat production in China currently ranks second to pig meat; per capita availability of food fish in China has increased from 4.5 kg in 1984 to 26.5 kg in 2006. In most developing countries, an important contributing factor to the high demand for staple food fish, in particular inexpensive farmed freshwater fish species feeding low on the aquatic food chain, is the greater affordability of such fish to the poorer segments of society.

## Contribution to social development

Fisheries and aquaculture provide direct and indirect livelihoods support to millions of people around the world. In 2008, out of an estimated 44.9 million people who were directly engaged full time or part time in capture fisheries or aquaculture, an estimated 10.7 million people were involved in aquaculture, or about one-quarter (24 percent) of the total number of workers (Table 6).[12] Of the 44.9 million people employed in capture fisheries and aquaculture, 12 percent were women. The majority of fish farmers are in developing countries, mainly in Asia, which accounted for almost 96 percent of all people employed in the sector (FAO, 2010a).

TABLE 6
**World fish farmers by continent**

| | 2000 | 2008 |
|---|---|---|
| **Continent** | *(Thousands)* | |
| Africa | 78 | 123 |
| Asia | 6 647 | 10 143 |
| Europe | 66 | 80 |
| Latin America and the Caribbean | 187 | 443 |
| North America | NA | NA |
| Oceania | 5 | 4 |
| World | 6 983 | 10 793 |

*Note:* NA = not available.
*Source:* FAO (2010a).

[12] Employment figures are indicative and they underestimate the real numbers, as some countries do not disaggregate aquaculture from agriculture or fisheries, and some countries' national systems do not yet account for fish farming. This section mainly uses data from FAO (2010a), but also refers to data from other sources, as appropriate.

In addition to fishers and fish farmers involved in direct primary production of fish, a large number of people are engaged in other ancillary or secondary activities, such as processing, net and gear making, ice production, manufacturing of fish-processing equipment, packaging, marketing and distribution. Another group is involved in research, development and administration connected with the fishery sector. While no official data exist for such groups of people, it has been estimated that fishers, aquaculturists and those supplying services and goods support the livelihoods (including dependent family members) of a total of 540 million, or 8.0 percent of the world population (FAO, 2009a, 2010a).

The average annual production of fish per person varies among regions and countries, reflecting the degree of industrialization of aquaculture-related activities and the key social role played by small-scale farmers, particularly in Africa and Asia. In the aquaculture sector, for example, fish farmers' average annual production in Norway is 172 tonnes per person, while in Chile it is about 72 tonnes, in China 6 tonnes and in India 2 tonnes.

According to a recent ad hoc estimation of employment in world aquaculture by FAO, it has been reported that aquaculture employs about 23.4 million full-time equivalent workers, which includes 16.7 million direct (about 1.2 percent of the population employed in agriculture worldwide) and 6.8 million indirect jobs. The global estimate for employment in world aquaculture was attempted only for 2005, as the most complete information was available for this year. Considering an average family size of five members, it can be inferred that aquaculture contributed to the livelihoods of about 117 million people or 1.8 percent of the global population. As expected, Asia (including the Far East) accounts for more than 92 percent of total employment. In terms of labour productivity, it is highest in North America and Europe, an indication that the sector in these regions is highly industrialized (Valderrama, Hishamunda and Zhou, 2010).

Studies show that with increased livelihoods opportunities arising from aquaculture development, there has been a decrease in migration from rural areas to urban centres in many countries, such as in Viet Nam (Mekong Delta), Greece and the United Kingdom (FAO, 2003). The decreased need for urban migration, particularly in many developing countries, is considered as aquaculture's contribution to reducing pressure on the overburdened urban infrastructure and support services because of high population growth and lack of proper urban development planning.

Women also contribute to household food security and income through their participation in various aquaculture activities, such as feeding and harvesting of fish and collecting of prawn larvae and fish fingerlings. However, their most important role is at the processing and marketing stages. While in some countries women have become entrepreneurs in fish processing, carrying out activities in their own cottage-level industries, there are also a large number of women who work as wage labourers in the processing industry.

Furthermore, in the context of employment in Asia, it is estimated that in Viet Nam more than 700 000 people are employed in aquaculture, although this figure does not yet reflect the large number of people employed in affiliated industries (e.g. fish feeds, equipment, fish processing and marketing). The average annual per capita income of people employed full-time in the fisheries sector (including aquaculture) in China was about US$540 in 1999, which was more than double that of rural terrestrial farmers. In Southeast Asian countries such as Cambodia, Indonesia and Thailand, a similar situation can be found; farmers engaged in aquaculture typically generate higher household incomes than those who are not. In Viet Nam, 50 percent of the farmers involved in aquaculture consider it as their main source of income and derive on average 75 percent of their households' income from it. Catfish and shrimp culture, specifically in recent years, have provided an average annual household income of more than US$1 000, which is significantly more than that generated by comparable agriculture practices (FAO, 2003).

*Harvesting freshwater prawn,* Macrobrachium rosenbergii, *in an FAO supported aquaculture development project in Sri Lanka.*

COURTESY OF ROHANA SUBASINGHE.

COURTESY OF ROHANA SUBASINGHE

*Rural fish farmer in Hubei Province of China collecting grass to feed his grass-carp.*

In Africa, it is estimated that employment from aquaculture per country ranges between 18 000 and 30 000 jobs (Satia, 2011). The number will increase if temporary employment is added, as in the case of Madagascar, it jumps to an additional 60 000 jobs. In the Near East and North Africa region, it is estimated that more than 86 000 people are employed, of whom 70 percent are from Egypt, the region's largest producer. In western Africa and some southern African countries, fish processing, retailing and the local trading of fish are mainly carried out by women. There are also cases where many of the women are heads of households, and fish trading provides the only source of income (e.g. in western Zambia). On prawn farms, women account for about 30 percent of the workforce and are involved in post-harvest operations and administration (Krouma, 2011; FAO, 2006a).

For Latin America and the Caribbean, aquaculture employs an estimated 221 500 workers, of whom 75 percent are male and 25 percent are female (FAO, 2006a). Women are engaged mainly in processing, accounting for more than 90 percent of the labour force. In specific areas where aquaculture is practised, as in the case of salmon farming and other aquaculture activities in southern Chile, employment opportunities are relatively better. It has been estimated that direct employment figures in southern Chile could be as high as 39 000, while indirect opportunities could exceed another 15 000 jobs. In the early 1990s, aquaculture accounted for about 5.8–8.4 percent of total employment in the Lakes Region of Chile (the salmon region) and for 38.9 percent of employment by 2001. However, the fast-paced development of industrial aquaculture in Chile completely overshadowed small-scale farming activities related to algae, oyster and mussel production in the southern regions. Nonetheless, about two-thirds of those rural producers generate a major part of their incomes, in most cases more than 70 percent, through aquaculture.

Direct and indirect employment in aquaculture in North America has registered a modest increase in the past decade. It has been estimated that the number of jobs increased from 40 212 in 1998 to 52 129 in 2007. This increase is also region-specific (e.g. farmed salmon in British Columbia in Canada and channel catfish in the states of Arkansas, Louisiana and Mississippi in the United States of America). In terms of gender, male employees account for over 72 percent of Canadian jobs. Recent statistics on gender-based occupation in aquaculture in the United States of America are not readily available, but according to the United States Census Bureau, it is likely that in 2009 there were more women than men employed in the sector (Olin, Smith and Nabi, 2011).

In Europe, some 123 000 people are employed by the aquaculture industry, with three countries – the Russian Federation (27 200), France (21 600) and Spain (11 900) – accounting for half of those employed (Váradi *et al*., 2011). However, the number of people employed in Faroe Islands, Norway and Greece, the three countries where aquaculture has the highest relative economic weight, constitutes only 9 percent of the region's total, indicating skilled workers' high labour productivity in the automated salmonid and seabass/seabream farming industry. In contrast, labour productivity is considerably lower in the traditional, extensively practised mussel-culture and carp-farming sectors, which offer more jobs than their relative economic weights. Concerning gender-based occupation, the majority of the workers are men, with the exception of the Russian Federation, where women constitute up to 70 percent of the total staff in some fish-breeding farms (FAO, 2006a).

## Contribution to economic development

Aquaculture makes valuable contributions to the local, national and regional economies through goods and services sold on the domestic and export markets. Generally, subsistence and small-scale aquaculture contributes directly to the alleviation of poverty and achievement of food security. In addition, small-scale and large-scale commercial aquaculture as practised in many developed and developing countries with species such as shrimp, salmon, tilapia, catfish, grouper and carps can enhance the production for domestic and export markets and generate employment opportunities in the production, processing and marketing sectors. Indirectly, tax revenues from commercial aquaculture enterprises and foreign exchange export earnings allow governments to invest in sectors that add to the achievement of food security. Moreover, planned development of aquaculture (e.g. zoning, and the cluster approach) could lead to improvements in infrastructure such as roads, bridges and electricity, thereby boosting local economies.

In many countries, aquaculture's contribution as a proportion of total gross domestic product (GDP) is small, but its importance to the national economy in terms of poverty alleviation and nutritional benefits is significant, particularly in developing countries. At the regional level, aquaculture's contribution to the economies of many countries in the Asia–Pacific region is relatively higher, with Viet Nam at 16 percent of GDP in the lead. Table 7 shows the 11 leading aquaculture countries in terms of aquaculture's contribution to national GDP.

TABLE 7
**Contribution of aquaculture to GDP in the Asia-Pacific region in 2006**

| Country | Percentage of GDP |
|---|---|
| Viet Nam | 16.0 |
| Myanmar | 8.8 |
| Lao People's Democratic Republic | 4.4 |
| Democratic People's Republic of Korea | 2.4 |
| China | 2.3 |
| French Polynesia | 1.9 |
| Bangladesh | 1.9 |
| Philippines | 1.5 |
| Cambodia | 1.3 |
| Thailand | 1.3 |
| Indonesia | 1.0 |

*Source:* Lymer *et al.* (2008).

