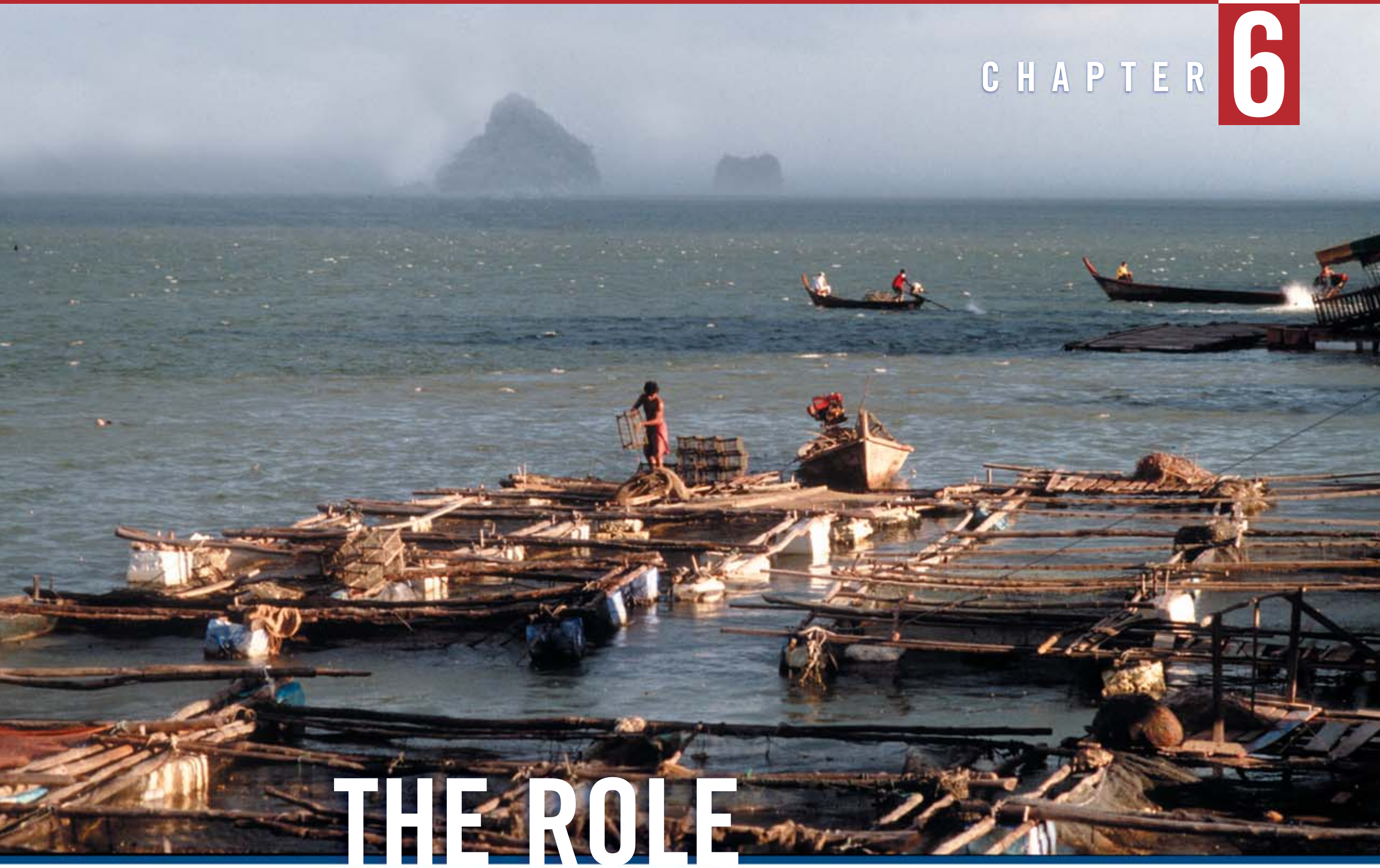
CHAPTER 6



FAO/18557/R. FAIDUTTI

THE ROLE OF AQUACULTURE:

IS IT HELPING TO SUSTAIN FISHERIES AND FEED THE POOR?

WHAT IS AQUACULTURE?

The practice of aquaculture—the farming of fish and shellfish—dates back 3,000 to 4,000 years in China and Mesopotamia. In those times, fish farming was mostly carried out by farmers who raised fish in small ponds to supplement their diet. Since then, aquaculture has evolved considerably, and today comprises a broad spectrum of systems, practices, and operations ranging from simple small-household ponds to large-scale, highly intensive, commercially oriented practices (see *Box 6-1*).

The term "aquaculture[6]" entails the controlled farming of aquatic species such as molluscs, crustaceans, aquatic plants, and finfish; or interventions in aquatic systems that will enhance their production, such as stocking lakes, rivers and oceans with hatchery-born juveniles to increase the wild stock; or taking wild-caught juvenile fish or hatchery-raised fish and raising them in enclosed facilities in open sea waters. Land-based aquaculture operations include ponds, paddies, and other artificial facilities built on dry land, while water-based systems include pens, cages, and rafts, commonly found in sheltered coastal or inland waters (FAO 2000b). Aquaculture products fall into two general groups if evaluated from an international market perspective: high-valued species that mainly target export markets, and comparatively low-valued species that are primarily sold locally in developing countries. Most large-scale, intensive aquaculture operations target high-value species, such as shrimp and salmon, which are commercialized in developed countries, mainly the United States, Japan, and Europe, and require large capital investments.

[6] The specific farming of marine fish and shellfish is also referred to as "mariculture".

Extensive or rural aquaculture on the other hand usually targets species for local or domestic consumption, such as tilapias and cyprinids, which require low capital investment and often provide affordable fish for local markets.

HOW SIGNIFICANT IS AQUACULTURE IN GLOBAL FISHERIES PRODUCTION?

Aquaculture produced 37.9 million metric tons of fishery products in 2001, nearly 40 percent of the world's total *food* fish supply and valued at US$55.7 billion (FAO 2002a; Vannuccini 2003). Over the past three decades, aquaculture has become the fastest growing food production sector in the world; it has increased at an average rate of 9.2 percent per year since 1970—an outstanding rate compared to the 1.4 percent rate for capture fisheries or the 2.8 percent rate for land-based farmed meat products (FAO 2002a). Aquaculture has achieved this rapid growth by expanding, diversifying, and intensifying production, as well as by introducing technological improvements in its operations. In comparison, capture fisheries production has been stagnant with increasingly larger quantities of fish being caught to produce fishmeal and fish oil—about 31 million metric tons in 2001, or one third of capture fish production (Vannuccini 2003).

