Aquaculture Development and Sustainability in Southeast Asia

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Abstract

Countries in Southeast Asia still display a vivid spectrum of developmental stages in aquaculture, the most and the least developed seen in contiguous areas despite geographic similarities. The Network of Aquaculture Centres in Asia-Pacific is actively involved in the development of aquaculture in the region, approaching it from a holistic viewpoint by integrating issues in environment, resource management, and socioeconomics into its program of work. Constraints related to site, inputs, and markets have assumed more importance in many countries, but transfer of technology is still the problem in about half the region. More intense culture systems, especially shrimp pond and fish cages, have resulted in serious problems of self-pollution, which affects the industry's own sustainability. A recent FAO-NACA regional study indicated that non-aquaculture sectors such as industries, agriculture, urbanization, and tourism have serious impacts on aquaculture, but there is little evidence that aquaculture is seriously affecting non-aquaculture sectors. Sustainability of aquaculture has to be considered along with economic and environmental sustainability. It appears from examples in the region that aquaculture that seriously damages the environment is economically unsustainable. Various constraints that impinge on the sustainability of aquaculture in the region are discussed.

Introduction

The Asia-Pacific region in 1991 accounted for a total aquaculture production of 13.9 million metric tons (83% of the world production) valued about US$22 billion (FAO-RAPA 1993, FAO 1993). The global aquaculture production increased to 18.9 million tons in 1992, the Asia-Pacific accounting for 16.5 million tons or 87% of it (FAO 1994). The average annual growth rate of aquaculture in developing countries in Asia was 9.6% in 1981-1991, whereas for the rest of the world, the average rate was 5%. The total aquaculture production for Southeast Asia in

1992 was about 2 million tons, about 12% of the global and 14% of the Asian production (FAO 1994).

The availability of successful technologies has resulted in the rapid expansion and in the remarkable increases in production of aquaculture in southeast Asia. However, further aquaculture development is being increasingly constrained by environmental problems caused by poorly managed aquaculture operations and by resource-use conflicts (ADB-NACA 1991, Pullin et al. 1993). The problems include infectious diseases, public health risks due to contamination of aquaculture products, and losses due to pollution and habitat destruction. The ADB-NACA (1991) regional study on fish diseases and health management concluded that the diseases of aquatic animals and plants are closely linked to the environment and that environmental issues including disease control must be considered in the broader context of farming systems design, siting, and management. The Office of Environmental Policy and Planning (1994) also concluded that to sustain the high production of shrimps achieved through improved technologies in Thailand, aquaculture has to be viewed in its total context - technological, socioeconomic, and environmental.

Many ecological disasters have occurred as a result of unsustainable use, abuse and misuse of natural resources and have clearly demonstrated that long-term and sustainable development can be achieved only through sound environmental management (Pillay 1992). A clear understanding of the environmental problems of aquaculture and their economic impact is essential for the formulation of effective strategies for mitigation at the national and international levels and that of the farmer. The Network of Aquaculture Centres in Asia-Pacific (NACA) has developed a regional program that promotes sustainable development of aquaculture within the broader context of the environment, resource management, and rural socio-economics. NACA adopts and encourages the holistic approach in the planning and management of aquaculture development programs.

This paper reviews the aquaculture production in southeast Asia and some of the constraints in shrimp and carp aquaculture. The review includes the results of an FAO-NACA (1994) study on the effects of aquaculture on non-aquaculture sectors, and vice-versa. The concepts of sustainable development and aquaculture are also reviewed before a discussion on the sustainability of aquaculture in the region.

Aquaculture Production in Southeast Asia

Aquaculture production is regularly reviewed by FAO and other organizations; in addition, sectoral reviews have been made (e.g., Kutty 1980, ADCP 1989a, 1989b, Csavas 1993). Table 1 shows the total aquaculture production in 1984, 1988, and 1992 in the Asia-Pacific. The highest producer in southeast Asia is the Philippines with 734,373 tons, followed by Indonesia with 682,647 tons in 1992.

