

# ***Towards Sustainable Aquaculture in Southeast Asia and Japan***



**TU Bagarinao and EEC Flores, Editors**



**Southeast Asian Fisheries Development Center**



**Japan International Cooperation Agency**



**Canadian International Development Agency**



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**Proceedings of the Seminar-Workshop on  
Aquaculture Development in Southeast Asia  
Iloilo City, Philippines  
26-28 July 1994**

**TU Bagarinao  
EEC Flores**

**Editors**



**Aquaculture Department  
Southeast Asian Fisheries Development Center  
Iloilo, Philippines**

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## Foreword

Aquaculture has produced an increasingly greater amount of food fish in southeast Asia and Japan. The SEAFDEC Aquaculture Department (AQD) has made significant contributions in science and technology for the aquaculture industry. AQD has endeavored to respond to the needs of the industry through frequent dialogues and assessments with the industry practitioners, government agencies, and other researchers.

The convening of ADSEA '94, the third Seminar-Workshop on Aquaculture Development in Southeast Asia, was very timely. It responded to one of the major recommendations of the 1992 United Nations Conference on Environment and Development (or the Earth Summit), which was to establish integrated coastal zone management to protect coastal ecosystems and achieve sustainable development of coastal areas. The theme of ADSEA '94, *Sustainable Aquaculture Development*, was very appropriate.

By sustainable aquaculture, we mean the appropriate use of coastal resources for aquaculture with technologies and developments consistent with present and especially future needs. The Earth Summit emphasized that sustainable development embraces three aspects: economic development to improve the quality of life of the people, environmentally sound development that protects resources and ecosystems, and socially and culturally appropriate development with equitable distribution of benefits among various sectors. These three aspects are considered in AQD's research programs, which are now directed to the generation of aquaculture technologies that are economically feasible, environment-friendly, and socially equitable.

ADSEA '94 included reviews of the status of aquaculture development in southeast Asia and Japan and of the research conducted by the Aquaculture Department to contribute to this development. Invited scientists then talked on various special topics including responsible aquaculture, mollusk and seaweed culture, integrated farming, shrimp culture, diseases and health management, and transgenic fish. The meeting was capped by workshops to determine the present constraints to aquaculture in the region and to decide the priorities for research and development at AQD during the next three years.

This proceedings volume documents the presentations at ADSEA '94. As always, the SEAFDEC Aquaculture Department offers its research, those of others, and the discussions of these, for use by the scientific community, by the industry, and by government policy makers, ultimately for the benefit of society.

Many people made valuable contributions to the planning, conduct, and especially to the discussions and deliberations during ADSEA '94. These efforts and others help ensure that we get closer to the goal of sustainable aquaculture. It is my hope that this goal stays always in our minds as we go about our research, business, decision making, and policy making.

*Maitree Duangsawasdi*  
**Secretary-General of SEAFDEC**

Bangkok, 1 May 1995



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## **SEAFDEC AQD and ADSEA**

The Southeast Asian Fisheries Development Center (SEAFDEC) is a regional treaty organization established in 1967 with five Member Countries: Japan, Thailand, Malaysia, Singapore, and the Philippines. SEAFDEC has four Departments: the Marine Fisheries Training Department in Samut Prakan, Thailand; the Marine Fisheries Research Department in Singapore; the Marine Fishery Resources Development and Management Department in Kuala Terengganu, Malaysia; and the Aquaculture Department in Iloilo, Philippines.

The SEAFDEC Aquaculture Department (AQD) was organized in 1973 with three mandates:

- Undertake aquaculture research relevant and appropriate for Southeast Asia
- Develop human resources for aquaculture in the region
- Disseminate and exchange aquaculture information

The Seminar-Workshop on Aquaculture Development in Southeast Asia (ADSEA) was conceived about a decade ago as a means to assess the contribution of SEAFDEC AQD to the development of the aquaculture industry in the region. ADSEA seminar-workshops were convened by AQD in 1987, 1991, and 1994. These were attended by invited scientists and representatives of SEAFDEC Member Countries, the academe, the aquaculture industry, and government agencies. ADSEA '94 was also attended by representatives from Vietnam and Indonesia. All these meetings ended with lists of recommendations and priorities for research. The recommendations became the basis of the three-year research programs of AQD.

## Acknowledgements

ADSEA '94 was funded by the Governments of the Philippines and Japan, the Canadian International Development Agency through the ASEAN-Canada Fund, and the Japan International Cooperation Agency. The members of the ADSEA '94 Committees, led by organizers RM Coloso, LMaB Garcia, AQ Hurtado-Ponce, CR Lavilla-Pitogo, OM Millamena, and GF Qunitio did a superb job. LAT Espada prepared the lay-out for this volume.



## ERRATUM

The correct logo of the  
Canadian International Development Agency  
appears below:



# **Recommendations for Responsible Aquaculture**

**Imre Csavas**

FAO Regional Office for Asia and the Pacific  
Phra Atit Road, Bangkok 12020, Thailand

Csavas I. 1995. Recommendations for responsible aquaculture, pp. 1-12. In: Bagarinao TU, Flores EEC (eds) Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines.

## **Abstract**

Aquaculture has grown rapidly in Asia. In 1992, out of the 52.8 million tons of total production of aquatic organisms, as much as 17 million tons (32.2%) came from aquaculture. However, unplanned and uncontrolled development of aquaculture has led occasionally to environmental damage and social disruption in many countries. Now attention has focused on the sustainability of aquaculture. Negative impacts of shrimp culture have been well publicized, but problems have also been caused by overinvestments in fish and mollusk culture. As sustainability is a highly complex issue, it is important to develop internationally accepted principles and guidelines for responsible aquaculture, with the use of technologies not detrimental to natural resources, ecosystems and human communities. FAO is now in the process of developing an International Code of Conduct for Responsible Fishing based on the Declaration of Cancun. One chapter of the Code will deal with aquaculture. Unfortunately, information is rather scanty on the environmental impacts of various aquaculture systems and the carrying capacity of aquatic ecosystems, especially in tropical areas. Therefore, research on these topics should receive high priority. Similarly, tightening and enforcing the rules and regulations governing existing and new aquaculture ventures is a pressing task that responsible government agencies can not postpone any longer.

## **Introduction**

Aquaculture development in the 1980s has changed once and forever the supply of aquatic products in Asia. By 1992, about one-third (32.2%) of the total production of aquatic organisms was provided by aquaculture, and for several major commodity groups, this ratio was even significantly higher. As much as 96.9% of seaweeds, 46.6% of mollusks, and 72% of freshwater fishes were cultured (Table 1). The contribution of aquaculture was only 22.9% for crustaceans and 1.2% for marine fishes, but a species by species analysis shows outstanding shares for several high-value commodities.

Table 1. The share of aquaculture in the total production of the fisheries sector in Asia in 1992. Data from FAO (1994).

Commodity group	Total fisheries production ( $\times 1,000$ tons)	Aquaculture production	
Freshwater fishes	10,240	7,371	72.0
Diadromous fishes	1,198	514	42.9
Marine fish	26,638	323	1.2
Crustaceans	3,511	803	22.9
Mollusks	5,732	2,672	46.6
Seaweeds	5,497	5,329	96.9
Total*	52,816	17,012	32.2

\*Without marine mammals and miscellaneous aquatic vertebrates and invertebrates.

Development was fast in all major species groups (Fig. 1), but at considerable cost. Much of the development especially in coastal areas was propelled by commercial interests that disregarded the limited nature of resources and the interests of local communities. Governments were unable to control the excesses of the profit-oriented rush (e.g., in shrimp culture) because suitable rules and regulations did not exist, or the authorities did not have the means or the political clout to enforce them.

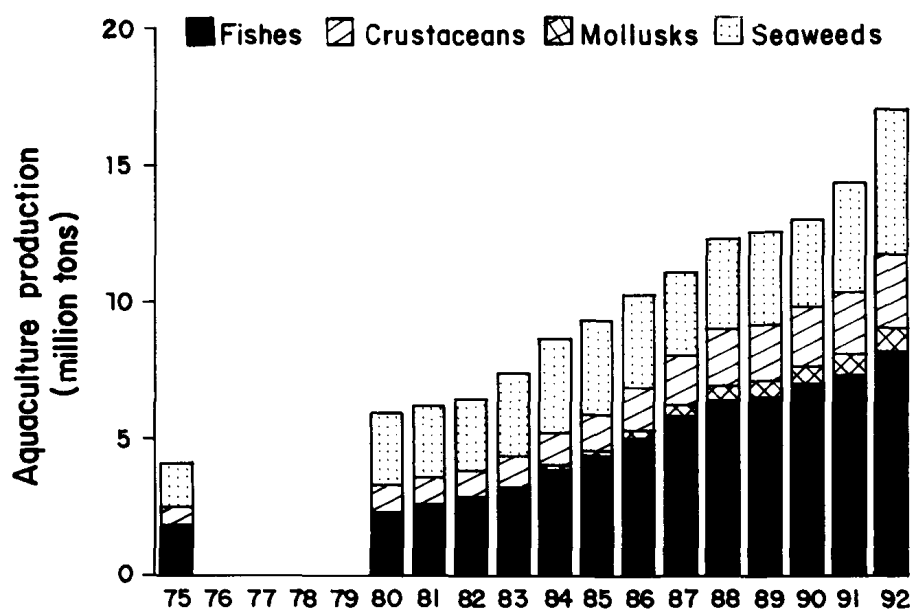


Fig. 1. Growth of aquaculture production in Asia. Data from Csavas (1988) and FAO (1994).

The unplanned and uncontrolled development of aquaculture led occasionally to suicidal environmental damages and social disruptions, especially in shrimp culture in Taiwan, China, Thailand, and Indonesia, but also in freshwater fish culture (e.g., in Laguna de Bay in the Philippines), marine fish culture (e.g., in the Seto Inland Sea in Japan), and even in mollusk culture in Japan and the Republic of Korea.

The occasional negative impacts of aquaculture development were widely publicized, but it was seldom pointed out that in all major cases of environmental damage attributed to aquaculture, there were other guilty parties as well: industrial and communal polluters (e.g., in Laguna de Bay, inner Gulf of Thailand, Bohai Bay, Seto Inland Sea) or destructive logging of mangroves (e.g., in the Philippines). In fact, an analysis has demonstrated that the northern European salmon and trout industry, which developed as rapidly as shrimp culture did in Asia, contributed only 0.4% of the total nitrogen load and 1.5% of the total phosphorus load of the sea (Knell and Ackefors 1992). Atmospheric deposition of nitrogen was two times higher and municipal sewage contributed 2.5 times more nitrogen and 6.6 times more phosphorus load than the salmon and trout farms, despite the fact that Nordic countries have efficient sewage treatment, unlike Asian urban centers.

In order to avoid a biased public opinion, aquaculturists have to tell the true story, admitting their own mistakes but also demonstrating the responsibility of others. It is imperative to map with scientific accuracy the ecological and social limits of aquaculture development and to ensure the sustainability of future growth.

### **Ecological Limits of Aquaculture**

In terms of national averages, aquaculture is far from its ecological limits in Asia, although the continent produced 88.2% of the global aquaculture output in 1992. The aquaculture production per capita per year was only 21.6 kg in the Republic of Korea, 11-13 kg in Taiwan, the Philippines, and Japan, and was below 9 kilograms in the rest of Asia, including major producers like China and Thailand (Table 2, column 2). It is misleading, of course, to use such averages and more detailed analysis is needed to trace ecological limitations.

First of all, inland and coastal aquaculture have to be scrutinized separately as they differ in many respects. Currently, only 44.3% of the total aquaculture production in Asia comes from inland areas (Table 3). Inland aquaculture produces primarily fishes (99.6%), and crustaceans and others make up 0.4%. Most of the inland fish production in Asia comes from photosynthesis-dependent ponds of small farmers that blend well in the rice-based agroeconomies and social structures of the continent.

In inland areas, the most important limits to aquaculture development may be the scarcity of land or water. When inland aquaculture production is averaged per unit land area, the figures are highest indeed in densely populated areas. But even in Hong Kong, Taiwan, and Bangladesh, it is below 5 t/km<sup>2</sup> (Table 2, column 3). In the rest of the continent, this indicator is below 0.5 t/km<sup>2</sup>.

Table 2. The major aquaculture producers in Asia in 1992 by various indicators. Indices computed from production data from FAO (1994).

Producer	Total aquaculture production (kg/capita)	Inland aquaculture production			Coastal aquaculture production per length of coastline (t/km)			
		per land area (t/km <sup>2</sup> )	per renewable fresh water (t/km <sup>3</sup> )	Total	Seaweeds	Mollusks	Crustaceans	Fishes
Rep Korea	21.6	0.20	317	382.7	240.3	140.3	0.2	1.9
Taiwan	12.7	3.68	na	80.1	6.9	39.4	11.8	22.0
Japan	11.3	0.24	165	95.2	42.4	33.3	0.2	19.3
Philippines	11.3	0.33	306	28.3	15.5	1.6	3.5	7.7
DPR Korea	9.0	0.11	194	75.9	48.7	22.0	5.2	0
China	8.8	0.53	1,777	374.7	245.0	110.2	15.5	4.0
Thailand	6.4	0.22	1,007	77.1	0	20.5	55.9	0.7
Malaysia	4.2	0.05	35	13.6	0	12.2	0.6	0.8
Indonesia	3.6	0.13	93	8.3	2.4	0	3.2	2.7
Laos	3.6	0.07	59	-	-	-	-	-
Vietnam	2.7	0.45	391	11.6	1.4	0	10.2	0
Bangladesh	1.9	1.61	154	36.2	0	0	36.2	0
Hong Kong	1.6	4.93	na	6.1	0	0.7	0	5.4
India	1.6	0.45	730	1.9	0	0.2	1.7	0
Singapore	0.9	0	0	12.2	0	6.1	2.0	4.1
Iran	0.7	0.03	361	0	0	0	0	0
Asia average	5.5	0.34	516	64.4	36.2	18.1	5.3	4.8

na, not applicable

Table 3. Inland and coastal aquaculture production in Asia compared with the rest of the world. Data from FAO (1994).

Sector Species groups (contribution)	Production (million tons)	
	Asia	Rest of the world
Total	17.033	2.278
Inland aquaculture	7.538	0.936
Fishes (99.6%)	7.508	0.902
Others (0.4%)	0.030	0.034
Coastal aquaculture	9.495	1.342
Fishes (7.4%)	0.703	0.307
Seaweeds (56.2%)	5.336	0.060
Mollusks (28.2%)	2.678	0.830
Crustaceans (8.2)	0.779	0.145

The order of countries is distinctly different when inland aquaculture production is related to renewable internal freshwater resources. China and Thailand are the leading countries in this respect, producing 1,000-2,000 tons per cubic kilometer of their renewable freshwater resources (Table 2, column 4), which translates to 1-2 g/m<sup>3</sup> per year. The achievements of these countries are commendable, but obviously still far from the limits of inland fish culture in terms of freshwater resources.

In inland areas, the most vulnerable ecosystems from the point of view of aquaculture are the natural lakes and man-made reservoirs. There are several examples regionwide that show that the carrying capacity of these waters is limited and can be breached with cage or pen culture with intensive feeding. One of the earliest such problems emerged in Laguna de Bay in the Philippines (Librero 1988).

Most of the environmental troubles, however, have been caused by the uncontrolled development of coastal aquaculture. The 55.7% contribution of coastal aquaculture to the total production (Table 3) itself reveals a discrepancy. The coastal zone used for aquaculture is a strip only a couple of kilometers wide on the continental shelf and on the low-lying flatlands beyond the tidal zone. This narrow strip produces more cultured aquatic commodities than the vast land areas they skirt. The total length of Asia's coastline is 147,400 km. With an average width of 10 kilometers (a generous overestimate), the continent's coastal area is about 1.5 million km<sup>2</sup>. The total land area of Asia is 15 times bigger — 22.2 million km<sup>2</sup>.

The problem is aggravated by the stiff competition between various sectors of the economy for the use of the coastal zone and the fluid state of the use rights there. Not so long ago, much of the coastal area was an open-access resource; now it is increasingly privatized, legally or illegally. Aquaculturists are active, but not the only or even the strongest, players in this privatization (Bailey 1988, Bailey and Skladany 1991).

The volume of aquaculture commodities produced in the narrow coastal zone is amazing indeed. The output of the Republic of Korea and China reached almost 400 t/km coastline and those of Japan, Taiwan, Thailand and the DPR Korea were between 75 and 100 t/km (Table 2, column 5). Of course, it is important to know what commodities are produced in various countries as there are significant differences between the major commodity groups in terms of their environmental impact. In Asia, seaweeds dominate coastal aquaculture; in 1992 they represented 56.2% of the total production (Table 3).