According to the most recent survey, at least 300 fish, crustacean, and mollusc species are cultured worldwide (FAO 2000b). In 2001, freshwater finfish accounted for the largest share (50.5 percent) of the global aquaculture production in terms of quantity, followed by molluscs (23.3 percent) and aquatic

Box 6-1: Basic Types of Aquaculture Systems and Practices

In general, aquaculture systems fall into three major groups with some degree of overlap: extensive to semi-intensive or rural aquaculture; intensive or industrial aquaculture; and culture-based fisheries, e.g. stocking and sea-ranching (Le Sann 1998).

Extensive to semi-intensive aquaculture systems take advantage of the natural environment and try to increase production with minimum external inputs. Extensive systems commonly raise species groups that are lower in the food chain (herbivores/omnivores), such as carp. These systems use simple technology and rely on natural food (algae, plankton, etc.) which can be supplemented by livestock waste and agricultural residues, or processed fish feed in the case of semi-intensive operations. Usually only the adult part of the species' life cycle is controlled—wild-caught juvenile fish are raised until they reach full growth, as opposed to hatchery-raised juveniles that are more commonly used in intensive systems. The most significant example of extensive aquaculture is the traditional or artisanal operation widely practiced in Asia and in rural Central Europe (FAO 2000b). These aquaculture systems are often integrated with crops and livestock production; typically use rice fields, ponds, and cages; and involve polyculture (i.e., the practice of raising more than one species in the same pond). Despite very high yields—16.4 million MT of carp, barbel, and other cyprinids in 2001—and its critical contribution as protein to the human diet, especially in Asia, the importance of these "low-tech" aquaculture practices are under-appreciated at the global level because of the relatively low export value of the farmed products. For instance, the average price of one metric ton of cultured carp, barbel, and other cyprinid fish is US$973, while a metric ton of aquaculture produced salmonids is US$2,908, and one metric ton of shrimp and prawn is US$6,635 (Fishstat 2003).

Intensive aquaculture practices try to maximize output from a given production unit. These practices are carried out in a controlled environment with a higher level of technological inputs and management over the entire life cycle of the cultured animal/plant. Compound, manufactured pellet feed is regularly used, along with antibiotics to prevent diseases in facilities with higher stocking densities. This level of input and management requires considerable investment; hence, production is primarily targeted toward the monoculture of species with high commercial value, which are generally oriented to the export market. Common intensively farmed fish include carnivorous species such as shrimp, salmon, trout, seabream, yellowtail, and eel. Shrimp and salmon, in particular, require large amounts of high-protein fishmeal and fish oil as feed, and are in terms of value, the most significant sectors in aquaculture. Farmed Atlantic salmon, for example, represents 99.5 percent of all Atlantic salmon production (capture and aquaculture), while cultured shrimp and prawn represent 30 percent of all shrimp and prawn production in 2001 (Fishstat 2003).

Culture-based fisheries, such as stock enhancement[a] ***or stocking***, are aquaculture practices that fall somewhere between farming and capture fisheries. The practice consists of releasing juvenile fish or invertebrates raised in hatcheries or captured elsewhere in the wild into a sea, lake, or river for subsequent fishing when they have reached a larger size (Munro and Bell 1997). The most commonly stocked freshwater and diadromous fish include common carp, rainbow and brook trout, Atlantic salmon, and Nile tilapia (FAO 1999a). Stocking is also used to increase production of some marine species such as abalone, scallop, lobster, cod, and flounder (Svåsand et al. 2000; Jennings et al. 2001). Japan is the leading country in the use of marine stocking, with ongoing commercial and experimental programs for numerous species, such as scallops, Japanese flounder, and red and black seabream, among others (Bartley 2002; Fushimi 2001). Success of these stock enhancement practices varies. For some species like scallops and chum salmon, stocking seems to have worked; for other species, particularly finfish, results are not as clear because of high mortality rates of juvenile fish once they are released into the wild, and because of inadequate methodologies to assess effectiveness and track released juveniles (Kitada 1999; Svåsand et al. 2000).

Sea ranching (or sea farming) is also considered a form of aquaculture, and the term is many times used interchangeably with stocking of marine fish, and recently with the term open ocean aquaculture. For the purpose of this report, we limit the term sea ranching to the practice of raising wild-caught juvenile fish within controlled boundaries in the open ocean, where they grow using natural food supplies or formulated feed. Once the fish reach a certain size they are harvested, and production is therefore reflected in aquaculture figures, instead of capture statistics.

[a] Some authors use a broader definition of the term "stock enhancement" to include a variety of practices used to increase harvests including habitat rehabilitation, the introduction of exotic species, etc. (Bartley, pers. comm. 2004).

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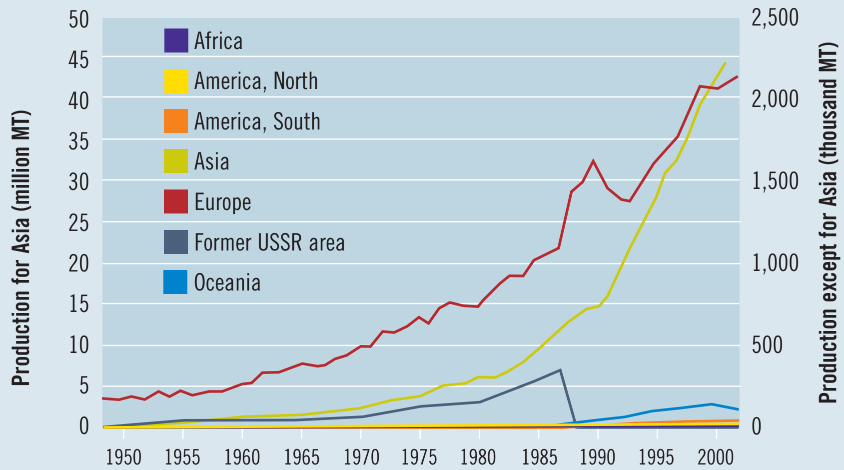
plants (21.8 percent) (Fishstat 2003). And although crustaceans accounted for only 4 percent of the share in terms of quantity, in terms of value they reached nearly 19 percent, mostly from shrimp production for the export market (Fishstat 2003).

