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Agriculture Technology Notes

Rural Development Department (RDV) The World Bank

Sustainable Aquaculture

Seizing Opportunities to Meet Global Demand

In a world facing future food shortages, the global importance of aquaculture continues to rise. According to FAO statistics, 1995 worldwide production from aquaculture represented about 21.3 million tons (19 percent) of the total annual fish production from all sources.

Aquaculture — the farming and husbandry of aquatic organisms such as fish, crustaceans, mollusks, and seaweed — grew at an annual average rate of 10 percent during the last decade (Fig. 1). During the same period, however, the catch of wild fish from both inland and marine waters (capture fisheries) averaged an annual growth rate of less than 2 percent. Moreover, the contribution of aquaculture to human nutrition between 1990 and 1995 increased, while that from capture fisheries declined by about 10 percent (FAO, 1997a and 1997b). This role reversal occurred because an increasing percentage of the wild catch is species of lower value that are used to produce fish meal for feed and fertilizer.

Current Situation

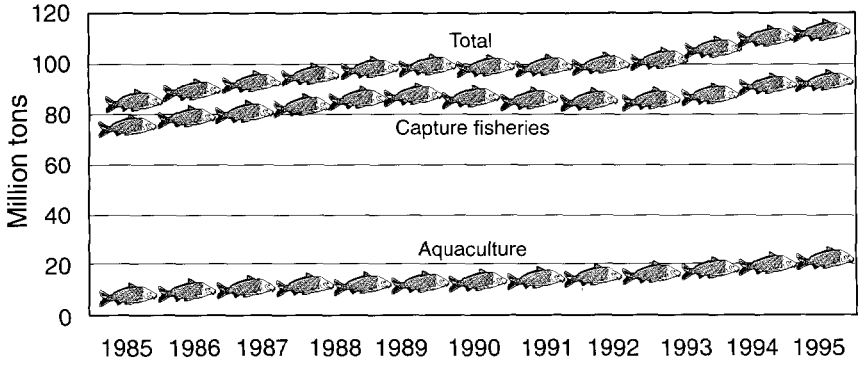
Regional experience. As of 1995, the majority of aquaculture development had occurred in Asia (91%), particularly China, which produced about 57 percent of the world's aquaculture products (Fig. 2) (FAO, 1997a). Although China clearly dominates aquaculture production, it is important to note that production from the rest of the world about doubled between 1984 and 1995. Technological advances such as hatchery development, feed formulation, disease control, engineering, and production system management, particularly from Asia, have global significance and applicability as the demand for aquaculture spreads to other, less experienced regions. While China has dominated aquaculture, practitioners in Latin America, the Caribbean, Europe, the Middle East, and Africa also have a valuable base of knowledge and experience upon which to build.

Future demand. The 1995 per capita consumption of fish products was about 14 kg. With a world population expected to reach 7,000 million by 2010, and assuming that production from capture fisheries will have reached its limits, current annual aquaculture production will need to double to about 42 million tons to maintain this same level of consumption. Although doubling production by 2010 may appear insurmountable, it should not only be possible, but production could conceivably rise to nearly 90 million tons if the 10 percent annual rate of increase between 1985 and 1995 is maintained. The estimated capital investment to double the 1995 production level is estimated to be between US$ 60,000 and 90,000 million.

Ronald Zweig/World Bank

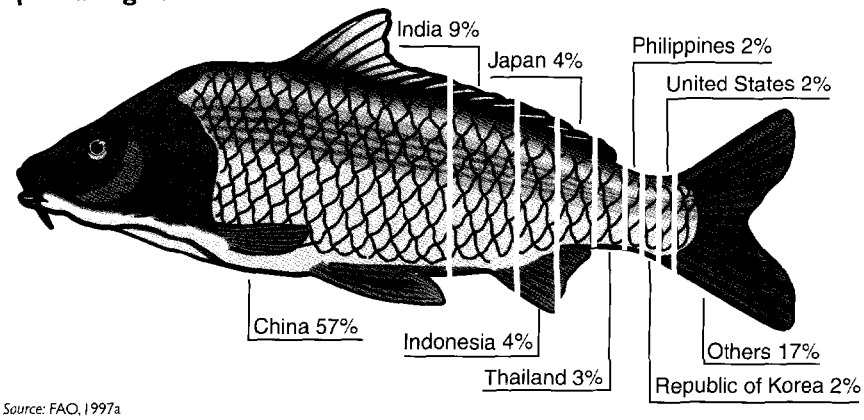
A woman contractor tends her oyster culture plot on a coastal mud flat in Geihai, Guangxi Autonomous Region, China.