In contrast to Asia–Pacific, in Europe, aquaculture value-added contributes a mere 0.02 percent of the region's total GDP of US$20.2 trillion (Váradi *et al*., 2011). However, in absolute terms, the US$4.2 billion value added is no doubt significant, especially when compared with the GDPs of many countries of the world, which are relatively lower. Another common pattern seen in Europe and elsewhere is the variation in terms of aquaculture's contribution to GDP within the countries in the regions (e.g. Faroe Islands, 2.95 percent; Norway, 0.31 percent; and Greece, 0.12 percent).

In North America, aquaculture's contribution to agricultural production is very small, but its contribution to local economies is considered extremely important to some communities in both Canada (e.g. farmed salmon in British Columbia) and the United States of America (e.g. channel catfish in the states of Arkansas, Louisiana and Mississippi) (Olin, Smith and Nabi, 2011).

For Latin America and the Caribbean, despite the region's success in salmon farming at the international level, it is interesting that aquaculture's contribution to the region's economy remains low. However, the region has demonstrated an upward trend in terms of aquaculture's share of total fish production, rising from 4.8 percent in the period 1999–2001 to 8.8 percent in the period 2005–07 (Wurmann, 2011). Again, within the region, there are variations with regard to aquaculture's contribution to the respective economies. For example, a report from 2005 indicates that the contribution of shrimp farming in northeast Brazil to local GDP was extremely significant for at least six of the ten municipalities, with shares ranging from 21 to 63 percent of the respective GDPs (Sampaio and de Farias, 2005).

Chile, the world's second-largest exporter of salmon, is another country in the region that exhibits a country-specific situation similar to northeast Brazil. Salmon farming in Chile makes substantial contributions to the national foreign exchange earnings, to rural and local development and to employment generation, including high-paying technical and management jobs. However, the aquaculture sector's dominance of a single product has its downside as well, as in the case of any sector's reliance on a single economic activity. For example, the outbreak of infectious salmon anaemia (ISA) in 2009 had devastating impacts on the aquaculture sector, including financial losses and reduced employment opportunities.

Fisheries, including aquaculture, generally make a small contribution to the national economies of Africa, ranging from 1.1 percent in Tunisia to 5.3 percent in the Gambia (Satia, 2011). Similarly, the contribution of fisheries, including aquaculture, is negligible in the Near East and North Africa region, with all of the countries having contributions of less than 1 percent.

## SALIENT ISSUES AND SUCCESS STORIES

### Salient issues

While it is acknowledged that aquaculture provides an important source of livelihoods to millions of people around the world, it is important to substantiate this claim with hard data and rigorous analysis. Proper positioning of aquaculture's contribution is, therefore, particularly important to persuade policy-makers and development partners to invest more resources in its development.

Driven by falling fish prices, environmental pressures and competition for space, the aquaculture industry, particularly in the developed regions and in some countries in the developing regions, is expected to move further towards concentration through mergers and acquisitions and automation, leading to rising labour productivity. However, this trend raises a social sustainability-related issue, as local communities and rural people are gradually being excluded from the sector. Many developed countries have well-developed social support systems in place to address such issues. Although the aquaculture sector in developing countries still does not provide such support programmes, it is important that social assistance, such as safety-net assistance and finance or technical assistance to affected people, is provided so that they have the option either to remain engaged in the sector or to look for alternative opportunities.

### Success stories

An important area where aquaculture has made a significant contribution is in the empowerment of women, including single-headed households, particularly in developing countries in the Asia–Pacific, Africa, and Latin America and the Caribbean regions. In those countries, women in large numbers are actively engaged in the value-chain business, mainly in post-harvest and marketing of products. Even in developed regions such as North America, there are many opportunities for women as farmers. Moreover, women are often at the forefront of research, bringing new discoveries and technologies to the aquaculture sector.

Another major contribution that could be showcased as a good model for replication is the employment opportunity provided to HIV/AIDS-affected households, including those headed by widows in several countries in Africa. Studies have shown that the nutritional status of these families has improved through fish consumption and that the incomes received from fish sales are used to purchase further health care, including HIV/AIDS care.

## THE WAY FORWARD

Poverty and food security-focused aquaculture interventions that have proved to be successful are characterized by: ownership by the beneficiaries; the use of participatory approaches; being small-scale in terms of investment; being demand-led, with farmers first; use of people-centred approaches; the growing of species that feed low on the food chain (e.g. carp, catfish and tilapia); the targeting of all household members; and the use of farmer-field-school-type methodologies and of technologies that are developed according to the local context with network approaches. On the other hand, aquaculture interventions that failed to contribute to the alleviation of rural poverty

COURTESY OF ROHANA SUBASINGHE

*Semi-intensive culture of Asian swamp eel* (Monopterus albus) *in small net cages installed in ponds in Hubei Province in China.*

and the achievement of food security generally: made use of inappropriate subsidies and training allowances; established large centralized hatcheries; used technology-led interventions; were short-term; and had management, extension and planning approaches that were top-down (FAO, 2003).

There is hope that the lessons learned to alleviate poverty and ensure food security through aquaculture interventions will be noted by world leaders, as was demonstrated at the November 2009 World Summit on Food Security. World leaders unanimously adopted a declaration pledging renewed commitment to meet the targets of Millennium Development Goal 1 (eradicate extreme poverty and hunger) and the World Food Summits by 2015. The commitments and actions are based on a set of principles (Box 11).

Of particular relevance to aquaculture is the world leaders' commitment to give special attention to aquaculture and other agricultural activities, with a focus on smallholders. Other related commitments are: providing access to, and sustainable use of, land and water; maintaining the health and productivity of all ecosystems; and better management of the biodiversity associated with food and agriculture. The challenge for the aquaculture sector is to remain proactively engaged with policy-makers and planners and ensure that commitments are translated into actions.

# 7. External pressure on the sector

## STATUS AND TRENDS

The most important external pressures that could either threaten or benefit the financial, social and environmental sustainability of global aquaculture are climate change, global economic crisis, political instability and civil unrest, and global pandemic diseases.

### Climate change

A common opinion expressed by national and international experts on aquaculture development is that despite the importance of climate change at a global political level, as was evident at the United Nations Climate Change Conference in Copenhagen (including the Fifteenth Conference of the Parties [COP 15]) in December 2009, the impacts of climate change on global aquaculture are not yet fully known. Based on the few studies that have been completed and some others that are under way, the potential impacts of climate change on global aquaculture may include: rising sea-surface temperatures, sea-level rise, increasing ocean acidification, higher incidence of extreme weather events, increasing risks of transboundary pests and diseases, and altered rainfall patterns and river flows.

In addition, the experts concluded that the impacts are likely to be both positive and negative and will arise from both direct (e.g. through physical and physiological processes) and indirect (e.g. through variations in fishmeal supplies and trade issues) effects. Moreover, as the positive and negative effects are greatly dependent on regional, subregional, national and local contexts, it is not possible to make global generalizations. Detailed recent analyses of the impacts of climate change on aquaculture are provided in FAO reports (De Silva and Soto, 2009; FAO, 2010f).

Rises in sea-surface temperatures are likely to alter the range, growth and distribution of many species, which carry both risks and benefits for the aquaculture sector. A potential negative effect of higher water temperatures is the growth of harmful algal blooms that can release toxins into the water or cause direct physical damage (e.g. high densities of dinoflagelates) and kill fish and shellfish. In particular, cage-based finfish aquaculture and shellfish aquaculture will be highly susceptible to increased toxicity levels. A positive aspect is that higher water temperatures could increase the availability of new sites, such as along the northern coastlines of Canada, where cold temperatures currently restrict aquaculture. However, in the context of the Asia–Pacific region, higher water temperatures are unlikely to have any major impacts, as the bulk of the aquaculture production takes place in the tropics where such temperature increases will be within the thermal tolerance levels of most cultured species. In the Latin America and the Caribbean region, the periodic El Niño events warm the Pacific waters off Chile and Peru and cause a much better growth in scallop fisheries and farming off Peru and in scallop farming in Chile. The events also result in significant fluctuations in the stocks of small pelagic species that are mostly used for fishmeal and fish oil production. Higher water temperatures are also likely to result in increased disease incidence, such as parasitic sea lice, which develop more rapidly in warmer waters and higher salinities, and are a major problem for the salmon aquaculture sector. In addition, higher water temperatures at the limit of physiological tolerance can stress farmed organisms and thereby increase their susceptibility to diseases.

Among the other impacts of climate change, sea-level rises are likely to cause salinity intrusion into culture areas, resulting in losses of areas suitable for aquaculture, particularly in the deltaic regions of the Asia–Pacific and in the Nile Delta in Egypt, where there is the largest production of tilapia in Africa. On the other hand, while sea-level rise could damage coastal agriculture, but mariculture could provide new opportunities and alternative livelihoods to land farmers. In North America, ocean acidification is currently considered the most serious near-term impact of climate change because of its potential to alter ocean ecosystems dramatically in a relatively short period. For aquaculture, ocean acidification particularly influences shell formation and affects filter-feeding shellfish.

Globally, the frequency and severity of extreme weather conditions appear to have already increased. Hurricanes Katrina and Rita in the Gulf of Mexico, Cyclone Nargis in Myanmar, and tsunami and floods in the Asia region are recent examples that demonstrate how aquaculture could be seriously affected by such events. However, there is no scientific consensus that such events are connected to climate change. In addition, the higher frequency and intensity of storms are likely to cause greater damage to both shellfish gear and fish cages, increasing the risk of escapes.

In the case of impacts of weather conditions related to drought, particularly in Africa, it has been pointed out that water stress due to precipitation and evaporation could limit aquaculture productivity and intensification (Brugère and Ridler, 2004; Handisyde *et al*., 2006; Satia, 2011). According to estimates by the Inter-Governmental Panel on Climate Change (IPCC, 2007), by 2020 between 75 million and 250 million people in Africa are expected to be under water stress, and freshwater availability in Central, South, East and Southeast Asia, particularly in larger river basins, is projected to decrease. South America and Europe are expected to be better placed.