An increasing portion of seaweeds is produced for extraction of phycocolloids rather than for direct human consumption. Despite the recent successes of several tropical countries, seaweed culture is still dominated by the traditional producers. China and the Republic of Korea each produce almost 250 t/km coastline (Table 2, column 6). As seaweeds are consumers of dissolved nutrients and producers of oxygen, seaweed culture is the most environmentally compatible form of aquaculture. However, in the leading countries, seaweed culture is a high-tech industry with indoor hatcheries, genetic manipulation of stocks, and intensive fertilizer application in the grow-out areas occupying significant stretches of the coastline. These advanced monoculture systems are increasingly dependent on external inputs and their social and ecological impacts should not be ignored.

The major producers of cultured mollusks are almost the same ones producing high volumes of cultured seaweeds. The Republic of Korea and China produce 110-140 t/km coastline, and tropical countries lag way behind (Table 2, column 7). Culture of filter-feeding mollusks is usually considered environmentally beneficial; however, their metabolites can contribute significantly to the organic load at the culture site. Overuse of traditional oyster culture grounds in Korea and Japan has led to self-pollution and the deterioration of the environment (Mito and Fukuhara 1988, BH Park, personal communication), not unlike the effect of shrimp and fish farming. Mollusk culture is declining already in the Republic of Korea where it peaked in 1987 with 185 t/km, and stagnates in Japan where the current level of 33 t/km was reached in 1988. Thus, ecological limits do exist in mollusk culture and these have already been surpassed at several locations.

The negative impacts of shrimp culture are well documented, especially in Asia. The collapse of the Taiwanese shrimp industry in 1988 sent clear warning signals about the ecological limits of aquaculture (Lin 1989, Macintosh and Phillips 1992). Before the collapse, Taiwan reached an average production of 55.9 t/km; this was reduced to 11.8 t/km by 1992 (Table 2, column 8). The current leader, Thailand, reached a shrimp production of 55.9 t/km in 1992, and the production is apparently still increasing. However, a more detailed analysis of the Thai shrimp industry reveals that shrimp culture has peaked and collapsed after 1988 in several provinces in the Inner Gulf of Thailand (Csavas, unpublished data from the CURSI-ORSTOM Project, Chulalongkorn University). Samut Prakan, Samut Sakhon and Samut Songkhram reached shrimp production levels of 217, 356, and 582 t/km, respectively, before they crashed. Right before the collapse, there were 336 hectares of shrimp ponds on every kilometer of Samut Songkhram's coastline, equivalent to a 3.4 km wide contiguous belt of ponds. New investments in other sections of the Thai coastline (Fig. 2) kept the total national output increasing, even as the pioneering provinces suffered environmental damage not unlike that experienced in Taiwan.



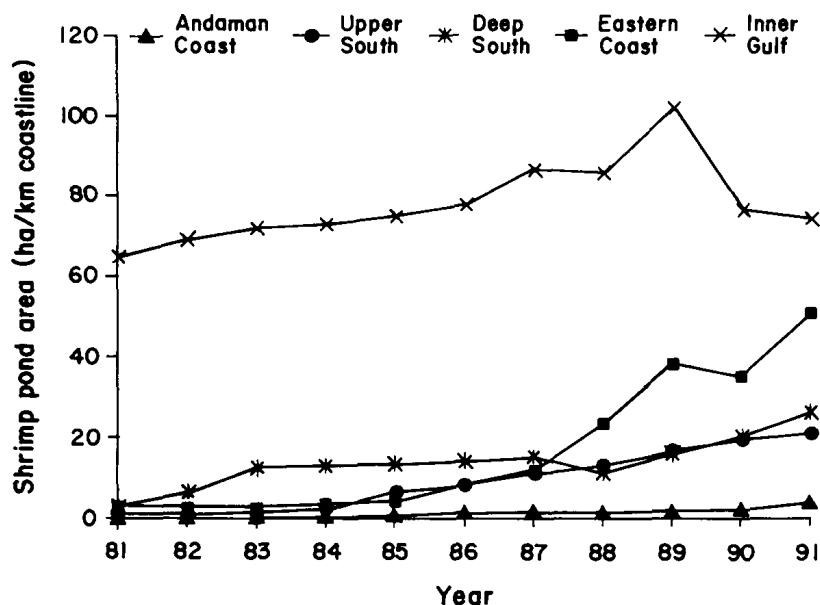


Fig. 2. Increase of shrimp culture area in coastal regions of Thailand. From Csavas (unpublished manuscript, Coastal Aquaculture in Thailand, CURSI-ORSTOM Project, Chulalongkorn University).

Local overinvestments in shrimp culture also caused similar problems in 1993 in China and Indonesia, although these countries do not show dangerously high levels of production per hectare or per kilometer of coastline. This again shows that broad averages can be misleading.

Marine fish culture did not reach such extreme production levels per kilometer of coastline, although the national averages for Taiwan and Japan are rather high, around 19-22 t/km (Table 2, column 9). It is important to note, however, that the present level in Taiwan is well below the peak 65 t/km reached in 1990. The Japanese marine fish production has also declined slightly since 1991. Obviously, there is an ecological problem in the more frequent algal blooms that result in massive fish kills even in the well regulated Japanese fish culture industry (Y Taki, personal communication). It is clear that domestic and industrial pollution are significant factors in the deterioration of the environment, but self-pollution can not be ignored either.

All these negative examples in the early 1990s called the attention of both the government and the industry to the need of addressing the problems caused by overinvestments in certain commercial aquaculture systems. At that time 'sustainable development' was already a hot issue in agriculture circles.

## Sustainable Development

Initially, 'sustainable development' was used and interpreted in different, sometimes incompatible ways, according to the biases of the users. Finally, FAO (1991) proposed and used the following definition at the 44th session of its Council:

Sustainable development is *"the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, and plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable."*

The above definition, which was prepared originally to be used in agriculture, is comprehensive and suitable for use without any modifications in both capture fisheries and aquaculture. However, sustainability, even in its broadest sense, addresses only the supply side of the problem faced by the fisheries sector at the end of the twentieth century.

Aquaculturists have learned the hard way that in the mature phase of the industry, supply and demand become balanced and further growth depends on processing and marketing rather than on additional investments in culture facilities. To increase demand is the only way to maintain growth once markets are saturated with a commodity. The predicaments of the 'pork cycle,' that is, the periodically oversupplied markets, are now all too familiar to aquaculturists (Csavas 1994). This is the reason why the new term, 'responsible fisheries and aquaculture,' was coined to cover both the sustainability of production and the desirable postharvest handling, processing, and marketing.

### **Responsible Fisheries and Aquaculture**

The International Conference on Responsible Fishing held at Cancun, Mexico, in 1992, launched the concept, and its Declaration of Cancun requested FAO to draft an International Code of Conduct for Responsible Fishing (FAO 1992). At its Twentieth Session in March 1993, the FAO Committee on Fisheries considered the possible scope and content of such a Code and concluded that 'responsible fishing' means the sustainable utilization of fishery resources in harmony with the environment. 'Responsible fishing' encompasses sustainability of production, proper transformation processes to add value to fishery products, and appropriate commercial practices that provide consumers good quality products (FAO 1993).

Given the wide scope contemplated for the Code of Conduct, it will be elaborated in such a manner that parts of the Code may be readily incorporated in national laws and regulations and may also be adopted as separate international legal instruments. The Code of Conduct on Responsible Fishing will consist of a section on general principles and six sections covering major thematic areas, one of which will be aquaculture development. Each section of the Code will be elaborated through appropriate consultations with experts and concerned organizations, of which SEAFDEC is an important one in the Asia-Pacific region. For this purpose, the FAO Secretariat has prepared the first draft of the Proposed Preliminary Principles and Guidelines for Responsible Aquaculture in March 1994.

Interested governments will be invited to consider and adhere to a set of preliminary principles related to responsible aquaculture practices. These principles are a summary outline of the possible duties and responsibilities of states under the International Code of Conduct on Responsible Fishing. Based on these preliminary principles, a set of guidelines is proposed,

addressed primarily to responsible government agencies, but also to public or private institutions and persons engaged in promoting or practicing aquatic farming. It is understood that given the diversity of natural, social, and economic conditions and aquaculture practices, more specific guidelines must be developed on a country by country basis to meet local requirements.

The draft of Preliminary Principles for Responsible Aquaculture proposes three sets of principles, one for the national level, one for international level, and one for the farm level as follows:

1. *States and their fishery and aquaculture authorities, aiming to promote responsible development and management of aquaculture within their national jurisdiction, agree, in principle, to:*
  - a. *Establish and maintain an appropriate administrative and legal framework for aquaculture*
  - b. *Produce and regularly update comprehensive aquaculture development strategies and plans to ensure that all aquaculture development is appropriate, sustainable, and in the public interest, to allow for compatible use of resources shared by aquaculture and other activities*
  - c. *Establish procedures to undertake appropriate environmental impact assessment and monitoring to minimize adverse ecological changes resulting from water extraction, effluents, use of drugs and chemicals, and all other farm activities*
  - d. *Ensure adoption of appropriate practices in the genetic improvement of broodstocks, and in the production, sale and transport of eggs, larvae or fry, broodstock, or other live materials, in order to avoid adverse effects on wild and cultured stocks*
2. *States and their fishery and aquaculture authorities, aiming to protect international seas, rivers, and lakes, especially the living resources of those waters, from irresponsible aquaculture practices within their territories, agree, in principle, to:*
  - a. *Accept the obligation to their neighboring States to ensure responsible siting and management of aquaculture activities in or bordering international waters*
  - b. *Develop appropriate means to monitor the economic performance of their aquaculture activities and their impacts on other activities*
  - c. *Share relevant data to permit forecasting of aquaculture development opportunities and needs at national, regional, and global levels*
  - d. *Promote joint research efforts and exchange of knowledge and technical assistance on aquaculture systems most suitable to their regions*
  - e. *Promote regional trade in equipment, feeds and other inputs with neighboring states, and, at the same time, to develop adequate regulatory mechanisms to control the appropriateness and quality of such materials when produced and traded*

- f. *Contribute to the protection and enhancement of stocks of endangered species by supporting the development of appropriate techniques for aquaculture of endangered species*
  - g. *Conserve genetic diversity and maintain genetic integrity of aquatic communities and ecosystems by minimizing the risks of introducing non-native species or genetically altered stocks used for aquaculture into waters where there is a significant potential for spreading into the waters of other States*
- 3. *States, farming communities, producer organizations, and farmers should ensure responsible aquaculture practices at the farm level, by undertaking efforts to:*
  - a. *Promote active participation of local communities and farmers in the management of aquaculture practices*
  - b. *Improve selection and use of feeds and feed additives*
  - c. *Improve selection and use of manures and fertilizers*
  - d. *Improve the use of hormones, drugs, antibiotics or other disease-control chemicals as well as the disposal of excess veterinary drugs, and of hazardous offal, dead, or diseased fish*
  - e. *Improve product quality through particular care before and during harvesting, on-site processing, and in storage and transport of the products*
  - f. *Promote the use of appropriate procedures for selection of broodstock and production of seed*

The document Preliminary Principles and Guidelines for Responsible Aquaculture, distributed among participants of the ADSEA '94, is now under revision and redrafting. Every interested institution or individual is encouraged to raise recommendations that would help in the process of improving, correcting, or completing it. Send comments to the FAO Regional Office for Asia and the Pacific (Phra Atit Road, Bangkok 10200, Thailand) or the Inland Water Resources and Aquaculture Service (FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy).

### **Recommendations for Responsible Aquaculture**

The International Code of Conduct on Responsible Fishing attempts to provide a comprehensive set of guidelines for the sustainable development and management of the whole fisheries sector, including aquaculture. The following recommendations are especially relevant in Asia:

1. *Develop suitable rules and regulations to restrict the establishment of production capacities that exceed the carrying capacity of the environment.*

Licensing of aquaculture production units has to be based on solid scientific and engineering principles. Licenses must regulate the size of the culture facility, production volume,

culture techniques, water intake, and the volume and quality of wastewater discharge. The allowable conversion of farmlands, wetlands, mangroves, and coastal waters into aquaculture facilities must be carefully scrutinized site by site. The regulations, guidelines, and standards applied in developed countries with moderate climates must be carefully revised and adapted to the climatic and social conditions of developing tropical countries.

2. *Enforce the rules and regulations and monitor regularly.*

It is naive to expect responsible behavior from profit-oriented producers when rules and regulations are not enforced. The biggest difficulty with enforcement is the lack of a suitable monitoring system or methodology. Remote sensing has proven to be a very efficient technique to enumerate and regularly monitor production capacities, especially ponds. In order to set globally applicable standards, the Joint Group of Experts on the Scientific Aspects of Marine Environment Protection is currently developing international procedures for monitoring the ecological effects of coastal aquaculture.

3. *Involve the local community in the management of resources.*

Community-based management of resources and production facilities is more efficient than reliance on government controls only. The rape-and-run approach of outsiders caused most of the severe environmental damage in Asia in recent years. Rural communities are expected to be, and usually are, less exploitative and more caring of the local resources and environment.

4. *Conduct research on the carrying capacities of sensitive ecosystems.*

The determination of allowable nutrient loads to the environment is essential in developing scientifically sound guidelines and standards related to licensing aquaculture facilities. Unfortunately, there is scarcely any information on this topic, especially under tropical climates. Accelerated research is necessary to determine the carrying capacity of coastal areas, natural lakes, and man-made reservoirs.

5. *Conduct research and development in the use of the open seas for aquaculture.*

The overstressed coastal ecosystem may be relieved somewhat if more aquatic commodities were produced through searanching or in offshore cages. Both these technologies are extensively studied and used in Japan. However, the cultured species may be different under tropical climates. Technologies from Japan and other developed countries must be adapted and verified in the culture of local species in southeast Asia.

6. *Study the macroeconomic and social feasibility of intensive monoculture systems.*

The profitability of the export-oriented feedlot-type intensive systems is generally easily demonstrated at the farm level, but their benefits may be more dubious at the national level, especially when the macroeconomic costs of resource use and the social costs of displacing traditional users are also considered. Such studies are still rare and this keeps the decision-makers biased in favor of the environmentally problematic intensive systems.

7. *Apply the principles of integrated farming.*

One of the environmental advantages of freshwater fish farming over coastal aquaculture is that the former is easily inserted in the farming systems of small farmers in Asia. This allows sustainable levels of production and develops interdependence of the various elements of the farming system even without direct integration of fish with swine, poultry, or plant crops. A similar indirect integration of fish and shrimp with mollusks and seaweeds would prevent oversteering the coastal environment. Research and development in direct and indirect integration of aquaculture and agriculture must be given high priority.

8. *Improve public relations.*

The mistakes committed in the development of aquaculture and the occasional negative effects of aquaculture on the environment are widely publicized. However, not much is done to inform the general public about the positive aspects of aquaculture or about the environmental damage caused by other sectors, along with aquaculture. Scientists publishing only in scientific journals do not keep the general public sufficiently informed. The relevant information must be disseminated in the language of the common man, through media accessible to the broadest segments of the population.

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# **Coastal Fisheries and Mollusk and Seaweed Culture in Southeast Asia: Integrated Planning and Precautions**

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McManus JW. 1995. Coastal fisheries and mollusk and seaweed culture in Southeast Asia: integrated planning and precautions, pp. 13-22. In: Bagarinao TU, Flores EEC (eds) Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines.

## **Abstract**

Capture fisheries in Southeast Asia are characterized by rampant overfishing, made worse in many areas by problems of overpopulation and by inappropriate management strategies based on misconceptions about tropical fisheries. Mollusk culture and seaweed culture are frequently cited as means to alleviate fishing pressure and to provide substitute protein. There is great potential for expansion of these types of mariculture in terms of area used, species employed, and products generated. However, large-scale mariculture rarely provides significant employment, and the provision of low-cost protein in markets does not alleviate poverty in countries where food production is the primary means of employment. In cases where conflicts have arisen between mariculture development and ecosystem maintenance, mariculture has been favored by inappropriate economic valuations. Small-scale mariculture designed to provide alternative livelihood for fishers is worth developing, although limited by larval supplies and suitable farming areas. Mariculture should be approached as a species-diverse, small-scale enterprise within the framework of integrated coastal management.

## **Introduction**

The increasing awareness of the fact that most capture fisheries in Southeast Asia are overexploited has focused attention on the mariculture of invertebrates and seaweeds to provide alternative protein and incomes. This paper briefly considers the overfishing problem, the prospects for mollusk and seaweed mariculture, the potential benefits of integrated mariculture systems, and the need for caution and proper perspective in planning such enterprises.