Tables 2-5 show the commodity-wise aquaculture production in 1991. Southeast Asia produced 580,330 tons of freshwater fish, about 8% of the global production. Indonesia produced 249,670 tons or 43% of the regional total (eight countries, Table 2). Total production of marine and diadromous fishes was 395,015 tons, about 29% of global. The Philippines with 245,598 tons was the highest producer among five countries (Table 3).

Table 1. Aquaculture production in the Asia-Pacific region in 1992. Data from FAO (1994).

Country	Production (tons)		
	1984	1988	1992
Australia	8,369	13,213	15,492
Bangladesh	117,025	154,834	230,097
Brunei Darussalam	0	2	17
Cambodia	1,149	4,741	7,670
China	4,083,668	6,626,015	10,350,474
Cook Islands	0	0	0
Fiji	6	111	141
India	512,300	896,105	1,374,789
Indonesia	326,418	493,163	682,647
Iran IR	18,369	28,900	42,420
Japan	1,013,386	1,190,206	1,150,439
Korea DPR	656,300	395,800	202,500
Korea RO	667,354	874,924	939,156
Laos	2,500	7,000	16,000
Malaysia	67,653	46,636	78,712
Myanmar	4,297	5,673	4,425
Nepal	1,997	5,125	9,371
New Zealand	10,945	27,82	51,3101
Pakistan	8,500	8,850	12,670
Papua New Guinea	0	7	8
Philippines	478,345	599,464	734,373
Samoa, West	0	0	0
Singapore	1,019	1,779	1,957
Solomon Islands	28	5	6
Sri Lanka	3,010	5,669	4,200
Thailand	111,109	217,983	358,480
Vietnam	114,000	146,700	187,000
Asia-Pacific total	8,207,747	11,750,726	16,454,354
World total	10,148,420	14,239,656	18,933,859

Table 2. Inland aquaculture production in southeast Asia in 1991. Data from FAO (1993).

Countries	Production (tons) Carps and other cyprinids	Tilapias and other cichlids	Others freshwater fishes	Total
Cambodia	5,560	160	370	6,090
Indonesia	133,040	54,200	62,430	249,670
Lao PDR	3,600	-	-	3,600
Malaysia	5,000	1,144	211	6,355
Myanmar	4,237	-	-	4,237
Philippines	4,897	76,570	100	81,567
Thailand	18,900	25,400	54,511	98,811
Vietnam	130,000	-	-	130,000
SEA total	205,234	157,474	117,622	580,330
World total	6,257,234	404,255	606,321	7,267,810

Table 3. Production of marine and diadromous fishes in southeast Asia in 1991. Data from FAO (1993).

Countries	Production (tons) Milkfish	Sea bass	Snappers	Groupers	Mullets	Others	Total
Indonesia	133,400	2,000			7,500		142,900
Malaysia	-	1,954	840	144	-	86	3,024
Philippines	234,124	4,698	-	6,765	-	1	245,598
Singapore	239	-	83	198	-	503	1,023
Thailand	230	1,100	-	1,030	110	-	2,470
Vietnam	-	-	-	-	-	-	
SEA total	367,993	9,752	995	7,947	7,610	590	395,015

The penaeid shrimps produced in six southeast Asian countries amounted to 319,699 tons in 1991, about 44.5% of the world production. Thailand had a production of 127,300 tons and Indonesia had 111,570 tons that year (Table 4). In 1993, Thailand had a record shrimp production of 155,000 tons whereas Indonesian production slumped to 80,000 (Rosenberry 1993b). Changes in shrimp production in Asian countries are shown in Table 5.

Table 4. Aquaculture production of penaeid shrimps in southeast Asia in 1991. Data from FAO (1993).