Asia is the leading region in aquaculture production, with China producing 70 percent of the global total (Sabatini 2001), although recent reviews of Chinese production statistics show an overestimation of figures during the 1990s (FAO 2002a). Much of China's increased aquaculture production is attributed to carp culture (12 million metric tons in 2000, or one third of the world's aquaculture), destined mostly for domestic consumption. Significant increases can also be observed in South and Southeast Asia, Europe, and North America. Whereas production in Latin America and Africa is still relatively low, but increasing, and Chile is now the world's top producer of farmed salmon (FAO 1997a; Fishstat 2003) (see *Figure 6-1*).

Much of the world's aquaculture production comes from small-scale, extensive to semi-intensive systems. These systems dominate the production of many farmed species, including 70-80 percent of tilapia and shrimp production; 80-90 percent of carp, catfish, and milkfish, and 90-100 percent of freshwater prawn and crayfish (Tacon 1996). However, as demand for fish and the associated incentives for cash income increases, extensive systems are shifting toward more intensive operations that require higher levels of inputs. The use of compound feeds, for example, appears to be increasing in China, where extensive fish ponds have been the norm for decades (Tacon 1997). This intensification is more common in coastal provinces, where larger-scale farms account for 40 percent of production, while in remoter Chinese provinces traditional integrated extensive systems still predominate (FAO 2000b). The number of cultured species in China has also increased dramatically in the last 20 years, from about 10 fish species being commonly farmed in the 1970s to over 40 indigenous and exotic species introduced to inland aquaculture today (Miao and Yuan 2001). The newly introduced species include high-valued fish, crab, prawn, and soft-shelled turtles (Miao and Yuan 2001). This shift to more input-dependent aquaculture practices is also reflected in China's import of fishmeal, which increased by 51 percent since 1999 and almost three times since 1990 (Globefish 2001).

Figure 6-1: Growth in Aquaculture Sector by Continent



Source: Fishstat 2003.

THE AQUACULTURE DILEMMA: IS IT POSITIVE OR NEGATIVE FOR BOTH PEOPLE AND ECOSYSTEMS?

There are many different kinds of aquaculture and each system has its own strengths and weaknesses, which may positively or negatively affect the environment and people's livelihoods. Small-scale, extensive aquaculture has become widely recognized as a significant contribution to local economies and diets, as well as being associated with a lower degree of environmental impacts, although the cumulative impact of a large number of small farms can be just as damaging as a large-scale operation.

The trend in most countries is to intensify aquaculture operations toward more input-dependent practices. And while aquaculture products have certain advantages over wild-caught fish, such as a more regular supply, job security, and income generation, there are often negative environmental implications. Some of the major concerns surrounding aquaculture today include the use of wild-caught fish as aquaculture feed, which consequently places additional stress on already depleted wild stocks; social concerns that aquaculture is taking considerable amounts of fish—to make fishmeal—from the poor; and that aquaculture operations are destroying natural habitat—especially mangroves—and contaminating vast expanses of coastal and inland waters. While these are legitimate concerns, they are not as clear-cut and straightforward as these statements imply. Below, we briefly discuss the main advantages and disadvantages of aquaculture and then assess some of the key disputed concerns.

Aquaculture operations, especially intensive production systems, pose serious environmental concerns. The heavy dependence of intensive systems on human input—feed, water, chemicals—and the effects on ecosystems and species are major constraints in the sustainability and future growth of this industry.

In general, the advantages of aquaculture include:

- ***Regular supply and lower prices.*** Controlled production makes it possible to meet market demand regardless of natural fluctuation in wild stocks and seasonal changes. Technical advancements—including genetic improvements—allow for industrial operations where mass production can reduce costs and hence lower the price for the consumer. The price of farmed salmon for example, has consistently declined as aquaculture production expanded and consumption increased in the last 15 years (Globefish 2002b). Stocking of reservoirs and rice fields can also improve the supply of fish from these waterbodies.
- ***Income generation.*** Aquaculture is an income-generating activity and can provide considerable foreign exchange revenue for developing countries. For example, in 1997, shrimp aquaculture production in Thailand was valued at nearly US$1.6 billion (SEAFDEC 2001a).
- ***Food Security.*** Aquaculture's contribution to food security and livelihoods is of enormous significance, especially in remote and resource-poor areas. Small-scale, low input aquaculture that is done in combination with rice cultivation can "increase household resilience through diversification of income and food sources" (FAO 2000b). Extensive aquaculture of carp, for example, increases the amount of dietary protein that is available to the rural poor—needed protein that otherwise these communities cannot afford. China is a good example: per capita consumption of fish in the country has increased four-fold in the last 20 years, as its inland aquaculture has expanded (Laurenti 2002).
- ***Improvement in water quality.*** According to some aquaculture proponents, certain types of aquaculture, such as mollusc and seaweed farming can help clean water supplies. Shellfish, such as oysters and mussels, serve as natural filters, by removing nutrients, toxins, and sediment from the water column while feeding on microscopic plants and animals. Scientists estimate that each American oyster, for example, is capable of filtering up to 50 gallons (190 liters) of water per day (NCDMF 2003). Some scientists believe that the Chesapeake Bay's once flourishing oyster populations could have filtered the estuary's entire water volume of excess nutrients in 3 to 4 days (Newell 1988); of course, natural oyster populations are much better at filtering water into a bay, than randomly placed aquaculture structures. In addition, complex-structured oyster reefs can serve as nursery grounds for a variety of fish, crabs and other marine invertebrates, that can potentially enhance fisheries.

But aquaculture operations, especially intensive production systems, pose serious environmental concerns. The heavy dependence of intensive systems on human input—feed, water, chemicals—and the effects on ecosystems and species are major constraints in the sustainability and future growth of this industry. Nonetheless, recent technological advancements in some modern, efficient aquaculture operations, particularly in the more developed regions of the world, are helping to lessen the environmental impacts of these practices.

Below are some of the disadvantages arising primarily from, but not limited to, intensive aquaculture operations:

- ***Dependence on wild fisheries.*** Modern aquaculture operations use high-tech facilities and often depend on processed feed made from fishmeal and fish oil from wild-caught fish. Intensive aquaculture of high-valued

An oyster farm just off the coast of Malaysia.

carnivorous species (e.g., salmon and shrimp) in particular, requires large quantities of artificial feed derived from lower-value fish (e.g., anchovies and mackerels) from capture fisheries. Raising one kilogram of shrimp for instance, requires about 2 kg of high-quality fishmeal (New and Wijkström 2002), or an equivalent of up to 10 kg of pelagic fish assuming a pelagics-to-fishmeal conversion factor of 5:1 (Tacon 1997)—a rather high feed conversion rate. It is important to note that the conversion rates of high-quality feed to protein in efficient salmon aquaculture operations in particular, has improved considerably in recent years.