A root cause of climate change is carbon emissions, viz. accumulation of greenhouse gases in the atmosphere, driven by anthropogenic activities. The greenhouse gas contributions of fisheries and aquaculture and related supply chain operations are small compared with other sectors. Studies show that aquaculture can provide good-quality protein with a much lower carbon footprint than comparable terrestrial animal production systems. In fact, some aquaculture systems, such as the mariculture of filter-feeders and seaweeds, have minimum or no incidence of greenhouse gas emissions. On the contrary, they can provide ecosystem services such as filtering and absorbing excess nutrients in the water (FAO, 2008a). However, life cycle assessment studies indicate that any farmed aquatic organism relying mainly on fishmeal and fish oil for feeds is costly in terms of energy. Thus, further R&D efforts need to be made to reduce the use of these feed components (see also Chapter 3). On the other hand, aquaculture ponds, if well managed, can contribute to carbon sequestration, especially if pond sediments are recycled for agricultural purposes.

While climate change will directly and indirectly affect all the regions in the world involved in aquaculture, there are concerns that the impacts will be more pronounced at the small-scale level, particularly in the Asia–Pacific, Africa, and Latin America and the Caribbean regions. It has been stressed that these resource-poor and marginalized groups, including women, are most vulnerable through changes in the physical environment and impacts on infrastructure and livelihoods options. However, it also needs to be emphasized that large-scale producers in North America, Europe and some countries in the Latin America and the Caribbean regions are also likely to be adversely affected by climate change, possibly incurring substantial financial losses that might even lead to closures.

In terms of risk management, large producers are likely to pay higher insurance premiums, which in turn will increase their production costs. As it now stands, storm damage accounts for a high percentage of aquaculture insurance claims. For example, in Spain, a poll of more than 40 insurers co-insuring agriculture risk has estimated that claims for weather-related risks will continue to increase both in the coastal and inland (trout) sectors of the country (Váradi *et al*., 2011).

## Global economic crisis

In the current era of globalization, where economies of the world are interdependent, it is only natural to expect that, in the event of a global economic crisis, countries would be affected in varying degrees depending to a large extent on the strength of their macroeconomic policies and the coping strategies. Thus, as an integral part of a country's economic sector, the aquaculture industry would not remain immune to this phenomenon, and the impact could be significant and multifaceted.

The ripple effects of such a crisis, particularly in developing countries, are likely to include a decline in lending to aquaculture entrepreneurs by domestic financial institutions, lower foreign direct investment, a fall in official development assistance and a reduced budgetary allocation to the sector (in terms of investments, research, extension services and capacity building). On the latter, a case in point is Africa, where in most countries, agriculture (including aquaculture) remains a relatively low-priority area in public spending, receiving less than 6 percent of total budgetary allocation, well below the 10 percent agreed in Maputo, Mozambique, in July 2003 (Satia, 2011). Aquaculture's share of the total allocation is generally very small. Moreover, it has been reported that as a consequence of the ongoing economic crisis, governments are allotting the bulk of their national budgets towards addressing the impacts of high fuel and food prices. In essence, all these factors are likely to affect both the profitability of aquaculture businesses and food security, particularly of small-scale producers. The situation in the Asia–Pacific region would also be similar.

Another example of the ripple effects of a global economic crisis is seen in the increase in prices of aquafeeds. As a response to soaring increase in food prices, particularly cereal grain prices, all over the world in the period 2007–08, FAO conducted a study to understand the corresponding impact of rising feed ingredient prices on aquafeeds and aquaculture production. The study focused on Asia and Europe, considering that Asia contributes over 90 percent of global aquaculture production and that Europe has a well-developed aquafeed sector (Rana, Siriwardena and Hasan, 2009). A number of factors are reported to have led to this sharp increase in food prices, namely reduced production of cereal crops worldwide and continued increases in oil prices, resulting in higher freight costs.

COURTESY OF MOHAMMAD R HASAN

*Off-shore culture of marine fish in increasingly sophisticated cage systems is expanding in Europe.*

As cereal grains are the usual sources of carbohydrates in most of the aquafeeds, an increase in cereal grain prices could have a ripple effect on aquafeed prices as well. Moreover, given that the aquaculture industry uses many of the ingredients, such as fishmeal, fish oil, corn and rice, that are internationally traded and also demanded by other sectors, it cannot insulate itself from global market shocks and volatility. A case in point is world fishmeal price, which remained between US$500 and US$700 per tonne in the period 2000–05, and then spiked to US$1 210 per tonne in May 2008. In addition, the average price of other feed ingredients used in aquafeeds also increased by from 20 to 92 percent between June 2007 and June 2008. To put the price increase into perspective, it is useful to note that aquafeeds generally account for 50–70 percent of production costs.

While a follow-up study would be useful to better estimate the impact of increased prices of feed ingredients on production and learn from the coping strategies adopted by governments, private sector and farmers, the above study reports, as a case study, that costs of aquafeeds to some farmers in Viet Nam increased by 30–50 percent, requiring them to secure additional funds. In some cases, farmers were compelled to borrow money at significantly higher rates of interest and travel long distances to buy cheaper and/or alternative feed. In addition, in the Mekong Delta price rises reduced the area under catfish production by as much as 50 percent. As coping strategies, it has been suggested to build institute–industry research partnerships to find ways to increase dietary nutrient retention, promote low-polluting feeds and decrease FCRs, improve knowledge on the dietary requirements of many commercially important species, and improve natural productivity (e.g. via the use of fertilizers) in relevant production systems.

As in other regions, North America has been affected by ongoing economic downturns. However, in the case of Canada, the aquaculture sector managed to insulate itself owing to stability in exports and a rise in demand for Canadian salmon in the United States of America. The increase in demand was the result of to an outbreak of ISA and consequent decline in salmon production in Chile, a major salmon supplier to the United States of America.

### Political instability and civil unrest

Political instability and civil unrest are major hindrances to economic development. They usually lead to non-functioning institutions, declining local and foreign investment, capital flight, damages to physical infrastructure and loss of skilled human resources, factors that are no doubt detrimental to aquaculture development as well. The recent experiences of some African countries that had very active and promising aquaculture sectors substantiate this phenomenon. However, the African experiences also demonstrate that return to normality offers new scope for development of the aquaculture sector through rehabilitation and reconstruction if governments are committed and provide an enabling environment.

Similarly, in Asia, as part of its development plan to assist fish farmers in areas affected by the recent conflict, Sri Lanka, with the assistance of the United States Agency for International Development, is assessing the feasibility of generating new income sources and employment opportunities through aquaculture in the conflict-affected Eastern Province (USAID, 2009).

### Pandemic diseases

Global pandemic diseases such as swine influenza and avian influenza could have a beneficial impact on aquaculture because of a substitution effect caused by consumers' preference for other sources of animal protein. Such an effect would lead to an increased demand for fish, including farmed fish, and hence a corresponding increase in prices, which would eventually be profitable for the aquaculture industry. However, in developing countries, as small-scale aquaculture producers are also generally engaged in other economic activities such as poultry and livestock (including integrated aquaculture practices) to supplement their household earnings, an outbreak of such a pandemic disease could have an adverse impact as well. There are concerns that, in addition to losing animals, such practices may imperil certification of the aquaculture produce and marketability. Therefore, there is a need to adopt precautionary approaches as part of BMPs.

## SALIENT ISSUES AND SUCCESS STORIES

### Salient issues

Governments and donor partners need to pay special attention to small-scale producers, which are most vulnerable to the impacts of climate change, economic crisis and political instability and civil unrest. Another area that warrants the immediate support of governments and other stakeholders is the need to generate knowledge and create awareness about the impacts of climate change on aquaculture.

### Success stories

The Canadian salmon industry on the Pacific coast provides a good example of forward planning with regard to an adaptive climate change strategy. Considering that it is neither simple nor efficient for existing operations to move to new locations, the Canadian salmon industry has expressed interest in having new locations selected and pre-approved for various climate change scenarios (Olin, Smith and Nabi, 2011).

## THE WAY FORWARD

There is a need for a better understanding of the potential impacts of climate change on global aquaculture development, thereby facilitating the formulation and provision of adaptation and mitigation options to governments. Accordingly, FAO, with the endorsement of the COFI-AQ, and in association with other international organizations and agencies, has been engaged in a number of initiatives to increase its technical support on climate change implications for aquaculture to Members. The initiatives include: formation of the Global Partnership on Climate, Fisheries and Aquaculture (PaCFA); and conducting expert workshops and carrying out field and normative activities, with the current focus on defining indicators of vulnerability for fisheries and aquaculture and pilot assessment activities. Comprising 20 international organizations and sector bodies, PaCFA aims to support the process of the United Nations Framework Convention on Climate Change (UNFCCC) in response to the need for concerted action on fisheries, aquaculture and climate change. The immediate aim of PaCFA was to highlight key issues and to inform decision-makers and climate change negotiators at the 2009 United Nations Climate Change Conference in Copenhagen (FAO, 2010f).

Climate change concerns emphasize the need for development and implementation of policies and strategies to enhance the resilience and adaptability of the aquaculture sector, with particular emphasis on assisting small-scale producers. It is acknowledged that adaptation strategies will have to be context- and location-specific and will need to consider both short-term (e.g. increased frequency of severe events) and long-term (e.g. reduced freshwater supply) impacts. In addition, countries' aquaculture strategies need to be mainstreamed into national climate change strategies. Adaptive measures could include, *inter alia*: implementation of an EAA, including application of BMPs; implementation of research on, and adoption of, integrated aquaculture, including agro-aquaculture and multitrophic aquaculture, which offers the possibility of recycling nutrients, assisting carbon sequestration and using energy and water more efficiently; implementation of aquaculture insurance schemes; promotion of aquaculture diversification programmes; and application of capacity-building programmes on forecasting and early warning systems, including the use of geographic information systems (GISs), remote sensing and mapping for spatial planning.

On economic crises, governments, in particular those in developing countries, need to have sound macroeconomic and public-sector management programmes in place in order to cope with the likely impacts thereof. Governments also need to consider providing safety-net support to vulnerable groups, including those engaged in aquaculture activities. In addition, the continued support of donor partners would be useful to sustain the economic and social achievements.