Countries	Production (tons) *Penaeus monodon*	*P. merguiensis* *P. japonicus*	Others	Total
Indonesia	70,560	18,000	23,010	111,570
Malaysia	2,184	155	-	2,339
Philippines	45,740	1,445	4,429	51,434
Singapore	0	55	0	55
Thailand	115,000	7,800	4,500	127,300
Vietnam	-	-	27,000	27,000
SEA total	233,484	27,455	58,759	319,699
World total	245,361	41,501	359,156	718,897

Table 5. Production of marine shrimps from aquaculture. Production data for 1991 from FAO (1993), for 1992 from Rosenberry (1993a), and for 1993 from Rosenberry (1993b). Growth rates for 1986-90 is for all crustaceans, mostly shrimps (97% in India, 94% in Thailand and 96% in China). Taiwan's production peaked in 1987 at 90,957 tons; the annual growth was 53% in 1975-80. Modified from Kutty (in press).

Countries	Annual growth rate, 1986-90 (%)	Production (tons) 1991	1992	1993
China	17.8	187,000	140,000	50,000
Thailand	41.1	127,300	150,000	155,000
Indonesia	20.8	111,570	130,000	80,000
Philippines	11.4	51,434	59,657	25,000
India	13.4	27,540	45,000	60,000
Vietnam	7.4	27,000	35,000	40,000
Taiwan	8.9	24,195	30,000	25,000
Bangladesh	4.9	19,555	25,000	30,000
Japan	5.9	2,400	3,000	not given
Malaysia	34.0	2,339	3,500	not given

Mollusk production in four southeast Asian countries in 1991 was 158,485 tons, 5% of the world production. Thailand (80,000 tons) and Malaysia (48,292 tons) were the highest producers (Table 6).

Seaweed production in the region was 395,783 tons, mostly *Echeuma* from the Philippines (Table 7). The Philippines is the world's largest producer and exporter of *Eucheuma.* Total export of seaweeds in 1992 was 30,448 tons — 14% raw materials and 86% carrageenan (GC Trono, personal communication).

Table 6. Mollusk production from coastal aquaculture in Southeast Asia in 1991. Data from FAO (1993).

Countries	Production (tons)				
	Oysters	Mussels, clams	Cockles	Others	Total
Indonesia					
Malaysia	-	1,563	46,625	104	48,292
Singapore	-	694		-	694
Philippines	12,154	17,345		-	29,499
Thailand	1,500	66,000	12,500	-	80,000
Vietnam	-	-		-	-
SEA total	13,654	85,602	59,125	104	158,485
World total	900,386	1,088,692	577,401	178,291	3,095,345

Table 7. Seaweed production in southeast Asia in 1991. Data from FAO (1993).

Countries	Production (tons)		
	Eucheuma	*Gracilaria*	Total
Indonesia	110,000		110,000
Malaysia	-	-	-
Philippines	283,783	-	283,783
Singapore	-	-	-
Thailand	-	-	-
Vietnam	-	2,000	2,000
SEA total	393,783	2,000	395,793
World total	394,452	69,151	463,603

Csavas (1995) calculates several indices to compare aquaculture production in Asian countries. These indices consider the limitations of resources - land area, amount of renewable water resources, and length of coastline - and are thus some measure of potential sustainability or lack thereof.

Constraints to Aquaculture in the Region

There is a multiplicity of culture systems and methods practised in the countries in Asia owing to geographic, sociocultural, and economic realities. Most countries in southeast Asia strive to establish shrimp culture. Traditional, extensive, or semi-intensive farming systems (particularly for non-shrimp commodities) still prevail in most countries, but intensive systems (particularly shrimp culture and fish culture in cages) are practised in some countries. Several countries still need transfer of improved technology to increase production, but many others are moving towards stabilizing production and increasing the market demand.

ADB-NACA (1994) has an on-going regional (16 countries) study on aquaculture sustainability and the environment. The study collects both descriptive and quantative information about shrimp and carp farming systems and production. At the start of the study, a regional overview of the constraints in shrimp and carp culture was obtained through a questionnaire. The constraints were scored from 0 (not a constraint) to 3 (highly serious). The data for five southeast Asian countries are summarized in Tables 8 and 9.

