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2 Aquaculture and Sustainable Food Security in the Developing World*

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INTRODUCTION

Despite, and sometimes because of, endeavors to transform and develop the biosphere for human ends, many of the world's poor and low-income people still lack reliable access to enough food to sustain their health and normal daily labors—they lack food security.[1] The absolute numbers of food-insecure people are growing annually, although at a global scale the percentage of people living in poverty is shrinking. In 1993, 1.3 billion people were classified as "the absolute poor," and 800 million people as not having sufficient and regular supplies of food (World Bank statistics, quoted in Commission on Global Governance, 1995).

Since this book is about one sector of economic activity, namely aquaculture, there is a necessary focus on the sector itself, including a bias toward the producers. However, I have tried to avoid a narrow sectoral approach and to highlight how the sector serves consumers, and how it relates to and is affected by other sectors and by trends and events in the larger general social, economic, natural, and political environment. Aquaculture development can be viewed as a special part of rural development.

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[1]Food security is defined as "physical and economic access, by all people at all times, to the basic food they need" (AGROVOC, FAO's thesaurus used for AGRIS). Food security therefore embodies stable, sustainable, and predictable food supply, equity through access for all (though access to the means of production and/or purchasing power), and quality including nutritional adequacy for life functions. Speth (1993) noted that sustainable food security "fuses the goals of household food security and sustainable agriculture," therefore embodying the aspects listed and "the protection and regeneration of the resource base for food production—terrestrial, aquatic and climatic."

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From the end of World War II to the late 1960s, development had an urban bias and was concerned primarily with economic growth and industrial modernization (Auty, 1995; Hettne, 1995). By neglecting rural development, governments overlooked the highly significant rural producers and consumers.

In the late 1960s and early 1970s, development models began to change, environmental awareness grew, and the green revolution in agriculture began to bear fruit. The green revolution demonstrated that farmers would adopt new technologies, provided the risks appeared acceptable, and therefore that rural investment could be viable (Auty, 1995). The incorporation of ecological sustainability into agriculture and rural development is now receiving attention (Breth, 1996). This is also the case in aquaculture, as demonstrated by the present book. In addition, women's roles and the increasing participation of civil society in development are getting greater attention in development.

SUSTAINABLE FOOD SECURITY

Sustainable food security depends on the sustainable supply of food, access to that supply, and its nutritional adequacy. Sustaining food supply requires protecting the environment as the basis for production. In the face of growing food demands from increasing urban and rural populations, the supply of all foods is important, and setbacks in any food production sector will place greater pressure on other sectors. However, most calculations of the adequacy of the food supply have focused on grains only since these are the staples of the diets of low-income people and any change in their availability signals changes in the overall food situation.

For global level consumption, increases in the average per capita supply and consumption of most plant foods (grains, cereals, legumes, roots, and tubers) has plateaued (Pinstrup-Andersen, 1994; FAO, 1994). Consumption of livestock products continues to increase, but consumption of fish and other aquatic products appears to have peaked in 1989 and to now be declining (Figure 2.1).

Little has been written on the consequences of interactions in food availability between grains and animal proteins, including fish. Delgado (1995) reviewed studies on responses of fish consumption to income and price of fish in Africa. For sub-Saharan African countries, he found that fish consumption rose as income rose, and fell as the price of fish rose. In Côte d'Ivoire in West Africa, cheap imports of frozen pelagic fish and fresh West African beef were good substitutes, displaying symmetric cross-price elasticities.

Fish has made larger gains than other foods over the last four decades. The 1990 per capita level was approximately 1.7 times the 1961 level for the developing world and 1.5 times the 1961 level for the developed world, despite significant increases in population during the period. The increases came largely from natural fisheries resources and only more recently from aquaculture. Now, however, after more than four decades of increase, the contribution of fish to sustainable food security is undergoing a transition to increasing scarcity. The solution will include increased aquaculture production (Williams, 1996).

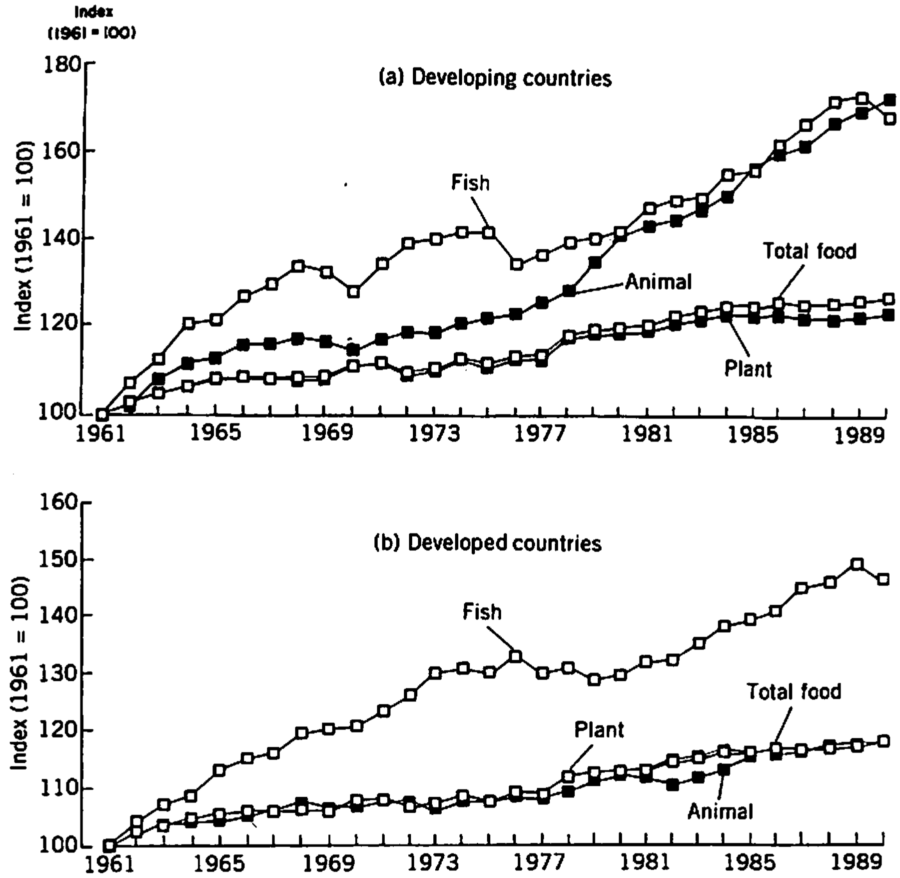

Figure 2.1. Daily per capita calorie consumption, 1961 to 1990. Reprinted with permission from the International Food Policy Research Institute (Discussion Paper 13), using data from FAO 1993.

Part of the transition has been characterized as "from hunting to farming fish" (ICLARM 1995). This part of the transition is under way, mobilized by rising demands for fish and improving technical knowledge. Since the Food and Agriculture Organization of the United Nations (FAO) first started collecting detailed aquacultural statistics in 1984 and until 1992, annual per capita fish supply from aquaculture increased by 67% (FAO, 1995a). Globally in 1992, aquaculture contributed an average of 2.5 kg of food per capita.

In December 1995, 95 nations met in Kyoto, Japan, to consider the issues of the contribution of fish to sustainable food security. This meeting represented a turning point in fisheries affairs as, for the first time, nations officially recognized "a potential shortfall by 2010 of the supply of fish and fishery products to meet demands from an increased human population, which in turn will adversely affect world food security" (Kyoto, 1995).

Predicting fish demand is complex. At Kyoto, the present per capita supply figures were used in projections, although as noted above these are a historical high. In the case of nutritious high-protein foods such as fish, demand is increased by economic factors and population growth. During the period 1970 to 1990, population growth accounted for only half the growth in fish consumption (Westlund, 1995). Economic and cultural factors such as greater disposable income, the price of fish relative to other animal proteins, trade opportunities, and dietary and health preferences all contributed to fish consumption patterns (Westlund, 1995). Many of these factors have acted positively on the demand for fish as well as on its price and tradability, thus putting pressure on all forms of supply and tending to limit access to it by poorer people. This is a break with the past in the developing world, when fish from natural stocks used to be considered "the poor man's protein" due to its low price and/or to the fact that the very poor who owned no land or other means of production nevertheless could often exploit open-access fisheries resources as commons.

With specific reference to aquaculture, documents presented at the 1995 Kyoto Conference projected that aquaculture production in 2010 would be between 27 million and 39 million tonnes (or metric tons, MMT), up from a 1993 total of 16 MMT (FAO, 1995b), thus providing the greatest potential hope for maintaining per capita fish supply. Marine and inland fisheries were predicted to stay steady, decline, or at best increase more modestly than aquaculture (5 MMT each as the most optimistic increases).

At an aggregate level, therefore, aquaculture is the major, though not sole, hope for improving the world's fish production. Few would deny that aquaculture will continue to make great progress as technology, know-how, and investment race ahead in the sector. But how will success in increasing aquaculture production help those who are food-insecure?