Wild fish are not only used for feed, but also as juvenile stock or as seed fish for aquaculture practices, especially in the highly profitable and rapidly expanding sea ranching operations. Eel aquaculture, for example, relies completely on wild-caught juveniles—called glass eels—for seed, causing a complete collapse of the wild stocks in Europe, where most of the juvenile catch comes from (Dekker 2003). Many shrimp farmers in South and Central America, Bangladesh, and India also depend on wild-caught post larvae shrimp (shrimp fry), usually harvested by local fishermen (World Bank 2002).

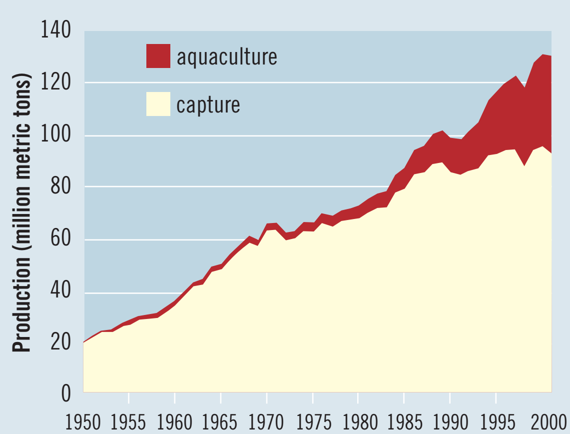
- ***Resource intensive.*** Intensive aquaculture operations maintain high densities of fish and shellfish under stressful conditions, often requiring the use of antibiotics, pesticides, hormones, vitamins and other chemicals to control diseases or to improve production. In the United States alone, between 204,000 and 433,000 pounds of antibiotics are used annually in the production of seafood sold for domestic consumption (Benbrook 2002). In addition, these systems may require other energy dependent resources such as the mechanical addition of oxygen to the water, and frequent water exchanges (up to 30 percent per day) to aerate and filter the ponds, although the rate of water use is much improved in recent years (Boyd and Clay 1998; World Bank 2002).
- ***Destruction of natural habitat and vegetation.*** To set up aquaculture facilities natural vegetation is often cleared, especially along the shore where brackish species, such as shrimp, are raised. As of 1998, Asia had 1.2 million hectares of shrimp ponds (Boyd and Clay 1998), and in Central and South America the creation of new farms continues unabated. Although precise estimates of the area cleared for aquaculture is not globally documented, one estimate is that some 40 percent of small shrimp farms in Asia displaced mangroves (Boyd and Clay 1998). Other important nursery and spawning grounds that disappear when vegetation is cleared for aquaculture are inland and coastal wetlands and seagrass beds.

- *Water pollution.* Discharge from aquaculture facilities can be loaded with pollutants, including excess nutrients from uneaten fish feed and fish waste; antibiotic drugs; and other chemicals including disinfectants, such as chlorine and formaline; antifoulants such as tributyltin; and inorganic fertilizers such as ammonium phosphate and urea (GESAMP 1997). These chemicals can significantly degrade the surrounding environment, particularly at local scales. In the North American Great Lakes, for example, rainbow trout aquaculture operations have increased phosphorous levels, reduced water transparency, lowered dissolved oxygen, and caused algae blooms (Great Lakes Fishery Commission 1999). Such water quality degradation can cause fish kills, odor problems, and reduce the productivity of some fisheries, as well as impair the water supply quality for neighboring communities.

The use of antibiotics and other man-made drugs can also have serious health effects on humans, the ecosystem and other species. For instance, the transfer of antibiotics to wild fish and benthic microbial communities may influence natural bacterial decomposition in bottom sediments, impacting the ecological structure of the surrounding environment (World Bank 2002). The use of the antibiotic chloramphenicol, for example, can cause human aplastic anaemia, a serious blood disorder which is usually fatal. And while many countries have banned the use of chloramphenicol in food production, the level of enforcement varies considerably from one country to another (GESAMP 1997; Health Canada 2004). Another risk from antibiotic use is the spread of antibiotic-resistance in both human and fish pathogens. This resistance can hamper the effectiveness of treatments and further decrease the number of available drugs that can be used during disease outbreaks (Harper 2002). The U.S. Center for Disease Control and Prevention reported that certain antibiotic resistance genes in *Salmonella* might have emerged following antibiotic use in Asian aquaculture (Angulo 1999 as cited in Goldburg et al. 2001).

- *Introduced species and "genetic contamination".* Farmed fish are often genetically different from local wild populations. Sometimes the farmed species are exotics, other times they are genetically distinct varieties of the same species that occurs in the wild. These farm-raised fish often escape from aquaculture facilities or are intentionally released into the wild to boost stocks. Once in the wild, farm-raised fish breed with native populations of the same, or closely-related species causing loss of unique genetic fish varieties among the wild population, interbreeding problems, and consequently altering the species composition and the structure of native ecosystems.

Figure 6-2: Increasing Proportion of Aquaculture in Fish Production



Source: Fishstat 2003.

At a global scale, aquaculture seems to have been making up for the slowed growth in capture production over the last 15 years, rather than reducing the pressure of overfishing on wild stocks.

Inbreeding is of great concern, especially among salmon populations, where it can potentially reduce the fitness, productivity, and characteristics of local salmon varieties and runs (McGinnity et al. 1997; Doubleday 2001). In the Pacific coast of the United States, scientists have documented that between 1987 and 1996, at least a quarter million Atlantic salmon escaped from farms (McKinnell and Thomson 1997), putting in jeopardy the already depleted native Pacific salmonids. Experience in Ireland has shown that offspring of farmed salmon grow faster and out-compete native young Atlantic salmon in rivers, but are likely to have lower survival rates at sea than native salmon (McGinnity et al. 1997; Doubleday 2001).

The concern is that a relatively large number of farmed fish will replace the native spawners, who will then be unable to sustain themselves in the long term (Doubleday 2001). Escapees can also impact the wild populations by competing with them for food and habitat, acting as predators, or by spreading disease and parasites.