In shrimp culture, Thailand and the Philippines scored the most constraints and Malaysia and Vietnam scored half as much (Table 8). The most serious constraints are the worsening water quality due to external pollution, and the insufficient supplies of water, spawners, and seeds. Moderately serious are the high costs of land, feeds, seed, and other inputs, security at site, incidence of diseases, and inter-sectoral conflicts.

In carp culture, Thailand and the Philippines had the most constraints (Table 9). The most serious constraints are the low price of carps and the decreasing water supply. Other serious problems are the poor genetic quality of carps, high cost of feeds, poor water quality due to external pollution, natural disasters like flooding, and lack of credit. Moderately problematic are the high capital investment, low returns and profitability, worsening water quality due to self-pollution, low feed quality, and conflicts in land and water use.

Similar constraints as shown by the ADB-NACA (1994) survey for shrimp and carp culture were identified for aquaculture in general by Rabanal (1988, 1994) during previous ADSEA seminar-workshops. The country papers in the present proceedings volume also discuss particular problems. In the future, it would be worthwhile to refer back to the list of constraints and check what advances have been made to solve them, or how much worse they have become.

Table 8. Constraints to the shrimp industry in southeast Asia. Constraints were scored: 3 highly serious, 2 moderately serious, 1 not serious, 0 not a constraint. Maximum score by country is 126. Data from ADB-NACA's (1994) study on aquaculture sustainability and the environment.

Constraints	Score					
	Indonesia	Malaysia	Philippines	Thailand	Vietnam	Average
No space for expansion	2	2	1	2	0	1.4
No suitable sites for shrimp farm	3	2	0	2	0	1.4
Ownership problems	1	1	1	3	0	1.2
High cost of land	3	3	2	2	0	2.0
High capital investment	3	3	2	2	0	2.0
Insufficient water	3	2	3	3	0	2.2
Decreasing water supply	3	2	3	2	0	2.0
Worsening water quality due to:						
external sources	3	3	3	3	1	2.6
self-pollution	3	0	3	2	1	1.8
pond deterioration	2	1	3	2	1	1.8
Natural disasters, e.g. flooding	1	0	2	2	1	1.2
Lack of seed	2	1	3	2	2	2.2
Lack of spawners	2	2	3	2	2	2.3
Unreliable seed supply	2	1	3	2	1	2.0
High cost of seed	1	2	2	2	2	2.0
Insufficient feed supply	1	2	2	1	1	1.4
Feed quality in hatchery	1	0	2	2	1	1.2
Feed quality in grow-out	1	0	1	1	1	0.8
High cost of feed	2	2	2	3	1	2.0
Lack skilled farm labor	2	2	1	2	2	1.8
High cost of labor	0	3	2	2	1	1.6

Table 8 Continued.

Constraints	Score					
	Indonesia	Malaysia	Philippines	Thailand	Vietnam	Average
High cost of other inputs	2	2	0	2	2	1.6
High cost of materials	2	3	3	2	0	2.0
Culture-related constraints	2	0	2	2	1	1.4
Lack advanced technology in						
hatchery	1	0	3	2	2	1.6
grow-out	1	0	2	2	2	1.4
disease control	2	0	2	3	3	2.0
Transport risk	1	0	1	1		0.8
Poor cold storage, postharvest	0	0	1	1		0.6
Uncertain prices	1	0	2	2		1.2
Lack of credit	1	1	3	2	2	1.8
High interest rates	2	0	3	2		1.6
No crop insurance	1	0	2	3		1.4
Licensing problems	1	0	1	3		1.2
Remoteness of sites	2	0	1	3		1.4
Security at site	2	2	3	2		2.0
Conflicts with non-aquaculture						
water use	1	0	2	2		1.2
navigation	1	2	2	1		1.4
land use	2	0	2	2		1.4
tourism	2	1	1	2		1.4
polluted seawater	2	0	3	2		1.6
red tide	1	0	3	3		1.6
Total by country	71	45	84	90	44	

Table 9. Constraints to the carp industry in southeast Asia. Constraints were scored: 3 highly serious, 2 moderately serious, 1 not serious, 0 not a constraint. Maximum score by country is 111. Data from ADB-NACA's (1994) study on aquaculture sustainability and the environment.