FISH AND FOOD SECURITY

Fish and all other aquatic products contribute to food security directly as nutritious human food supplying protein, essential amino acids not found in staples, and in some of their forms calcium (e.g., bones and scales in dried and canned fish), iodine, some vitamins, minerals, and other trace elements (Rogers, 1990). For developing countries, fish from aquaculture and fisheries combined currently supply 19% of total animal protein consumed and just over 5% of all protein (FAO, 1995b). Indirectly, but importantly also, fish assist food security by providing income for fishers and fish farmers, and livelihoods for workers in fisheries, aquaculture, fish processing, marketing, and allied supply and service industries such as feeds, extension, hatcheries, and so forth.

The three dimensions of food security—sustainable supply, access to food, and nutritional adequacy—are now each addressed.

Sustainable Supply Options

Fish supplies can no longer be left only to nature. Whereas most fish (85% of total fish or 79% of food fish) still comes from natural stocks, the majority of these are impacted negatively by heavy fishing (including overfishing), habitat degradation (including pollution), and habitat loss. Many management regimes are not adequate to sustain the resource base, and aquatic environments continue to suffer the downstream effects of most terrestrial and atmospheric events, including climate and climatic change. Even without the prevalence of negative impacts on natural fish production, the biophysical limits to natural production from natural stocks appear to have been reached or exceeded (Pauly and Christensen, 1995). Encouraging more people to catch fish for food or profit is no longer an option in most parts of the world. Moreover, encouraging people to grow their own fish or participate in artificial stock enhancement schemes are increasingly viable options.

Despite great technical advances, modern aquaculture is still a new technology and requires further progress to meet the supply challenges ahead. Enhanced development of aquaculture is only recent. Even though the aquaculture of carps began at least 2500 years ago in China, carps were only successfully bred in hatcheries as recently as the early 1960s. Most current aquaculture is still quite rudimentary, relying on natural supplies of seed stock, unimproved wild types of fish, and simple culture technologies and inputs. Feeds are also largely unimproved, and the nutritional requirements of most species are not known at all except in general terms from studies of diet and feeding preference.

The example of Norway's extraordinary success with the domestication and mass production of Atlantic salmon shows that the bounds to increasing supply through greater production efficiency are only now being explored. To some extent, the impetus to reach these bounds will come from the technology push itself. A greater impetus will be market demand for fish and local pressures for new forms of livelihood and enterprise.

The majority of aquaculture production occurs in developing countries, and production in the developing world has been increasing much more rapidly than that in the developed countries, due mainly to developments in Asia.

Have these rapid advances in supply benefited low-income people, and if so, how? Kent (1995) concluded that intensive aquaculture did not benefit the poor, and some forms may even have negative impacts. Extensive traditional forms are more likely to benefit the poor in developing countries.

Losses and shortfalls of supply from natural stocks are not directly replaced by aquaculture. The species showing the largest increases in aquaculture production are carps, tilapias, shrimps, and salmons. Shrimps and salmons satisfy luxury export markets and increasingly lower-priced markets in the developed world as cost of production drops (Anonymous, 1996), but not basic food needs. In Asian countries and in some North American export markets, tilapias are substituting for generic whitefish formerly supplied only by marine demersal species. Carps satisfy a range of low to middle price markets, especially in Asia, but tend not to replace either marine fish or small native freshwater fish in markets. There is virtually no export

TABLE 2.1. Number of Species Used in Aquaculture

	Number of Species	Percentage of All Species
Extant finfish	24,618	100.0
Fish used in industrial and artisanal fisheries	2,576	10.5
Fish used in aquaculture[a]	179	0.7
Fish used as bait	134	0.5
Fish used in ornamental trade	1,980	8.0
Marine fish	546	
Freshwater fish	1,434	
Mainly artificially reared	773	
Fish used as sport fish	798	3.2
Total used by humans	4,572	18.6
Finfish affected by humans		
Threatened	770	3.1
Introduced[b]	221	0.9
Finfish affecting humans		
Dangerous[c]	437	1.8

Note: Although FishBase does not yet contain all species, the above statistics should already provide a reasonable estimate, since ICLARM has made an effort to include all species that are used by humans. The number for fisheries is underestimated because many species that are important in artisanal fisheries are not reported in the literature. The same is true for bait fishes.

[a]Species used for food or stock enhancement in commercial aquaculture.

[b]Species transferred to and established in another country.

[c]Species that are, for example poisonous or traumatogenic (causing adversely altered mental states).

Source: ICLARM (1994); Williams (1996).

market for carp, so most is consumed locally. Larger carps command higher prices than smaller species such as silver barb (*Puntius goniotus*) which is cultured in its native Thailand and Cambodia and in Malaysia, Brunei, Bangladesh, and Indonesia, into which it has been introduced.

The greatest supply gap for coastal people will be in marine fish for which, in Asia, Csavas (1994) estimates that only 1.2% is presently supplied by aquaculture but for which demand is high. Many desirable marine species are carnivores, and their cultured forms are likely to remain out of the reach of low-income people. Tilapias are a replacement in some countries, such as the Philippines.

Aquaculture production will directly assist the supply of fish for food-insecure people if they grow it themselves or indirectly if it is grown cheaply enough for them to purchase or barter. Given the wide range of species and types of aquaculture (Tables 2.1 and 2.2), different types of enterprises and different scales of enterprise will have different, often location-specific impacts on food security (Table 2.2). For example, commercial enterprises producing luxury fish or shellfish may have positive impacts on food security through providing some local employment and general

TABLE 2.2. A Classification of Aquaculture and Stock Enhancement Enterprises, with an Emphasis on Developing Countries

Type of Enterprise	Main Distinguishing Features	Operators, Labor	Disposal of Production	Examples in Developing Countries
1. Leased pond or other small waterbody	Use arranged with owner or government; inputs minimal and depend on access to credit; extensive to semi-intensive	Landless people; usually rural poor	Lessee's family and/or local market	Bangladesh (Ahmed, 1992)
2. Subsistence farm pond (micro-enterprise)	Very small scale; minor part of agriculture/rural system, which is often a mixed-crop system, crop-livestock system, or farming-fishing system; inputs small and local in origin, many from farm byproducts or waste; extensive to semi-intensive; sometimes natural reseeding	Small landholders' own family; specialized labor may be used for part of the culture cycle (e.g., pond construction, harvest)	Farmer's family, neighbor's, and sometimes local market	Malawi (ICLARM and GTZ, 1991); mussel and oyster culture, Philippines (Newkirk, 1993); rice-fish farming in Asia; giant-clam farming; extensive coastal shrimp farming with natural reseeding
3. Small aquaculture enterprise	Small-scale; aquaculture major part of enterprise; inputs and services largely purchased; some inputs imported from nonlocal suppliers; semi-intensive to intensive	Owner and family; hired labor, usually seasonal	Almost all product sold on local or more distant (e.g., urban) markets	Thailand mussel and oyster farming (Newkirk, 1993); milkfish farming in Philippines; carp polyculture in China
4. Large aquaculture enterprise	Large-scale requiring large capital investments and infrastructure; most inputs imported from non-local suppliers; usually higher technology inputs and services required; intensive	Managed as a commercial business; all labor hired; most labor specialized	All marketed commercially, usually in urban markets; may be traded internationally	Penaeid shrimp culture in Asia, Central and South America; seabass culture in Thailand; some milkfish culture in Philippines

(continued)

TABLE 2.2. (continued)

Type of Enterprise	Main Distinguishing Features	Operators, Labor	Disposal of Production	Examples in Developing Countries
5. Cage culture	Cage culture is major part of owner's livelihood; inputs and services largely purchased; some inputs usually imported from nonlocal suppliers; usually intensive	Owner and family; hired labor, usually seasonal	Almost all product sold on local or more distant (e.g., urban) markets	Milkfish and tilapia cage culture in lakes and Philippines; carp and goldfish culture in cages, Indonesia dams
6. Public sector–supported stock enhancement	Large production hatcheries produce seed for distribution; extensive to semi-intensive	Government-sponsored management and labor for seed production; private sector harvesting similar to natural fisheries	Local, urban, and sometimes export markets depending on species and method of catching of product	Shrimps in Shandong province, China
7. Traditional culture and stock enhancement systems	In use since before modern aquaculture began	Local households, often organized along traditional community lines	Community consumption, local markets; highly dependent on local and traditional ownership rights	Damming of natural depressions and drain-in-ponds: Egyptian *howash* systems, *whedos* in Benin, Cameroon, Togo; fish aggregation devices: simple refuge traps and brushparks in Asia (Bangladesh, Philippines, Cambodia, China, Sri Lanka), Africa, Pacific, and Indian Oceans on fringing reefs; more complex brushparks such as the *acadja*, Benin (ICLARM and GTZ, 1991)
8. Small-scale, community-based stock en-	Similar to no. 7 above but recent development or new in given locality; reservoirs, ox-bow lakes, coastal	Local community; seasonal hired labor or specialized ser-	Product consumed in community households and sold on local	Oxbow lake systems, Bangladesh; Sri Lanka reservoirs

				Cambodia, China, Sri Lanka). Africa, Pacific, and Indian Oceans on fringing reefs; more complex brushparks such as the *acadja*, Benin (ICLARM and GTZ, 1991)
8. Small-scale, community-based stock enhancement (modern)	Similar to no. 7 above but recent development or new in given locality; reservoirs, ox-bow lakes, coastal bays, and estuaries with community tenure; some inputs e.g. fish seed, purchased; operations usually extensive or at most semi-intensive	Local community; seasonal hired labor or specialized services	Product consumed in community households and sold on local, urban, and rarely export markets	Oxbow lake systems, Bangladesh; Sri Lanka reservoirs
9. Wastewater and sewage fish systems	Large-scale; often associated with municipal wastewater systems	Commercial operators; infrastructure extensive	Product consumed on local commercial markets	Hanoi, Calcutta (Edwards, 1996)
10. Dams and reservoirs	Large-scale; artificial stocking, often with introduced species; cages culture may be added	Commercial-scale but may be small- as well as large-scale operators	Product consumed on local commercial markets	Most countries, and an increasing potential source of fish production, as more natural water resources are impounded

economic gain. At the same time, the enterprises may have negative impacts through physically displacing small-scale farmers or fishers who are those most likely to be living in poverty.