## Coastal Marine Fisheries

The analysis and management of tropical fish stocks has traditionally been based on temperate Fishery paradigms. This has led to a history of misconception and faulty advice in the management of Southeast Asian fishery systems (Smith 1981, Pauly in press). A simple, fixed-price bioeconomic model (Gordon 1954; Fig. 1) illustrates the tendency for unemployed people in a relatively open-access fishery to enter the fishery until no substantial profit is left to share. In most temperate, developed countries, the equilibrium based on the actual cost of fishing is rarely approached, because of enforcement of regulations, or because alternative employment and welfare funds allow an effective equilibrium further to the left on the production curve (Smith 1979). However, in countries such as Indonesia and the Philippines (as well as many countries in Africa and the Caribbean), there is a large excess labor force, which is not provided alternative livelihood and not protected by a welfare system. National budget restrictions do not allow full enforcement of regulations and fisheries are left open to access. Thus, fisheries in these countries tend to be overharvested to a greater extreme.

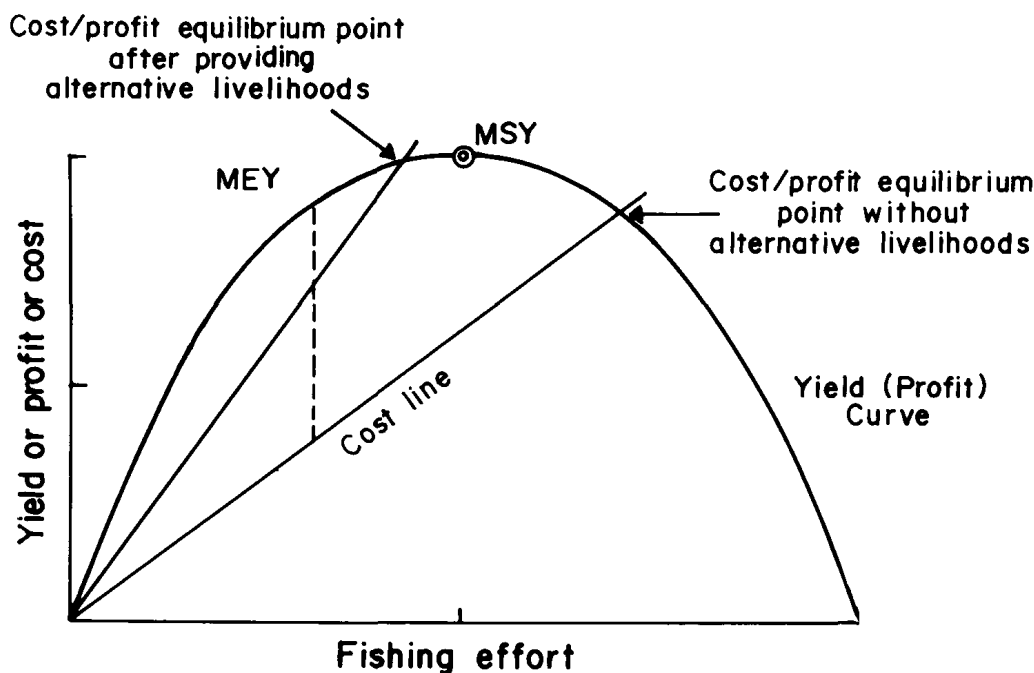


Fig. 1. Fixed-price model for profit and cost in an open-access fishery. In a society with open-access fisheries and an excess labor force willing to work for marginal profits, fishers tend to enter the fishery until virtually no net profit is to be made. MSY (maximum sustainable yield) coincides with the point of maximum gross profit. However, the maximum net profit occurs at the MEY (maximum economic yield), the point at which the difference is greatest between the cost of fishing and the gross profit. MEY is often attainable only after a 60% reduction in the fishery labor force or in the fishing intensity through provision of alternative livelihood. Efforts to lower the cost of fishing, such as providing fishers more efficient gear or low-interest loans, generally only drive the cost-profit equilibrium lower and result in severe depletion of the fishery. After McManus et al. (1992).



When complaints have arisen from fishers about the lack of fish, the typical response of governments, as well as international funding agencies, has been to provide low-interest loans for better gear. This has often been supported by the misconception that there are large, untapped stocks of fish in deep waters. However, unlike temperate seas, most tropical seas have a permanent thermocline that limits biological productivity primarily to upper waters. There are very few fish below 100 meters, and the bulk of the biomass is generally above 40 meters (Fig. 2; Pauly 1987). The improved gears have then merely worsened the overfishing problem in shallow waters. The fact that most such loan programs involved widespread defaulting produced an effective lowering of the cost of fishing and an increase in fishing effort to a new no-profit equilibrium point. Studies have clearly shown that both pelagic and demersal fisheries in the Philippines are overfished (Figs. 3 and 4), and so are those of most of southeast Asia.

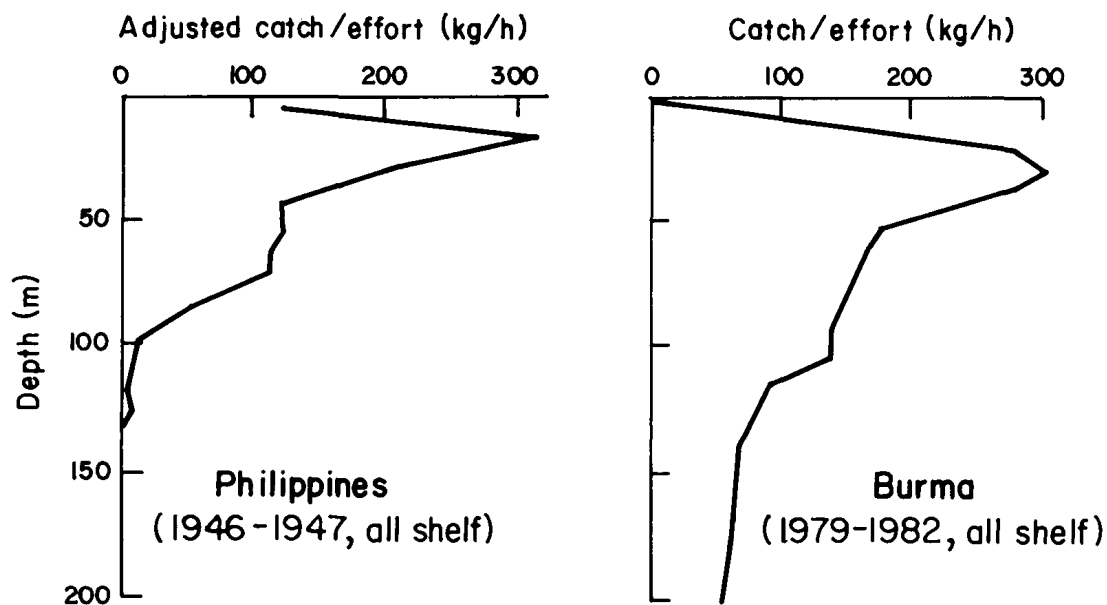


Fig. 2. Variation in abundances of demersal fish with depth prior to major exploitation in the Philippines and Burma. After Pauly (1987).

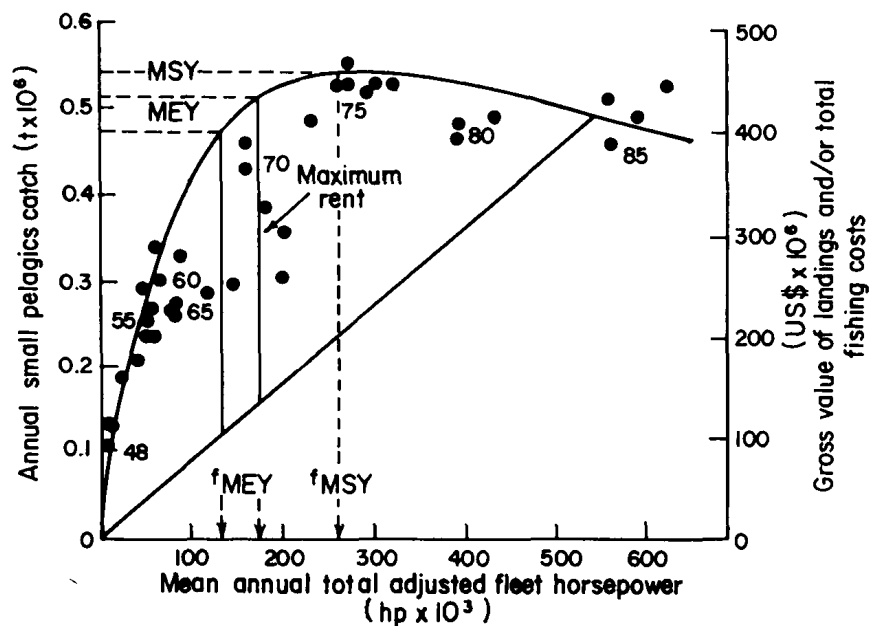


Fig. 3. Fixed-price bioeconomic model of Philippine pelagic fisheries, showing approximate levels of overfishing vs. maximum economic yield ranges. Points are yearly catches; numbers indicate years from 1948 to 1985. From Dalzell et al. (1987).

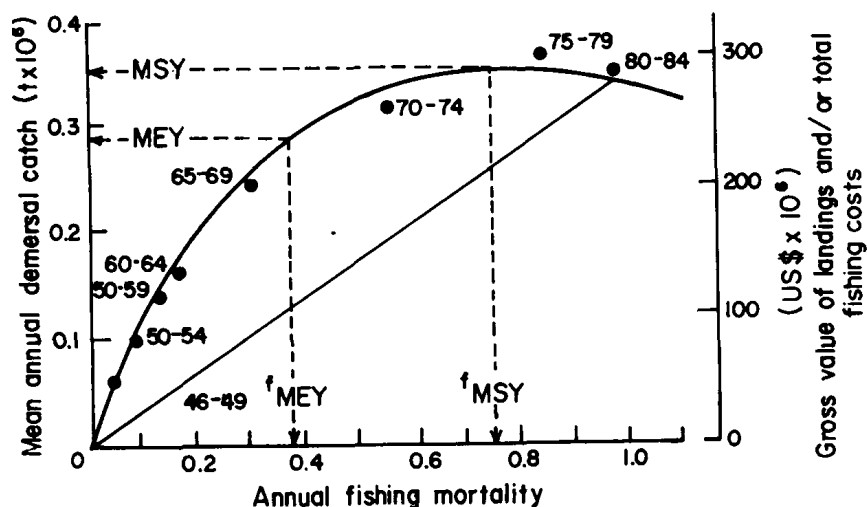


Fig. 4. Fixed-price bioeconomic model of Philippine demersal fisheries, showing approximate levels of overfishing vs. maximum economic yield ranges. Points are mean catches for 5-year periods. From Silvestre G, Pauly D. Estimate of yield and economic rent from Philippine demersal stocks. Paper presented at the IOC-WESTPAC Symposium on Marine Science in the Western Pacific, 1-6 Dec 1986, Townsville, Australia.

The ideal level of fishing is generally believed to be at the point where the vertical distance between the cost and profit lines is maximal, i.e. the point of greatest aggregate profit or maximum economic yield (MEY). A rule-of-thumb approximation indicates that normally, a work force operating at the cost-profit equilibrium should be reduced by about 60% to achieve MEY (McManus 1992). It is reasonable to assume that throughout the Philippines and much of Indonesia, there are more than twice as many fishers as there should be. An appropriate reduction in the work force may not result in an increase in total catches, as can be seen in the small difference between the production levels at the cost-profit equilibrium and at the MEY point in most graphs. However, the catches *per fisher* would roughly double, incomes would increase, and the ecosystem would be harvested at a more benign and presumably more resilient level.

A final misconception pertains to the interpretation of the production curve itself. The so-called Schaefer model on which it is based was originally justified in terms of the population dynamics of a single fish stock in relative isolation from other species both ecologically and in the fishery (Pauly 1979). These assumptions are quite reasonable when dealing with certain temperate fish stocks with little predation on adults and with very specific fisheries, such as for cod. However, most tropical fisheries involve hundreds of fish species with complex interactions captured in diverse groups. The distribution of individuals among species is such that most species are, in fact, uncommon or rare in a given assemblage (McManus 1986). Thus, the optimal fishing effort for the average species in a tropical fishery is likely to be dangerously too intense for many other species. This fact and the habitat modification caused by fishing gears raise concerns about sustainability with respect to biodiversity.

The overfishing situation is compounded greatly by the high population growth and inequitable distribution of resources. These all lead to the state of desperation known as Malthusian overfishing, which fosters the use of habitat- and self-endangering gear such as blasting devices and crude aircompressors for diving and spearfishing. A comprehensive solution must involve a reduction in the human population growth rate. However, some symptomatic relief can be achieved by providing alternative livelihood and reducing the fishing force. One important, though possibly overemphasized means of producing such livelihood is through coastal mariculture.

## Mollusk Culture

There are hundreds of species of edible mollusks in Southeast Asia and several hundreds that are valuable for their shells. However, local abundances, established markets, local food preferences, traditions, and technology currently limit mariculture to a few well-known species:

	Reference
• Mussels <i>Perna viridis</i> and <i>P. indica</i>	Vakily (1989)
• Cockles <i>Anadara granosa</i> and <i>A. antiquata</i>	Broom (1985)
• Pearl oysters <i>Pinctada maxima</i> and <i>P. margaritifera</i>	Gervis & Sims (1992)
• Slipper oyster <i>Crassostrea iredalei</i>	Glude (1984)
• Top shell <i>Trochus niloticus</i>	Heslinga (1981)
• Green snail <i>Turbo marmoratus</i>	Murakoshi et al. (1993)

- Giant clams *Tridacna derasa*. Lucas (1986),  
*T. gigas*, *T. squamosa*, *T. crocea*, John Munro (personal  
*T. maxima* and *Hippopus hippopus* communication)

All these species are edible. Pearl oysters are valuable not only for their pearls, but also for their shells as a source of mother-of-pearl. The shells of green snails and topshells are similarly valuable, the latter being particularly suitable for the production of buttons. The shells of giant clams are widely sold for decorations, and young giant clams are in great demand as aquarium species. Cockles are often used in shellcraft. Some idea of the potential for expansion in the range of species cultured may be found in the study of Guzman (1990) who found 27 species of mollusks gathered from the reef flats in Bolinao, Pangasinan (western Luzon), primarily for the shellcraft industry. Similarly, Amornjaruchit (1988) found 39 species of commercial mollusks and 13 others locally consumed across Thailand.

A major constraint in mollusk culture is the supply and abundance of larvae. Generally, culture is limited to areas with natural spatfalls. Efforts are underway to develop hatchery systems to enhance and disperse production. This includes work to increase the production of pearl oysters, which are valued at over US\$60 million per year for the Indo-Pacific region excluding Australia. Current research on giant clams includes collaborative efforts in the Solomon Islands, Palau, the Philippines, Fiji, Tonga, and the Cook Islands to develop hatchery, rearing, and marketing techniques. This does involve some reintroductions of species to sites where they have become locally extinct from overharvesting. The significance of such reintroductions for local wild populations will be limited, as the original cause of the local extinctions, overharvesting, has not been reduced, and in general will have increased. Efforts to repopulate marine protected areas are the most promising.

All the species listed above can be grown on reef flats. The mussels, cockles, and slipper oysters can also be grown in semi-enclosed or estuarine coastal areas where the currents, tidal range, plankton abundance, and water quality are appropriate.

## Seaweed Culture

Seaweed culture is an attractive source of alternative livelihood for several reasons. Seaweeds are primary producers (low on the food chain), are minimally disruptive of the environment, and provide a rapidly growing list of money-making products. Species that are currently farmed in the Philippines and nearby countries include *Eucheuma denticulatum*, *Kappaphycus alvarezii*, *Caulerpa lentillifera*, *Enteromorpha clathrata*, *E. compressa* and *E. intestinalis* (Liana 1991). Japanese cultivation techniques may be adapted for the local varieties of *Porphyra*. Other species that are widely utilized but not extensively farmed include *Codium edule*, *Sargassum cristaefolium*, *S. granuliferum*, *S. nigrifolium*, *S. polycystum*, *S. siliquosum*, *Gracilaria verrucosa* and *Gelidiella acerosa* (Liana 1991). The total number of economically important seaweeds is about 150, mostly used directly as human food or livestock feed. The farmed species are primarily for the production of phycocolloids, but *Caulerpa* is grown in ponds for direct human consumption.

There are three classes of commercial phycocolloids derived from seaweeds. Carrageenan in lambda, kappa and iota forms depending on gel characteristics, comes from various species of

red algae such as *Eucheuma* (Critchley 1993). Carrageenan is used in a wide variety of foods (ice creams, cakes, gel desserts, beer, macaroni, etc.) and for non-food products such as toothpaste, mineral oils, and paints. Agar is extracted from red algae such as *Gracilaria* and *Gelidiella* and comes in three grades: bacteriological, sugar-reactive and food-grade (Critchley 1993). Alginate comes primarily from brown algae such as *Sargassum* and is used in textiles and food. The uses of carrageenan, agar, and alginate are very diverse and constantly growing more so.