Constraints	Score					
	Indonesia	Malaysia	Philippines	Thailand	Vietnam	Average
No space for expansion	2	2	1	2	0	1.4
Ownership problems	2	0	1	2	0	1.0
High cost of land	2	2	1	2	0	1.4
High capital investment	2	3	2	2	1	2.0
Water supply insufficient	1	2	1	3	2	1.8
Water supply decreasing	2	3	2	3	2	2.4
Decreasing water quality due to						
external sources	2	3	3	2	1	2.2
self-pollution	1	2	0	2	1	1.2
Pond siltation	1	2	2	2	0	1.4
Natural disasters i.e. flooding	1	2	3	3	2	2.2
Genetic quality deteriorating	3	0	3	2	3	2.2
Lack of seed	1	1	2	2	0	1.2
Unreliable seed supply	2	0	3	2	0	1.4
High cost of seed	1	1	2	2	1	1.4
Feed supply insufficient	1	0	1	2	1	1.0
Lack of quality feed	0	0	1	1	2	0.8
High cost of feed	3	2	1	3	2	2.2
Lack of skilled farm labor	1	1	2	2	0	1.2
High cost of labor	0	1	1	2	0	0.8
High cost of other inputs	0	2	1	2	1	1.2

Table 9 Continued.

Constraints	Score					
	Indonesia	Malaysia	Philippines	Thailand	Vietnam	Average
Lack advanced technology in						
hatchery	1	1	2	2	2	1.6
grow-out	0	1	2	3	1	1.4
disease control	1	2		2	3	1.6
Technology transfer to farmers	0	1	2	2	1	1.2
Culture-related constraints	0	2	2	2	1	1.4
Transport risk	0	2	2	2	0	1.2
Cold storage facilities	0	2	1	2	0	1.0
High interest rates	1	1	3	2	0	1.4
Lack of credit	1	2	3	3	2	2.2
No crop insurance	0	-	3	2	0	1.0
Low price of carp	2	3	2	3	3	2.6
Declining demand	0	1	1	2	1	1.0
Low returns/profitability	2	2	1	3	2	2.0
Conflicts with non-aquaculture						
water use	2	3	0	3	1	1.8
navigation	0	1	0	2	0	0.6
land use	2	1	0	2	2	1.4
tourism	2	1	0	1	0	0.8
Total by country	45	59	68	89	42	

Effects of Aquaculture on the Environment

FAO-NACA's (1994) project on environmental assessment and management of aquaculture development considered the effects of aquaculture on the environment and on the non-aquaculture sectors. These are briefly described below. It is prudent now to develop a strategy for public management of these impacts as aquaculture will likely intensify.

Inland aquaculture can have adverse ecological effects: reduction in water quality and quantity, introduction of exotic species, loss of wetlands, and changes in biodiversity (FAO-NACA 1994). The modification of water quality and the loss of wetlands are minor problems compared to urban and industrial pollution. Exotic species have been known to affect biodiversity, but the problem is difficult to quantify. The present regulations on exotics seem to be inadequate and it is not clear how government can manage them. Social problems arise in terms of the rights to use water and the encroachment of aquaculture on agricultural lands.

Shrimp culture has well documented ecological and socioeconomic effects (Phillips et al. 1993, Primavera 1993, Phillips 1995). These include loss of mangroves, loss of wild larvae harvested with shrimps, illicit international trade in mature breeders, salinization of soils and water, land subsidence, water pollution, and conflicts with traditional users of resources diverted into shrimp farms. Public management of the negative impacts of shrimp culture is important. Exaggerated statements about the damage are difficult to refute because quantitative information is lacking. Given the general concern with deteriorating coastal environments, this lack of information is particularly harmful to the interests of shrimp farmers. Some preliminary studies have shown that shrimp farms are a minor contributor to pollution and that it is possible to have intensive culture systems less polluting than semi-intensive ones (FAO-NACA 1994). Even when they occupy only a small portion of available land, shrimp farms must follow government regulations to avoid the problems that automatically set in as soon as farms are allowed to congregate in an area.