As can be seen from Table 2.2, aquaculture and stock enhancement already provide human food, employment, and income through a myriad of methods, systems, and species. In addition to these enterprises, there are ancillary services and enterprises that are needed to support aquaculture production. These include hatcheries, fingerling grow-out, fry collection from nature, feed processing, pharmaceuticals, specialist engineering services and suppliers, harvesters, postharvest processing, marketing, and storage.

Access

During the 1980s, studies on poverty and hunger shifted their emphasis from food-supply-based analyses to income-based analyses (Drèze and Sen, 1989). This shift is relevant to understanding how aquaculture may contribute to improving access to food security because the sector produces a highly marketable product. Nevertheless, aquaculture is also a direct supplier of food to those who culture fish.

Many studies have shown that aquaculture gives direct access to the household food supply in those low-income households that begin to grow their own fish and, depending on proximity to markets and quantities of fish produced, also contributes to improving their income and/or barter trade. Where producers are close to urban or local community markets, and as the market price appreciates, more fish will be sold for cash, making fish and aquatic products fully commercial rather than subsistence or artisanal staples.

Much of the fish grown by low-income farmers is eaten at home. Gupta et al. (1992) showed that fish produced by low-income families in Bangladesh increased animal protein consumption because 70% of fish produced was consumed in the household. Gupta and Rab (1994) found that about half of the fish grown in leased ponds by landless people in a study in Bangladesh was eaten in the home, the rest being sold at the local market. Aquaculture thereby improved access to food by direct growing of fish and by improving income to purchase foods and other needs such as housing, education, and medical services. In a study of 1200 farms in Guatemala that added a farm pond to land holdings of 2 ha (hectares) and less of land, about half the production (23 kg/yr per 120-m^2 pond) was eaten in the household, 20 kg was sold and 5 kg were used for restocking or given to neighbors (Popma et al., 1995). The household consumption of fish increased from 0.5 kg per person to 3.3 kg per person as a result of growing fish; and household income increased by 18% from the sales (Popma et al., 1995). In Malawi, small-scale fish farmers frequently barter fish for other food because markets are often distant from rural households, and affordable and reliable transport severely limits market access (Brummett, 1995).

Aquacultural types 1, 2, 6, to 8 in Table 2.2 seem therefore to definitely lead to greater direct access to food, including fish for home consumption by poor people. These categories may be where attention could be focused for aquacultural development assistance if food security outcomes are desired, although we should not assume that aquaculture is the only type of enterprise that could assist. Aquaculture may bring additional benefits if it enables households to rise above subsistence farming levels and into more commercial scales of operation, not necessarily only in aquaculture (Brummett, 1994).

Aquaculture also can improve access to food by those who labor for wages on larger enterprises and in ancillary activities and who thereby gain income.

More difficult questions concerning how aquaculture affects access to fish as food are (1) whether aquaculture will bring the cost of producing fish down sufficiently to allow low-income people who do not grow their own to purchase it, and (2) whether aquaculture is a better food-securing technology than others, for a particular place and time. These will be particularly important questions in those areas where natural fish supplies are or were the mainstay of local animal protein diets and where these supplies are no longer adequate. In these countries or locations, aquaculture tends to receive the most attention because the focus is on replacement or complementary supplies of fish. Candidate developing countries are Bangladesh; most Southeast Asian countries and parts of the Indo-Chinese countries surrounding the Mekong River, its tributaries, and the Great Lake in Cambodia; Malawi, parts of many other sub-Saharan African countries surrounding the Great Lakes, Senegal, Ghana, Nigeria, and Egypt; and Indian Ocean, Pacific, and Caribbean island countries.

For low-income people who cannot catch or grow their own fish in these countries, affordable new products are essential, but these will not always be direct replacements for traditional species. Cheaper fish are most likely to come from species with short production cycles, which require low inputs and therefore little capital investment. Omnivores and herbivores (carps, barbs, and tilapias) are good candidates. Production of these species has increased dramatically over the last decade in Asia. However, the increasing availability of seed for these species and the rising price of fish could cause their larger scale and more intensive cultivation; this could provide greater production but also greater incentive for more expensive, value-added products that are less affordable and/or less available on local markets. The extreme variation in prices of some products from the same species depending on market niche is a phenomenon almost unique to fisheries products. For example, there is a great difference between the prices of canned tuna and sashimi tuna.

However, aquacultural activities are not purely additional to all other forms of rural food production, employment, and income generation. The net impacts of aquaculture on food security have yet to be investigated in any specific location.

On land there is a finite amount of space available, which creates competition for it access. Aquaculture is often more profitable than farming alternate staples such as rice. Fish ponds therefore are starting to encroach on existing agricultural land at a time when these lands are at a premium. For example, in China, growing freshwater crabs (*Echiochiera chinensis*) produces 20 times the value of the same land area sown to rice (Li S., 1995). Fish farms are reported to be taking over agricultural land, encouraged by government policy "to create wealth from aquaculture" (Tyler, 1995).

The forms of aquaculture most likely to cause negative as well as positive impacts on food access are those producing products of high value or at least higher value than prior land uses and those that result in habitat destruction. These often displace existing uses, and rarely do high-value enterprises remain in the control of low-income people, even when the costs of production are low. Penaeid shrimps, milkfish (*Chanos chanos*), sand goby, and carnivorous fish for the live restaurant trade are examples.

Shrimp culture has received prominence because it has been one of the fastest growing forms of aquaculture in the developing world. In just over 10 years it has risen from negligible production to supplying about 800,000 metric tons, or a third of total world shrimp production. The coastal tropical and subtropical range of the major penaeids cultured has made this kind of aquaculture predominantly a developing-country activity targeted at export markets in the developed world. However, most of the sites most suited for shrimp farms were already sites for numerous other coastal activities, often but not solely associated with mangrove ecosystems and almost exclusively exploited by the poor for fishing, farming, and forestry.

In the coastal zone, removal of large areas of mangroves, particularly during the 1980s and early 1990s in Southeast Asia and southern Asia, to make shrimp and milkfish ponds has negatively affected coastal rice fields and fisheries and left large swaths of the coast unprotected from typhoons and storm surges (Phillips, 1995). The results have frequently led to conflict between the interests of the wealthier shrimp farmers and the poorer rural inhabitants. One observer commented that, in India, "shrimp farms have come to symbolize islands of prosperity in a sea of rural poverty" (Jayaraman, 1995). Most of the shrimp produced is exported from the local region, often to international markets. Frequently, the shrimp farm owners are also based in the cities; thus, income from the farms also leaves the rural economies. Many farm inputs are purchased from outside the area.

The situation in the Philippines illustrates the divide between the economic scales of enterprises. Under the government's Comprehensive Agrarian Reform Law, fishponds and prawn (shrimp) farms were specifically exempted by a major amendment in the sixth year of a 10-year program of redistribution of various tracts of land to farmer beneficiaries (Villanueva, 1994). The reasons given were that these aquacultural industries are highly technical and capital-intensive and small holders could not benefit from redistribution of such land. Subsequently, however, provision was made by the Philippine government to give priority to small farmer cooperatives and organizations when approving the conversion of public agricultural lands to fishponds and prawn farms.

Similar conflicts between shrimp farming operations and other rural activities have been reported from other localities such as the eastern Indian coast (Jayaraman, 1995), Malaysia (Hiebert, 1995), and Java, Indonesia (Bailly and Malistyani, 1996).

On the other hand, culture of some other high-value species such as giant clams, some algae, and some parts of pearl farming enterprises are feasible for low-income people, especially those who hold household or community tenure over marine territory. Inputs for these enterprises are inexpensive and therefore within the range of rural people. The returns on investment are high.

Human Nutrition

Per capita supply statistics are averages and therefore do not indicate the distribution of food among households. Inadequate nutrition is rarely caused by lack of supply of a single commodity such as fish but rather by poverty or inadequate income, some cases of which can be due to falling supplies and prices of fish.

Aquaculture should bring higher income and more animal protein into the household, at least for those households that retain their access to the means of production. However, studies on the commercialization of agriculture in many countries have shown that increased household income does improve nutrition but more slowly than expected (Kennedy and Bouis, 1993). Health, education, and sanitation programs seem necessary for families to benefit fully. Where capture fisheries occur, the nutritional adequacy of aquacultured fish may depend on whether it takes the nutritional place of the fish that were traditionally eaten. Culture often focuses on large, fast-growing species such as carps and larger tilapias. The traditional fish eaten in much of Africa and parts of Asia are small and eaten whole, often dried. The bones, scales, and skin of these fish provide valuable dietary calcium and other minerals (Deelstra et al., 1994), elements lacking in the muscle of a large fish.