Figure 1. Global trends in capture fisheries and aquaculture production.



Source: FAO, 1997a and 1997b

Figure 2. Percentage of 1994 aquaculture production by major producing countries.



Source: FAO, 1997a

Advantages and options. In addition to contributing protein to the human diet, aquaculture is often beneficial in other ways:

- consumers benefit from fresh products and reduced spoilage when aquaculture is located nearby;
- decentralized employment is often possible;
- diverse aquaculture technologies provide a broad range of potential applications, many of which have a role for direct management by women; and
- exports of some aquaculture products may generate foreign exchange.

The recent rapid expansion of the industry, including the culture of numerous finfish, shellfish, and aquatic plant species, has accompanied the development of reliable production technologies that often require training only in simple management skills. Options for aquaculture development can involve production at household, community, or industrial scale in ponds, net pens, net cages, flow-through raceways, and water recirculation systems.

Aquaculture increasingly produces stocking materials for community-based enhancement of open water such as irrigation and hydropower reservoirs, lakes, and coastal areas, which has also provided lessons about proper management of the aquatic environment. Some areas that are not suitable for agriculture because soils are water-logged, saline, and/or alkaline can often be effectively used for aquaculture pond development, provided they have not been identified as critical habitats.

Aquaculture can be integrated with other farming systems. Inland fish culture is also conducted in farm ponds with direct links to animal husbandry and agriculture, where by-products of each subcomponent are recycled as resources for the others — fertile pond water irrigates crops on pond dikes, crop residues feed fish and livestock, and livestock manure fertilizes ponds and/or dike crops. Pond culture on farms of this kind often includes the culture of many fish species that feed on grasses, legumes, benthic invertebrates, detritus, zooplankton, and phytoplankton. Fish culture has been gaining application in rice fields where a second benefit is control of insect pests, reducing the need to apply toxic pesticides.

For marine aquaculture in China, filter-feeding bivalves (clams, oysters, scallops, etc.), seaweed, and bottom-dwelling sea cucumbers are often reared in the vicinity of finfish cages as a means to capture fish wastes and improve water quality. These integrated systems, although somewhat more complex to manage, have the added advantage of reducing market risks to farmers from potential diseases or price fluctuations that affect any one product. Aquaculture also includes the production of freshwater and marine pearls.

Fish monoculture systems have also been developed for a wide range of species that are most often grown on processed feed diets in ponds or raceways and irrigation canals with flowing water. Fish wastes that enter irrigation canals become a supplementary fertilizer for crops.

World Bank role. The demand for aquaculture development in World Bank

Box 1. China

Coastal. The development objectives of the *Sustainable Coastal Resources Development Project* are to establish integrated coastal zone management plans that include zoning of mariculture, which involves the production of fish in cages and ponds, oysters, hard clams, several species of seaweed, and shrimp in four coastal provinces. Improved shrimp culture methods are being piloted to find methods to control the disease pandemic that devastated the shrimp culture industry in China in the early 1990s. The project also includes a component to provide training in seafood processing techniques and upgrade processing plants. The *Southwest Poverty Reduction Project* includes an aquaculture component to provide employment for people from desperately impoverished inland areas in Guangxi Autonomous Region while currently supporting the establishment of enterprises involved in the production of domestically consumed and exported seafood products, including fish, shellfish, and pearls.