COURTESY OF KOJI YAMAMOTO

*Lobster cage culture in Thailand.*

# 8. The role of shared information: research, training, extension and networking

## STATUS AND TRENDS

In the past decade, there has been a growing recognition of the importance and benefits of sharing information on emerging issues and new developments in the aquaculture sector at the national, regional and international levels. Improved and timely information flows at all levels avoid duplication of efforts; reduce costs; encourage consistency in areas such as policy, planning and regulations; and increase institutional capacities, thus contributing to efficient management of the aquaculture sector. These benefits are being achieved by: promoting dissemination of appropriate aquaculture research and development results and subsequent adoption by industry; strengthening national and regional capacity through training and extension; and providing mechanisms for access to information and data through networking, using new information and communications technology (ICT).

The rapid growth of the aquaculture sector in the past decade has, to a large extent, been stimulated by the application of R&D-led technological innovations in a variety of areas, namely: genetic improvement of farmed fish, better health management, better feed management and sophisticated cage designs for fish culture in offshore sites. Moreover, an encouraging development has been the recent expansion of the scope of R&D from technological to institutional, social, economic and environmental issues.

COURTESY OF MATHEW BRIGGS

*Dubai fish market.*

There is also increased collaboration between the public sector and other stakeholders, including private companies, academia and farmers associations, in setting national and regional research priorities and disseminating results. While investments in research are generally funded by the public sector, mainly in developing countries, there is an increasing trend towards research, including training and extension, being carried out by the private sector as well in both developed and developing countries. Furthermore, there is an increasing trend towards undertaking of joint training and research programmes within and between the regions (intraregional, inter-regional and South–South cooperation), facilitated by regional and global networks on aquaculture.

The following sections analyse the regional status and trends with regard to research and development, training and extension, and networking. The use of ICT for knowledge dissemination is discussed at the end.

### Research and development

Among the regions, Europe enjoys a relatively rich aquaculture research environment, contributing substantially to global development and taking a lead role in many international initiatives to solve global problems. The level of research is technically advanced, using new research tools. Some of the priority research areas and associated topics for European aquaculture, as identified by stakeholders (including users, industry and the NGO community) in the European Union Sixth Framework Programme, Future of European Aquaculture and Fisheries Research initiative are summarized in Table 8.

There is, however, considerable room for improvement in Europe's research programmes. Generally, research is very diversified and fragmented between public and private institutes, universities and private companies. In addition, there is a considerable overlap in research programmes and dissemination. The diversity of languages also acts as a barrier to communication and cooperation in certain European countries.

Recognizing the need to address these R&D issues, in 2000, the EU established the European Research Area, creating a unified area across Europe to enable researchers to move and interact seamlessly, benefit from world-class infrastructure, coordinate research programmes, and develop strong links with partners around the world. To decrease overlapping in aquaculture and fisheries research, the European Fisheries and Aquaculture Research Organization brings together 23 research institutes in 19 European countries and the Network of Aquaculture Centres in Central-Eastern Europe (NACEE), currently consisting of 45 institutions from 15 countries. In addition, under the ongoing EU Seventh Framework (FP7, 2007–2013), new initiatives are addressing interregional cooperation between Europe and other regions: sub-Saharan Africa through the Sustainable Aquaculture Research Networks in sub-Saharan Africa, Asia through the Asia–Europe Meeting (ASEM) Aquaculture Platform, and the Mediterranean through the AQUAMED initiative.

There have also been new developments in dissemination and outreach of research activities. An example of the former, AquaFlow, established by the European

TABLE 8
**Research priorities for European aquaculture**

| Principal research area | Associated topics |
|---|---|
| Development of diversified healthy seafood for consumers | New species for aquaculture (biology of native species as well as introduced species) |
| Decreasing the environmental impact of aquaculture | Decreasing "genetic pollution" of wild stocks from escapes |
| Development of non-food products | Production of biofuels from algae and microalgae |
| Improvement of rearing system technologies | Fish growth and welfare in high-density recirculation systems |

*Note:* This is not a complete list. Only some topics are listed.
*Source:* FEUFAR (2008).

Aquaculture Society to disseminate EU research to industry, provides one-page summaries in 16 languages. The outreach activities include interactions between, for example, producer organizations and environmental or conservation NGOs, as well as among consumer organizations. Another important recent development has been the establishment of the European Aquaculture Technology and Innovation Platform to provide a framework for stakeholders, led by industry, to define research priorities that focus on exploiting the potential for innovation and technological development in the European aquaculture value chain.

As in the case of Europe, research makes significant contributions to the growth and diversity of the North American aquaculture sector. In the last decade, the Governments of both Canada and the United States of America have significantly increased funding support for research programmes (Olin, Smith and Nabi, 2011).

In Canada, Fisheries and Oceans Canada (DFO) is the lead agency responsible for research and technology transfer, while in the United States of America, the United States Department of Agriculture and NOAA share this responsibility. In Canada, the industry currently participates in two DFO-supported research and development programmes that promote industry competitiveness and diversification. The first one, the Aquaculture Collaborative Research and Development Program (ACRDP), has been in operation since 2001; the second one, the Aquaculture Innovation and Market Access Program (AIMAP), began in 2008. The ACRDP has an annual funding of US$4.3 million. For each project, the industry partner contributes 30 percent (cash or kind) of the funding requested from the ACRDP. Funding is based on three objectives of the programme: best performance in fish production, optimal fish health and industry environmental performance. The objectives influence establishment of national and regional priorities. Funding allocation under the AIMAP, which currently has a budget of US$22.3 million for five years, is determined on the basis of four objectives: sustainable production, increased diversification, green technology and market access.

In the United States of America, NOAA developed the National Marine Aquaculture Initiative (NMAI) in 1998 to foster the growth of the aquaculture industry through R&D. The initial focus of NMAI on sustainable aquaculture technologies evolved to include an ecosystem-based approach. It has supported the growth of shellfish farming by providing support for oyster disease research, introduction of new candidate species (e.g. cobia and Atlantic cod) for commercial aquaculture and stock enhancement, and development of an environmental policy and codes of practice for the shellfish industry on the west coast of the United States of America.

Two technological developments in the region are considered to have contributed significantly to the growth in aquaculture production: transfer of net-pen technology for Atlantic salmon aquaculture to British Columbia and the Atlantic maritime provinces in Canada; and the steady growth of shellfish production, especially the development of the longline mussel industry in Atlantic Canada. These developments have also affected the global aquaculture sector favourably in terms of dissemination of technical knowledge and overall increase in global aquaculture production.

In the Asia–Pacific, although quantitative information is not readily available, the general notion is that overall research output has increased significantly and the amount of funds available has also increased. Moreover, some countries, such as Thailand and Viet Nam, have increased the amount of funding for aquaculture research substantially (FAO/NACA, 2011). It is also noteworthy that, in the past decade, the region has contributed to breakthrough research programmes, in particular the closing of the life cycle of southern bluefin tuna (*Thunnus maccoyii*) and the development of the GIFT strain of Nile tilapia (Box 1).

A vital role in the region's R&D programme is being palyed by NACA, an intergovernmental organization, plays. One of its core activities is conducting


*Salmon is one of the most researched aquaculture species in the world. Technologically advanced salmon processing factory in Norway.*

COURTESY OF YNGVE TORGERSEN

collaborative R&D programmes with the 17 member states in the region. Participating research centres share technical resources and experience in order to avoid duplication of effort and facilitate aquaculture development in a cost-effective manner. Major technical support is provided by five regional centres: China (Integrated Fish Farming Centre); India (Central Institute of Freshwater Aquaculture); the Islamic Republic of Iran (Coldwater Fishes Research Center); the Philippines (Southeast Asian Fisheries Development Center, Aquaculture Department); and Thailand (Inland Fisheries Research and Development Bureau). In addition, NACA is engaged in inter-regional research collaboration programmes, e.g. the sharing of research information on aquatic genetic resources of commonly valued finfish species with NACEE.

In the Latin America and the Caribbean region, encouraging trends in the R&D area are emerging. Several R&D-related initiatives, backed by governmental financing in countries such as Argentina, Brazil and Chile, are currently focusing on practical results, as desired by local industries (Wurmann, 2011). In essence, basic research work is gradually giving way to practically oriented research aimed more directly at problems faced by aquaculture producers. However, this R&D approach will require a lengthy preparatory time to express its real potential, which might take several years in each country.

In terms of new openings, an R&D area that merits special attention is the development of farming techniques related to endemic species, as opposed to the past emphasis on introduced species. It is stressed that, in doing so, past mistakes need to be avoided (e.g. working in parallel with too many species, working on species with limited market prospects and working on isolated issues).

With the exception of a few countries, R&D in Africa is at a preliminary stage. Africa continues to be plagued by a number of factors, such as low spending for aquaculture research and institutional weaknesses. In many countries, aquaculture research is part of the overall agricultural research programme. Agriculture as a whole is very poorly funded, with many countries hardly reaching 4 percent of GDP. The amount of the budget allocated for agricultural research is even lower, thus further weakening aquaculture's position. Aquaculture research allocation is said to be a mere 0.7 percent of agricultural GDP, compared with the desired rate of 2 percent (Satia, 2011). However, the relative budgetary situation is better in some countries such as Egypt and Ghana, where the growth in aquaculture is linked to investments in aquaculture research.

In terms of external support to R&D, at the regional level, under Pillar IV of the Comprehensive Africa Agriculture Development Programme, coordination of agricultural research, including aquaculture research, technology dissemination and adoption is undertaken by the Forum for Agricultural Research in Africa.[13] However, there has not been any significant progress so far owing to a lack of regional research structures for these disciplines. Regional R&D support is also provided by WorldFish Center, which has a hub for Africa in Zambia. WorldFish Center is active in a number of countries, working mainly on tropical aquaculture technology, systems research, fish breeding and genetics, and development of low-cost feed.

### Training and extension

Europe has some of the leading academic and research institutions on aquaculture in the world, contributing to the body of knowledge on sustainable development of aquaculture. In addition, a number of European networks are contributing to training and knowledge sharing on aquaculture development. For example, the ASEM Aquaculture Platform fosters staff and student exchanges between the Asia and Europe, promotes joint degrees and identifies collaborative research projects (EC, 2008).

[13] The Comprehensive Africa Agriculture Development Programme is the agricultural programme of the NEPAD, which in turn is a programme of the African Union.