Seaweed culture in Southeast Asia is principally confined to reef flats. The production in most cases involves tying vegetative propagules of algae to lines suspended from wooden or bamboo frames which are either anchored or staked to the bottom. The effects of seaweed culture on the ecology of the reef flat are presumably minimal. However, increases in the abundance of rabbitfish (*Siganus* spp.) have been noted. These herbivorous fishes are a problem for small seaweed farms, but because they are limited by other factors, they do not increase proportionately as farms become larger (Doty 1981). Fishes are only some of the potential pests to be reckoned with. Exposure to storms is another critical factor that severely limits the range of seaweed farm sites.

Seaweed production is generally on the increase. However, both production and price vary widely from year to year depending on import restrictions, investment climates, catastrophes, and bottlenecks in processing plants overseas.

### **Integrated Planning and Precautions**

Mariculture operations are sharply divided between large-scale commercial operations and those involving ownership by truly artisanal operators (Newkirk 1993). Large farms do very little to alleviate the Fishing pressure in the coastal zone. A typical operation involves only a few personnel for a farm of 30 hectares. Most post-harvest processing occurs far from the farm or in distant countries. Most of the income goes to a few investors who most likely spend it outside the local communities. Often, such large farms effectively redistribute local resources from the local coastal people to outsiders and distantly based concerns. At best, large seaweed farms contribute to the growth of the economy at the national level.

Artisanal mariculture specifically channel local resources into local economies. The localized benefit can be greatly enhanced by also localizing the processing of the harvested seaweed. For example, *Sargassum* and other seaweeds can be processed with very little equipment into liquid fertilizer before being sold outside the communities (McManus et al. 1992). The production of semi-refined carrageenan (Liana 1991) might be practical at the local level, whereas that of refined carrageenan is not feasible. Similarly, it is often better to locally produce shellcraft from cockles and giant clams rather than to export the shells for this purpose. Innovative ways that further localize the processing of mariculture products can increasingly provide alternative employment along crowded coastlines.

Artisanal mariculture systems lend themselves to the integration of multiple products in a single farm (Newkirk 1993). Some examples of integration were outlined by Doty (1981), who listed 35 species that could be grown in various combinations on reef flats: arthropods, corals, echinoderms, mollusks, seaweeds, and vertebrates. Given the wide range of mollusks and seaweeds

that are widely used but not currently farmed, some well-focused research could greatly extend the list of organisms that could be grown in integrated mariculture farms.

Mariculture operations that involve habitat destruction are particularly problematic. Often in the past, pond development in mangrove areas has been justified in terms of incomplete or flawed valuations of the mangroves. Dixon (1989) divides mangrove products and benefits into four classes. He showed that marketed products from on-site (wood products, etc.) are usually considered in economic analyses. Marketed products from off-site (e.g., adjacent fish stocks) are sometimes included. Unmarketed benefits on-site (fish nursery, biodiversity) are seldom included, and unmarketed benefits off-site (nutrient support for adjacent ecosystems, storm buffering) are usually ignored.

Resource economists valuating ecosystems have often applied substantial rates of discounting to the future value of the ecosystem. Recently, a large number of economists and ecologists have shown that the assumptions behind such discounting have been flawed and ignore such principles as the increased value of a resource as it becomes scarce, and the responsibility for intergenerational transfer of resources (from parents to the children and grandchildren). These arguments are summarized in the volume *Ecological Economics* (Costanza 1991) and have been further developed in a regular journal of the same title. Recent work underlines the importance of carefully evaluating the potential impacts of any mariculture development on the environment, be it a direct conflict such as deciding between building fishponds or rejuvenating damaged mangrove areas, or more subtle effects such as widespread shading of reef flat areas.

Finally, it is important to maintain a reasonable perspective on the future. The evaluation of mariculture potential extends far beyond the practice of totalling areas of coastal water of a given depth range. Even with the introduction of hatcheries, most mollusk culture will still be restricted to areas with favorable tides and currents. Seaweed culture will be favored only in reef flats protected from excessive waves. All types of mariculture will continue to be severely limited by storm paths. The continued growth of large-scale mariculture will do little to alleviate the excessive fishing pressure on the coastlines of Southeast Asia. The provision of low-cost protein to markets is no solution to the poverty in areas where most of the employment comes from food production. In such a situation, the production of protein with high market value is most helpful. Moreover, mariculture could not in the foreseeable future make up more than a small portion of the total fishery production in Southeast Asia. Thus, mariculture could not be made an excuse for allowing coastal ecosystems and fisheries to decline from improper management. There is reason to be enthusiastic about the future prospects of mariculture, but only when it is viewed as a part of a larger program of coastal and national development.

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# Brackishwater Integrated Farming Systems in Southeast Asia

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## Abstract

Integrated aquaculture-agriculture systems are more common in fresh water than in brackish water. Nevertheless, southeast Asian countries already have considerable research and experience in brackishwater integrated farming systems. In the Philippines, the effects of animal wastes on water quality and production of fish have been studied: chicken wastes on the mixed culture of milkfish *Chanos chanos*, tilapia *Oreochromis niloticus*, and shrimp *Penaeus indicus*; chicken and cattle manures on *P. monodon* and *Artemia*; and swine wastes on tilapia *O. mossambicus*. In Indonesia, about 60 hectares of fish farms have crops (pumpkin, spinach, cassava, maize, and chili) or livestock (cattle, goat, sheep, chicken, and duck) grown on the dikes of milkfish ponds. In Vietnam, culture of the giant prawn *Macrobrachium rosenbergii*, *Scylla serrata* and marine shrimps has been integrated with coastal rice farming. Aquaculture-silviculture is a flourishing venture in Vietnam and Indonesia and gaining ground with experimental sites in Thailand and the Philippines. The seaweed *Gracilaria* has been cultured with fishes and shrimps in Taiwan, Vietnam, Thailand, and the Philippines. The production of *Artemia* cysts and biomass has been integrated with salt-making and fish or shrimp farming in the Philippines and Thailand. Production inputs and outputs from these integrated farming systems vary widely and socioeconomic information is nil. It is imperative to conduct follow-up research and evaluation of each system in terms of production and socioeconomics.

## Introduction

The continuous population growth and demand for food dictate that farm lands be used more efficiently and productively. Integrated farming improves farm productivity and profitability by: (1) growing species that could coexist and share water or land space, (2) growing species that could supply each other's production inputs, and (3) effectively using idle or available land, water,

farm labor, and facilities. Use of land and water resources both for aquaculture and agriculture or forestry is one way to increase farm efficiency, productivity, and profitability.

Freshwater integrated farming systems (FIFS) usually consist of two or three commodities: a fish or crustacean, a plant crop, and one or other species of livestock. There is a great diversity of aquatic species, livestock, crops, and even forest products that can be included in FIFS. Figure 1 shows the sharing of space by fish, crops, and livestock and the flow of materials produced and used in the different components of an integrated farming system. As the number of species in a system increases, so does the technical knowledge that is required. The culture conditions in an integrated system must be modified to allow harmonious coexistence of species and thus satisfy the concept and objective of integration.

Diverse FIFS have been documented in various parts of the world and significant advances have been achieved in many of them (Pullin and Shehadeh 1980, Hopkins and Cruz 1982, de la Cruz et al. 1992, Haller and Baer 1992, Jeney 1992, Lin and Lee 1992, Mukherjee et al. 1992). The greatest scope for further development of integrated crop-livestock-fish farming is in the humid tropics and this is also where the need is greatest (Edwards et al. 1988). A technology information kit on farmer-proven integrated agriculture-aquaculture has been put together by IIRR-ICLARM (1992) for extension purposes.

The integrated aquaculture-agriculture systems in freshwater environments can also be developed in brackish water especially in Southeast Asia, which has more than 781,892 hectares of brackish water ponds: 276,442 in Indonesia, 222,907 in the Philippines, 189,000 in Vietnam, and 72,796 in Thailand (see country papers, this volume), 18,665 in Taiwan, 1,975 in Hongkong, and 107 in Singapore (de la Cruz 1983). In addition to existing ponds, Southeast Asia has considerable areas of brackishwater ricefields and tidal flats that could be tapped for integrated aquaculture, agriculture, and forestry.

Brackishwater integrated farming systems (BIFS) could be a mix of crops thriving concurrently or alternately in brackish water and fresh water, in brackish water throughout, or in marine to brackish waters. BIFS could be of three types: (1) aquaculture-agriculture, (2) aquaculture-silviculture, and (3) brackishwater and marine polyculture.

This paper reviews the status of BIFS in Southeast Asia and includes similar research done elsewhere in Asia for the lessons they provide. Only Indonesia, the Philippines, Thailand, and Vietnam have had experience or at least research in both integrated aquaculture-agriculture and aquaculture-silviculture. Taiwan has pioneered in integrating marine seaweeds, particularly *Gracilaria* sp., with fishes or shrimps in brackishwater ponds.

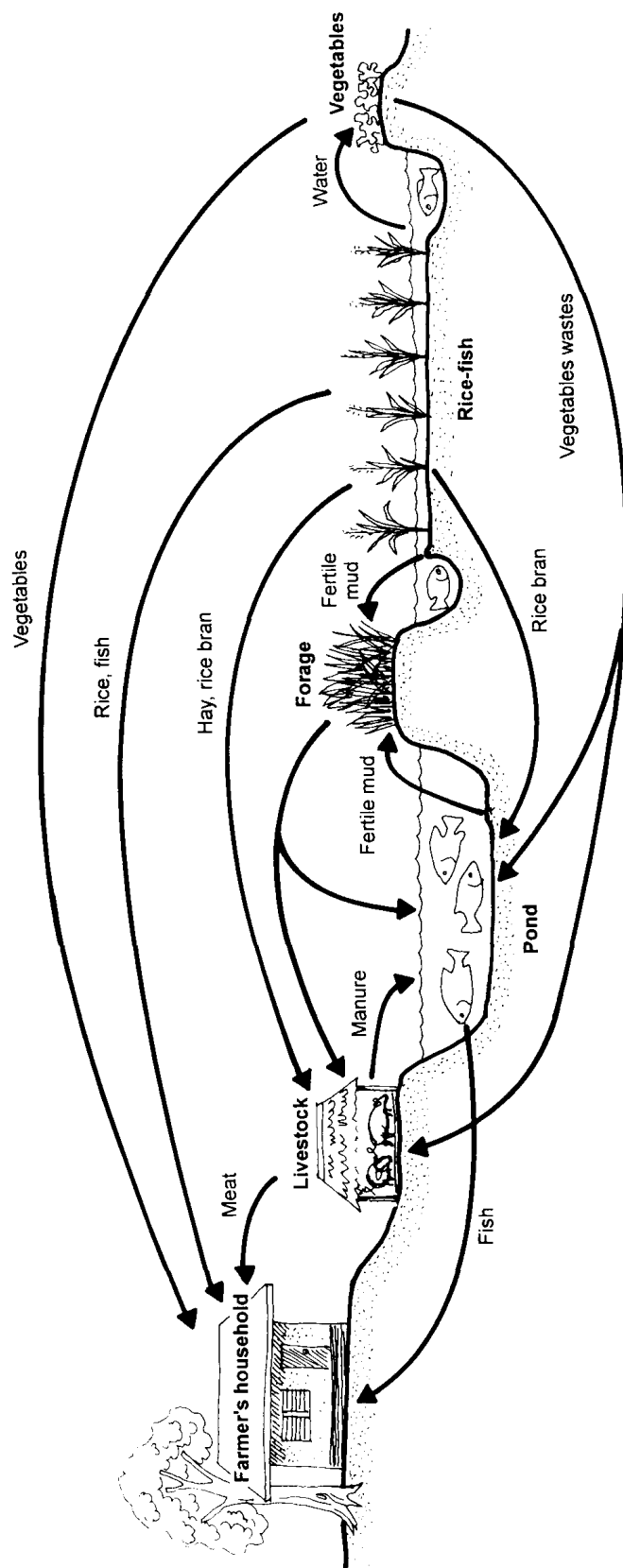


Fig. 1. Integrated farming of plant crops, livestock, and fish. Arrows show flow of materials (inputs and outputs).

## Brackishwater Aquaculture with Agriculture

### Tilapia with swine

Tamse et al. (1985) studied the use of piggery waste effluents (from biogas digesters) in fish ponds. They determined the duration of fermentation necessary to produce a nutrient-rich slurry. The highest nutrient levels were observed on the 14th to 17th week of fermentation at temperatures of 25-30°C. The levels in mg/l were: total phosphorus 1,100-1,300; available phosphorus 17.2-21.9; total nitrogen 3.9-5.2; and dry matter 9.2-13.2.

The optimum dose and frequency of application of slurry for the production of all-male tilapia *Oreochromis mossambicus* was determined in twenty 40-m<sup>2</sup> ponds (Tamse et al. 1985). Production of tilapia significantly increased to 545 kg/ha when slurry was applied 5x a week, and to 469 kg/ha when slurry was applied 2x a week. Ponds that received slurry once a week had net production of 316 kg/ha and those without slurry had 372 kg/ha.

### White shrimps, milkfish, and Nile tilapia with poultry

Pudadera et al. (1986) evaluated the feasibility and profitability of integrating broiler chicken with shrimp and fish in 1,000-m<sup>2</sup> ponds. Broiler chickens (180/pond) were housed in the middle of the ponds for one culture period and these supplied manure to a mixed culture of Nile tilapia *Oreochromis niloticus*, white shrimp *Penaeus indicus*, and milkfish *Chanos chanos*. Tested for production were combinations of 50,000 white shrimp, 2,000 milkfish, and either 5 000, 10 000, 15 000, or 20 000 tilapia per hectare. Net production after a 120-day culture period were: tilapia 337-670 kg/ha, shrimp 192-284 kg/ha, milkfish 75-117 kg/ha, and broiler chickens 1,810-2,170 kg/ha. The highest tilapia production (670 kg/ha) was obtained at the stocking rate of 15,000/ha. However, it was at this stocking density that yields were lowest for shrimp (192 kg/ha) and milkfish (75 kg/ha). Thus the total productions (680-936 kg/ha) were not significantly different among the treatments.

The highest net earnings were obtained at the tilapia stocking density of 15,000/ha. The lowest earnings were obtained at 20,000/ha due to higher inputs of juveniles but lower net production and smaller harvest size. The economic analysis indicated a 16% return on investment for the integration of 1 800 broiler chicken, 50 000 white shrimps, 2 000 milkfish, and 10 000-15 000 tilapia per hectare.

### Tiger shrimps with cattle, poultry, and brine shrimp

Ogburn et al. (1986) studied the integrated production of cattle and poultry with the tiger shrimp *Penaeus monodon*. Various ways of manuring were tried in developing the system. One way was to add manure during pond preparation and shrimp grow-out. Another way was to wash manure from a cattle-fattening shed into shrimp ponds. A third way was to apply liquid manure to 'kitchen ponds' where natural food (the brine shrimp *Artemia* and the cyanobacterial mat 'lablab') could be grown.

Organic manure applied during pond preparation (prior to stocking) stimulated the growth of 'lablab'. However, pond water quality deteriorated towards the end of the culture period.

Plankton analysis showed excessive blooms of nanno- and picoplankton that were not utilized by the shrimps.

The kitchen pond produced 40 kg/day of *Artemia* and 'lablab' through the daily addition of manure (dry weight 100 kg/ha) during a three-month period. An area ratio of 1 kitchen pond to 5 shrimp ponds resulted in shrimp production of 200-400 kg/ha-crop. A combination of 'lablab' and medium-quality feed pellets increased production to 700-1,000 kg/ha-crop, where stocking density was 30,000/ha and survival was 60-70% after 130 days. Feed costs were significantly reduced. The advantages of using an *Artemia*-lablab' kitchen pond were discussed by Ogburn et al. (1986).

### **Milkfish with chili, maize, cassava, spinach, and pumpkin**

Integrated farming in brackishwater farms is being encouraged as a way to improve farmers' income in Indonesia, where the average farms are small: 1.42 hectares in Central Java, 2.41 hectares in West Java, and 3.62 hectares in East Java (Manik and Tiensongrusmee 1979). A study was conducted in Pati District, Central Java where about 60 hectares of ponds were operated under two integrated systems: fish with agricultural crops and fish with livestock.