THE DISTRIBUTION OF BENEFITS AND POLICY

Adoption of any new technology or variant of a previous technology will potentially benefit many people, but technological benefits are never equitably distributed and rarely totally free of risks; e.g., see Conway and Barbier (1990) and David and Otsuka (1994) on the outcome of the so-called green revolution in agriculture.

The issues relating food security and aquaculture indicate that the benefits of increased aquaculture adoption and production, sometimes called the "blue revolution," will not be equitably distributed. Some forms of aquaculture are only accessible to commercial operators and may even disadvantage poorer people. Capital and labor costs, technical skills, and the financial security to bear the risk of a new enterprise restrict many from venturing into some forms of aquaculture.

National policy objectives are important to the development of aquaculture and can have major impacts on the distribution of benefits. In all countries where aquaculture is judged to be succeeding, national governments have identified it as a priority for national interests, be they for export earnings, import substitution, food supply, technological advantage, or national security through decentralizing industries into remote areas (Katz, 1995).

Csavas (1994), drew attention to the tension between six pairs of common national policy objectives found by an FAO review of national aquaculture policies in the late 1970s and early 1980s (Table 2.3). All of these policy objectives influenc-

TABLE 2.3. National Policy Objectives for Aquaculture in Asia

Pairs of Contrasting Objectives	
Highest volume of edible products	Highest income for producers
Highest foreign exchange earnings	Import substitution
Highest absorption of labor	Highest productivity of labor
Highest utilization of resources	Conservation of resources
Mobilization of private investments	Assistance to small farmers
Development of vertical integration	Community development

Source: Csavas (1994).

ing aquacultural development can have positive contributions to food security, but some will not ensure it. For example, income generation alone will neither deliver the best outcome for food security in the developing world, nor ensure long-term environmental sustainability. Policy interventions must contribute collectively to sustainability and equity as well as profitability. In addition to government policies, market demand for fish, private-sector investment, and institutional factors affect how aquaculture will develop and how the benefits will be distributed.

Regional Analyses

Production statistics show that aquacultural development has been very uneven across regions and between the developing and developed world. From 1984, when detailed statistics were collected, until 1993, developed-country production grew by 30% (to 3.33 MMT from 2.55 MMT), whereas developing-country production has grown by 177% (from 4.8 MMT to 13.3 MMT) (FAO, 1995a).

In 1993 by continent, Africa produced 0.4% of aquaculture production, Asia 85.8%, South America 1.5%, North America 3.5%, Europe 7.3%, the former USSR 1.1%, and Oceania 0.4%. The global average of aquaculture production as a percentage of total food fish supply was 14% in 1992; this breaks down to 24% for Asia, 1.9% in Latin America and the former USSR, and 1.3% in Africa. Many major developing-country producers have doubled (e.g., China, India, and Thailand) or nearly doubled (e.g., Brazil, Ecuador, Philippines, and Vietnam) production since 1984. In Asia, only North Korea has declined as a major producer. Production has increased in all major groups, especially carps, milkfish, tilapias, penaeid shrimps, scallops, and mussels. Developing-country production of freshwater carps and barbs increased by 227% from 2.4 MMT in 1984 to 5.5 MMT in 1991.

Information on aquaculture production is uneven across regions. In Africa, for example, the bulk of North African production was estimated by the FAO rather than directly reported by countries until 1990; in sub-Saharan Africa, the percentage estimated has increased since 1988, thus making actual production figures uncertain (FAO, 1995a, 1995b).

In all regions, however, small-scale and subsistence production are the most difficult to estimate, and much is likely to be omitted altogether from published statistics. Since most freshwater fish in most regions are grown in earthen ponds, occasional estimates of the number of ponds give some estimate of aquaculture activity but are very inadequate for estimating production. The regional analyses that follow are therefore based on research reports rather than production statistics.

Asia. The first and major beneficiaries in Asian aquaculture have been the middle to large-scale commercial farmers and the consumers. Nevertheless, powered by growing industrial economies, the successes of technology, strong market demand, the ready availability of many inputs such as fish seed and fingerlings, and the popularity of easy-to-grow species such as carps and tilapias, Asia has also produced many small-scale winners and could produce even more. For example, studies in progress in five Asian countries (Bangladesh, China, Philippines, Thailand, and Vietnam) show that elasticity of fish demand with price varies across socioeconomic groups. In Bangladesh, where fish has traditionally been an important animal protein, lower-income people would eat more fish if the price were lower, whereas demand by higher-income groups is inelastic to lower prices (M. Dey, ICLARM, personal communication, 1996).

In many Asian countries, the gap between urban wealth and rural poverty is widening as industrial development is fueled by the industrial and information technology revolutions. A few forms of rural endeavor, however, also benefit from urban growth. Commercial aquaculture is one. It is driven by growing affluence as well as growing population numbers. It usually requires high capital inputs, technical know-how, and ownership of or access to land and water or coastal space. It is usually not an option for low-income people and, as shown by the shrimp farming example, it can be more lucrative than other forms of agricultural land use. Nevertheless, the efficient production of lower-value species such as carps and tilapias will put them within the reach of more low-income consumers.

The most important producer options for low-income people are in rural systems these people control themselves, i.e., those Newkirk (1993) described as "peasant microenterprises." Four are discussed here for Asia: integrated aquaculture-agriculture (including rice-fish culture), coastal aquaculture, use of natural and manmade water impoundments, and ancillary activities. Although comparative statistics are not available, it is likely that Asian small-scale producers are far more numerous than those in other regions, given the numbers of rural, (including coastal) people and the traditional popularity of fish.

Integrated Aquaculture-Agriculture (Including Rice-Fish Culture). On land, agriculture is the dominant land use in Asia. Aquaculture can be integrated into many different farming systems via use of multipurpose farmponds and other water sources. Economic and environmental benefits ensue, including the production of fish, improved recycling, better on-farm natural resource management, and the ability to spread financial risk through farm diversification.

The best-known form of integrated aquaculture-agriculture and one with a long history in parts of Asia is raising fish in rice fields and in ponds on rice farms. This is part of the popular image of Asian agriculture. Until the 19th century, this activity was more a feature of Chinese farms and of those in Bengal (West Bengal of the present India and Bangladesh) and Kerala regions of southern Asia, rather than generally widespread throughout Asia. Fish farming was rare in Southeast Asia, inland fish farming having been introduced into most countries by Chinese immigrants in the late 19th and early 20th centuries (Le Thanh Luu et al., 1995). Coche (1967), quoted in Ali (1992), sourced earlier introductions in Southeast Asia to India about 1500 years ago. One of the few Southeast Asian indigenous systems of rice-fish culture is based on a strain of the common carp (*Cyprinus carpio*) in northern Vietnam and northern Laos (Le Thanh Luu et al., 1995). According to Edwards and Little (1995), probably fewer than 10% of Southeast Asian farms culture fish even today.

In China, rice-fish culture includes fish raised in rice fields, fish in rotation with rice, and fish in waterways supplying irrigation water to the rice fields. Even in China, where rice-fish culture is nearly 2000 years old (Cai et al., 1995), fish culture has never been as widespread as at present; modern approaches to improve rice-fish production have been applied only during this century. During the early 1960s to mid 1970s, rice-fish production declined drastically as rice production intensified and chemical insecticides were heavily applied. From the mid-1970s on, however, less toxic chemicals, better varieties of rice, and the upsurge in availability of fish seed as aquaculture developed, all led to renewed interest in fish production from rice fields. Between 1981 and 1986, the area of rice-fish culture in China rose from 121,000 ha to 988,000 ha; and the number of provinces and municipalities reporting rice-fish culture rose from 4 in 1981 to 18 in 1986 (Cai et al., 1995).

Across nine Asian countries,[2] out of a total of 114.3 million ha of rice-field area, 10.2 million, or nearly 10%, are thought to be suitable for rice-fish culture. Far less than this, however, is currently used. For example, only about 20% of China's suitable area was estimated to be used in 1986 (Lightfoot et al., 1992).

Through rice-fish culture, a large number of small rural producers are benefiting from aquaculture in their rice fields. The fish produced are either fingerlings for on-growing in other aquacultural systems or table fish for domestic market and household consumption. In one study in the mid-1980s, Lin et al. (1995) reported that rice-fish culture led to financial returns that were 41% higher than rice alone. Part of the increase was due to increasing rice yields as a result of the apparent mutualism of rice-fish production; i.e., adding fish to rice fields tends to increase, or at least not decrease, rice yields. A review across Asia in 1988 showed few cases of decreased yield and even then the declines were very small (Dela Cruz et al., 1992).

Rice-fish culture is an important form of integrated aquaculture enterprises, especially in Asia, although it does not demonstrate the full range of features possible in the technology, such as the recycling of nutrients from ponds to fruit, vegetable, terrestrial livestock, and fodder production and of animal and plant waste into pond fertilizers. The concept of integrated resources management has been

[2] Bangladesh, China, India, Indonesia, Korea, Malaysia, Philippines, Thailand and Vietnam; see Table 1 (p. 2) from Lightfoot et al. (1992).

developed to encompass not only integrated aquaculture-agriculture, but other forms of resource flows within farming systems (Lightfoot et al., 1993).