In North America, both Canada and the United States of America have an array of universities offering undergraduate and advanced degrees in aquaculture-related disciplines. In addition, there are many community colleges, especially in coastal areas, that impart training to aquaculture technologists. Moreover, universities in both countries collaborate with public and private research institutions and industry on various research programmes. Extension support is provided by NOAA (to improve management of coastal and marine resources) and the United States Department of Agriculture (to cooperative extension agents who provide aquaculture extension services nationwide).

In Asia–Pacific, the level of aquaculture education has increased significantly, with more people undertaking undergraduate and postgraduate training in aquaculture and related fields. For example, in Viet Nam the number of aquaculture faculties increased from two in 2000 to eight in 2010, with a potential graduate output trained in aquaculture of more than 700 each year. The region has also made significant progress in providing intraregional, inter-regional and South–South Cooperation training in a range of areas, with NACA playing a major facilitating role (Box 12).

Furthermore, under the Technical Cooperation among Developing Countries (TCDC), China has been playing an important role in the dissemination of aquaculture knowledge. With support provided by FAO, the United Nations Development Programme (UNDP) and other donor agencies, China's Freshwater Fish Farming Centre in Wuxi has so far trained more than 1 000 aquaculture specialists in aquaculture technologies and management, including integrated fish farming, from 80 countries, mostly from Africa, Latin America, and Asia–Pacific. At the global level, although much of the TCDC has been carried out through bilateral arrangements, FAO has assisted its members by providing experts and technicians to share aquaculture techniques and experiences through its Special Programme for Food Security. As of 2009, such assistance was provided in 37 countries involving some 300 experts and technicians.

In the case of Africa, although universities in many countries offer undergraduate and graduate courses in aquaculture, including some universities that also provide distance learning/education programmes, it is widely acknowledged that the region lacks a critical mass of fisheries and aquaculture scientists. However, the region

BOX 12

**Asia–Pacific aquaculture training programmes**

**Highlights**

- Training on whiteleg shrimp (*Litopenaeus vannamei*) culture for the Indian private sector in China, Thailand and Viet Nam.
- Farmer–farmer learning (Vietnamese catfish farmers learning from Indian shrimp farmers on the social and cluster organizational aspects of small-scale shrimp farming and subsequently adopting a cluster-based approach in their programmes).
- Series of exchange visits of personnel (from farmers to higher-level scientists) from an array of African countries to the Asia–Pacific region to learn about small-scale farming operations.
- Training on the application of business management principles in small-scale aquaculture, jointly conducted by Network of Aquaculture Centres in Asia-Pacific (NACA), Nha Trang University, Viet Nam, and the United Nations University Fisheries Training Programme.

*Source:* Adapted from FAO/NACA (2011).

is undertaking various initiatives to increase the number of qualified aquaculture scientists. A recent example is the launching of the Fisheries University Network (FishNet), led by NEPAD, in February 2010. FishNet will recruit and train scientists on fisheries and aquaculture at member universities, in line with both national and pan-African development priorities. FishNet will also ensure that research findings are disseminated to and applied by farmers throughout the region.

Another recent development towards providing training opportunities to African scientists and practitioners is the launching of postgraduate degree programmes in aquaculture and fisheries by the Regional Universities Forum for Capacity Building in Agriculture, a consortium of 25 universities in Eastern and Southern Africa, established in 2004 and hosted by the University of Malawi. In addition, to supplement national governments' initiatives, several international and bilateral development organizations, including FAO, DFID and WorldFish Center, and many NGOs, are providing capacity-building support in the areas of aquaculture research and training.

Concerning the status of aquaculture extension services in Africa, most extension services suffer from lack of funds, as in the case of the R&D programme. As a consequence, there is inadequate access to transport, equipment and extension materials. Moreover, in most countries, the institutions are weak and staff lack adequate training. The training and visit model is still the most widely used extension method. However, the transfer of advice through manuals, leaflets and visual aids has been of high quality in some countries such as in Egypt, Madagascar and Nigeria.

### Networking

A large number of networks have been promoted globally in the past decade in response to stakeholders' growing needs for a variety of information about the aquaculture sector. Networks have been useful in sharing and exchanging information on new developments and issues, and in influencing policy decisions.

Established in 2004, NACEE, comprising 38 institutions and organizations from 15 countries, was considered a good model for regional networking at the Third COFI-AQ Meeting in September 2006. It aims to facilitate the integration of R&D institutions in Central and Eastern Europe into the European Research Area and promote partnership between science and practice, especially with regard to small and marginal enterprises and other producers associations.[14]

AQUA-TNET, a pan-European education network, is considered another good model on networking that could be adopted by other regions. AQUA-TNET, comprising more than 100 partners from almost every EU member country, as well as associated partners from countries outside Europe, is the European thematic network in the aquaculture, fisheries and aquatic resource management sector. Moreover, it is acknowledged as a leading network for collaboration between higher education institutions and other partners, such as research institutions and industry.

The World Aquaculture Society, an international non-profit organization with more than 3 000 members, comprising producers, researchers and agency representatives in about 100 countries, facilitates information sharing on emerging issues globally. The Aquaculture Association of Canada, with more than 900 members, including producers, suppliers, scientists, academia and government officials, is an active networking platform for aquaculture professionals. The association plays an important role in creating public awareness and understanding of aquaculture. The Fish Health Database of the British Columbia Salmon Farmers Association is another important network in Canada involving partnership between government and industry. The sharing of information on aquaculture production and fish health in a transparent manner helps to counteract negative public perceptions. In the United States of America, the National Aquaculture

[14] More information is available at: www.agrowebcee.net/nacee/about-nacee

Association, a producer-based association, works with the federal government to create a supportive regulatory and policy environment.

In addition to networks, both Canada and the United States of America have a number of international conventions and treaties that address both fisheries and aquaculture issues. As an example, in the 2008 memorandum of understanding (MOU) between Canada and Chile, the two countries agreed to, *inter alia*, promote the exchange of scientific reports and cooperate in aquaculture-related projects.

Networking has also been extensively tried in the past three decades in the Latin America and the Caribbean region, with the Latin American Regional Centre for Aquaculture (Centro Regional Latinoamericano de Acuicultura) established in 1978 with UNDP and Italian Cooperation funding support as one of the earliest. However, the lengthy history of cooperation has had limited success, as the programmes were eventually not sustainable. Lack of funds was identified as a major issue (Wurmann, 2011). A recent development has been the formation of the Network of Aquaculture in the Americas (Red de Acuicultura de las Américas).[15] Its mission is to contribute to the sustainable and equitable development of aquaculture among the countries of the Americas. As highlighted in its governing principles, it is expected to promote good governance, small-scale farmer development and gender equity (FAO, 2010g).

Sustainable Aquaculture Research Networks in Sub-Saharan Africa, funded by the European Commission (EC), is a continent-wide aquaculture research network in Africa. The network provides a forum for exchange of technical information among stakeholders throughout sub-Saharan Africa and beyond. Its Web site provides a link to various African research institutes, African farms, fish farmers associations and commercial suppliers. In 2006, the Committee for Inland Fisheries and Aquaculture in Africa facilitated establishment of an Aquaculture Network for Africa, with membership open to all African countries. The network aims to foster collaboration and linkages, improve knowledge management, promote information gathering and dissemination, and identify and coordinate research. There are plans to transform it into an intergovernmental organization under the African Union Commission, coordinated by the NEPAD Secretariat (Satia, 2011).

In the Asia–Pacific region, NACA is a successful intergovernmental organization on aquaculture development. In fact, there have been reiterated acknowledgements from governments of the benefits from NACA, broad agreements among NACA's partners of the advantages of collaborating with NACA and an expectation from the other regions to emulate a NACA-like arrangement or model. Analysing why and how a NACA-like arrangement works, Bueno (2007) highlighted five core attributes that should exist simultaneously, namely: collective commitment of members, continuity of participation of members, pursuit of common objectives, implementation of an effective coordination mechanism and use of a cost-effectiveness approach.

Encouraged by the rapid expansion of aquaculture in the Persian Gulf Region, RECOFI established its Working Group on Aquaculture (WGA) in 2003. The tasks of the RECOFI WGA include: advise RECOFI on technical and policy matters related to aquaculture; encourage technical cooperation and coordination among the member countries; and organize training courses, seminars and workshops. To facilitate information sharing among member countries, the WGA has established a Web-based Regional Aquaculture Information System. To ensure the system's utility, it is expected that all members would continue to input validated national data and information. The WGA is also engaged in development of a regional aquatic animal health strategy, sustainable marine cage aquaculture and a legal and policy framework for aquaculture (Lovatelli, 2009).

[15] More information is available at: http://racua.org/index.php?lang=EN

**Information and communications technology**

Rapid advancements in ICT are creating new opportunities to communicate, analyse data, impart training and share knowledge in a timely and cost-effective manner. As is the case with other emerging development sectors, aquaculture is making efforts to keep pace with these advancements and reap the benefits of the information boom. The aquaculture sector is making increasing use of the Internet, Web-based and mobile service technologies, the three most significant advancements in technologies, to reach out to a larger number of stakeholders at the national, regional and international levels, and to improve its public image. For example, it is now common practice for agencies involved in R&D to have a strong Web presence with links to their research portfolios, archives and publications that can be easily accessed by scientists and the public at large from different parts of the world.

In many countries in the Asia–Pacific, Africa and Latin America and the Caribbean regions, ICT-driven models are even allowing small-scale farmers located in remote regions to access updated information on product prices and supplies (e.g. hatchery and feed supplies) and obtain online solutions to technical problems. For example, fish farmers in Aceh (Indonesia) affected by the tsunami of December 2004 receive technical advice and information services using Web sites and a voice-over Internet protocol (VoIP). The ICT model has provided a platform for improving farmers' businesses and collaboration among stakeholders (Box 13).