Due to rains, old pond dikes have reduced salinity. In Bakalan Village, the salt content of dikes is below 1 ppt and it is possible to grow agricultural crops. The dikes of most ponds are wide and suitable for growing farm crops such as chili *Capsicum annum*, pumpkin *Legenaria leucantha*, spinach *Amaranthus* spp., cassava *Manihot utilissima*, and maize *Zea mays*. These crops are grown in November-April. Among these crops, chili commands a good price and provides high returns to the farmers. A two-hectare pond in the Pati District could provide net returns of about Rp 310,000 (US\$1 = Rp 625) from milkfish culture and one crop of chili a year. The returns may be further increased to Rp 1,940,500 per year with a system that combines shrimps, milkfish, and two crops of chili a year (Manik and Tiensongrusmee 1979).

### **Milkfish and shrimp with sheep**

Sheep, goats, and chicken are also raised with fish in Pati, Central Java. In Langenhardjo village, a farmer operating a 4-hectare fish-sheep farm (out of his 15-hectare fish farm) was able to increase his sheep stock from seven females and one male in 1975 to 75 sheep in 1979. About 40 male sheep could be sold each year and the remaining herd could provide about 100 kg of manure each month for the ponds. The net returns from an integrated system with milkfish, shrimp, and sheep was about Rp 395,625/ha-year (Manik and Tiensongrusmee 1979).

### **Fish, prawns, and shrimps with rice**

Various combinations of coastal rice with shrimps and fishes have been reported from Vietnam with the corresponding farming schedules. The Mekong Delta has about 2,000,000 hectares of ricefields, 41% of the total ricefield area in the country. The freshwater prawn *Macrobrachium rosenbergii* and other shrimps and fishes are produced in ricefield aquaculture systems, rivers, canals, and brackishwater areas in the Mekong Delta (Mai et al. 1992, Lin and Lee 1992).

Three types of integrated farming systems dominate in the Mekong Delta (Mai et al. 1992). One is year-round rice with freshwater prawn or fish, e.g., in Thanh Loc in Thot Not District and Cai Con and Mang Ca in Phung Hiep District. Another is year-round rice with brackishwater shrimp or fish, e.g., in Giong Co in My Xuyen District. A third system is rice rotated about every six months with shrimp or fish, e.g., in Long Thoi Commune, Nha Be and Duyen Hai Districts. Examples of integrated cropping patterns and yields are shown in Table 1, and an example production calendar in Figure 2.

Table 1. Cropping patterns and production of rice with shrimp or fish in Vietnam during the wet and the dry seasons. Modified from Mai et al. (1992).

Cropping patterns	Rice yield (t/ha)		Shrimp & fish yield	
	wet	dry	wet	dry
WSR-fallow	2.4			
(WSR+F+S)-(F+S)	2.4		S 2-2.5 kg/day, F 15 kg/day	S 2.5-3 kg/day
WSR-DSR	5.2	5.7		
(WSR+S)-(DSR+S)	5.2	5.7	S 187 kg/ha	
(WSR+F+S)-(DSR+F+S)	5.2	5.7	F 214 kg/ha	
WSR-DSR	3.9	4.0		
WSR-TR	3.9	3.5 TR		
(WSR+S)-(TR+S)	3.9	3.5 TR	S 79 kg/ha	
(WSR+S)-(DSR+S)	3.9	4.0	S 48 kg/ha	

DSR dry season rice; WSR wet season rice; TR traditional rice; F fish; S shrimp

In the third system, rice is grown during the wet season when freshwater is available and shrimp or fish is cultured when the rice paddies turn brackishwater (Le 1992). When salinity remains lower than 10 ppt in the dry season, farmers can raise a second crop of *Macrobrachium* without rice. Where salinity is 10 ppt or higher, marine shrimps (Penaeidae) migrate into tidal flats at spring tides. Farmers use fallow ricefields to trap and grow shrimps. Data collected from 55 rice-prawn farms in Duyen Hai District indicated that 55% had yields of 100-300 kg/ha-crop and 23% had yields of more than 300 kg/ha-crop (Le 1992). Farmers with prawn yields lower than 100 kg/ha had net benefits less than US\$400/ha-crop. Yields of more than 300 kg/ha netted higher than \$1,000/ha-crop (Le 1992).

### Mudcrabs with rice

Fanners in Vietnam also collect juveniles of the mudcrab *Scylla serrata* and stock them in fallow ricefields or backyard ponds 300-500 m<sup>2</sup> in size (Le 1992). There are two systems: molting-crab culture and crab fattening. In molting-crab culture, four pairs of walking legs are removed from small crabs less than 100 grams. Crabs molt 13-25 days after leg removal. The

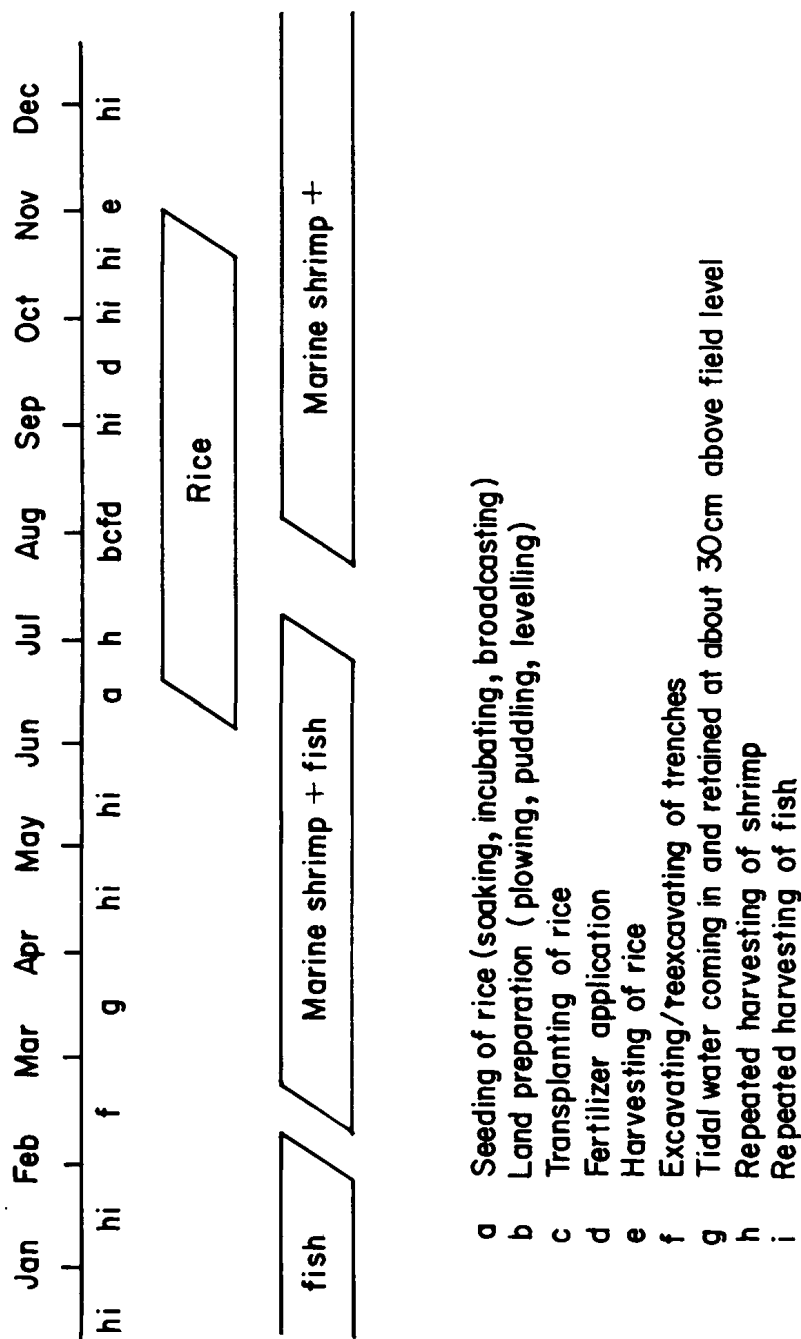


Fig. 2. Fanning calendar for rice and shrimp or fish farming in Giong Co Hamlet, Tham Don Village, My Xuyen District, Hau Giang Province, Vietnam. From Mai et al. (1992).

appropriate salinity range is 8-25 ppt so farmers engage in molting-crab culture in the dry season. In crab fattening, large but thin crabs >100 grams are fed well in earthen ponds fenced with nipa fronds or bamboo. Farmers engage in crab fattening mainly from August to November.

Fanners can get 50-70 kg of soft-shelled crabs from 100 kg of hard-shelled crabs in 300-500 m<sup>2</sup> ponds. Net income from soft-shelled crabs can reach US\$50-70/month, 5-10x that from hard-shelled crabs. From fattened crabs in a 300-m<sup>2</sup> pond, the net income is \$100-150/month, 3x more than for thin crabs. More information about mudcrab culture is given by Le (1992).

### **Shrimps with rice: the 'pokkali' and 'bhasabadha' systems**

Ghosh (1992) reported on integrated culture of coastal rice with marine shrimps and fish in West Bengal, Kerala, Goa and Karnataka in India. During the monsoon, coastal rain-fed fields are planted with rice; during the summer months when salt content is high, the fields are used for fish farming. The 'pokkali' system involves the trapping of shrimps such as *Metapenaeus dobsonii*, *M. monoceros*, *Penaeus monodon*, *P. indicus*, *P. semisulcatus* from the tidal water that entered the ricefields. Lately, the system has been modified to include selective stocking of desired shrimp species.

The ricefields are desalinated after the shrimp crop in time for the rice crop. The 'pokkali' plots have crisscross trenches to quickly drain the runoff water and wash away the surface salts from the shrimp culture phase. The topsoil is scraped to better remove the salts and is then heaped away from the plots. After these heaps have been washed by the rain, the desalinated soil is again spread over the rice plots. With the 'pokkali' system, production amounts to 785-2,135 kg/ha-year (80% shrimps), whereas traditional plots normally produce 500-600 kg/ha-year of aquatic crops (Ghosh 1992).

A slightly different farming system, the improved 'bhasabadha', involves selective stocking of fishes (tilapia, mullets, and others) and marine shrimps. Production from the 'bhasabadha' system could be 600-1,000 kg/ha-year. The return on capital investment could be 29% in the traditional 'pokkali' and 56% in the improved 'bhasabadha' systems (Ghosh 1992).

### **Tilapia with alfalfa**

In Kuwait, fresh water is a very precious commodity used solely for household consumption and brackish water is used for limited agriculture. Some farmers are currently engaged in a pilot BIFS using alfalfa *Medicago sativa* with tilapia *Oreochromis spilurus* (EM Cruz, personal communication). The system involves flow-through of brackish irrigation water (7-12 ppt) into concrete or fiberglass tanks (10-50 m<sup>3</sup>) with tilapia. From the fish tanks, nutrient-enriched water is then released to fields (5-10 hectares) of alfalfa used as forage for sheep and cattle.

## **Aqua-silviculture: Fishes and Shrimps with Mangroves**

Marginal coastal sites such as denuded and overexploited mangrove areas and unproductive or abandoned fishponds can be made productive and economically profitable through the integration of aquaculture with silviculture, the harmonious co-existence of fishery species and mangrove trees in a semi-enclosed system. This integrated multi-use system mimics the natural mangrove forests



and swamps that protect the coasts, maintain ecosystem integrity, and provide various goods. Aqua-silviculture may help solve the conflicting interests between the coastal fishery and forestry sectors and can provide both ecological and economic stability (Beukeboom et al. 1993).

Aqua-silviculture is in its early stage of development. The layout or design of this farming system varies in different places. The system usually consists of 1/4 pond area for shrimps or fishes and 3/4 forestry area for planted trees. The ponds are deeper than the planted area. Water is controlled such that both the ponds and the trees are inundated. During the first 3-5 years, the planted trees are in the seedling or sapling stage and the ponds can be used for fish production. In the next 5-10 years, the mangrove saplings (2-10 cm in diameter) and trees (>10 cm in diameter, 5 meters high) limit light penetration into the water and the production of natural food. The trees may be thinned or pruned and the wood used as fuel, posts or low-cost housing materials, and the leaves as forage for livestock.

### **Vietnam**

The shrimp-mangrove integrated system in Vietnam is the most developed in southeast Asia (MJ Phillips, personal communication). The very southern part of the Mekong Delta lost large areas of mangroves during the Vietnam War (1966-1975). In Ngoc Hien District in Minh Hai Province, about 44,918 hectares were destroyed and 24,700 hectares of these were replanted with *Rhizophora* (Le 1994). There are now several thousand hectares of shrimp-mangrove integrated farms operated by the local government and allocated to farmers as the so called 'State Forestry-Fisheries Enterprises.' Each household receives 5-10 hectares of land, of which 70-80% is meant for *Rhizophora* planted at 20,000 trees per hectare and 20-30% is for shrimp farming, canals and dikes (Ngo 1993, Nguyen 1993). Annual production of shrimp is about 250 kg/ha during the first two years, then declines to 100-170 kg/ha after the fifth year of production. The decline is due to limited light penetration due to the dense canopy and poor water quality due to decaying leaves. The loss in shrimp revenues is compensated by income derived from thinning and harvesting of trees.

The economic returns from shrimp-mangrove systems in Vietnam have recently been surveyed. The systems are extensive as far as shrimp is concerned but those with 40-60% mangrove cover are the most economically efficient in terms of shrimp yields (MJ Phillips, personal communication). If the revenues from timber and secondary forest products are added, a higher percentage of the mangroves within the pond area may be justified. The shrimp-mangrove system has been widely accepted by fisher-farmers, who are looking into various ways to increase yields. Aqua-silviculture has reduced the disorderly clearing of mangroves for shrimp production, restored some of the destroyed mangroves, and created new job opportunities (Nguyen 1993).

### **Indonesia**

Aqua-silviculture began with 15-hectare and 25-hectare pilot projects in 1986-1987 in Ciasem Pamanukan and Cikiong Sub-Forest Districts (Sastroamidjojo 1993). Since 1990, the system has spread throughout West Java, where each family is allocated 5 hectares, of which 80% is for mangrove forests and 20% for ponds. The ponds are generally the traditional kind and the species cultured are milkfish, tilapia, and assorted shrimps. There are about 25,000 hectares of mangrove forests with traditional ponds yielding 30,200 tons of fish each year and providing

livelihood to at least 5,000 families. Improved aqua-silviculture designs or models are presently under experiment (Sastroamidjojo 1993).

### Thailand

About 173 hectares of mangrove forest in Kung Krabaen Bay were distributed to 104 families. Of the 1.6 hectares given to each family, 1 hectare was for shrimp pond, 0.5 hectare was for mangrove trees, red tilapia, grouper, and a settling pond, and the rest for ditches and dikes (Chantanee 1993). Benefits came in the form of more mangrove trees planted, entrapment of sediments and organic matter, and improved incomes (about 5x greater). Farmers' production of shrimps averaged 3,762 kg/ha valued at Baht 247,000/year per family (Chantanee 1993; US\$1= Baht 25).

### Philippines

There are about ten aqua-silviculture sites in the provinces of Quezon, Oriental Mindoro, Negros Occidental, Bohol, Cagayan, and Guimaras (SR Bacongus, personal communication). Milkfish is the main species stocked. Other species cultured are shrimps, crabs, tilapia, and siganids. A newly established site in Oriental Mindoro grows mixed species in ponds with natural seeding. The trees planted are *Rhizophora* spp., *Avicennia* spp., and *Nypa fruticans*.

Aqua-silviculture in the Philippines has shown varying degrees of success, ranging from poor to good harvest of shrimps and fishes, up to 3.24 t/ha of milkfish and 3.17 t/ha of tilapia per year (SR Bacongus, personal communication). Poor harvests were due to poaching, typhoons, and lack of skill in pond management

## Brackishwater-Marine Aquaculture Systems

### *Gracilaria* with fish or shrimps in ponds

Extensive cultivation of *Gracilaria verrucosa*, *G. gigas*, and *G. lichenoides* is done in brackishwater ponds in southern Taiwan. About 5,000-6,000 kg of the seaweed are seeded per hectare of pond, at the bottom 50-80 cm deep (Chiang 1981). Pond water is maintained 30-40 cm deep most of the time, but is reduced to 20-30 cm when water temperature falls below 10°C and increased to 50-60 cm at >32°C. Frequent exchange of water is necessary to maintain the salinity at 10-20 ppt and to provide nutrients for the seaweed. When needed, urea is applied at 3 kg/ha or fermented pig or chicken manure is used at 120-180 kg/ha. The seaweed is harvested every 30-35 days; annual yield (dry) is about 16-43 tons/ha (Chiang 1981). Milkfish stocked at 1,000/ha increase production and also control the competitors of *Gracilaria* — the green algae *Enteromorpha* and *Chaetomorpha* (Lin et al. 1979, Chiang 1981). Milkfish will consume *Gracilaria* when the other algae are gone, so the large juveniles must be harvested and small ones stocked anew (Chiang 1981).