Inland. The *Freshwater Fisheries Project* developed integrated fish farming complexes around eight major Chinese cities, providing a source of fish close to markets. The *Shaanxi Agricultural Development Project* achieved its objectives of providing new employment for about 2,200 households and incremental fish production of about 8,500 tons of fish a year from the development of 1,500 ha of integrated fish ponds on saline, alkaline, or water-logged soils. It also introduced yeast as a protein-rich feed supplement to replace fish meal as a feed ingredient, reducing the cost of feed and dependency upon foreign exchange to import high-quality fish meal from outside China. Tourism has emerged as an unexpected benefit as tourists are attracted to view migrating birds that have been drawn to some of the project fish ponds.

projects has been on the rise in recent years. The full range of options discussed above, except intensive water recirculating production systems, has been included as components. At present, 15 projects that included aquaculture have been completed, 15 are under implementation, and 6 are in preparation. Generally, a majority of Bank-assisted projects that have had aquaculture development as their main focus or as project components have been successfully implemented. There are a number of lessons that have been learned from the experience, many of which pertain to problems that are more generic project issues in terms of consultation, financial management, and provision of technical assistance. IFC assistance has also been provided for two private-sector shrimp farm developments in Madagascar and Belize.

Issues

Aquaculture development has not grown without problems, including devastating disease pandemics such as those with shrimp farming worldwide and carp culture in South Asia. In addition, intensification that exceeded carrying capacity has led to levels of fish waste that caused massive death of crops from anoxic conditions. Proper planning and facility monitoring have helped to manage a majority of systems, although consistent disease control has not always been achieved for some species. New tools for predictive modeling of water quality have also become available.

Public and private sectors. There are clearly defined private and public-sector roles for aquaculture development. Although a high percentage of aquaculture production is generated through private-sector involvement and management, including operation of support facilities such as hatcheries and feed processing mills, the public sector can play an important role in formulating a regulatory framework. Licensing private aquaculture enterprises will help ensure minimal adverse environmental and social effects, as well as any required mitigation of these effects. Guidance materials are available through initiatives such as FAO's Code of Conduct for Responsible Fisheries (FAO, 1995) and the five supporting technical guidelines issued to date.

> *Give a person a fish, and that person will have food for a day. Teach a person to grow fish, and that person will have food for a lifetime.* — Chinese proverb

Public-sector assisted services can also provide critical information through basic and applied research programs, technical extension and training, as well as assistance in disease diagnosis, prevention, and control. Moreover, to alleviate poverty, the public sector can uniquely provide access to publicly-owned lands and waters that are suitable for conversion to aquaculture through developing and/or leasing these areas to poor households that would otherwise lack productive assets. World Bank assisted projects have provided the wide range of necessary investments, including production facilities, support services, research, training, and institutional strengthening.

Key sustainability standards. Key regulations and policies that could help to support sustainable aquaculture include:

- forming integrated coastal zone and rural development plans;
- using artificially propagated, hatchery-produced seed stock;
- emphasizing use of processed feeds and not fresh feeds such as low-valued marine fish;
- setting water quality standards for aquaculture and fisheries; and
- establishing quality standards for processing and sale.

Forming *integrated coastal zone and rural development plans* can help identify suitable areas for aquaculture development. In addition, these plans can ensure that such development does not negatively affect critical natural habitats and is at an acceptable level of risk for possible industrial or municipal pollution that might inadvertently affect the enterprise. Environmental and social impact assessments need to be included in the process of site selection. The World Bank has prepared a summary of the generic environmental issues and an assessment strategy for aquaculture (World Bank, 1991).

Seed used for aquaculture production should to the degree possible be derived from hatchery production to minimize the impacts on natural populations of cultured species in the wild. Collection of seed in the wild should be discouraged.