It seems that the benefits of integrated aquaculture-agriculture often come more from the nonfish components of the farm, particularly from vegetable production. Prein (1966) showed in Ghana that 95% of the added economic benefits of a farm pond came from vegetables and only 5% from fish. The environmental benefits of recycling and farm diversification could not be quantified, but there are also nonfish benefits of having a farm pond.

Integrated aquaculture-agriculture has a patchy record of development, despite benefits that have been demonstrated experimentally. The potential use of integrated systems in Asia is enormous, including on small family farms; extensive integrated shrimp farming in mangroves systems; small-scale garden-pond-livestock pen systems; and large-scale industrial enterprises involving pigs, chickens or ducks, and [illegible] as well as field crops, fruit, and vegetables. Larger systems can be fully commercial enterprises, almost all within reach of the more lucrative urban markets. Recent studies in Australia have shown that diversified farms perform better in the long term because they are able to cope better with market and climate fluctuations than nondiversified enterprises (Kokic et al., 1995). However, the constraints to diversification, in terms of the economic investments and the knowledge needed, [illegible] high.

Most of the emphasis on integrating aquaculture into agricultural systems has focused on the landowner or its lessee. Work in Bangladesh has shown that, where [illegible] water bodies already exist, even technically landless rural people can take up aquaculture by leasing these water bodies, often with the assistance of nongovernmental organizations (Gupta and Rab, 1994). However, private and individually [illegible] water bodies were more likely to have better fish-farming systems than [illegible]ly owned ones (Ahmed, 1992), and these owner operators were better off than [illegible] of the rural population (Ahmed et al., 1993).

[illegible] Aquaculture Enterprises Throughout Asia, coastal space is limited and in [illegible] from a great range of urban, industrial, tourism and other uses including [illegible]. In [illegible] typhoon and cyclone-prone countries, natural seasonal haz[illegible] particularly [illegible] on the coastal fringe.

[illegible] shrimps, except in some extensive forms integrated with [illegible] of a detriment than a benefit to food security. Likewise, [illegible] of milkfish has had mixed outcomes for food security. [illegible] large areas of natural mangrove have been cleared to [illegible] Philippines, Chong et al. (1984) described the dualistic [illegible] wherein a minority of farms were extensive and used no [illegible] the intensive farms using fertilizers, inputs, and there[illegible] farm, were often restrained by their costs, the market [illegible] farmers' willingness to learn from other farmers. The [illegible] are therefore much better for those who start with

Mollusk culture, chiefly of bivalves, has been the dominant form of small-scale coastal aquaculture in Asia. More recently, seaweed culture is also becoming more important.

Despite the large number of edible mollusks in Asia, only a small number are cultured and most are limited to areas with natural spatfalls (McManus, 1995). Throughout most of coastal Asia, blooms of toxic dinoflagellates increased during the 1980s, placing major seasonal constraints on shellfish culture. In acute situations, seasonally affected coastal communities in the Philippines have been given "food aid" (Anonymous, 1995).

Seaweed culture has taken over from the collection of natural resources in some Asian countries. In the Philippines, the aquaculture of *Eucheuma*, *Gracilaria*, and *Caulerpa* now derives totally from cultured stands, and production is increasing, chiefly for export. It is seen as a good industry for coastal communities since it requires low inputs, and provides good returns and employment because it is labor intensive (Pagdilao et al., 1993). In parts of Indonesia, however, culture is limited by its remoteness from markets and by the people's lack of technical knowledge. Therefore collection of natural resources still predominates (Hatta and Purnomo, 1994).

Further development of various forms of coastal aquaculture suitable for small-scale operators is possible but will require considerable special investments in research and development, including into technologies, and in understanding local cultural and economic circumstances. McManus (1995) has pointed out the limited coastal environment of suitable quality (depth, currents, and water quality). He suggests that production of high-value products, rather than high-volume, low-value ones, should be targeted, but only as part of integrated coastal and national development programs, including proper management of coastal fisheries.

Lakes, Dams, Reservoirs, and Other Water Bodies. As more water is being impounded for urban, agricultural, and industrial use, natural aquatic systems are being disrupted, but new aquacultural and stock-enhanced fisheries potentials are also being created. In China, for example, the water area in reservoirs accounts for 40% of the total inland water surface area (Li and Xu, 1995). Natural lakes also provide fish-culture opportunities, albeit with risks to local biota.

Cage culture, floating net culture, and fenced or bay culture are all possible with suitable institutional and technical support. De Silva (1995) has proposed that reservoirs and lake systems have a much greater potential than many other aquatic resource systems for productivity increases. He bases his conclusions on the increased volumes of water being impounded, their presently underestimated production, the relative ease with which they can be stocked, and the ready availability of technology for their stocking.

A World Bank project involving the Saguling and Cirata reservoirs in western Java (Indonesia) in the late 1980s demonstrated that job opportunities for the rural people displaced could be created in fisheries and aquaculture with the appropriate training and early financial assistance. The report of this project warned, however, that these and nonagricultural job opportunities would not happen without assistance, since the rural people displaced initially lacked the financial means and training (Soemarwoto, 1990).

Ancillary Employment. Service industries for large-scale aquaculture are typically full commercial enterprises and have little direct benefit to low-income people. In Asia, notable exceptions are in service or allied industries where small operators have created niches. The enterprises that have developed are location-specific. Three examples are described below: fry collection from the wild, hatchery-to-pond operations in Bangladesh inland aquaculture, and postharvest processing.

In both shrimp and milkfish farming, small-scale industries have developed to collect natural fry or postlarvae along the shore. While creating employment for many poor people, these activities are at best very seasonal, and usually temporary until hatcheries become established. They may also be threatened by coastal environmental pollution, degradation of the habitat, and overexploited breeding stock (Castro, 1995). Collection of *Penaeus monodon* (giant tiger prawn) postlarvae in Bangladesh employs many thousands of poor fry collectors, but it also results in the destruction of 99 zooplankton individuals for each *P. monodon* postlarva collected, many of these are even fish larvae (Mahata et al., 1995). Since hatcheries are unlikely to be established in the near future, the collectors are being taught how to better sort the collections and release the non-target specimens live.

In Bangladesh during the 1980s, small-scale fish hatcheries producing carps, tilapia, and catfish seed developed to serve the needs of fishponds. There then developed a chain of small-scale employment involving up to 17 distinct activities to transfer the fry from the hatcheries to fingerling ponds, thence to sale and transport across country before purchase by pond operators. For example, young boys provided manual aeration, and women changed the water in fingerling containers en route.

Postharvest processing and marketing of fish is dominated by women in many Asian countries. Marketing chains for capture fisheries and aquaculture are often different due to the different sources of supply. In Bangladesh, Ahmed et al. (1993) found that a chain of traders and middle agents greatly reduced the profit margins of the capture fishers, but these have not yet developed to the same extent in aquaculture.

Pacific, Indian Ocean, and Caribbean Island Countries. Pacific, Indian Ocean, and Caribbean island countries, including many microstates, depend on seafood; their populations are growing fast, and their natural marine resources are often heavily exploited. On the face of it, this would seem a powerful combination of factors driving aquaculture. However, the resource situation and population pressures are relatively new, and extending fishing grounds and technologies, including fishing deep-water slope species, has managed to help fish supply meet rising demands until recently. Sporadic aquacultural efforts over the last three decades have been promoted by technological interests and often have not been tailored to the circumstances and development needs of island people.

The needs and the approaches to development are changing. Aquaculture is now in demand from more rural communities, and its development is now viewed more as part of rural development than as a separate sector or even as a part of the fisheries sector. With still too few technologies on offer, however, aquaculture is still not an automatic and integral rural development option.

Thorne-Miller and Jaildagian (1995) have proposed three principles for sustainable aquaculture development in the Caribbean: diversification (farming a variety of species both in polyculture and over any region), integration with the ecosystem and other socioeconomic activities, and localization (meeting local needs, including nutritional needs).

By paying careful attention to local human and biological resources, markets, and feasible technologies, several successes have been won in the culture of high-value invertebrates for export markets, notably for pearl oysters in French Polynesia and the Cook Islands (Gervis and Sims, 1992) and for giant clams (Tridacnidae) in Palau and the Solomon Islands. New technologies being developed for seaweeds and for invertebrates such as holothurians (sea cucumbers), green snails, and trochus offer further hope.

To achieve food security, high-value species, preferably those that are low on the food chain, are readily processed, and are easily transported to distant markets, will be best (Munro, 1995). Aquaculture should have little or no negative ecological impacts and use affordable technologies so that low-income people can become producers. Few reef fish are economically viable in this regard unless close to markets such as tourist resorts. However, given the apparent large natural wastage of reef fish larvae, sea ranching through grow-out of live-caught juvenile reef fish may be feasible.

As for coastal environments, suitable culture environments must still be defined for many island and reef species. Marine tenure systems also govern culture development. Hviding (1993) has examined the case of Solomon Islands for giant clam culture. Access to most reefs in the country is regulated by customary marine tenure. He concluded that in one sense this limits access to aquaculture sites, but in another it provides secure rights to farming territory.