Mollusk culture contributes to sedimentation problems through excreta. Filter-feeding bivalves that accumulate red tide toxins or heavy metals become health hazards to consumers. The rafts, stakes and other culture structures for mollusks and seaweeds can interfere with the rights of passage, or spoil the coastal scenery for both tourists and residents. To maintain an equitable-use and healthy coastal environment, there must be zoning for various uses, and also regulations on spacing of culture units and farm management practices (FAO-NACA 1994).

FAO-NACA (1994) concludes that the impact of aquaculture on the environment at large is not serious, except through self-pollution. At times it is difficult to distinguish the relative contributions to pollution of shrimp farms, agriculture, urban sewage, and industries. Still, it is obvious that the sustainability of shrimp farms is threatened more by self-pollution, i.e., by degradation of the environment within the ponds and immediately around the farms. The collapse of shrimp farming in Taiwan, Inner Gulf of Thailand, China, and Indonesia (Table 5) was due mainly to self-pollution and outbreak of diseases (Lin 1989, Csavas 1995).

Effects of Other Sectors on Aquaculture

Inland aquaculture is adversely affected by water pollution, destruction of forests and wetlands, reduced access to water and land, and encroachment of other sectors on aquaculture sites (FAO-NACA 1994). The problems are severe in densely populated rural areas and in proximity of urban areas as in China. The pollution suffered by inland aquaculture is qualitatively different from the one it causes. Aquaculture effluents are essentially non-toxic (except for the occasional use of chemicals) whereas industrial wastewater, urban sewage, and agricultural run-off are inherently more dangerous. Inland aquaculturists have limited success in limiting pollution through direct negotiations with polluters. In cases of non-point sources, it is difficult to identify who is responsible to what extent among the large number of possible offenders, and virtually impossible to establish the damage function. With industrial pollution, it is sometimes possible to identify the polluter but impossible for the aquaculturist to afford the transaction cost to reach a settlement (FAO-NACA 1994).

Public management of the pollution that affects inland aquaculture can be much improved, but such efforts are not high priority. In most situations, aquaculturists must form alliances with other groups affected by polluted waters to have the clout to obtain redress. Where redress for pollution has been obtained, it is generally because some larger interest group has forced the solution, for example, environmentalists lobbying for industries to adhere to effluent or emission standards. Aquaculturists must change the public perception of them as polluters. With their present reputation, for example, aquaculturists can not form alliances with environmental groups (FAO-NACA 1994).

Coastal aquaculture suffers from polluted fresh and brackish waters, agricultural run-off, industrial wastes, untreated sewage, siltation, oil spills, and loss of mangroves and other coastal habitats. However, these adverse effects on aquaculture are not well quantified. In shrimp farms located in semi-enclosed areas (for example, inner Gulf of Thailand and Bohai Bay in China), the effects of poor water quality (usually disease outbreaks) can be extremely damaging. However, it is difficult to determine the relative contribution of self-pollution to such losses. It is extremely difficult for shrimp farmers to obtain redress from a large number of other farmers, urban dwellers, or hotel owners, for polluted water (FAO-NACA 1994). The farmers' only choice seems to be to improve farm management to reduce the incidence of diseases, or to abandon or relocate the farms.

Inspite of the economic importance of shrimp farming to many countries, there is little effective assistance by the public administration to reduce the environmental impacts on shrimp farming. Most countries have regulations to reduce industrial, agricultural, and urban pollution of coastal waters, but these are not stringently enforced. However, in China and RO Korea, the administration actively helps shrimp farmers to obtain compensation from the guilty party. Again, to obtain redress, shrimp farmers have to team up with others who suffer from the pollution of fresh and coastal waters.