Tiger shrimp at 10,000-20,000/ha or mudcrab at 5,000-10,000/ha can be stocked with seaweed for additional income (Gomez 1981). *Gracilaria* species have been grown successfully with tiger shrimp, mudcrab, and milkfish in brackishwater ponds in the Philippines, Thailand, India, China, and elsewhere (Gomez and Azanza-Corrales 1988). In Thailand, fish farmers harvest

the *Gracilaria* that grows on the polyethylene net and bottom of cages stocked with the seabass *Lates calcarifer*. Total yearly production of seaweed and fish is 50-100 kg per 10 m<sup>2</sup> cage (Tachanavarong 1988). *Gracilaria* culture has been carried out in shrimp pond effluents (Chandrkrachang et al. 1991).

In China, an experiment on mixed culture of *Gracilaria tenuistipitata* and *Penaeus monodon* was conducted to develop new methods to prevent shrimp diseases (He et al. 1990). *Gracilaria* absorbs the abundant ammonia in shrimp ponds. Through photosynthesis, abundant oxygen is produced, oxidation of organic matter is accelerated, ammonia and hydrogen sulfide are reduced, and water quality is improved. The stress factors are reduced, and so are the levels of fungi, parasites, and pathogens. Polyculture of shrimp with *Gracilaria* increased shrimp production by 76% (He et al. 1990).

### ***Artemia* and salt with fish or shrimp**

The integration of fish, shrimp, *Artemia*, and salt is now a well established venture in Thailand. Annual per hectare production is about 23 kg wet *Artemia* cysts, 8 300 kg wet *Artemia* biomass, 62 tons salt, and 1 125 kg fish and shrimp (Tarnchalanukit and Wongrat 1985).

In the Philippines, several experiments on the culture of *Artemia* in salt ponds have proven it feasible (Santos et al. 1980, Jumalon et al. 1986). The monthly per hectare production from these trials were 7.45-20 kg dry *Artemia* cysts and 2-7 tons wet *Artemia* biomass, and 100 tons salt (Jumalon et al. 1986, 1987). Salt and *Artemia* are produced during the dry season in ponds with salinities higher than 90 ppt; fish or shrimps are produced during the wet season in ponds with much lower salinities.

## **Discussion**

The review revealed that BIFS in southeast Asia are a fertile area for research and development. In Indonesia, the integrated system is aquaculture-based and additional income accrues from farm crops. In Vietnam, the integrated system is agriculture-based and additional income comes from fish crops. Integrated agriculture-aquaculture and aqua-silviculture have had visible impact in Vietnam and Indonesia. The systems developed in Vietnam seem to be promising, expanding rapidly, and socially acceptable to farm households. Indications are positive that the potential of ricefield aquaculture and aqua-silviculture systems are being realized in Vietnam. The extent of development or adoption of integrated agriculture-aquaculture in Indonesia, however, is not clear as follow-up reports are not available.

The scale of operation or size of the fish farm is an important consideration in establishing an integrated system. A fully integrated farm usually involves huge operation and capitalization and as such is not feasible for small farmers. For BIFS to be appropriate and sustainable technologies, the research, development, and dissemination of BIFS should focus on small-scale coastal fish farms, more or less adapting the Indonesian experience. In inland areas that are predominantly agriculture-based, there is much to learn from the Vietnamese and Indian experiences.

The studies done so far on BIFS in the Philippines are still experimental. Concerted follow-up research should focus on improving production efficiency. Research must determine optimal pond design and water management schemes, ascertain the quantity and quality of manure in relation to the potential production of selected aquatic species cultured with agricultural crops or livestock, and find ways to reduce pollutants (e.g., non-use of pesticides and pre-treatment of manure before use in ponds).

In aqua-silviculture, more research is needed on the proper spacing, density of trees, felling of trees, water level regulation, and other variables and techniques. Productive and compatible aqua-silviculture models must be developed, taking into account pond engineering and management, the appropriate species to be cultured, and the socioeconomic characteristics of coastal communities.

The polyculture systems in brackishwater and marine environments can be improved. Screening of more marine species for culture in brackishwater should continue. For example, in China and Korea, seaweeds are integrated with mollusks and sea cucumbers; in Japan, seaweeds are grown with fish in cages (MJ Phillips, personal communication).

BIFS could still be developed in both theory and practice. Experiences and research done on BIFS must be collated to assess the state of the art and identify the necessary research to facilitate its further development. Along with the technology generation and development of BIFS, socioeconomic studies must also be made. Socioeconomics data help identify the location and the conditions under which a given BIFS would prove viable.

The increase in human population and thus the demand for freshwater necessitate the use of other types of water for food production. Southeast Asia is fortunate in that freshwater is still available for agriculture and aquaculture. Nevertheless, there are localized or seasonal shortages of freshwater throughout the region. In the Gulf countries, Kuwait for example, freshwater is so valuable that it is purely for household use. In southeast Asia, we must now start to integrate agriculture and brackishwater aquaculture to conserve freshwater and improve the livelihood and income of coastal communities.

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# **Shrimp Culture and the Environment**

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## **Abstract**

This paper reviews the interactions between shrimp culture and the natural environment. It considers and gives details of the effects of shrimp culture on the environment and the effects of environmental change on shrimp culture. Examples are given where the environmental impacts on and of shrimp culture have caused serious economic losses to shrimp farmers. The paper concludes that economic sustainability is and will continue to be closely related to how the shrimp farming industry deals with environmental problems. Strategies are considered for improved environmental management of shrimp aquaculture, and priorities are highlighted for future research on the relations between shrimp culture and the environment.

## **Introduction**

Shrimp culture has been one of the major growth areas in worldwide aquaculture over the past decade, with 80% of production coming from the eastern hemisphere, mainly Asia. However, aquaculture production of shrimps in 1993 was only 609,000 tons, 16% less than in 1992 (Anonymous 1993). The reasons for the decline include a major collapse in China (from 140,000 tons in 1992 to 50,000 tons in 1993), a decrease in Indonesian production from 130,000 to 80,000 tons, and a further slight decline in Taiwan from 30,000 to 25,000 tons.

The development of shrimp farming industries in many countries has been accompanied by sporadic growth, local collapses of the industry, and sometimes abandonment of shrimp ponds. Such problems, widely attributed to disease outbreaks linked to environmental deterioration, have raised major questions about the sustainability of shrimp farming. Thus, although shrimp aquaculture has contributed to rural employment and economic development in the Asia-Pacific, concerns have grown over the sustainability of the industry.

There have been several reviews on the relations between shrimp culture and the environment (e.g., Macintosh and Phillips 1992, Primavera 1993). The present paper provides an overview of shrimp culture and the environment based on the literature, a major recent assessment of environmental problems in Asian aquaculture (FAO-NACA 1994), and more detailed studies

carried out recently in Thailand (Office of Environmental Policy and Planning 1994, Marsden 1994).

Shrimp culture, like other aquaculture and agriculture enterprises, requires natural resources. Such enterprises may bring large profits, but if badly planned and managed, may cause irreversible environmental damage, lost opportunities, and rehabilitation costs that can easily lead to net economic loss (Odum and Arding 1991). The principal natural resources required for shrimp culture are land, water, and biological resources, including seed and feed. The available resources and the manner in which they are used determine in large part the economic success and sustainability of shrimp farming. The major issues related to these resources are discussed below.

### **Land Requirements**

Shrimps are cultured almost entirely in land-based ponds. The area of land required depends on the culture system, although farmer decisions are modified by the availability and price of land. Traditional extensive culture systems occupy large land areas, with ponds often 2-20 hectares, sometimes even 200 hectares. Semi-intensive and intensive culture systems tend to be in smaller ponds, although the total farm area can be large.

The price of coastal land depends on the availability and competition with other coastal 'users' and also affects which areas are used. Land price also stimulates investor decisions to enter shrimp culture, and plays a role in intensification. Limited coastal land and higher land prices such as in Taiwan (Liao 1990, 1992) stimulates development of more intensive shrimp culture systems to get greater economic returns per unit area. In countries such as Indonesia and Vietnam, with cheaper and more abundant coastal land, semi-intensive and extensive systems predominate. The cost of coastal land forces shrimp farm investors to maximize profits per unit area, usually leading to more environmental problems. Shrimp farming itself can also have a dramatic effect on the price of coastal land. In the Upper Gulf of Thailand, land prices increased from US\$2,500 per hectare in 1985 to \$25,000 per hectare in 1989 (Macintosh and Phillips 1992).

The type of land used for shrimp farming affects the success of shrimp farming itself and the kinds of environmental impacts and conflicts with other coastal resource users. Shrimp farms have been constructed on a variety of coastal lands, including salt pans, agricultural lands, abandoned and marginal lands, and wetlands, including ecologically important mangroves and marshes. The traditional preference for low-lying coastal wetlands has changed to an industry preference for supra-tidal land where ponds are cheaper to construct and drain and the soils are normally better.

Land use for shrimp culture varies considerably and it is not possible to generalize. For example, in Thailand, land use for shrimp culture varies from province to province. Earlier studies in the Upper Gulf of Thailand showed that only 21% of new shrimp ponds were converted from mangroves (Csavas 1990). A recent study in the south of Thailand showed that only 14% of shrimp farms were in mangrove areas and 49% were converted from rice fields (Table 1).



Table 1. Land use prior to construction of intensive shrimp ponds in the southern provinces of Thailand (S Piamsomboon, personal communication).

Land use	% of farms
Rice fields	49.0
Orchards	27.5
Extensive shrimp ponds	3.9
Mangrove forests	13.7
'Unproductive' or 'unclassified' land	5.9

Productive agricultural lands have been converted into shrimp ponds in several countries (Mahmood 1987), although in many instances the use of marginal or unproductive land for shrimp culture makes more economic sense. Conversion of land to shrimp farming has been reported to lead to adverse ecological impacts or conflicts with other users (e.g., Primavera 1992). Conflicts arise when impacts spread beyond the confines of the shrimp farm, such as in the Philippines, where use of freshwater from underground aquifers has resulted in subsidence of coastal land (Primavera 1989). Subsidence around the Pingtung coastal area in Taiwan in 1970-83 was 0.3-2 meters, mainly due to groundwater extraction for shrimp and eel ponds (Chiang and Lee 1986). Not surprisingly, this led to very significant conflicts between shrimp and fish farmers and other coastal inhabitants.

Salination of soils as a result of shrimp farming further devaluates already marginal agricultural land. A remote sensing study in two provinces in southern Thailand showed that 3,344 hectares of shrimp ponds had led to salination of 1,168 hectares of agricultural land, mostly rice fields (Office of Environmental Policy and Planning 1994).

The short-term profits possible with shrimp farming result in very rapid changes in land use and new entrants create pressure to construct ponds on lands only marginally suitable for shrimp farming. In some places, the existing infrastructures (particularly water supply systems such as canals) are inadequate to support the quickly developing industry. In the Upper Gulf of Thailand during the 1980s, many intensive shrimp ponds were built on old extensive shrimp farms or salt pans. Although this was probably a good use of available resources, these old pond sites rarely had the water supply to cope with the higher water demand of more intensive culture. The effect of this can be seen in Samut Songkhram, Samut Prakan, and Samut Sakhon where the shrimp industry has declined since 1989 due to overproduction, water pollution, and the inadequate water supply from the *klongs* or canals (Macintosh and Phillips 1992).

### Mangroves and Shrimp Culture

Mangrove forests occur throughout the tropics and in some subtropical areas on sheltered shores with soft intertidal sediments (Macintosh 1982). The impact of shrimp culture on mangroves has received considerable attention, both in the scientific and popular press (Primavera 1991). Although it is true that expansion of shrimp culture has led to destruction of mangroves, shrimp culture is just one of many coastal activities leading to the loss of the region's mangroves

(FAO-NACA 1994) and yet is often unfairly blamed. Csavas (1990, personal communication) has also pointed out that much recent semi-intensive and intensive shrimp culture has occurred in non-mangrove areas, or in mangrove areas earlier cleared for extensive shrimp or fish culture, or other purposes. In China (the major shrimp producer in 1991), shrimp ponds are mostly in non-mangrove areas.

In Malaysia, shrimp farms have encroached onto mangrove reserves (Chua et al. 1989b). In Indonesia, most of the estimated 200,000 hectares of shrimp ponds have been converted from former mangrove forests. The total pond area is just 5% of the massive Indonesian mangrove resource of 4,251,011 hectares, but construction of ponds for shrimp and milkfish culture has contributed to very significant local denudation in Java, Sulawesi and Sumatra (FAO-NACA 1994). In the Philippines, a combination of shrimp and milkfish culture is responsible for reducing the mangrove area from 448,000 hectares in 1968 to 110,000 hectares in 1988, with 60% of this decrease thought to be due to conversion to milkfish ponds (Primavera 1991, 1993). The Philippine Fisheries Code promulgated in 1975 slowed down the conversion but shrimp culture during the 1980s removed an additional 30,000 hectares for new ponds.

In Thailand, 38.3% of mangrove areas lost between 1979 and 1986 were used for aquaculture; this means 38,000 hectares or 13% of the 287,300 hectares of mangrove resource in 1979 (Arbhabhirama et al. 1988). However, it is important to avoid generalizations. Shrimp ponds in some parts of the country have certainly encroached on mangrove areas, but other major shrimp farms are in areas with limited mangroves, such as Songhkla in the south (Table 1). In the Mekong Delta in Vietnam, clearance of mangroves for timber and shrimp farming has been serious, estimated at 60,000 hectares between 1985 and 1988 and still continuing, adding to the catastrophic losses of mangrove forests during the Vietnam War (Mekong Secretariat 1992).

The loss of mangrove areas can adversely affect the ecology, economics, and societal life in coastal localities, as described by several authors (e.g., Macintosh 1982, Snedaker and Getter 1985, Bailey 1988, Primavera 1991). Some of the problems that emerge where there is large-scale conversion of mangroves to shrimp ponds can be seen in the Mekong Delta of Vietnam (Table 2, Hong 1993). Loss of mangroves has serious implications for the sustainability of various coastal activities. The productivity of some coastal fisheries appears to be positively correlated to the abundance of mangrove forests adjacent to the fishing grounds (Turner 1977, Martosubroto and Naamin 1977, Kapetsky 1987). In Chantaburi, Thailand, fishermen reported declines in catches due to restricted access to previously accessible mangrove areas (Sirisup 1988).

In Bangladesh, expansion of shrimp farming into mangrove areas has reduced fish catches and the socio-economic condition of traditional coastal fishermen (Asian Institute of Technology, unpublished data). The loss of life and structural damage caused by the 1991 cyclone in southeastern Bangladesh may have been made worse by the earlier loss of mangroves, and coastal shrimp ponds themselves suffered severe damage (Anonymous 1991). The economic impacts of mangrove destruction ultimately can be very significant and may far outweigh the short-term benefits from conversion to shrimp ponds.

There is a growing realization that mangroves themselves can contribute to the sustainability of aquaculture. Certainly, pond construction should not proceed indiscriminately in mangrove areas (Csavas 1988). The traditional extensive culture method uses up large areas of mangrove, but has very low productivity in return. For this reason, extensive culture systems are

difficult to justify, neither ecologically or economically, as a way for long-term sustainable use of coastal resources. Turner (1977) has shown that one hectare of mangroves can yield 767 kg of wild fish and crustaceans, more than the yields in extensive systems (usually considerably less than 500 kg/ha-yr).

Table 2. Adverse effects on the environment of the loss of mangrove forests in the Mekong Delta of Vietnam. Modified from Hong (1993).

Adverse effects
Increased vulnerability to storm damage and coastal erosion in Tien Giang, Ben Tre, Cuu Long, and Minh Hai provinces
Salt intrusion damaged 2,000 hectares of rice fields at Gan Gio district, Ho Chi Minh City in 1991
Decline in abundance of shrimp postlarvae and in the yields of extensive shrimp ponds from 297 kg/ha in 1986 to 153 kg/ha in 1988
Decline in the mangrove-dependent mudcrab population and reduced export earnings
Acidification of pond water and soil through formation of acid sulfate soils

Of additional concern is that the shrimp ponds on mangrove land often support profitable shrimp culture for only short periods. Mangrove areas are often not the places to build sustainable aquaculture farms. In extensive culture systems, loss of mangrove nursery areas can affect the supply of postlarvae for the ponds, a trend that has appeared in Bangladesh and may be threatening the sustainability of traditional shrimp culture in the Mekong Delta of Vietnam (Mekong Secretariat 1992). In semi-intensive or intensive shrimp culture, acid sulfate soils common in mangrove areas may affect farm sustainability.