The aquaculture industry is going to be affected by many different issues and trends over the coming years, often operating concurrently, sometimes in unexpected ways, and producing changes in the industry that may be very rapid indeed. Without a doubt, virtual technology[16] and decision-support tools (including GIS, remote sensing and

COURTESY OF ANTONIO VIEIRA

*Gilthead bream* (Sparus aurata) *farm in Alvor, South West Portugal, using computerised technology for farm management.*

[16] Virtual technology as defined by Ferreira *et al.* (2011) is any artificial representation of ecosystems that support aquaculture, whether directly or indirectly. Such representations, exemplified by mathematical models, are designed to help measure, understand and predict the underlying variables and processes in order to inform an ecosystem approach to aquaculture.

BOX 13

**Use of information and communications technology by fish farmers in Aceh, Indonesia**

The tsunami that struck Aceh Province in Indonesia in 2004 devastated coastal aquaculture livelihoods. The Asian Development Bank-assisted Earthquake and Tsunami Emergency Support Project, approved in 2005, engaged fish farmers to build and operate four Aquaculture Livelihood Service Centers (ALSCs). To compensate for the lack of extension services in aquaculture, a specialized Aceh Aquaculture Communication Center was also set up.

Using both traditional extension methods and modern information and communication technologies, the Aceh Aquaculture Communication Center: facilitates communication between fish farmers and other stakeholders; offers free technical information and advice to ALSCs and fish farmers through Web pages, phone linkages, manuals, newsletters, and posters; and provides ALSCs and fish farmers with information, technical expertise, and disease diagnostic and training services.

Among the lessons learned are:

- Fish-farmer-owned Web sites facilitate effective business communication between aquaculture communities and business partners.
- Communication gaps for effective dissemination of better management practices can be reduced through aquaculture communication centres.

*Source:* Adapted from Coutts, De Silva and Mohan (2010).

mapping) will play an important role in addressing many of these, and will therefore underpin many of the elements of the Bangkok Declaration and Strategy. Some of the directions and challenges are: innovations that will drive virtual technology, information exchange and networking; links between industry and research centres; collaboration between developed and developing countries; strategic alliances in developing countries; and making virtual technology tools more production- and management-oriented. Even if attractive and promising, these tools will have to be adapted to local realities and conditions to really become useful (and used) in the future, in particular if they are applied for consensus generation and to encourage a participatory approach to management. This requires a compromise with respect to ease of use, data requirements and scientific complexity. In the future, virtual technologies will play an increasingly important role in the planning of potential aquaculture siting and production, environmental impacts and sustainability. The next decade will bring about major breakthroughs in key areas such as disease-related modelling and witness a much broader use of virtual technology for improving and promoting sustainable aquaculture in many parts of the world. To ensure widespread use of these tools, particularly in developing countries, there is a need to increase awareness of the benefits and provide capacity-building support through technical assistance support.

Another contribution made by ICT is the development of Aquatic Commons (http://aquaticcommons.org/) by FAO and its partners, including WorldFish Center and NACA. In summary, Aquatic Commons is an open-access (Internet-accessible) digital repository for the aquatic sciences, including fisheries and aquaculture (Collins, 2007).

## SALIENT ISSUES AND SUCCESS STORIES

### Salient issues

In the area of R&D, the pace of development has not been even in all the regions. Europe and North America continue to lead the way, although important research contributions have been made by some developing countries under various North–

South collaboration programmes. Moreover, while the aquaculture sector has made considerable progress, it needs to pay more attention to minimizing overlaps in research programmes, avoid research programmes that are not production-oriented or pragmatic applied research, and undertake further research programmes using participatory approaches that meet the needs of small-scale producers. In addition, national governments and international partners (such as FAO and WorldFish Center) need to renew their efforts to reverse the stagnation of investments in aquaculture research and advisory (extension) services.

### Success stories

In the past decade, despite some of the shortcomings highlighted above, the aquaculture sector has made significant contributions to the generation and dissemination of information and knowledge through R&D and training, and has successfully used the services of many national, regional and international networks that have played an important facilitating role. While it is difficult to quantify such contributions, it is widely recognized that the sector has benefited in terms of increased global aquaculture production.

Broadly, the sector has achieved successes in a number of areas, namely: closing of the life cycle of southern bluefin tuna and the development of the GIFT strain of Nile tilapia, the use of regional aquaculture networks to promote sustainable development of aquaculture, the growth of South–South (TCDC) and North–South collaboration in dissemination of knowledge, and the use of ICT to allow small-scale farmers access to market and technical information.

North America has contributed significantly to growth in aquaculture production in two areas: transfer of net-pen technology for Atlantic salmon aquaculture to British Columbia and the Atlantic Maritime provinces in Canada; and steady growth of shellfish production, especially the development of the longline mussel industry in Atlantic Canada. These developments have also affected the global aquaculture sector favourably in terms of dissemination of technical knowledge and overall increase in global aquaculture production.

## THE WAY FORWARD

The increased availability and accessibility of aquaculture information globally in the last decade has been phenomenal and has favourably positioned the sector to meet the challenges of the coming decade in a much-informed manner. Moreover, with continuous technological innovations taking place in the ICT sector globally, web-based technologies will continue to play a much more important role in R&D, extension and training than in the past. In addition, as travel becomes more expensive and as farmers become more pressed for time, innovative approaches, such as virtual meetings, are likely to be the preferred choice of the sector to increase the flow and dissemination of information and knowledge.

In the near future, as the ocean ecosystems increasingly come into use to meet the growing demand for aquaculture products, the sector will need to focus on greater interregional cooperation through sharing of information and developing collaborative R&D programmes using state-of-the-art ICT for better understanding of the complex ecosystem resource base. In addition, ICT is expected to be increasingly used for R&D and training purposes in other related areas, such as genetics, biosecurity, fish welfare and health, and aquafeeds. In short, there is no doubt that ICT presents enormous potential, but the ability to exploit it to benefit the sector rests solely with the countries, which need to: formulate conducive policies; commit increased funding for R&D, extension and training; and create an enabling environment for increased private-sector participation in these priority areas. Moreover, as part of the sector's future development programme, with the assistance of donors and networks, a global study could be undertaken to evaluate objectively the impact of the various research programmes on sustainable aquaculture development and, based on the lessons learned, promising programmes could be scaled up.

COURTESY OF FRANCESCA OTTOLENGHI

*Farmed tuna helps to bridge the demand gap for captured tuna.*

# 9. Governance and management of the sector

## STATUS AND TRENDS

Globally, it is now recognized that good governance is central to achieving sustainable economic, institutional, environmental and social development in a country. Accordingly, governments throughout the regions are increasingly focusing their efforts to establish good governance. While governance is a complex notion that is difficult to capture in a single and simple definition, it has been directly or indirectly referred to (McCawley, 2005) as: the process by which governments are chosen, monitored and changed; the systems of interactions between the administration, legislature and judiciary; the ability of governments to create and implement public policy; and the mechanisms by which citizens and groups define their interests and interact with institutions of authority and with one another.

The characteristics underlying good governance are: participation, consensus orientation, strategic vision, responsiveness, effectiveness and efficiency, accountability, transparency, equity and rule of law (UNDP, 1997; ESCAP, 2009). These characteristics are guided by three founding principles of good governance (Schaffer, 2008): the promotion of inclusiveness, the promotion of lawfulness and the promotion of accountability.

In the case of the aquaculture sector, good governance is fundamental to successful formulation and implementation of aquaculture development policies, strategies and plans. Although some of the characteristics and principles of good governance are beyond the mandate of the aquaculture sector, their proper application by governments certainly facilitates better aquaculture management and development, as is being demonstrated in various countries in the regions. Moreover, recognizing that aquaculture affects and is affected by other sectors, as part of their aquaculture governance programme, many governments are developing the sector in a holistic manner through application of the principles of the EAA (Brugère *et al.*, 2010; FAO, 2010d; and Box 5).

The following sections summarize the regional status and trends with regard to some key elements of governance, namely: policies, strategies and plans; legislation and regulatory frameworks; economic incentives; sector self-governance; and data collection.

### Policies, strategies and plans

With growing expectations of the aquaculture sector's contributions to food security, poverty alleviation, economic growth and sustainable development, the need for sound planning is increasingly being acknowledged by governments. Good planning and policy-making are the key means by which governance can be improved. Planning guides the evolution of the sector by leading to policies, strategies and action plans that provide incentives and safeguards, attract investments and boost development. Improved planning and policy formulations require a number of challenges to be addressed: integrating and managing multiple stakeholders' interests, ensuring availability of adequate funding, developing human capacity, preventing conflicts and developing mitigation measures, and having supportive legislation in place (Brugère and Ridler, 2004; Brugère and Hishamunda, 2007; Brugère *et al.*, 2010). Brugère *et al.* (2010) provide practical guidance to aquaculture policy-makers and implementers on policy formulation and processes, starting with a review of governance concepts and a definition of "policy", "strategy" and "plan" in the context of aquaculture development.

As aquaculture has matured in the past decade, an encouraging trend is that an increasing number of countries in all the regions have formulated, or are in the process of formulating, fisheries policies, strategies and plans that facilitate the growth and efficient management of the aquaculture sector. The increased engagement of stakeholders in the process of developing these policies, strategies and plans and their subsequent participation in implementation are also considered as significant achievements that have contributed to positive outcomes (FAO, 2006c). Specific examples of biosecurity governance are demonstrated by several governments (e.g. Australia, Bosnia and Herzegovina, Canada, Chile, Thailand and the United States of America) that have developed and are at various stages of implementing national strategies on aquatic animal health or national aquatic biosecurity plans.

This policy formulation trend is all the more inspiring for the global aquaculture sector when considering that even the least aquaculturally developed regions, such as the Pacific Island countries, are giving high priority to it. As examples, Palau and the Marshall Islands have drafted their respective policy frameworks and development plans, Fiji is reviewing its freshwater aquaculture action plan of 2005–2010, and Vanuatu already has an aquaculture development plan covering 2008–2013 (Izumi, Pickering and Bueno, 2010). Moreover, a study by FAO on the integration of fisheries into key national policy documents relating to poverty reduction and rural development showed that the sector has been most effectively mainstreamed in Asia (in the case of poverty reduction strategy papers and national development plans), closely followed by Africa (Thorpe, 2004).