- ***Disease and Parasites***. Infectious disease is currently the single most devastating problem in shrimp culture and presents ongoing threats to other aquaculture sectors (FAO 2003c). In addition, when infected farmed fish escape from aquaculture facilities, they can transmit these diseases and parasites to wild stocks, creating further pressure on them. Infectious Salmon Anemia (ISA), a deadly disease affecting Atlantic salmon poses a serious threat to the salmon farming industry. ISA was first detected in Norwegian salmon farms in 1984, from which it is believed to have spread to other areas, being detected in Canadian salmon (1996), in Scotland (1999) and in U.S. farms (2001) (Doubleday 2001; Goldburg et al. 2001). Norwegian field studies observed that wild salmon often become heavily infected with sea lice (parasites that eat salmon flesh) while migrating through coastal waters, with the highest infection levels occurring in salmon-farming areas (Goldburg et al. 2001). Wild Norwegian salmon stocks have also been impacted by another parasite, *Gyrodactulus salar*, that probably originated from Swedish salmon used in stocking programs (Bakke et al. 1990).

IS AQUACULTURE HELPING TO REDUCE THE PRESSURE ON WILD STOCKS?

At a global scale, aquaculture seems to have been making up for the slowed growth in capture production over the last 15 years, rather than reducing the pressure of overfishing on wild stocks. As seen in *Chapter 3* it is obvious that capture fisheries alone cannot keep up with the world's increasing demand, and that much of the increase in annual global fisheries production now comes from aquaculture (see *Figure 6-2*).

However, the question of whether farmed products of one fish species can reduce the pressure on the wild stock of the same species is less clear. In theory, aquaculture products in the market can outcompete wild capture products of the same species group, and hence reduce the demand for the wild fish. However, the market response is not as simple. There are certain characteristics of wild-caught fish and farmed fish that differentiate the demand for each product—in general, captured fish is considered more "healthy" because of its lower fat content and finer flavor than farmed fish; hence, consumers are willing to pay more for the capture products (Brigante 2001). For example, a study of sea bream and seabass markets in Italy shows that wild-caught and farmed fish occupy different niches in the market, and that one does not affect demand for the other (Brigante 2001). Another important factor is that while most seafood products have several substitutes, these substitutes tend to come from other species (Asche and Bjørndal 1999), not from farmed varieties of the same fish. For example, new farmed species, such as tilapia, have carved out market share in the United States and Europe as a substitute for traditional white fish such as cod and haddock which are overfished and consequently more expensive and harder to find in the market (Alceste and Jory 2002).

Nevertheless, a few exceptions do exist. One condition under which a farmed product may displace the demand for wild fish is when supply from aquaculture rapidly increases and saturates the market, lowering the price, as in the case of salmon and catfish, or of seabass in the Mediterranean. The price of salmon has declined and is now at a record low, as more salmon became available from successful aquaculture production operations in Norway and Chile in the last 15 years (Globefish 2002b). Another example is when the characteristics of the cultured product are actually favored over that of wild fish. Farmed Norwegian Atlantic salmon, for example, is out-competing wild Alaskan salmon in the Japanese market—the world's leading importer of frozen salmon—because of its higher fat content which is preferred by Japanese consumers (Globefish 2002b).

FAO/19901/G. GREPIN

Shrimp fry collectors on the Passur River, Bangladesh.

Wild stocks are used for feed

As mentioned earlier in this Chapter, aquaculture is increasingly using more wild-caught fish to produce processed fish feed. In 2001, aquaculture used 35 percent of the global fishmeal supply and 57 percent of the global fish oil supply (Nautilus Consultants Ltd. 2003)—most of it for just salmon and shrimp production (Delgado et al. 2003). Herbivorous and omnivorous species, such as carp and tilapia, which do not need to consume fishmeal because they can process plant protein better than carnivorous species, are now being fed artificial feeds in order to boost growth. This is particularly true in China, where most carp production has not utilized fish feed until recently.

A future concern for fishmeal producers, and for fisheries managers, is that because most of the stocks currently used as feed have already reached their maximum production levels, market pressure to harvest relatively unexploited species may increase. One of these relatively unexploited fisheries that has excellent nutrient potential for fish feed (New and Wijkström 2002), but at the same time could have devastating ecosystem-wide effects is krill—a microscopic crustacean living in Antarctic waters. According to the FAO, the use of krill as an aquaculture feed is likely to increase in the coming years (FAO 1997d). This usage, however, requires special monitoring because increased harvesting of krill—which forms the base of the Antarctic food chain—could alter entire food webs and potentially harm numerous species and ecosystem structures. In the Antarctic Ocean krill fisheries operate during periods when many species—from whales to fish—are directly or indirectly dependent on this resource (Parkin 2003); a drastic change in available krill, could affect the survival of these species.

Wild stocks are used for seed

Similarly, the use of wild-caught juveniles as seed fish in aquaculture operations can have a serious impact on wild fish stocks. Such is the case with the declining population of European eel, whose juveniles are collected from the wild in European waters for aquaculture operations elsewhere in the world—mostly in Japan (see *Chapter 3* for further discussion on the condition of the European eel stock). Another serious and more recent concern is the sea ranching of tuna species, especially the highly valuable bluefin tuna, one of which usually sells for thousands of US dollars in the Japanese sashimi market. Tuna ranching or fattening is the practice of capturing wild juvenile tuna and placing them in open-ocean pens where they are fattened with formulated feeds to improve their oil content. This is done to produce the expensive, but very flavorful "fatty tuna" so much in demand by sushi and sashimi lovers the world over. The tuna farming industry is rapidly expanding. Total production of "fattened" tuna increased from 5,000 metric tons in 1997 to over 20,000 metric tons in 2001 (Ukisu 2001). The major producing countries include Spain, Croatia, Malta, Italy, Australia, and Japan, with production in the Mediterranean making up more than half of the world total and almost all exported to, and consumed in Japan (Tudela 2002).

NOAA PHOTO LIBRARY

Offshore fish ranching pen.

This faming method, however, is raising concerns with fisheries managers, fishers, environmentalists, the FAO, and the various International Tuna Commissions. Fishermen catch the juvenile tuna before they have had a chance to reproduce and renew wild stocks, thereby increasing fishing pressure on the already depleted wild populations and putting long-term yields and any hope for sustainability at risk.

In addition, fish caught by Mediterranean purse seiners are now being transferred directly to pens and cages for fattening, without landing them at port and reporting the catch so it can be integrated into catch statistics to guide quota allocations and fisheries management rules (Tudela 2002). The International Commission for the Convention of Atlantic Tuna (ICCAT) has not only expressed serious concern on this matter, but has gone further by approving a recommendation on bluefin tuna farming in 2003 that, among other things, requires all ICCAT members to report all transfers of tuna to fattening facilities (ICCAT 2003a).