Coastal households in island countries are already involved in a multiplicity of microenterprises. Therefore, Hviding (1993) has concluded, most new aquaculture will be part-time. Bell et al. (in press) has found that those enrolled in village trials growing clams in the Solomon Islands are mainly farmers who devote about 25% of their time to clam farming operations.

The risks in new enterprises are high, due not only to lack of knowledge by farmers but also to the very novelty of the enterprises themselves. The domestication from scratch of new species requires extensive research and experimentation. Again we consider the giant clam example, noting that these species gain their nutrition by photosynthesis and thus do not even need feeds; early village trials showed survival rates of 20% to 80% before the factors governing successful grow-out in lagoons were better understood (Bell et al., in press). Until basic husbandry is understood, therefore, most small-scale rural farmers cannot afford the levels of risk required. Research investments are essential for development.

An account of the full benefits of island aquaculture will often include cultural and aesthetic values. Giant clams and other shells are powerful traditional symbols in many island cultures (Hviding, 1993).

Africa. The African continent is the most threatened by rising food insecurity due to steeply increasing population, large-scale climate uncertainty, and declining levels of external assistance. While capture fisheries production has stagnated throughout the continent at about 8 kg per person, aquaculture has continually increased from 50 g per person in 1984 to 100 g per person in 1992 (FAO, 1995a). However, this is still only 1.3% of total fish intake, and this on a continent where many have predicted great potential for aquaculture development, given the availability of suitable fish species and water resources. A recent study by Kapetsky (1994) found that 31% of the area was suitable for warm-water subsistence aquaculture and 9% of the land in sub-Saharan Africa is suitable for commercial aquaculture.

In most African countries, aquaculture would be called an emergent subsector (less than 1000 metric tons of production and few species produced) under Katz's (1995) scheme. A few, such as Egypt, Nigeria, and South Africa, could be classified in the established but simple subsector. Africa is all but invisible in worldwide commercial considerations. For example, a recent market survey of companies listed only one company in one African country (Zimbabwe) in its tables (Ratafia, 1995).

Commercial and Rural Development Roles. Aquaculture plays two important roles in Africa (Williams and Brummett, in press): commercial and rural development. Both forms have parallels in other regions, but the commercial aquacultural sector, like most other commercial sectors in Africa, is less developed than in any other region. Commercial developments focus on high-value species, usually those close to major markets or for export. In Africa, these enterprises are often short-lived due to the range of circumstances common to many agricultural industries including poor infrastructure, price fluctuations, and difficulty of obtaining essential inputs.

Much of the description that follows on the role of small-scale aquaculture in rural development also applies to all other regions. In Africa, however, the issues have received more attention because there this sector has not been overshadowed by rapid commercial aquacultural development. In Asia, commercial successes have taken the focus off small-scale development, although the small-scale sector's problems are very similar to those in Africa.

The two types of aquacultural development make different contributions to African economic development, and each has different needs. Development has shifted its emphasis over time between the two, as shown in Table 2.4.

Currently, about 97% of total aquaculture production comes from the rural development sector (King, 1993) and is produced by cash-poor small-scale farmers in small ponds supplied only with on-farm inputs such as brans, manures, and weeds. The overall performance of aquaculture is poor, and repeated reviews over the last decade (e.g., King and Ibrahim, 1988; Huisman 1986a, 1990; Harrison et al., 1994) have confirmed its slow progress.

TABLE 2.4. Milestones in African Aquaculture

1920s	*Development:* Fish culture starts in Kenya (1924).
1930s	*Development:* Fish culture starts in Zaire (1937).
1940s	*Development:* Fish culture intensifies in Zaire (1946+); starts in Zambia (1942), Cameroon (1948), Congo-Brazzaville (1949), and Zimbabwe (1950).
1950s	*Development:* Rapid development including an increase in the number of ponds, spreads to many countries. *Research:* Tilapia culture
1960s	*Development:* Spread and development of fish culture peaks; regression begins. *Research:* Tilapia culture and biology.
1970s	*Development:* Regression continues; second wave of development begins. *Research:* Tilapia culture systems, pond culture systems, *Clarias*, "other" species biology
1980s	*Development:* The "second wave" continues in Côte d'Ivoire and Kenya. Small- and large-scale private-sector farming starts in Côte d'Ivoire, Egypt, Kenya, Nigeria, and Zambia; shellfish farming is initiated in Tunisia, South Africa, Morocco, Senegal, Zimbabwe, Malawi, Mauritius, and Reunion. A serious crisis of confidence occurs in subsistence-scale aquaculture, where 90% of development assistance is concentrated. *Research:* Tilapia culture systems, *Clarias*, oysters, "other" species biology, surveys, economic/commercial aspects, subsistence-level integrated aquaculture-agriculture
1990s	*Development:* Commercial development and diversification continues in many countries; production gradually mounts. Directions for small-scale aquaculture and contributions to food security of the poor are reexamined. Many countries and regional bodies (e.g., Southern African Development Community) start development plans for aquaculture. Private sector/governmental and nongovernmental organization roles are reexamined. Sustainability, natural resource management (including biodiversity), and climate considerations begin to impinge on the sector. *Research:* broader range of biological, socioeconomic, interdisciplinary, and intersectoral research

Source: Adapted from Powles (1987) and extended to the present period, with especial reference to Huisman (1990), New (1991), Satia (1991), Lazard et al. (1991), and Harrison et al. (1994).

In some African countries, a group of enterprises exists in a stage intermediate between rural and commercial development. These small-scale commercial systems are often the target group for development assistance projects because they represent the greatest hope for the transition to full commercial development (Satia, 1991; Brummett and Noble, 1995). These systems purchase some of their inputs but maintain their connections to the local communities. Failure by many of these enterprises to maintain this balance and thereby provide the predicted growth in aquaculture is widespread and has been part of the cause of widespread disillusionment with African fish farming (see, e.g., Lazard et al., 1991; Harrison et al., 1994; Huisman, 1990).

While commercial systems have not blossomed as expected, evidence exists that aquaculture is expanding among small farmers across the continent (Nathanael and Moehl, 1989; Molnar et al., 1991; van den Berg, 1994; Campbell, 1995; Murnyak and Mafwenga, 1995; Ngenda, 1995; Scholz and Chimatiro, 1995; ALCOM, 1994). This expansion now seems to be more demand- than technology-driven.

In Africa, experts are still divided on the question of the role of small-scale pond aquaculture in development. Since development efforts in Africa are dominated by help to small-scale farmers—more than 300 assistance projects were initiated from the early 1970s to the early 1990s, 90% of these in small-scale development—their lack of performance has led to a crisis of confidence and what Williams and Brummett (in press) call the "Great Small Scale African Pond Debate"—a debate over where assistance is best targeted and how its impacts should be measured.

The different views in this debate were somewhat clarified by Harrison et al.'s (1994) review. These authors pointed out that policy makers face the choice of targeting the resource poorest for food-security outcomes or focusing on technological developments that may be viable in the long term but which have little short-term impact on food security. Harrison and colleagues propose an overall aquacultural development strategy that hinges on planners first clarifying their objectives. These objectives may have to recognize that those most likely to benefit from fish farming will not be the worst off. In addition, food security outcomes are not well measured by the quantity of fish produced.

The relatively better-off farmers are usually the adopters of new practices (Harrison et al., 1994). In addition, Huisman (1986) pointed out that aquaculture is still a novel farming activity in much of Africa and therefore inherently risky for low-income people.

The novelty of the technology in Africa also suggests the need for a much greater research investment. To date, the share of worldwide research into African aquaculture mirrors the production level. A search of *Aquatic Sciences and Fisheries Abstracts* shows that about 1% of aquacultural papers (173 of 16,176) between 1978 and 1995 were on African aquaculture. The proportion rose marginally from 0.9% in 1987 to 1.15% in 1988 to 1995. Of the African papers, however, 38% were from South Africa.

Future Prospects. Katz (1995) has given Africa the lowest rating of any region with respect to commercial aquacultural potential, based on policy, physical, technical, production, and marketing attributes. Given the poor economic prospects for much of Africa at present, population growth will be the main force driving the demand for fish, compared with more balanced combinations of economic growth and population in other regions (Westlund, 1995). Africa exports and imports less fish than any other continent so markets are largely domestic. The difficult structural adjustments of the 1980s and 1990s have negatively affected all food production sectors. However, Delgado (1995) points out the relative inelasticity of demand for cheap fish in many sub-Saharan African markets. Together with population growth and urbanization, this inelasticity creates good outlets for smaller-scale producers who can efficiently grow low-value species.

As shown in other regions, national planning has helped pick up the pace, at the least, of commercial activities in countries around the Mediterranean. Ben Yami (1995) have reported that the governments of Egypt, Tunisia, and Algeria are promoting and supporting aquaculture through policies, services, and infrastructure and that this is paying off with increased production.