FAO (Hishamunda *et al.,* 2009) recently conducted a study covering seven countries in Southeast Asia (Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Viet Nam) to understand why and how aquaculture developed to a commercial level in some countries and failed to do so in others. The study found that the governments, in varying degrees, have endorsed aquaculture as a source of livelihood or of export earnings through adoption and implementation of various policies, such as, for example, policies towards better environment and feed and seed production. These policies are yielding tangible benefits, although results have not been homogeneous across countries, with Viet Nam demonstrating the greatest commitment to aquaculture, in line with its ambitious plan to double aquaculture output by 2010 (to 2 million tonnes). The study also highlighted the need to strengthen further the capacity of government officials in some countries to monitor policies and enforce regulations, and to ensure sufficient allocation of funds for such purposes.

In Africa, the spectacular development of aquaculture in some countries, such as Egypt, Mozambique, Nigeria and Uganda, has been the result of government policies in favour of the private sector (Satia, 2011). Another case of a policy-led growth is the provision of incentives to attract foreign investments, particularly in Madagascar, Mozambique, South Africa and the United Republic of Tanzania. It is useful to note that in the case of sub-Saharan Africa, participants at the 2004 FAO-organized workshop (small-scale aquaculture) in Cameroon agreed that the approach to national aquaculture development, based upon the Cameroonian Strategic Framework for Aquaculture Development, should: address the major constraints to expansion of the subsector in the region, facilitate the necessary public to private and public to civil society linkages, and propose mechanisms to maximize returns to the investment of both public and private-sector resources (Moehl, Halwart and Brummett, 2005; Satia, 2011).

In the EU, the Common Fisheries Policy (CFP) is the instrument for the management of fisheries and aquaculture. The CFP was reformed in 2002 to implement progressively an ecosystem-based approach to fisheries management. A further review of the CFP was launched in 2008 to analyse its achievements and shortcomings and look at experiences from other fisheries management systems for future action.[17] In terms of effectiveness of EU aquaculture strategy, the 2002 EU Strategy for the Sustainable Development of European Aquaculture (EC, 2002) broadly achieved its objectives in three areas: ensuring an environmentally sound industry, providing safe aquatic food, and guaranteeing animal health and welfare. However, the strategy failed to achieve its growth objective (Váradi *et al*., 2011). In 2007, following an evaluation of the 2002 strategy and as part of its good governance principle, the EC held wide-ranging consultations with stakeholders and developed a renewal strategy (EC, 2009a). The renewal strategy centres around three strategic objectives: help make EU aquaculture more competitive, ensure sustainable growth, and improve the sector's image and governance.

In the last decade, in North America, governments in both Canada and the United States of America have made concerted efforts to improve aquaculture governance (Olin, Smith and Nabi, 2011). These efforts have included the development of policies, strategies and plans that create conditions for sustainable aquaculture development. In 1995, Canada introduced the Federal Aquaculture Development Strategy, followed by the five-year Program for Sustainable Aquaculture in support of the strategy. The strategy was then followed by the Aquaculture Policy Framework. However, despite these initiatives, industry growth was below its full potential, partly because of the complex regulatory arrangement and partly owing to new conditions imposed by the market. To address the future challenges, the five-year Sustainable Aquaculture Program was launched in 2008. The programme has a number of pillars, including governance and regulatory reform.

In the case of the United States of America, national aquaculture policies were adopted by both NOAA (in 1998) and the Department of Commerce (in 1999) to foster aquaculture growth and improve the regulatory climate. However, the rate of projected growth was not achieved owing to a number of reasons: public opposition, user conflicts, multiple federal agencies with regulatory authority, lack of capital and foreign competition. As a follow-up, in 2007, NOAA adopted the 10-Year Plan for Marine Aquaculture, the goals of which are: development of a comprehensive regulatory programme for environmentally sustainable marine aquaculture; development of commercial aquaculture; public understanding of marine aquaculture; and increased collaboration and cooperation with international partners. In addition, NOAA intends to pursue a National Policy for Sustainable Marine Aquaculture, which will include development of coordinated federal standards for permitting aquaculture facilities in federal waters.

### Legislation

Aquaculture legislation is a useful instrument to promote, regulate and develop aquaculture in a sustainable manner. Effective application of legislation can reassure potential entrepreneurs that their investment will be secure, as well as encourage them to reinvest (Box 14). Accordingly, many governments have drafted or are enacting legislation specific to aquaculture. Moreover, a common pattern that has emerged in the regions is that countries are adapting to the ever-increasing environmental and social challenges facing the aquaculture sector by amending and strengthening their aquaculture legislation. These changes relate to such areas as licensing, zoning, enforcement, EIA, management and control measures, and ownership of produce.

However, an issue that merits attention by policy-makers at the national, regional and international levels is poor management of legislation, resulting from a combination of factors, namely: complicated and stringent compliance procedures; lack of adequate

[17] See: http://ec.europa.eu/fisheries/cfp/index_en.htm

BOX 14

**Key legislative issues of importance for aquaculture policy implementation**

1. Non-aquaculture-specific legislation should be considered for its support or hindrance to aquaculture policy implementation, as well as for its relationship to aquaculture-specific legislation.
2. A legal framework supportive of policies and supported by stakeholders is more likely when stakeholders are involved in the process to develop legislation itself.
3. Aquaculture policies should ideally ensure that aquaculture legislation is supportive of them before related activities are commenced, and if not, appropriate legislative changes should be sought.
4. Aquaculture legislation should contain dispute resolution mechanisms to deal with user conflicts and to ensure that local rules and regulations do not conflict with national-level legislation and policies.
5. Aquaculture legislation should specify the extent to which local autonomy in developing management rules and legislation will be accepted.
6. National aquaculture legislation should provide for a broad and flexible framework that enables a choice of strategic options, with detailed mechanisms set out in regulations that can be changed if necessary.
7. National aquaculture legislation may need to contain specific reference to certain key concepts (e.g. ecosystem approach to aquaculture) or to provide indirect support to key success factors that need legislative support (e.g. decentralization, and definition of boundaries).
8. Aquaculture legislation needs to ensure the security and enforceability of a right, and the ability and opportunity for rights holders to seek redress for violation of security and interests in the rights allocated.

*Source:* Macfadyen, Cacaud and Kuemlangan (2005).

enforcement and control of applicable regulations; and overburdened staff, often lacking capacity to efficiently carry out legislative work. While the legislation-related issue affects some of the other regions as well, such as Asia and Africa, it is considered a major factor constraining aquaculture development in the Latin America and the Caribbean region (Wurmann, 2011).

In most countries in the Latin America and the Caribbean region, procedures to obtain farming licences are complex and often cause delays extending for more than a year. Another case in point relates to demanding environmental assessments; for example, in most situations, mussel farmers in Chile are required to undertake a complete environmental and oceanographic assessment to demonstrate that the area is sanitarily acceptable. While the intention to have stringent requirements may be good, past experiences have shown that many aquaculture farmers (particularly small-scale producers) have not been able to cope with such requirements. Moreover, indiscriminate transporting of live biological materials along with lax sanitary measures and ineffective regulations were said to have contributed to the spread of several disease outbreaks, such as ISA to most farms in Chile where Atlantic salmon were grown. In contrast, the fact that the Canadian salmon industry in the North America region was not affected by the ISA outbreak demonstrates that the industry is relatively better prepared to protect the ecosystem and respond to biosecurity issues (Olin, Smith and Nabi, 2011).

In the context of the above problems confronting the Latin America and the Caribbean region, a related issue faced by the EU is access to suitable sites for aquaculture production, which is considered a major constraint to the development of EU aquaculture. While the issue is complex and arises from numerous factors, one that has been identified as a contributing factor relates to a general misunderstanding of the environmental impacts of aquaculture, leading to a disproportionate use of the precautionary principle (Váradi *et al*., 2011).

In the EU, the main environmental impact legislation (EC Directive 97/11/EC, amending 87/337/EEC) generally applies to all activities, including aquaculture, that are considered appropriate for application of an EIA. A recent review by the European Commission (EC, 2009b) identified inconsistencies in the approach to and the quality of EIAs, including in the environmental standards applied. One area for improved EIA procedures is quality control. A recent study concerning the quality of environmental statements for marine fish farming in Scotland, the United Kingdom, recommended adoption of a standard template-based EIA (RPS Group Plc, 2007). This approach is likely to be considered more widely in a European context.

At the global level, in general, governments also need to comply with both voluntary and mandatory requirements of a number of international instruments with relevance to aquaculture (e.g. FAO Code of Conduct for Responsible Fisheries; Convention on International Trade in Endangered Species of Wild Fauna and Flora; Convention on Biological Diversity; WTO; OIE; Codex Alimentarius Commission of FAO/World Health Organization). As an example, for exports, producers need health certificates and inspection certificates issued by competent authorities in accordance with OIE and Codex Alimentarius Commission standards.

Furthermore, at the global level, a governance-related challenge that the aquaculture sector needs to address is the regulatory vacuum for aquaculture in the high seas. While there is consensus among experts that most future aquaculture expansion will occur in the seas and oceans, certainly farther offshore, perhaps even as far as the high seas, the existing relevant principles of public international law and treaty provisions provide little guidance on the conduct of aquaculture operations in these waters (FAO, 2010a).

### Economic incentives

Application of economic incentives is considered an important tool to motivate both large and small-scale aquaculture producers to invest in responsible aquaculture operations in the expectation of achieving higher returns to investments. Advocates of economic incentives contend that they are more economically efficient than the traditional command-and-control regulations. Economic incentives could facilitate good governance by motivating the private sector to adopt BMPs, thereby enabling aquaculture producers to sell their products at a premium in the national and international markets.

Economic incentives could include provision of soft credit lines or even subsidies, depending on the merit of the case, to small-scale and marginal producers. The challenge for governments is to ensure that such incentives are administered in a transparent manner, reflected in the national budget and provided to intended beneficiaries. However, most governments have abandoned this type of incentive policy because of its apparent bias in favour of large farmers. In turn, many governments are now promoting loans without collateral to target small-scale farmers (FAO, 2008b). Moreover, to stimulate aquaculture development, many governments also provide fiscal incentives such as exemptions or reductions on income tax, land tax, sales tax and import duties, and tax holidays for foreign investors. For example, Viet Nam provides land tax exemptions to commercial farmers, which is in addition to three-year exemptions on income taxes for farmers who engage in aquaculture in non-productive land or lagoons. In addition, foreign investors can also be eligible for tax holidays (Hishamunda *et al*., 2009).