CHAPTER 6

The Role of Aquaculture: Is It Helping to Sustain Fisheries and Feed the Poor?

FAO/20044/ H. ZHANG

Mulberry field with fish ponds in the Taihu Lake area of Jiangsu province, China.

Reporting requirements include number of fish transferred, dates, names of vessels involved in the transfers, as well as locations where the tunas were caught and the names of the fattening facility operators (ICCAT 2003a). ICCAT has also approved recommendations that require imports of "fattened" tuna to have the appropriate documentation for tracking and monitoring these operations and facilities (ICCAT 2003a).

As with other forms of aquaculture, increasing farmed tuna stock may make more high-valued tuna available year-round and lower the prices, resulting in increased demand and more pressure on the wild stocks. Measures to monitor and track these practices, as well as strict enforcement of regulations, and willing collaboration from member states that are involved in these operations is not only needed, but essential if we are to sustain these fisheries in the long term.

IS AQUACULTURE HELPING TO FEED THE POOR?

As mentioned earlier, aquaculture operations can be divided into two general categories: large scale or intensive operations that target export markets, and small-scale or extensive operations that target local consumption. Intensive operations often require large financial investments and therefore tend to be owned by large companies. Developing-country producers certainly benefit from these operations through overall revenue and employment generation, but the local people who actually live in areas where the farming takes place do not always enjoy all the benefits. In addition, local communities also have to cope with a number of environmental and social problems arising from the operations such as polluted water and the reduction in wild fish for local consumption. In India and Bangladesh for example, local farmers and fishermen who depended on coastal resources were unable to access beaches and creeks due to shrimp farming activities—a significant factor contributing to the Supreme Court's ban on shrimp farming in India (World Bank 2002).

On the other hand, extensive, rural, or small-scale aquaculture tends to benefit local people and have lower environmental impacts. These operations supply food to local markets and support local livelihoods. Inland water carp aquaculture production, for instance, provides significant cash income to farming households in rural China and animal protein to much of the population. In China, per capita availability of fish and fishery products increased from less than 6 kg in the early 1980s to about 33 kg in 1999—40 percent of which came from inland fisheries and aquaculture (Laurenti 2002). More than 80 percent of the employment in the fisheries sector is estimated to be in inland fisheries and aquaculture in rural areas (Miao and Yuan 2001). In terms of cash income, the average income of people engaged in fisheries and aquaculture is nearly twice as much as the average income in the agricultural sector in general. In China, fish-culture related activities provide over 90 percent of the income to small-scale carp farming households in rural areas (Miao and Yuan 2001). For these reasons, a number of fisheries development and research agencies are now promoting more research and investment in developing small-scale or rural aquaculture (NACA and FAO 2000; FAO 2000b).

Despite its success in Asia, rural aquaculture development has not been as successful elsewhere. Attempts to introduce aquaculture practices to rural Latin America, for instance, have often failed partly because in some regions there is no strong tradition of a fish-based diet and fish farming, or because aquaculture was not introduced as an integral part of existing farming systems (FAO 2000b). In parts of Africa, competition from inexpensive capture fisheries, inappropriate aquaculture extension programs, low population densities, and lack of appropriate infrastructure have contributed to poor results at developing rural aquaculture (Harris 1993).

FAO/19611/ G. BIZZARRI

Women participate in fishing activities, by feeding pond-raised fish, cleaning, drying, salting, and preparing the fish for local consumption and export, Cambodia.

IS AQUACULTURE TAKING FOOD FISH AWAY FROM THE POOR?

One of the concerns surrounding aquaculture is the belief that intensive aquaculture is consuming vast amounts of processed feed derived from wild-caught fish that could be used to feed the poor. But the argument that industrial fishmeal production competes with domestic demand for small pelagic fish for food, has not been substantiated, at least for the moment. First, fishmeal and fish oil are primarily made of waste from fish processing factories, and of surplus production of small pelagic fish for which there is limited demand for direct human consumption. Second, the largest fishmeal and fish oil producers are in Peru, Chile, and the European Union, where small pelagic fish are so abundant that production more than surpasses domestic demand. Third, even in developing countries where a food deficit exists, much of the high-quality fishmeal used in intensive aquaculture is imported from Northern Europe, Japan, or Chile (World Bank 2002), rather than relying on domestic supplies of small pelagic fish.

Over the past three decades, the aquaculture sector has grown at an unprecedented pace and it seems that it will continue to do so. The challenge is to maintain the balance between support for further development of the sector and regulation to prevent potential adverse environmental and social impacts.

There are however, some isolated cases, where locally caught "trash" fish—fish that impoverished populations actually rely on—are used as aquaculture feed (Edwards and Allen 2003; World Bank 2002). In addition, a recent study of the industrial pelagic fishery in Peru that caters to the fishmeal industry shows that a large portion of the catch—more than 20,000 metric tons in 2003—is bycatch of fish such as sculpin and drum, which affects the stocks of important white fish that provide food to local markets (Segura et al. 2004). The destination of the bycatch is unclear, but this is certainly an example of the fishmeal industry indirectly taking food away from the poor.

While overall it may not directly take fish away from the poor, the fishmeal industry as a whole may want to review the environmental costs of its production processes. Untreated sewage from fishmeal factories in Peru for instance, has deposited a thick layer of fat on the bottom of the Bay of Paracas, rendering 18 km^2 or 95 percent of the Bay's seafloor a biological dead zone—decimating local traditional fisheries (Mundo Azul 2004).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Aquaculture pens in Thailand.

There is little doubt that dependence on fishmeal can pose financial constraints to aquaculture (as well as to poultry and livestock) in the future if the demand for fishmeal keeps increasing while the overall global supply is static (World Bank 2002). Global production of fishmeal and fish oil combined has averaged 8 million MT in the last 15 years. It is unrealistic to believe that the increase in capture fishery can increase the supply of fishmeal since most of the fishmeal-grade fish are already managed by some kind of total allowable catch system to prevent overfishing. Peru and Chile, the top fishmeal producers, apply strict catch regulations to protect their fish stocks. For now, the growing demand for fishmeal in the aquaculture sector might be offset by declining usage in the other agricultural sectors (poultry and livestock). The share of global fishmeal production being used for aquaculture has increased from 10 percent in 1988 to 35 percent in 2000 while usage for poultry declined from 60 percent to 24 percent (Barlow 2001). However, there are concerns that in the near future more fish species currently being consumed as food may be "downgraded" to become fishmeal material in order to meet the demand. If the price of fishmeal keeps increasing (Globefish 2001), the fishmeal market may start taking small pelagic fish away from people. However, this can be avoided by substituting vegetable oil and protein for fish oil, improving the efficiency of aquaculture facilities, and making better use of fish waste and capture fishery discards in the fishmeal production process (Barlow 2001).