Rural development planning that incorporates subsistence aquaculture for household food security and environmental objectives will be more widespread over the next decade in inland Africa, spurred on by the general move for rural, participatory development as a tool for alleviating poverty. This development will have to be fully integrated with other rural sectors, assisted by extension and research services, and supported by schemes for affordable financing and supply of inputs such as fingerlings. Purchased inputs must be minimized, however, if the farms are to be viable. Inevitably, pond production will be low so that only small quantities of fish will be produced. Many of these fish will be eaten directly by the farmers' households or bartered at the pond side, thus losing little from postharvest handling.

ALCOM (1994), an interregional aquaculture development program, estimated that five southern African development community countries (Tanzania, Mozambique, Angola, Malawi, and Zambia) should be able to produce 250,000 metric tons of fish from inland ponds, compared with the present 5000 metric tons produced. Diffusion of the small-scale aquacultural technology is occurring in these countries where 25,000 ponds are now estimated to be farmed. ALCOM (1994) recommended assistance and research to increase the productivity of these ponds with a view to increasing the farmers' incomes.

There is a growing consensus that government roles need to be redefined (Lazard et al., 1991) and will be anyway since government resources are, at best, not increasing (ALCOM, 1994). The appropriate roles would include national planning and legislation, infrastructure support of appropriate kinds (e.g., roads to market rather than government-run hatcheries), research, extension, and information services.

Extension is a weak area, and expert opinions have been divided as to whether aquacultural training and technology transfer should rest with fisheries or agriculture departments. Most remain in fisheries departments, which have little rural extension capability and little experience of rural development.

As an African case study, ICLARM and GTZ (1991) examined the detailed context of integrated aquaculture-agriculture systems in Malawi. Malawi has a strong dependence on fish protein due to the capture fisheries of the nearby Great Lakes. The report concluded that aquaculture is not a panacea for alleviating poverty, food supply, and access problems. It is rather a complementary and supplementary technology for producing food. Many constraints to development exist, and these cannot be understood except within the full national and local contexts.

The constraints range from poverty (e.g., in Malawi, the average small farm is only 1.2 ha, nearly two-thirds of these farmers sell no food but consume it all themselves or barter it, and 55% of farmers are unable to even grow amounts sufficient to feed their families—Brummett and Noble, 1995), costs, labor (Christensen, 1995), and lack of expertise in digging ponds. Social constraints include local food habits, mistrust of government extension, and land tenure and ownership arrangements. (For example, the Malawian matrilineal system deters men from digging ponds when the land reverts to the wife's family on her death or after divorce—Brummett and Noble, 1955). Biotechnical constraints also limit the potential: nitrogen is limited, water is not readily obtainable on most farms, and feed is limited. Average fish productivity is low in ponds, as is most African agricultural productivity, which is also limited by low levels of inputs (fertilizers, trace elements, and water).

However, the ICLARM/GTZ report still concluded that aquaculture in Malawi could succeed technically and economically at different scales of operation, from the small-scale farmer integrating a small pond into a mixed farming system up to large-scale stocking of dams and commercial-scale operations operated by the government and by estate owners, especially sugar and tea estates.

Stocking of small water bodies, coastal lakes, dams, reservoirs, and even some of the Great Lakes is thought to offer considerable potential for increased African fish production. Coates (1995) has estimated that, for sub-Saharan Africa alone, the optimum potential yield from small water bodies is of the order of 1 MMT/yr, but that even less optimistic outcomes would provide substantial benefits. Environmental degradation, socioeconomic factors, and the need for good management regimes are the major constraints, there being few technical problems.

Coastal aquaculture is mainly commercial and carried out close to urban centers or for export (e.g., from the North African countries to Mediterranean Europe). Similar comments apply to the prospects for coastal aquaculture in Africa as for Asia and the island nations.

Latin America. Aquaculture production increased by 15% per year in the Latin American and Caribbean region between 1984 and 1992, but aquacultural products still represented only 1.86% of the per capita fish supply in 1992 (FAO, 1995a). Ecuador and Chile dominated production (36% and 21%, respectively), and Mexico, Brazil, Columbia, and Cuba each produced more than 20,000 metric tons. In many other countries, however, expansion is occurring rapidly.

Trade flows are strong for most of Latin America's fish production, and the FAO (1995b) expects that export market demands will dominate future developments in Latin American aquaculture, as they have for shrimp in Ecuador and salmon for Chile. One such example is the efforts in Ecuador to diversify shrimp production systems to grow flounder and Pacific yellowtail for export markets (Benetti et al., 1995). These export-driven developments are keeping attention away from the small-scale and subsistence production and therefore from production of affordable fish by and for low-income people. A major change in approach would be required in Latin America for aquaculture to have a major food security contribution.

Some rural development is happening through small-scale aquaculture projects. Castillo et al. (1992) and Popma et al. (1995) report on one such successful project in Guatemala. Boll and Lanzer (1995) have shown that low-intensity fish production is apparently not economically sustainable on small farms in Santa Catarina Province, the second southernmost province of Brazil. Despite this, and as a result of a 20-year extension effort and good availability of on-farm inputs and fry of several fish species, 10% of 170,000 small and middle scale farmers in Santa Catarina are engaged in fish farming. Boll and Lanzer (1995) recommend development of markets and of new technologies to affordably improve productivity.

Much Latin American aquacultural development has relied on introduced species such as salmons, carps, catfishes, trouts, and tilapia. Attention is now being turned to cultivating native species such as tambaqui (*Colossoma macropomum*) and pacu (*Piaractus mesopotamicus*) in Brazil (see, e.g., Castagnolli, 1995).

Overall, Latin American aquaculture is not yet giving high priority to the needs of small-scale producers and low-income consumers.

Gender

A gender analysis of the distribution of benefits from aquacultural development is important, yet few studies are available. Among the food-insecure in rural areas, the transition to greater fish scarcity and the increasing pressures on scarce farming land places greater burdens on all the household members. Women usually bear the main burden, especially as the fishing and farming activities of the men may now bring in less food and money. Women may have to help augment the family income beyond their previous contributions. They may have to help more in the farming, fishing, and aquacultural activities or gain income through outside activities. Frequently, men and young people migrate to the cities or other districts to find work, creating more single-parent and female-headed households.

Another major factor affecting women's roles in aquaculture is due not to events in the sector but to changes in the world social and economic order. Women are gaining stronger roles in society, including greater participation in education, the economy, and in decision making from the household to the national level. Women in aquaculture have not been immune to the greater focus on their roles, although few would claim that progress, however defined, has been great.

In fisheries and aquacultural development as in other sectors, the call for more knowledge of women's roles has been heeded, and more studies and projects are targeted on women, although the numbers are still low. For example, prior to 1975 there was fewer than one article per year on women in fisheries in the research literature. From 1975 to 1979, there was one article per year on average. Throughout the 1980s, the numbers grew to about 17 articles per year. Globally, eight fisheries development assistance projects had components on women by 1989, compared with four in 1985. More recent data are not available.

Men and women tend to undertake different tasks in aquaculture, although the divisions of labor vary between cultures and are not fixed and absolute. Men dig the ponds and are usually responsible for stocking them with seed. Women tend the ponds and feed the fish, men harvest them, and women process and sell the fish.

Greater involvement of women in aquaculture can give them greater financial independence, often a greater say in household decision making, and more money going directly to the family's food. However, in many countries women already have a strong and often controlling position in family financial matters.

Women's roles in aquaculture are often overlooked. They should be given greater recognition and have a higher profile in the sector to promote these roles. Studies reported at a recent seminar on "Women in Fisheries in Indo-China" (Williams, 1996) showed that the position of men in the household was critical to the choices available to women and to their status. Cambodia and Vietnam have high proportions of female-headed households, many due to recent wars. Female-headed households are usually worse off than those with male heads.

Demands on women's time are heavy in most societies. Hviding (1993) has pointed out that women in the Solomon Islands are heavily occupied in gardening, domestic work, reef gleaning, gathering of firewood, and raising their children. This all leaves little time to take up new activities such as clam farming. In Bangladesh, however, women are prevented by religion from working in the rice fields and going to market. They therefore have available time to undertake new activities such as fish husbandry.

New rice-farming technologies such as broadcast planting and applying herbicides, have reduced women's rice-growing labor in Vietnam and freed them for diversified farm activities including aquaculture (Vo Thi Ngoc Ba and Tran Thi Thanh Hien, 1996).

In addition to the usual food and financial benefits women derive from aquaculture, women in Bangladesh report gaining aesthetic pleasure from fish culture (Gupta and Rab, 1994).

Opportunities and Constraints

Regional, country, and gender differences aside, common patterns of opportunities and constraints emerge from the above analyses of how aquaculture benefits are distributed.

Constraints. Aquaculture can make a valuable contribution to improving the lives of the rural poor, but its development remains constrained by many factors.

Limited Extension Services. To date, research and development in aquaculture still lag behind those in other sectors of the economy (Pullin et al., 1993). As such, extension services geared toward promotion of technologies for and adoption of aquaculture are wanting. Extension workers often lack without sufficient training and expertise on the subject. Likewise, government support for extension work is insufficient.

In the Philippines, many areas suitable for aquaculture, and even areas where aquaculture is prevalent, are hardly ever reached by extension services, because of poor infrastructure, lack of budgetary support, and even lack of extension workers.