Mollusk and seaweed culture may also be adversely affected by coastal pollution from the same sources mentioned above, by red tides, and conflicts of use. Pollution is a serious threat to large areas of mollusk and seaweed farms in RO Korea, China, and the Philippines. Fanners generally have no success in preventing external pollution and no management choices except to relocate the farms. Coastal zonation is necessary to protect aquaculturists. Mollusk and seaweed

culture must be carried out in relatively unpolluted waters and zoning must be introduced to safeguard such areas (FAO-NACA 1994).

Sustainable Development and Aquaculture

To discuss aquaculture sustainability, it would be pertinent to review some of the definitions of sustainable development and the explanations of related issues.

The Brundtland Commission (World Commission on Environment and Development) was tasked by the United Nations to formulate "a global agenda for change" and to propose long-term environmental strategies for achieving sustainable development by the year 2000 and beyond. Sustainable development is defined as one that "meets the needs of the present without compromising the ability of the future generations to meet their own needs" (WCED 1987). Aquaculture is given major importance in sustainable development: "expansion of aquaculture should be given high priority in developing and developed countries."

In line with the WCED approach, FAO (1988) defines sustainable development as "the management and conservation of the natural resource base, and the orientation of technological development and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations."

For sustainability, "the environment should be protected in such a condition and to such a degree that environmental capacities (the ability of environment to perform its various functions) are maintained over time, at least at levels sufficient to avoid future catastrophe, and at most at levels which give future generations the opportunity to enjoy an equal measure of environmental consumption" (Jacobs 1991, in Therivel et al. 1992).

The Rio Declaration (UNCED 1992) is the most important global document in recent times on sustainable development and human survival. Agenda 21, the Programme of Action for Sustainable Development includes the following principles:

Principle 4: "In order to achieve sustainable development, environmental protection shall constitute an integral part of the developmental process and cannot be considered in isolation from it."

Principle 9: "States shall enact environmental legislation. Environmental standards, management objectives and priorities should reflect the environmental and developmental context to which they apply."

Principle 13: "States shall develop national law regulating liability and compensation for victims of pollution and other environmental damage."

Principle 17: "Environmental impact assessment as a national instrument shall be undertaken for proposed activities that are likely to have significant adverse impact on the environment and are subject to a decision by a competent authority."

Principle 25: "Peace, development, and environmental protection are interdependent and indivisible."

The Rio Declaration adds that "the major objective of sustainable agriculture and rural development is to increase food production in a sustainable way." UNCED (1992) recognizes the multisectoral use of water resources for domestic consumption, sanitation, agriculture, industry, urban development, hydropower generation, inland fisheries, transportation, recreation, and other activities. It emphasizes the protection of the quality and supply of freshwater resources through application of the integrated approach to the use, development, and management of water resources.

The concept of sustainable aquaculture involves three interrelated aspects: production technology, social and economic aspects, and environmental aspects (ADB-NACA 1994, AIT 1994). Aquaculture technology must be sufficiently productive to make it an attractive option to alternative and possibly competing uses of resources. Maximum biological yields may not be the most appropriate goal, but rather those commensurate with the resources of a particular farmer. Sustainable aquaculture systems make environmentally sound use of resources. Such systems must not divert or replace resources that may be used in a more productive way for other purposes and must not degrade the environment that the livelihood of future generations is jeopardized. In short, sustainable aquaculture systems must be productive, socially relevant, profitable, and environmentally compatible (AIT 1994).

The ideas developed on sustainable development in general, and agriculture in particular, apply to aquaculture as well. ADB-NACA (1994) defined sustainability in terms of the specific site and aquaculture system that is able to continuously maintain profitable aquaculture production over at least ten years without degradation of the environment, provided that the initial environment was not degraded by upstream activities. Sustainability implies some flexibility to meet changing conditions within some limits. Environment-friendly aquaculture is more likely to be economically successful over the long term whereas environmentally damaging aquaculture is likely to be self-destructive and unsustainable. Economically sustainable aquaculture ensures an income sufficient over the long term to enable continued inputs, necessary developments, and profitability consistent with those of other long-term agriculture investments. Environmental sustainability is the capacity of surrounding and associated ecosystems to continuously absorb impacts from aquaculture without loss of integrity.