In some regions, such as Africa, Asia and Latin America and the Caribbean, as part of their overall privatization strategy, many countries engaged in promoting sustainable aquaculture development are also offering incentives by privatizing government facilities, particularly fisheries research stations and breeding centres, that have failed to meet their original purpose as hubs for extension. Europe provides a different form of economic incentive to aquaculture producers. The European Fisheries Fund, which is the principal financial tool for fisheries and aquaculture development, supports producers who make a commitment to use, for at least five years, production methods that help protect the environment over and above the requirements of existing regulations.

### Sector self-governance

Aquaculture producer associations perform a range of functions, including ones that contribute to good governance, such as: shaping and influencing policy and regulations; providing technical services and sharing of knowledge; and promoting a code of conduct, good aquaculture practices and BMPs based on self-regulation principles. Producers recognize that, in the long run, it is in their best interest to manage their operations responsibly in a manner that is environmentally neutral and socially acceptable. Self-regulation is a means that unifies producers to address common problems cohesively, increases production efficiency and strengthens bargaining power with providers of materials and services. Moreover, proper application of self-regulation principles offers opportunities to gain consumers' confidence and thereby improve the industry's image

However, another viewpoint is that, although self-regulation by producer associations offers the means of internalizing some of the negative externalities, self-regulation based on voluntary codes of practice is not an effective form of governance in the absence of mandatory legal obligations (FAO, 2008b). Nonetheless, a survey of national associations (in Asia, Latin America, Eastern Europe, Australia and Canada), a regional federation (the FEAP) and a global alliance of producers and allied industries (the Global Aquaculture Alliance) shows a range of motivations for organizing into associations, a number of which highlight the increasing tendency towards self-regulation, demonstrating the contributions of this approach to sustainable development of the sector (FAO, 2006a).

In Europe, the FEAP developed its own Code of Conduct for European Aquaculture in 1999 to promote the responsible development of aquaculture practices. In 2008, in consultation with stakeholders, the CONSENSUS programme and FEAP developed more than 30 sustainability indicators of sector performance (including best practice and sectoral benchmarking). The indicators were incorporated into the revised code of conduct. The FEAP and the Mediterranean Office of the World Conservation Union, with the support of the Government of Spain, are preparing a series of guidelines on sustainable development of aquaculture in the Mediterranean. To date, two guidelines have been prepared: a guide on interactions between aquaculture and the environment (IUCN, 2007); and a guide on aquaculture site selection and site management (IUCN, 2009; Váradi *et al*., 2011).

In the Latin America and Caribbean region, many producer associations have also produced their own codes of good practice and quality assurance standards, while others have gone beyond and are involved in research work in areas that are of value to the sector. Moreover, large-scale producer associations are extending valuable support to small-scale producers, which usually lack the opportunity to be well informed about regulations and markets (Wurmann, 2011).

In North America, producer associations have developed BMPs to improve farm-level efficiency and to address food safety issues. The BMPs are enforced under regulation on some aspects of farm operations, such as fish escapes. In addition, producer associations and government are jointly looking at ways to make better use of BMPs to reduce biological and business risks (Olin, Smith and Nabi, 2011).

Producer associations in Africa are also contributing to good governance, as in the case of the Catfish Farmers Association of Nigeria, which is imparting knowledge on BMPs to its members though training and workshops (Satia, 2011). In Asia–Pacific, adoption of self-regulation principles benefits not only large-scale producers but also small-scale producers, as in the case of shrimp farmers in India. Application of BMPs designed jointly by groups of small-scale shrimp farmers has resulted in such benefits as increased profits and improved access to services (Chapter 3). Other examples of promoting good governance by associations in the region include: the successful planting of mangroves or their rehabilitation by the Thai national shrimp farmers association, which improved the industry's image; and the unification of the Vietnamese aquaculture and Vietnamese fishery associations, and having their products and their farming and processing practices adhere to safety, quality and environmental requirements (FAO, 2006a).

### Data collection and management

In recent years, with the rapid growth of the aquaculture sector, the demand for reliable and timely data and information on the status and trends of aquaculture, including emerging social, economic and environmental aspects, has increased considerably in view of the need to more effectively: formulate and monitor policies, strategies and plans; respond to new information and reporting requirements of international agreements; and respond to increasing public demand for transparency and accountability. Despite aquaculture's long history, the collection of statistical data and other information is a recent endeavour in many countries. There is thus considerable variation in information gathering and dissemination by countries and regions (FAO, 2005).

For example, in North America, Canada has an advanced data reporting system. It has undertaken a sustainability reporting initiative and expects the first report to be available in 2011 (Olin, Smith and Nabi, 2011). In addition to its regular collection of aquaculture production data and value, it has enhanced collection to include information on social and environmental sustainability indicators. Canada follows the Sustainability Reporting Model provided by the Global Reporting Initiative, an organization that has pioneered the development of the world's most widely used sustainability reporting model.

In Europe, the FEAP collects data on European aquaculture production (volumes and values) for all species groups.[18] In addition, the FEAP has incorporated sustainability indicators in its code of conduct. Official government statistics on aquaculture production and value are compiled and published by FAO. In 2008, the European Parliament and the European Council adopted a Regulation (EC 762/2008) on aquaculture statistics that requires member states to collect and submit data on, among others, annual production (volume and value) and annual production of hatcheries and nurseries. There are also other cases of producer associations and private-sector engagement in data collection, management and dissemination (e.g. in the shrimp[19] and salmon sectors).

At the global level, the COFI-AQ identified data collection and reporting to improve knowledge and management of the sector as a key priority area and requested FAO, as a provider of global aquaculture statistics since 1984, to develop a strategic approach for improving reporting on aquaculture status and trends, with special attention to the quality of the information on which it is based. To this end, FAO has initiated a number of measures that include harmonization of aquaculture terminology and development of standard codes, development of improved progress reporting, and development of methods and indicators for evaluating the contributions of small-scale aquaculture to sustainable rural development (see Chapter 6).

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[18] See: www.aquamedia.org/home/default2_en.asp

[19] See: www.shrimpnews.com

In collaboration with participating inter-regional organizations having relevance and/or interest in aquaculture statistics, FAO has established a Coordinating Working Party (CWP) Aquaculture Group (AQ), similar to the long-established CWP on Fishery Statistics. The new structure of the CWP-AQ was endorsed by the CWP in 2010. Meanwhile, the revision of the aquaculture component of the CWP Handbook has been identified as a high priority task. The CWP Handbook is intended to provide a suite of harmonized concepts and definitions of terms used in fisheries and aquaculture statistics and data collection, as well as standard codes to be used (FAO, 2009d).

Another related measure includes improving the progress reporting on the implementation of the provisions of the 1995 FAO Code of Conduct for Responsible Fisheries relevant to aquaculture and culture-based fisheries, in particular Article 9. Accordingly, FAO prepared a proposal for a revised reporting mechanism with an interactive questionnaire format to evaluate the progress being made in the implementation of the Code. The proposal was received positively at the fourth session of the COFI-AQ (October 2008) and subsequently, as suggested by the COFI-AQ, a pilot version was tested in different regions (FAO, 2008c). Future work includes further revisions to incorporate feedback received and preparation of a manual of instruction.

## SALIENT ISSUES AND SUCCESS STORIES

### Salient issues

Improved governance is important for the development of the aquaculture sector, poverty alleviation and reduction of food insecurity, thereby improving, in particular, the well-being of millions of small-scale producers in the developing world. The sector needs to improve governance further by addressing the following issues that exist in many countries:

- ensuring continuous capacity-building support and adequate resources in the areas of policy formulation and implementation of strategies and plans and enforcement of regulations with regard to all segments of the aquaculture value chain in line with the principles of the EAA;
- ensuring the availability of reliable and timely data that enable formulation and implementation of sound policies, strategies and plans based on informed decisions;
- resolving complex regulations that have affected or could affect progress of the sector (e.g. lack of any common approach to licensing and other issues related to conduct of licensing procedures at the local level, resulting in approval delays, and a regulatory vacuum for aquaculture in the high seas);
- in the light of dwindling land resources suitable for aquaculture in some countries and regions, improving access to suitable marine sites for aquaculture production (e.g. exploring new opportunities, such as coastal and marine spatial planning).

### Success stories

Among the many countries promoting aquaculture, Viet Nam's commitment stands out. Aquaculture development is a national priority for economic development and is proactively supported by policy-makers using a variety of tools, such as tax incentives (e.g. exemptions for import of seed of marine species and materials for hatcheries and farms), inducements to foreign investors (e.g. exemption of value-added tax for marine seed production and reduced land tax), and establishment of public hatcheries. The Government's commitment has produced concrete results – aquaculture volumes and values have doubled since 1995, with plans to further double output by 2010 to 2 million tonnes (Hishamunda *et al.*, 2009).

## THE WAY FORWARD

The global aquaculture sector's long-term goal to achieve economic, social and environmental sustainability primarily depends on governments' continued commitment to provide and support a good governance framework under which the sector can operate. It is encouraging that the global trends in good governance in the past decade confirm that many governments remain committed, and that involving stakeholders, particularly producer associations, in strategic policy decisions is becoming an accepted practice.

While some policies and practices have not achieved the desired results, the challenge for the future is to adapt and re-orient policies and actions continuously in order to achieve long-term goals. The aquaculture sector must be cognizant of the relevant environmental and social concerns and make conscious efforts to address them in a transparent manner that is backed by scientific evidence. However, governments should at the same time be cautious so as not to over-react in ways that will negatively affect aquaculture producers, particularly small-scale farmers, for example, by framing legislation that is unnecessarily costly, time-consuming and/or difficult to implement.

In the past decade, there have been many successes for the aquaculture sector. However, there is no room for complacency, as global needs will continue to increase and challenge the sector to attain greater heights. As the new decade unfolds, a stronger and more confident sector will stand ready to face and overcome the challenges and move further along the path to sustainable aquaculture.