Mangroves protect the ponds built behind them and influence considerably the water quality in shrimp farming areas. Mangroves may remove nutrients, heavy metals, suspended solids, and toxic hydrocarbons (Landers and Knut 1991). Thus, coastal water quality may deteriorate through loss of the mangroves' filtering capacity. Conversely, mangroves can 'clean up' shrimp pond effluent. Robertson and Phillips (1994) have calculated the areas of *Rhizophora* mangrove forest required to remove nutrients from shrimp pond effluents (Table 3). These area estimates may be useful in local area planning.

Thus, there are mutually supportive functions of aquaculture and mangroves and there is now growing interest in integrating mangrove and shrimp farming in the coastal zone (de la Cruz 1995). Indeed, if the benefits of mangroves to sustainable shrimp culture are more clearly recognized, shrimp farming may provide an additional economic justification to preserve mangroves. In Indonesia, Thailand, and the Philippines, a mangrove buffer zone between the sea and the shrimp ponds has been advocated. Such zones can potentially serve the interests of both

the conservationists and the shrimp farmers. Indeed, some large private farms in Thailand now retain a protective mangrove buffer (personal observations). Further research on the mutual benefits between mangroves and aquaculture would be useful in order to develop planning guidelines.

Table 3. Estimates of area of *Rhizophora* mangrove forest that would be required to remove the nitrogen and phosphorus loads produced during the operation of shrimp ponds (Robertson and Phillips 1994).

Nutrient	Ratio (area mangrove forest: area shrimp pond)	
	Semi-intensive	Intensive
Nitrogen	2.4 : 1	7.2 : 1
Phosphorus	2.8 : 1	21.7 : 1

### Water Requirements

The quality and quantity of water used for shrimp culture is a critical factor affecting the sustainability of the industry. Water quality is critical in the hatchery and during the grow-out period in ponds. Most practical handbooks recommend that the water for shrimp culture should be free from agricultural, domestic and industrial pollution and be within the required salinity and temperature ranges (Apud et al. 1989). However, urbanization, industrialization and chemical use in agriculture is make it extremely difficult to find such pollution-free waters in many coastal areas. There is growing evidence that shrimp culture is severely threatened by growing water pollution in Asia (Chua et al. 1989a) as well as other parts of the world (Aiken, 1990).

The recent review by FAO-NACA (1994) has concluded that external environmental changes threaten the sustainability of shrimp culture in Asia. Unexplained shrimp mortalities in several countries — including Bangladesh, Thailand, China, Indonesia and the Philippines — have been blamed on agricultural or industrial pollution. In Taiwan, pollution of coastal waters was thought to have contributed to the collapse of the industry in 1987. In Thailand, pollution of water supplies with contaminants from industry, agriculture, and sewage is thought to have been at least partially responsible for the losses of the shrimp industry in the Upper Gulf of Thailand since 1989. Given the sensitivity of shrimps (particularly young stages) to pollutants, shrimp culture is highly risky in areas of intense agricultural, urban, and industrial development. It is often difficult to identify the cause of the water quality problems that crop up. Sadly, most studies on the water quality problems faced by shrimp farms do not assess the relative effects of external factors against those generated by the shrimp farms themselves.

Contamination of water supplies with organic material, hydrocarbons, heavy metals, and pesticides is significant in some shrimp farming areas (FAO-NACA 1994). Microbial contamination of shrimps with *Vibrio* and *Salmonella* have been reported, but it is unclear whether this is due to water pollution or poor handling and processing. The effects of coastal eutrophication and red tides on shrimp culture have been extremely serious, as in China in August

1989, when a *Gymnodinium* bloom around the Bohai Sea caused an estimated US\$67 million worth of damage to *Penaeus chinensis* farms (FAO-NACA 1994).

The quantity of water required by shrimp culture has some implications for sustainability. The amount required by shrimp hatcheries is small compared to the amount required by ponds (Phillips et al. 1993). Extensive shrimp farms require less water, and total water demand normally increases with intensification as more water is required to flush away metabolites and other wastes. In intensive culture systems, demand can easily outstrip supply in areas with poor tidal flushing or limited water. The switch from extensive to intensive culture puts pressure on the often already limited water resources, and leads to greater water pollution. However, there are trends towards reduced water use in intensive shrimp ponds (Office of the Environmental Policy and Planning 1994). Table 4 shows that water exchange in intensive farms in southern Thailand averages only 14% per day, 6-7 days each month.

Table 4. Water exchange in intensive low-water use shrimp ponds in southern Thailand, from a survey of 80 such ponds in Ranot and Huasai Districts. From Office of Environmental Policy and Planning (1994).

Month of culture	Water exchange	
	Days/month	Amount/day (%)
1	12.3	4.2
2	5.8	15.3
3	4.3	16.9
4	3.9	19.0
Average	6.6	13.8

The use of fresh water from underground aquifers for intensive shrimp farming in Taiwan, the Philippines and Thailand has resulted in saltwater intrusion and salination of freshwater aquifers (Primavera 1991, Liao 1992). Discharge or seepage of saline water from shrimp ponds has caused salination of freshwater supplies in Bangladesh (Mahmood 1987), Indonesia (Cholik and Poernomo 1987), and Thailand (PSU 1991, Office of Environmental Policy and Planning 1994). A survey in Chantaburi, Thailand showed that 16-22% of agricultural farms were affected by saline intrusion linked to shrimp pond expansion (Sirisup 1988). Salination seems to be particularly acute in areas where inland shrimp ponds receive pumped saltwater. These problems are partly due to the widely made recommendation to site shrimp ponds behind mangrove areas.

The use of fresh water to dilute salt water also gives rise to problems (Primavera 1991). However, more and more farmers (particularly in Thailand) now realize that tiger shrimp can be cultured successfully using full sea water, so there is now little need for farmers to dilute salt water. This trend has potential to reduce environmental impacts.

The economic impacts of freshwater use and salination have not been assessed, but are likely to offset some of the benefits of shrimp farm development. Freshwater supplies are limited

in many coastal areas in Asia and deliberate use for, and salination by, shrimp farms can not be justified in either social or economic terms. Abstraction of fresh water from underground aquifers is now banned in Taiwan and parts of Thailand. Proper site selection and well designed drainage systems can certainly help to reduce the problems.

## Seed Requirements

In some countries, the shrimp industry still relies on the wild shrimp fishery for broodstock and even postlarvae. In traditional extensive systems such as the Indian *bheries* and Indonesian *tambaks*, farmers relied on inflowing tidal water to bring postlarvae into the ponds. Farmers in the Mekong Delta also rely heavily on natural supplies of postlarvae (Mekong Secretariat 1992). Catches of wild tiger shrimp postlarvae have declined in India (Silas 1987), Bangladesh (Mahmood 1987), and Vietnam (Mekong Secretariat 1982). There may be natural fluctuations in abundance of postlarvae, but other aggravating factors include overfishing, pollution, and habitat destruction.

Deliberate stocking of either wild or hatchery-reared postlarvae has become the common practice in shrimp farms. The high demand for postlarvae, and the unpredictable natural supply, have led to the development of hatcheries to support the semi-intensive or intensive shrimp farms in many countries. Indeed, the development and dissemination of the hatchery technology for tiger shrimp was the key to the subsequent growth of shrimp culture in Asia (Liao 1990, Csavas 1990). In Vietnam, India, and Bangladesh, hatcheries are rapidly being developed to meet the needs of the expanding and intensifying grow-out ponds.

The quality and quantity of postlarvae affect the sustainability of shrimp culture. Some farmers still prefer wild postlarvae for pond stocking, and in Sulawesi, which still has large areas of *tambak*, this view is reflected by higher price. The poor quality of hatchery-reared stock in Taiwan contributed to the crash of the tiger shrimp industry there (Lin 1989, Chen 1990). Quality testing, improved hatchery technology, and greater awareness of the importance of postlarval quality are necessary to improve quality. Shrimp farmers in parts of Java are aware of the poor quality of antibiotic-treated shrimp and request antibiotic-free postlarvae from hatcheries, thus creating some market pressure for hatchery operators to avoid overuse of antibiotics (FAO-NACA 1994).

An important environmental issue is the impact on other Fisheries of the harvesting of wild shrimp postlarvae. Silas (1987) estimates that 10 kg of fish and shrimp larvae are killed during the collection of 1 kg of tiger shrimp postlarvae in the Sunderbans of West Bengal, India. BOBP (1990) reports that up to 5,000 postlarvae of other fishes and shrimps are killed for every 100 marketable postlarvae (including *Macrobrachium rosenbergii*) collected in Bangladesh. BOBP (1990) has developed alternative environment-friendly methods for seed collection combining conservation measures with methods to increase economic returns to fisher families.

Although the shrimp culture industry is moving away from reliance on wild-caught postlarvae, virtually all hatchery broodstocks in Southeast Asia come from the wild. The broodstock supply is unpredictable in some countries, although not yet regarded as a significant constraint to industry progress (Fast and Lester 1992). However, overfishing, pollution, and loss of coastal habitats will probably lead to future scarcity of broodstock. Some countries have or are

considering restrictions on broodstock collection and export to protect wild shrimp populations. Loss of wild shrimp resources represents loss of broodstock and genetic material for future selective breeding programs. In Japan, stocking programs have already been implemented to ensure the future of wild shrimp Fisheries (Fast and Lester 1992). In Thailand, tiger shrimps are also stocked in coastal waters (Department of Fisheries, personal communication). The effects of such stocking programs on wild populations is uncertain.

The availability of tiger shrimp broodstock may depend on the maintenance of coastal nursery habitats. For example, the tiger shrimp stocks in central Vietnam are thought to rely on a small but possibly critical coastal or riverine mangrove habitat (A Robertson, personal communication). The loss of such habitats may have serious consequences for the sustainability of the shrimp industry. FAO-NACA (1994) has recommended action to better identify and protect coastal habitats and stocks of marine shrimps and fishes critical to the long-term survival of the aquaculture industry.

Due to the uneven supply and demand of shrimp postlarvae and broodstock, there has been a considerable movement of animals, both within and between countries (De Silva 1989). For example, the Indo-West Pacific *Penaeus monodon* has been introduced to central America (Welcomme 1988, Lightner et al. 1989) and the East Pacific *P. vannamei* and *P. stylirostris* have been brought into the Philippines (Juliano et al. 1989). Four species (*P. stylirostris*, *P. vannamei*, *P. brasiliensis* and *P. schmitti*) have been brought into Taiwan from Latin America at various times (Liao and Liu 1989). Chiba et al. (1989) reports on the introduction of *P. chinensis* from China to Japan. A native of China, Korea, and Japan, *P. japonicus* has been introduced to Singapore from Japan (Chou and Lam 1989). Transfers of shrimp postlarvae or adults within the species' native ranges are also common in Asia, for example, *P. monodon* from the Philippines and Malaysia to Taiwan (Liao and Liu 1989).

Experience with aquatic species in general indicates that a number of problems may arise following the introduction of new species and even transfer of animals within their native range. Introduced species bring in diseases and parasites, disrupt the host community through competition, predation and stunting, and cause changes in habitats, genetic diversity, and even coastal socioeconomics (Welcomme 1988). Pathogens can be highly virulent to new species (Alderman et al. 1984, Welcomme 1988). Non-native shrimps escape from shrimp culture facilities into natural waters (Anonymous 1990), and pathogens from cultured shrimps are transmitted to wild stocks (Lightner and Redman 1992, JF Turnbull, personal communication). However, there is little concrete information on the effect of introductions and transfers on cultured and wild shrimps.

Shipments of shrimps have certainly helped the spread of pathogens. The infectious hypodermal hematopoietic necrosis virus or IHHNV is suspected of having spread from its natural range on the Pacific coast of Latin America to the Middle East and Asia through shipments of infected shrimps, and monodon baculovirus (MBV) has been found in tiger shrimp stocks introduced to Hawaii, Mexico, and Tahiti from southeast Asia and Taiwan (Lightner et al. 1989).

MBV is now also found in many wild-caught tiger shrimps in Southeast Asia, showing that the virus has crept into wild populations (or may already be widespread in the wild?). It is easy to see how this has happened. For example, about 10 million tiger shrimps were washed into the sea from ponds during serious flooding in southern Thailand in 1988. The recent economically

serious outbreak of 'yellowhead' disease in shrimp farms in Thailand seems to have been transmitted by wild shrimps (personal consultations). Thus, pathogen transfer to wild stocks can also have serious implications for the shrimp industry, as pathogens are impossible to eradicate in the wild and thus likely to come back to the ponds. The effect of pathogens on wild stocks is also uncertain. The recent FAO-NACA (1994) study has recommended further research on the interactions between cultured and wild stocks, including pathogen transfer, as a basis for improved understanding and regulations.

The introduction and transfer of shrimps and the spread of shrimp pathogens will likely come under close scrutiny in relation to international trade, following the Convention on Biological Diversity, which came into force on 29 Dec 1993 (Lesser 1994). There will likely also be increasing market pressure on the shrimp export industry to control disease problems. For example, the European Community is considering provisions for registration of all farms exporting aquatic products to the EC, and such registration would include the disease status. Importing countries will become increasingly conscious of the disease status of shrimp stocks from exporting countries. Such registration and other regulations (biologically justified or not!) will become increasingly common as shrimp markets become more saturated and competitive and as world trade markets change according to the General Agreement on Tariffs and Trade (Repetto 1994, Lesser 1994). Positive publicity and public awareness campaigns may be necessary to prevent unfair actions being taken against shrimp-producing countries.

### **Feed and Fertilizer Requirements**

The quantities of fertilizers and feeds used, and their effects on sustainability and the environment vary with the intensity of culture. Extensive systems have relied on natural productivity, sometimes supplemented with small amounts of fertilizers (usually organic). Semi-intensive and intensive systems require greater inputs of fertilizers and supplemental feeds, or complete feeds. The use of formulated diets is becoming increasingly common in Southeast Asia in support of intensive farming systems. The nutrient and phosphorus budgets for semi-intensive and intensive shrimp farms are shown in Table 5. Such data demonstrate that a high proportion of the nitrogen and phosphorus added to a shrimp pond as feed is wasted. The data also suggest an economic loss through poor feed utilization and a potential for on-farm water pollution.

The use of 'trash' fish and locally formulated 'fresh' diets is still common in some countries. In China, cultured shrimps are fed live and dead marine and brackishwater mollusks, small crustaceans, and polychaetes (Liu 1990). Both the use of fresh diets and intensive feeding with formulated commercial diets affect water quality and thus the environment. For example, the use of fresh diets is thought to have contributed to the severe shrimp losses in China.

### **Chemotherapeutants**

There has been considerable discussion about the effects on the environment of chemotherapeutants used in shrimp ponds to disinfect, prevent or treat diseases, to condition soil and water, to kill pests, and as feed additives. Antibiotics and several others of these compounds are potential threats to human health and the environment, as well as to shrimp health and product quality. For example, drugs like furazolidone and common chemicals like malachite green are



Table 5. Nutrient budgets for 10-hectare shrimp ponds in terms of the amounts of nitrogen and phosphorus in the feed input, shrimp output, and waste loads (wastes expressed in two quantities). Modified from Gavine and Phillips (1994).

Culture System	Nitrogen		Phosphorus					
	Feed (t/yr)	Shrimp (t/yr)	Waste (t/yr)	Waste (kg/t shrimp harvested)	Feed (t/yr)	Shrimp (t/yr)	Waste (t/yr)	Waste (kg/t shrimp harvested)
Semi-intensive ponds Potential harvest 3 t/ha-crop, 9 t/ha-yr; FCR 1.4	2.98	2.66	0.29	9.7	0.45	0.18	0.27	9.0
Intensive ponds Potential harvest 9 t/ha-crop, 27 t/ha-yr; FCR 2.0	38.3	23.99	14.34	53.1	5.83	1.59	4.24	15.7

Feed conversion ratio FCR = kg dry feed/kg wet shrimp.

potential carcinogens or allergens (Schnick 1991). The chemicals used in intensive shrimp farms in southern Thailand are shown in Table 6. Although of concern, these chemicals from shrimp culture are likely to have a smaller environmental impact than the agricultural chemicals used in most countries in the region (FAO-NACA 1994). Nevertheless, the risks exist and the problems certainly require better understanding.

Table 6. Chemicals used by 80 shrimp farmers in Songkhla and Nakhon Sri Thammarat in southern Thailand. Chemicals used by <5% of the farmers are not listed. From FAO-NACA (1994).