There are different views concerning the achievability of sustainable development and sustainable aquaculture (e.g., IFS-NRCP 1993, Pullin et al. 1993, since the "Club of Rome"). Nevertheless, I argue that most farming systems in Asian aquaculture have been sustainable, and would continue to be so. This is particularly true of carp culture in India, China, and other countries, and of freshwater integrated farming systems, which account for most of the global production (Tables 1 and 2). The question of sustainability comes when the resources of a specific culture system become limited, and the carrying capacities at the farm or pond level and at the ecosystem level are exceeded (Hepher 1975, Kutty 1986, Makinen 1991). Tested carrying capacity models like those referred to, improvements in technologies, and awareness and wisdom should help planners, administrators, and fanners steer away from catastrophes. For example, use of quality feeds and improved feeding techniques can reduce waste loading and result in better water quality. Reduction in the nitrogen content of fish feeds by 10% and the phosphorus content by 40% reduced the feed conversion ratio from about 2 to 1.4 in Scandinavia (Makinen 1991). I subscribe to an optimistic approach to aquaculture, as WCED (1987) and others have earlier encouraged.

Sustainability of Aquaculture in Asia

FAO-NACA's (1994) project on environmental assessment and management of aquaculture development yielded considerable information from 16 countries regarding the sustainability of aquaculture and the environment. For example, shrimp farming in Taiwan, Thailand, China, and Indonesia have collapsed at different times due to self-pollution and diseases. But the collapse was not just due to high farming intensity. Csavas (1995) compared shrimp production per kilometer of coastline, and found that the point of collapse can be at different levels in different countries, and can occur even at quite low levels of production. The farm density at the specific site and the related topography may be the important contributors to the collapse.

The carrying capacity of the environment in the vicinity of the farms is important in deciding both the density of the farms and the intensity of culture. Consideration of the carrying capacity must begin at the planning stage of the project. Phillips et al. (1993) point out that "effective and balanced planning, based on a clearer understanding of the interactions between shrimp culture and the environment, is the key to the use of coastal environments for shrimp culture, without which there is a distinct possibility that shrimp culture will not be sustainable."

How do we decide when the carrying capacity of the environment is being surpassed? I think there are ecological and environmental thresholds, analogous to physiological thresholds, for stimulus-response in an ecosystem; these thresholds have to be crossed to set off the collapse reaction. Studies such as those made by Smith (1993) on sediments in shrimp farms in Australia can provide some pointers in this direction. The current ADB-NACA (1994) study examines these possible thresholds through its farm-level survey. The study identifies and quantifies those inputs at the farm level that maintain or degrade the sustainability of both aquaculture and the environment, and measures the economic sustainability of shrimp and carp culture in relation to environmental sustainability. NACA also collaborates with the Australian Centre for International Agricultural Research to study environmental and other issues related to shrimp farming in Thailand. A study is in progress to identify key issues for research in sustainable coastal shrimp culture in Thailand.

The ADB-NACA (1994) study also examines the interaction of aquaculture and society (sociocultural context) since conflicts can arise between aquaculture and coastal and inland communities with regard to land use (e.g., tourism), market share (e.g., fisheries), water quality, and public health. To be sustainable, aquaculture must have appropriate sites and systems acceptable to the local communities. Sustainable aquaculture systems can avoid most conflicts among reasonable interests. The development objective of the ADB-NACA study is to improve aquaculture production and investment returns and ensure the long-term sustainability of aquaculture.

Finally, a complete economic appraisal of all inputs and variables, especially environmental, involved in aquaculture production, has to be made. Environmental accounting is a recent concept that is yet to be adopted widely in practice (Barbier 1989, Wimpenny 1991). The conventional cost-returns analysis of projects without environmental costing is no longer adequate.

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