TOWARD SUSTAINABLE AQUACULTURE

Over the past three decades, the aquaculture sector has grown at an unprecedented pace and it seems that it will continue to do so. The challenge is to maintain the balance between support for further development of the sector and regulation to prevent potential adverse environmental and social impacts. Because the aquaculture industry has expanded so rapidly, the legal and political frameworks for maintaining it as a sustainable business have lagged behind. Article 9—Aquaculture Development—of the FAO Code of Conduct for Responsible Fisheries (the Code) adopted in 1995, sets principles and guidelines for the sustainable development and management of aquaculture. (See *Chapter 9* for further discussion on the FAO Code of Conduct.) A brief overview of the key principles of Article 9 that relate to the environmental impacts of aquaculture and some of the progress in these areas follows.

Establishing Legal and Administrative Frameworks for Responsible Aquaculture

Under Article 9.1 of the Code, countries are encouraged to establish "legal and administrative frameworks that facilitate the development of responsible aquaculture" (FAO 1997c). Following these principles, many countries have started to implement national regulatory guidelines that address the environmental and social impacts from aquaculture in order to ensure its sustainability. A total of 140 codes or instruments to promote responsible aquaculture have been put in place in FAO-member countries both by government and industry (FAO 2003d). Canada, for example, has developed a comprehensive Aquaculture Action Plan, which provides clear guidelines for applying regulatory responsibilities to aquaculture under the existing legislation (DFO 2001). Canada has also implemented strict controls on the introduction of non-native species by establishing a National Code on Introductions and Transfers of Aquatic Organisms (DFO 2002a). Brazil, Malaysia, and Sri Lanka have made progress in establishing legal and regulatory frameworks for aquaculture (Emerson 1999), and the state of Tamil Nadu in India has enacted an Aquaculture Regulation Act, which calls for the establishment of an "Eco-Restoration Fund" for remedying environmental damages caused by aquaculture operations (FAO 1997d).

The seafood industry has also taken steps in this area. The Australian Seafood Industry Council has developed a voluntary Code of Conduct for a Responsible Seafood Industry (ASIC 2003), while the Australian Aquaculture Forum has developed a similar Code of Conduct for Australian Aquaculture (AAF 1998).

Encouraging the Use of Environmentally Sound and Sustainable Practices in Aquaculture

Despite such progress, aquaculture-producing countries still face enormous challenges to support responsible practices. While there are examples of environmentally sound practices, one of the limiting factors is the lack of financial resources for some countries to take advantage of the advanced technology that lessens the impact of aquaculture on the surrounding environment (Emerson 1999). Some of the more promising areas for lessening the environmental impacts of aquaculture practices include the following.

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Offshore fish ranching pen.

Closed or low-discharge systems

A recirculation or closed-cycle system is an innovative system of culturing fish in tanks using water that constantly recycles. It is considered more environmentally friendly than traditional open systems, because it conserves water and fishmeal, avoids wastewater discharges, and minimizes the use of land. A notable example is the expansion in tilapia production using indoor closed-recirculation systems in the U.S. freshwater farming sector (FAO 2003c). Multilateral and bilateral organizations financing aquaculture operations in developing countries should invest in aiding technology transfer, or at least request the agencies or NGOs implementing the projects to ensure the use of technological measures that will diminish the potential impacts of aquaculture operations on the surrounding ecosystems and communities.

Lessening the dependence on wild fisheries

Aquaculture can also help to lessen dependence on fishmeal from wild-caught fish. The use of plant protein in feeds has considerable potential, with some success to date. For example, some research shows the successful replacement of 33 percent of fishmeal-based protein with soybean meal and pea protein concentrate for Atlantic salmon feed (Carter and Hauler 2000). There are also a number of research activities investigating alternative sources of protein for shrimp, molluscs, and fish feed (FAO 2003c). Conversely, other studies have shown lower growth rates and higher mortality in several aquatic species when vegetable meal was substituted for fishmeal (Lim et al. 1998 as cited in Delgado et al. 2003). The complete replacement of fish oil is even more difficult than the replacement of fishmeal, because replacing more than 50 percent of the fish oil in feed for carnivorous fish (especially salmon species) may affect their growth, survival rate, as well as the fat content and therefore the flavor of the product (Wada pers. comm. 2003).

Nevertheless, there is ongoing research on protein feeds and biotechnological techniques that seem to increase the opportunities for developing non-fish based alternatives. For instance, improving of the dietary value of *Artemia nauplii* (brine shrimp, the most widely used live feed in shrimp aquaculture) through bioencapsulation (enrichment) has shown positive results in improving quality, survival, growth, and stress resistance of shrimp larvae (Merchie et al. 1995 as cited in FAO 2003c). Plant-based protein also has significant potential for lessening the problem of phosphorous pollution, because plants contain less phosphorous than animal protein, therefore diminishing the overall phosphorous levels in water discharges (FAO 2003c).

Advances in hatchery technology

It is widely felt that advances in hatchery technology, especially for the culture of marine species, has great potential to replenish wild fisheries. Unfortunately, much of the research into stocking marine species is still at the experimental stage (Bartley 1999). But despite the absence of adequate

Box 6-2: Use of Genetic Technologies in Aquaculture

The application of genetic biotechnologies in the farming of aquatic organisms has gained significant attention in recent years because of its potential to increase production. Gjedrem (1997) stated that by simply using selective breeding on more aquatic species, aquaculture could more than keep up with the rising demand for aquatic products. Chromosome set manipulation to make sterile animals has been used to keep animals from wasting energy on developing gonads, and to reduce the chance of animals breeding in the wild in the event they escape from culture facilities. Studies have shown that the growth of transgenic salmonoid species is, on average, 3 to 5 times larger, than those of non-transgenic salmonids under controlled conditions (Devlin et al. 1994). Similarly, studies on the use of hybrids in the culture of numerous species show considerable potential for improving yields (FAO 2003c, Bartley et al. 2001).