Similarly, in a study of two representative *thanas* (districts) in Bangladesh, only 7% to 8% of operators of farmed water bodies admitted receiving some form of extension service (Ahmed, 1992). For these reasons, most farmers engaged in or interested in aquaculture rely heavily on their own limited perceptions and their neighbors' and friends' experiences, rather than on more structured and scientific methods of aquaculture in their practice. This often results in a general disregard of "culture techniques and management procedures that are compatible with long-term capability of land and water resources." Women rarely receive formal aquacultural training, even though they are very active in the sector (Anonymous, 1996). Low levels of literacy among rural folk also hamper the effectiveness of existing efforts.

Poverty. Another limiting factor to the development of aquaculture is the abject poverty of many farmers in developing countries. Characteristically, incomes are much lower in farm households than in urban areas, so cash is limited and expenditures are concentrated to meeting basic household needs first. Thus, because of the rising cost of aquacultural inputs (such as feeds, chemicals, and fuel), coupled with difficulties in obtaining formal credit in rural areas, lower levels of inputs are used to reduce production costs, but this consequently leads to lower levels of production (Gupta et al., 1992).

Poor Infrastructure. For medium- to large-scale aquaculture enterprises, the poor condition of rural infrastructure also significantly affects aquacultural development. Lack of or impassable farm-to-market roads, poor telecommunication facilities, and unreliable electricity and transportation services limit aquaculture production and trade. In the Mekong Delta region of Vietnam for example, many fish farmers have difficulty in obtaining fries and/or fingerlings because of the distance to suppliers in the region, and with limited transportation available, obtaining them becomes an ordeal.

Water. Access to water of suitable quality is critical to the success of aquaculture. Marine and estuarine water quality and coastal space are severely limited by economic development and other uses. Aquaculture may itself produce effluents affecting water use. Freshwater quality and its availability are of increasing global concern (Gleick, 1993). Demand by aquaculture for adequate water will increase, although this use is rarely considered in major policies. Efficient systems for handling water, including closed systems, will need to be developed for many species, especially where intensification of culture increases the risks of negative off-site impact.

Challenge and Opportunities. Given due consideration, constraints to the development of aquaculture can challenge and provide opportunities for farmers, traders, researchers, government officials, and others.

The farmers' lack of financial resources and need for accessible credit facilities create opportunities for lending institutions to establish themselves in rural areas.

However, lending institutions are often hesitant to do so because of the perceived risks involved in lending to farmers. While farmers face a variety of production-related risks, creditors also face the risk of debtors defaulting on their loans. Thus, for lending institutions to even consider establishing and investing in rural areas, risks should be minimized. The risks are further increased in countries with high currency fluctuations and inflation.

Inadequacies in extension services can promote the establishment of cooperatives for fish farmers. Nongovernmental organizations often play a critical role in helping cooperatives get established. Once cooperatives are established, it would be easier and probably more effective for extension workers to disseminate information and training to well-organized groups than to individuals. Credit institutions likewise are more receptive to extending loans for bigger projects through cooperatives than for individual farmers because loans to cooperatives are easier to manage and monitor; hence the risk of default is lower. In this manner, the much-needed capital becomes more accessible to the fishers.

By integrating aquaculture into existing farming systems, costs can be minimized. It is imperative that aquaculture be considered as an integral part of the farming system for it to be viable and to get the most out of it. Expensive inputs such as chemicals, fertilizers, feeds, and even fuel and electricity should encourage farmers to try and make use of available resources within their farms. With proper planning and management, byproducts of other agricultural enterprises such as animal wastes can be used as biogas or as feeds and fertilizers for aquaculture, thereby saving on purchased inputs. Also, better farm management practices protect the environment and natural resources, which results in a more sustainable source of income and food (Lightfoot et al., 1993).

Many farm households, such as those in Bangladesh, have excess labor (Ahmed et al., 1995). The labor-intensive nature of constructing ponds and/or enclosing individual plots should serve as alternative employment opportunities for such surplus family labor. Christensen (1995), however, has pointed out that the returns on their labor are often low. Increasing pond productivity for higher returns therefore remains a challenge.

Governments should also be challenged to improve existing infrastructure facilities, or if nonexistent, to provide adequate infrastructure and telecommunication facilities. Doing so would help not only aquacultural development but rural development in general. With better infrastructure and telecommunications, more economic activities in rural areas can be generated, thereby contributing to the improvement of the quality of life in rural areas. Rural-to-urban migration, which has been recognized as a major problem in many developing countries, may also be discouraged.

There is much potential for higher foreign earnings from aquaculture (Pomeroy, 1992; New Zealand Trade Development Board, 1989), but lack of coherent and enforceable policies on international cooperation curb the development of aquaculture as a major foreign-exchange earning sector in developing economies. Governments must learn to take advantage of increasing world demand for aquacultural products and take appropriate steps to support aquaculture at all levels of production. A better accounting of the full costs of aquaculture will help to ensure that export returns are not gained at the expense of the local environment and livelihood.

Adoption Pathways

As an emerging technology, aquaculture has the potential to attract many new entrants and for existing practitioners to improve their production. In agriculture, extension services have been instrumental in introducing new methods and crops. In addition to the limitations discussed above, agricultural extension services are usually not technically competent in aquaculture. They are under challenge in many countries due to governmental financial stringency and to their perceived biases toward richer and male farmers and toward modern and exotic forms of farming (see, e.g., Chambers, 1983). Nongovernmental agencies are now playing a bigger role in technical extension in many countries.

Nevertheless, even extension programs involving government extension agents using well-tested methods developed by national research institutes can have major impacts on farmers' levels of knowledge and on their production of fish. In two districts of Bangladesh, fish production rose from the benchmark level of 618 kg/ha to 2728 kg/ha (Ahmed et al., 1995). The key factor influencing adoption before extension activities often was knowing about the technology. The intensity or degree of adoption was dependent on the size and previous history of culture of the water bodies used. Demaine and Turongruang (1996) have found that distance extension methods (e.g., radio programs, brochures, and videos) are effective in northern Thailand in reaching many more households than face-to-face services, especially because the extension materials and aquacultural techniques being promoted are well tested. However, better-off households are most likely to benefit.

The gap between existing knowledge and that required for a new complex technology such as integrated aquaculture-agriculture may be systematically narrowed as shown by a long-term (1982 to 1989) study in Guatemala. Castillo et al. (1992) have described the efforts to choose and train expatriate and local extension workers, and to introduce simple pond management and fish culture technology first and later progress to full integration of fish farming with small-animal production. The staged progression is seen as a major factor in the long-term success of integrated aquaculture-agriculture, especially where farmers have no tradition of culturing fish.

Causes of poor adoption of aquaculture include that it has been driven by available external technologies and that its promoters do not understand sufficiently the local conditions. In these cases, adoption requires more than promoting well-tested technologies. It needs simultaneous research, development, and adaptation of new technology.

Across all sectors, poor results in development projects have given rise to concepts of participatory development, a form of assistance with the dual aims of (1) empowering people by giving them a say in changes affecting their lives and (2) improving implementation efficiency by involving the target beneficiaries with their wealth of knowledge of local conditions (Mikkelsen, 1995). Participatory research has arisen from similar concerns over the poor adoption record for some research.

For aquacultural development, participatory extension and research approaches appear relevant where fish culture is not well developed or is not traditionally used. In such cases, adoption will occur only when practices, well suited to local conditions and the target beneficiaries, are developed.

Brummett and Noble (1995) have developed a participatory research approach because research experience in Malawi had shown that small-scale African farming systems, though using little modern technology, are complex, diverse, and not amenable to direct extension of existing technologies. In these authors' scheme, participatory research is instrumental in developing and modifying technologies that should then be better suited to adoption by farmers. Side benefits are two-way: the direct adoption of the technology by the small number of participating farmers and learning by researchers of real-world conditions. Harrison et al.'s (1994) review of African aquacultural development highlights extension issues from the farmers' and extensionists' perspectives; it recommends that extension workers be trained in more participatory approaches, basic aquacultural practice, and the role of ponds in the farming system beyond that of a fish production unit. Participatory extension approaches need improved coordination across government agencies, the private sector, and nongovernmental organizations (ALCOM, 1994).

DISCUSSION AND CONCLUSIONS

The demand for fish is rising in most parts of the world, and aquaculture will be the chief but not only source of supply to bridge the supply-and-demand gap. Aquaculture can contribute positively to food security in the developing world, but its contribution is neither automatic nor without problems. Maximizing this contribution requires certain interventions, including appropriate policies and planning, and development and adoption of new technologies. Interventions should be targeted especially to promote an equitable distribution of benefits and also the long-term environmental sustainability of aquaculture enterprises.

Aquaculture is a relatively new technology and hence risky for new entrants. Adoption depends on access to know-how, capital, water, space, and inputs such as fish seed and feed. It competes for space and resources with many other rural and coastal enterprises, sometimes to the detriment of other uses and users.

Aquaculture's most immediate and direct contribution to food security will come from maximizing the participation of small-scale enterprises that are producing whatever has the greatest immediate benefit to food security, be it low-cost food fish or high-value nonfood exports.

Mass aquaculture production of affordable fish for rural and urban consumers also contributes to food security. In some cases, such as small-scale aquaculture integrated with agriculture, the impact of aquaculture on sustainable food security is often not measured by fish production alone but by a range of fish and other crop products, and environmental and cultural benefits.

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