Processed feeds should be used instead of feeds derived wholly from wild fresh-caught fish and mollusks (e.g., as commonly used in operations that cultivate carnivorous marine fish in cages and shrimp in ponds). With increasing demand for feeds, the collection of fresh-caught

Box 2. South Asia

In **Bangladesh,** the *Third Fisheries Project* (TFP) was designed to enhance floodplain fisheries, improve extensive shrimp farming, and develop aquaculture by groups of women. The project not only contributed to increased fish production (about 20,000 tons), but also deepened the understanding of aquatic ecology and production dynamics, as well as the social complexities and policy issues of relevance to the livelihood of poor fisherfolk. These findings are being applied in the proposed *Fourth Fisheries Project*, which is emphasizing community participation and organization. The TFP was jointly financed by IDA, the UK Overseas Development Administration, the government of Bangladesh, and UNDP, with assistance from local NGOs.

In **India,** the *Shrimp and Fish Culture Project* focuses on increasing shrimp production on government lands converted to shrimp farms, with 75 percent of ponds leased to poor coastal households, providing access to the benefits of shrimp farming to those who otherwise could not afford to become involved. The inland component supports efforts by cooperative societies to gain access to fishing rights in lakes and reservoirs, credit to begin rearing fingerlings, and purchase of appropriate fishing gear and boats.

feeds can adversely affect biodiversity and fish populations. Moreover, the use of fresh-caught feeds may transmit diseases to cultured organisms, as has been documented most recently for brackish water shrimp species. At the same time, processed fish and shrimp feeds often contain varying percentages of fish meal. Alternatives to fish meal in these diets need to be found, such as lysine-rich yeast, a single-cell source of protein that is being widely used in China and other countries.

Water quality standards are important to ensure the optimal growth of the organism and product quality. Some waters in their natural state are not suitable for aquaculture due to high silt loading, soil run-off with organic matter, and/or presence of dissolved metals from natural mineral deposits. Pollution from anthropogenic sources can also adversely affect water quality. With the ongoing expansion of aquaculture development, those governments that lack guidelines for water quality will need to create them to assist potential entrepreneurs with site selection and help protect the consumer from eating tainted aquaculture products.

Post-harvest fish handling methods need to be available or included as part of project development to assure that a safe product reaches domestic and export markets. For export, the United States (NOAA, 1993) and the European Community have developed specific requirements for the seafood processing industry that also include safe and environmentally sound production methods as part of the production process. Necessary modifications to existing facilities are often simple changes requiring modest investments to assure quality products produced under hygienic conditions.

Conclusion

Expansion of aquaculture is inevitable. Its development is driven by an increased demand for products and a need to shift from a high dependency on overexploited inland and marine capture fisheries that have become increasingly threatened. Some species face extinction unless fishing pressure is suspended or vastly reduced. Expansion of aquaculture follows the historical changes from a high dependency on land-based hunting and gathering to agriculture and animal husbandry. Accordingly, greater reliance on aquaculture will further reduce dependency on aquatic natural resources and enhance the capacity to foster conservation of natural aquatic habitats and biodiversity — *carpe diem.*

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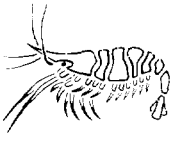

Additional Information

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Aquaculture Magazine. 16 Church Street, Asheville, NC 28801. Tel. (704) 254-7334, fax (704) 253-0677, e-mail aquamag@ioa.com

Aquatic Science and Fisheries Abstracts (ASFA). CD ROM from FAO of the UN World Aquaculture Magazine. 143 Parker Coliseum, Louisiana State University, Baton Rouge, LA 70832. Tel. (504) 388-3137, fax (504) 388-3493.

Fish Farming International. Emap Heighway, MEED House, 21 John Street, London WC1N 2BP, UK. Tel. (44-171) 470-6200, fax (44-171) 831-9362.

Food and Agriculture Organization of the United Nations (FAO): http://www.fao.org

NAGA: The ICLARM Quarterly. ICLARM (International Center for Living Aquatic Resources Management), MCPO Box 2631, 0718 Makati City, Philippines. Tel. (632) 812-8641, fax (632) 816-3183, e-mail iclarm@cgnet.com, web http://www.cgiar.org/iclarm/

Network of Aquaculture Centers in Asia (NACA): http://naca.fisheries.go.th

World Aquaculture Society: http://ag.ansc.purdue.edu/aquanic/was/was.htm

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