However, the use of Genetically Modified Organisms (GMOs)—the term applied to animals or plants that have been genetically altered to improve growth, yields, or disease resistance by means of gene-transfer or other modern genetic technologies—has become especially controversial (Bartley 2000). The use of GMOs in agronomy is more prevalent with over 60 million hectares planted with transgenic crops worldwide (Beardmore and Porter 2003).

Despite increases in production and yields, the use of GMOs raises concerns regarding their impact on human health and ecosystem integrity. Indeed, the impacts of genetically altered farmed fish on ecosystems and species are not well documented (NACA/FAO 2001). The high level of uncertainty regarding impacts mandates that a precautionary approach should be adopted as suggested by the FAO Code of Conduct for Responsible Fisheries, and the Convention on Biological Diversity. Some countries promote GMO projects while others vehemently oppose their use.

However, GMOs are just one category of genetic alteration and at present there are no GM aquatic species available on the market or available to the consumer. All genetically altered organisms should be evaluated as to their advantages and risks. Article 9.3 of the FAO Code recommends member states to "undertake efforts to minimize the harmful effects of introducing non-native species or genetically altered stocks." (FAO 2003d); and useful guidelines and mechanisms exist to regulate the use of GMOs and introduced species in aquaculture. These include the International Council for the Exploration of the Seas's Code of Practice on the Introduction and Transfers of Marine Organisms, the USA's Nuisance Species Protection Act, the U.S. Department of Agriculture Performance Standards for safely conducting research with genetically modified fish and shellfish, and the EU's Directive on the deliberate release into the environment of genetically modified organisms.

These guidelines are also detailed in the FAO Technical Guidelines for Responsible Fisheries. However, a survey conducted by FAO revealed that only a limited number of countries have actually introduced measures that encompass risk management, environmental impact assessment, or the application of the precautionary principles regarding the introduction of non-native species and the use of genetically altered stocks (FAO 2003d).

6

scientific information, there is a growing expectation amongst the aquaculture industry that hatchery technology and the farming of marine species could rescue the depleted wild stocks. Recent advancements in hatchery technology, for example, are making cod farming—the raising of juvenile codfish in ocean net pens—a promising enterprise. In Norway, cod farming is expanding rapidly. The Norwegian industry claims that by 2013, cod farms in the country will be producing five times the volume of the current cod catch harvested by the British fleet (*The Economist* 2004). Genetic technologies have also been successful at creating selectively bred varieties, e.g. carp and tilapia, producing useful hybrids and creating sterile animals that grow well and do not breed with the wild population if they escape (Bartley 2000; Bartley et al. 2001).

One advantage of improving the science of stock enhancement and hatchery technology is that it may help reduce the demand on wild-caught fish that are used as seed in aquaculture operations. The majority of the shrimp seed used in the world, for example, no longer relies on wild-caught larvae but comes from hatcheries and nurseries (World Bank et al. 2002). And even farmers in countries such as Ecuador who used to favor the use of wild seed for shrimp farms, are now shifting to hatchery-reared seed because they are perceived to contain fewer diseases (World Bank et al. 2002). Replacing wild-caught seed with hatchery-reared seed however, requires some transition, since the livelihood of many poor communities, such as those in Bangladesh, still depends on the collection of wild seed (World Bank et al. 2002).

Regardless of the positive impact that these technological advancements may have, the fast development of the sector underscores the need for a precautionary approach. This is particularly true given that information on the long-term impacts of these technologies on wild stocks (such as disease transfer, genetic contamination, predation, and competition) are not well documented or available, and the consequences of their use could prove devastating to wild species and ecosystems. For this same reason, the use of genetic engineering—creation of transgenic organisms or genetically modified organisms (GMOs)—in aquaculture, is especially controversial (see *Box 6-2*).

Use of best practices to mitigate impacts

It is important to recognize and promote the use of best practices that increase efficiency and productivity, and reduce impacts. Fish farmers can mitigate water pollution from aquaculture facilities by reducing the amount of feed they apply or by collecting sediments and solids prior to discharge. Farmers may also reduce the mortality of fish by reducing the fish density in a pond and in turn increase productivity. Research shows that careful management in combination with quality feeds, well designed culture systems, and a solids collection area can reduce nutrient discharges by as much as 50 percent (Miller and Semmens 2002). In Australia, the use of settlement ponds reduced total suspended solid loads by 60 percent, total phosphorous discharge by 30 percent, and total nitrogen discharge by 20 percent (World Bank et al. 2002). The use of biofiltration, including the use of molluscs, seaweed, and marsh plant species, is also being applied for effluent treatment (World Bank et al. 2002). These and other best practices should be promoted and disseminated among farmers for their adoption based on individual farm characteristics.

Integrating Aquaculture Operations into Rural Agriculture Practices to Support Livelihoods

The integration of aquaculture practices into agriculture practices, such as cultivating fish together with rice, should be supported, since it generates income for the poor with minimal negative impact on the surrounding ecosystem. In fact, integrated aquaculture systems can provide some positive environmental benefits (NACA/FAO 2001). For example, rice-fish systems reduce the amount of fertilizer needed, reduce the frequency of insect infestations, while increasing rice yields and providing farmers with extra income from fish sales (International Development Research Center Canada 1998). This integrated approach is now being used for environmental rehabilitation, such as the rehabilitation of former mangrove areas that have been cleared and converted to shrimp ponds.

In Vietnam, the Mekong Delta Master Plan integrates shrimp farming into mangrove rehabilitation projects to relieve land-use conflicts and reduce incentives to build illegal shrimp ponds (Primavera 2000). In Indonesia, a modern version of the traditional fish ponds farming systems in mangrove areas relying on natural food and seed (known as Tambak or Empang Parit) is now being promoted (Primavera 2000). Both examples allow for the use and development of aquaculture for food and income generation, while conserving mangrove forests.


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Fishermen bringing in tilapia, Lake Victoria, Uganda.

Providing Positive Economic Incentives

Finally, market incentives, such as certification for sustainably farmed products needs to be expanded to developing countries, because the existing certifying bodies are primarily restricted to a handful of organizations in developed countries, mainly Europe, North America, Australia, and New Zealand (See *Box 11-1 Seafood Certification: Incentive for Sustainability*). Price premiums for certified products not only give producers incentives to generate environmentally sound products, but also help consumers use their purchasing power to encourage such practices (FAO 2003c). Encouraging news indicates that market incentives are being considered and put in place in the developing world. For example, Thailand is considering a "certification" process for marketing shrimp aquaculture products that are produced in environmentally sound ways (NACA/FAO 2001).