Chemicals	% Farmers	Reason for use
Lime	24.5	pH control in pond preparation
Dolomite	6.4	Pond preparation
Zeolite	26.1	Water quality control
Teaseed cake	31.8	Predator control
Benzalkonium chloride	9.6	Water disinfectant
Oxytetracycline	17.3	Control of bacterial diseases
Other chemicals	6.7	Control of diseases

Specific examples illustrate the environmental dangers of widespread use of antibiotics in aquaculture. Studies on salmon farms have shown that antibiotic residues can be extremely persistent in marine sediments and lead to the development of antibiotic resistance among bacteria (Aoki 1992). Use of oxytetracycline in Taiwan, Thailand and the Philippines has resulted in resistant strains of *Vibrio*, such that treatment of *Vibrio* infections is now extremely difficult (Nash 1990). Similar increased resistance to chloramphenicol has emerged through misuse of antibiotics in shrimp hatcheries in the Philippines (Baticados and Paclibare 1992). Overexposure of postlarvae to antibiotics in Taiwanese hatcheries has been a major factor in the poor survival of tiger shrimps in grow-out ponds (Chen 1990).

Thus, misuse of antibiotics is a direct threat to shrimp farming because of the emergence of antibiotic-resistant pathogens. The spread of resistant strains of bacteria in Southeast Asia has probably been made easier by the frequent intermixing of effluent and influent water in congested culture areas. Moreover, there is concern that transfer of such resistance to human pathogens could have serious repercussions on human health (Brown 1989). Chloramphenicol, a widely used antibiotic in shrimp hatcheries, is of particular concern because of its importance in the control of human *Salmonella typhae* infections (typhoid fever).

Antibiotics and some other chemicals leave residues in shrimp flesh, which may lead to rejection of products in export markets. Residues of oxytetracycline were detected in cultured shrimps from Thailand and some other countries, and shipments were rejected in Japan (Anonymous 1991). In Thailand, fairly successful efforts have been made to control the problems with antibiotics through guidelines and a monitoring program for drug residues (Kungsuwan 1992).

## **Wastes and Effluents from Shrimp Ponds**

As shrimp farming becomes more intensive, the water quality problems created by farm effluents increase. Although minor local pollution has resulted from the discharge of hatchery wastewater, most environmental concerns relate to the discharge of effluents from grow-out ponds. To address the effects of shrimp pond effluents on the sustainability of shrimp farming, it is important to understand the nature and quantity of the waste materials and effluents from shrimp farms.

Extensive shrimp culture systems are characterized by low stocking densities, little or no fertilization or supplemental feeding, and low water exchange rates limited to spring tide periods. In consequence, extensive farms do not generate significant amounts of wastes and indeed may be net removers of nutrients and organic matter (Macintosh 1982). The fact that extensive ponds in Indonesia and the Philippines have been used for shrimp and fish culture for centuries testifies to their potential sustainability. The main effluent problem in extensive ponds may be the very acidic (pH 2.7-3.9) discharges from new ponds built on acid sulfate soils (Cholik and Poernomo 1987, Phillips et al. 1993).

Semi-intensive shrimp farms receive more fertilizers and supplemental feeds, and intensive farms rely on complete feeds. As a consequence, more nutrients, more organic matter, and more of other wastes affect the water quality more severely (Table 5). Supplemental and complete feeds are the most important inputs that contribute to the wastes from intensive culture systems, although fertilizers, antibiotics, and other drugs and chemicals add to the load. The wastes from shrimp ponds consist of: (a) solid matter, a mixture of uneaten food, feces, phytoplankton, and colonising bacteria, and (b) dissolved matter such as ammonia, urea, carbon dioxide, and phosphorus (Macintosh and Phillips 1992). The wastes include amino acids, proteins, fats, carbohydrates, fiber, minerals, and bacteria (Boyd 1989).

Feed quality is an important factor affecting waste output in aquaculture. Loadings of nutrients and organic matter are higher from fish fed 'trash' fish and fresh diets than from those receiving pelleted moist or dry diets (Warrer-Hansen 1982). Wickins (1985) found that fresh diets, infrequent feeding, and high stocking densities increase nitrogen loads from shrimps in recirculating tank systems. 'Trash' fish and invertebrates, advocated as an economic feed in some countries (Liu 1990), can lead to higher waste loads, poor pond water quality, and greater pollution of the receiving waters next to the farm.

The effluents discharged from ponds reflect the internal processes in the pond. The effluent quality during normal operation will be similar to the water quality in the pond. Effectively managed ponds are well mixed with water quality characteristics within acceptable range for shrimps. Table 7 shows the characteristics of inflow water, normal effluent, and effluents during harvest in nine intensive shrimp ponds in Thailand (Satapornvanit 1993). Water quality deteriorates during the grow-out cycle due to increasing feed inputs and shrimp biomass; thus the effluent has higher nutrients and organic matter than the influent, particularly at harvest. Boyd (1978) and Bergheim et al. (1984) demonstrated high 'shock' loads of solids, biochemical oxygen demand, nitrogen, and phosphorus during tank cleaning, loads that are several times higher than at other times.

Table 7. Water quality of the influent and effluent water of nine shrimp ponds in Thailand. Samples were collected throughout one grow-out cycle, Jan-May 1993. Modified from Satapornvanit (1993).

Water type	Total N	Total P	Orthophosphate	Concentration (mg/l)			NH3	Org Carbon
				Nitrite	Nitrate	Total ammonia		
Influent	0.28-0.77	0.05-0.29	<0.05-0.12	0.001-0.012	0.02-0.41	<0.05-0.63	<0.001-0.009	<0.10-19.02
31.7-34.3 ppt								
27.8-30.8°C								
pH 7.2-8.1								
Effluent (normal operation)	1.46-3.11	0.25-0.70	<0.05-0.14	0.003-0.043	0.01-0.43	<0.05-1.70	<0.001-0.006	18.86-37.25
35-37 ppt								
28.8-30.2°C								
pH 7.4-8.3								
Effluent (harvest)	1.57-5.06	0.21-1.30	<0.05-0.24	0.004-0.033	0.01-0.09	0.51-1.51	0.003-0.198	17.24-39.44
36-39 ppt								
29-32°C								
pH 7.0-8.3								

The effects of waste materials can be seen within the pond. The dissolved nutrients and organic solids stimulate the rapid growth of bacteria, phytoplankton, zooplankton, as well as the benthos. Phytoplankton dynamics affects the effluent quality, with high dissolved nutrient loads after phytoplankton blooms 'crash' in intensive fish ponds (Krom and Neori 1989). These plankton blooms are a common problem in shrimp farms, particularly during sudden changes in weather.

In spite of mechanical aerators in intensive ponds, a considerable amount of detrital material and dead plankton often accumulate on the pond bottom where water circulation is more sluggish. The magnitude of this sediment accumulation can be seen in Table 8 from the work of several investigators. This accumulation results in anoxic conditions and the release of hydrogen sulfide and methane, which are significant health risks to feeding shrimps (Boyd 1989). Harvest and cleaning of ponds can be difficult due to disturbance and release of materials previously bound to the sediment (Williamson 1989). In Thailand, draining the ponds and harvesting the shrimp at the outflow gate is thought to produce less damaging effluent than using nets, which disturb the bottom sediments. For the same reason, partial harvesting by netting (to reduce shrimp biomass) is also not favored by Thai shrimp farmers.

Table 8. Sediment accumulation in intensive shrimp ponds.

Study	Amount of pond sediment		
	Dry weight (t/ha-cycle)	Wet weight (t/ha-cycle)	Volume (m <sup>3</sup> /ha-cycle)
Tanvilai et al. (1993)	178-744		155-559
Briggs and Funge-Smith 1994	185-199	400-432	307-330
Musig (1992; in Boyd 1992)	157-290		650-850

Table 9. Sediment management in 160 intensive shrimp farms in provinces in Thailand. Data from Office of Environmental Policy and Planning (1994) and Marsden (1994).

Method of sediment management	Practising farmers (%)	
	Songkhla/Nakhon Sri Thammarat	Chantaburi
No removal (drying and oxidation only)	1.25	0
Bulldozer (mechanical removal)	90.0	12
High-pressure hose	2.5	88
Drying + bulldozer	6.25	0

The environmental impact of different forms of pond sediments and their management requires urgent assessment. Because of environmental concerns, some countries including Thailand have already restricted the discharge of sediments from shrimp farms (FAO-NACA 1994).

### Effects of Pond Effluents on the Environment

There has been much discussion of the environmental impact of shrimp pond effluents, but surprisingly little good data on the subject. A comparison of shrimp pond effluent, domestic wastewater, and fish processing effluent (Table 10) shows that the potential to pollute is much less with the pond effluents during normal pond operations. However, effluent discharged during pond cleaning is much more polluting, albeit for a shorter period. Although shrimp farm effluent is less noxious than other coastal wastewaters, large volumes are discharged, often within small areas with limited water supplies and poor flushing. This has given rise to self-pollution in shrimp culture areas. Unfortunately, it has been all too common in Asia for investors to rush into the same area, such that one farm's effluent becomes another (or the same!) farm's intake (New 1990).

Table 10. Waste load of shrimp pond effluent and other types of wastewaters. Modified from Office of Environmental Policy and Planning (1994).

Type of wastewater	BOD(5) (mg/l)	Total N (mg/l)	Total P (mg/l)	Solids (mg/l)
Shrimp pond effluent	4.0-10.2	0.03-5.06	0.05-2.02	119-225
Untreated sewage	300	75	20	500
Primary-treated sewage	200	60	15	
Biologically treated sewage	30	40	12	15
Effluent from fish- processing plant	10,000-18,000	700-4,530	120-298	1,880-7,475

BOD(5), biochemical oxygen demand over five days.

The discharge of nutrients from shrimp ponds may contribute to eutrophication, with increased primary productivity and possible phytoplankton blooms, but there is yet no evidence that this has happened. An assessment of the contribution of shrimp pond (and other aquaculture) effluents to the overall nutrient load in coastal areas in the Upper Gulf of Thailand and the Bohai Sea in China suggests that shrimp farms can hardly be blamed for coastal eutrophication (FAO-NACA 1994). Further research is necessary to put the pollution from shrimp farms within the overall context of coastal environmental conditions.

Discharge of effluents with high biochemical oxygen demand (Table 10) reduces the dissolved oxygen in the receiving waters. Release of organic matter can also be expected to result in siltation and changes in productivity and community structure of benthic organisms. Definitive studies are lacking but there is some anecdotal evidence from Thailand, Sri Lanka, and other countries, where irrigation canals became silted with organic matter discharged from shrimp farms (Phillips et al. 1993). On the other hand, recent studies in southern Thailand have shown increased mollusk harvests close to major shrimp farming areas (Office of the Environmental Policy and Planning 1994).

Where waste production exceeds the capacity of the receiving environment to dilute or assimilate the waste materials, major water pollution results. Self-pollution of shrimp culture areas by pond effluents is becoming more frequent in Asia. The major crash of the shrimp industry in Taiwan, then in the Upper Gulf of Thailand, and the losses from shrimp diseases in the Philippines, Indonesia, and China have all been linked to waste production exceeding the assimilative capacity of the local water bodies (Lin 1989, Liao 1992, FAO-NACA 1994). Chen and Sheng (1992) report deterioration of water quality due to pond effluents in Shandong and Hebei in China. On the west coast of Sri Lanka, major shrimp mortalities are blamed on pollution of the main water supply canal (the 'Dutch Canal') by pond effluents (Jayasinghe 1994).

Experience with other intensive aquaculture systems such as cage culture of Atlantic salmon or yellowtail clearly demonstrates that self-pollution is a major contributor to disease outbreaks and fish kills (ADB-NACA 1991). Such self-pollution is likely to be most serious in enclosed coastal waters, irrigation canals, or rivers subjected to heavy farming and poor water exchange. Farms located on open coastlines have better water exchange. Research is required to define the sustainable carrying capacity of coastal areas in terms of supporting production and assimilating wastes.

### **Effects of Water Pollution on Shrimp Farm Profitability**

There is strong circumstantial evidence that environmental deterioration has played a major role in the development of disease problems now affecting shrimp ponds in Asia. Serious production losses from disease outbreaks have been reported from several countries in the region. In Taiwan, shrimp production declined from 90,000 tons in 1987 to 20,000 tons in 1989 because of disease outbreaks. Environmental deterioration was linked to the intensification of shrimp culture and the overloading of coastal waters with pond effluents and domestic and industrial discharge (Lin 1989, Chen 1990). After a short recovery, the industry collapsed again in 1993 — again due to poor environmental conditions (Anonymous 1993).

In China, shrimp production in 1993 declined to 75% of that in 1992 due to disease outbreaks and red tides. Initial unconfirmed reports suggest economic losses of US\$750 million (Anonymous 1993). In Indonesia, production in central and eastern Java has been reduced by 30% in 1993 and in Medan, Sumatra, over 80% of the ponds were abandoned in 1993 due to crop failure (Anonymous 1993).

In Thailand, shrimp production from the Upper Gulf provinces was around 41,000 tons in 1989, but severe disease problems reduced production to 18,700 tons in 1991 (FAO-NACA 1994). In Samut Songkhram, Samut Prakan, and Samut Sakhon provinces in the Upper Gulf of Thailand, large areas of shrimp farms have suffered from mass mortalities and have been abandoned. Self-pollution and poor dispersal of pond effluent led to bacterial diseases. Abandoned ponds covered at least 10,100 hectares in 1991 and brought an economic loss of US\$180 million worth of shrimp exports per year. Table 11 shows higher economic losses from shrimp diseases among farmers using canal water than among those using water direct from the sea.

Table 11. Economic losses from shrimp diseases in intensive shrimp farms with different water sources, Huasai and Ranot Districts, southern Thailand (Office of Environmental Policy and Planning 1994). US\$1 = Baht 25.

Disease	Losses (Baht/ha-crop)	
	Farms with water direct from sea	Farms with water from canals
Yellowhead disease	395,313	717,681
One month death syndrome	128,925	119,444
Gill disease	73,863	919,531
Red body disease	34,375	145,813

The concern of shrimp farmers now is to control environmental deterioration leading to shrimp diseases, but in the future, the industry may also be affected by the market perception of shrimp farming in relation to the environment (Repetto 1994). Shrimp farmers and exporters may have to build up the image of shrimps as an environment-friendly product. Indeed, with increasing competitiveness in the international shrimp markets, commercial advantage can be gained through marketing of shrimps as a 'green' product. In any event, environmental management of shrimp culture will have to be a high priority for the industry, and government (public sector) support is crucial in ensuring sustainability.

### **Environmental Management of Shrimp Farms**

Environmental factors are closely linked to the causes of disease and the resulting production losses, but far too little is known of the pathways and interactions involved. A greater understanding of the relations between shrimp stress, diseases, and pond production would provide the basis for improved management of ponds. Improvements in the management of the pond environment can help overcome diseases. For example, faced with a decrease in production value



from US\$2.36 million in 1988 to \$0.52 million in 1989 in a shrimp farm in the Philippines, Mancebo (personal communication) was able to restore production through improved management — reduced stocking, improved water exchange, etc.

The environmental problems affecting shrimp culture can be tackled at two levels. At the farm level, solutions come in terms of initial farm siting, design, operation, and management. At the level of the coastal zone, shrimp culture can be integrated into the coastal zone in a way that avoids adverse effects, on it from other sectors (and itself through self-pollution), and of it on other sectors.

Numerous handbooks on shrimp culture are available (e.g., Fast and Lester 1992) but these tend to concentrate on the farm as an isolated unit, with very little (if any) consideration of the potential interactions between the shrimp farm and the external environment. This approach is certainly flawed. Guidance is lacking in environmental impact assessment for shrimp farming and projects often proceed without adequate environment and site surveys. Due consideration must be given to:

- Potential risks inherent at the site (e.g., soil and water quality)
- Potential effects on the external environment (e.g., effects of effluents)
- Potential impacts from the external environment (e.g., pollution from agricultural or industrial sources)

Each of these could be incorporated into a 'risk analysis', as advocated by Wiley (1992). As investors become more aware of the risks inherent in shrimp farms, they will place more emphasis on identifying environmental problems during farm start-up and on initiating action to control problems.

Site selection is critical. However, for small-scale farmers, many of whom have little choice in terms of 'textbook' site selection, individual actions can lead to severe environmental problems and shrimp diseases in areas with poor infrastructure. Governments can assist in supplying basic infrastructure such as water supply and drainage canals. Where even this is not possible, cooperation between farmers can be encouraged to reduce problems. For example, in Surat Thani province in Thailand, farmers cooperate by taking water into ponds and discharging effluents at the same time (conventionally, green flag for intake and red flag for discharge!). Thus they avoid directly polluting each other's water supply.

Semi-intensive shrimp culture has been advocated as a means to avoid both the unproductive use of large areas of land in extensive culture and the problems with diseases and effluents in intensive culture (Primavera 1989). Hirasawa (1988) has argued that semi-intensive shrimp culture may be an economically viable method for farmers to survive fluctuations in market price. Fast and Lester (1992) have also observed that semi-intensive culture systems have the greatest profit per unit production, and have remained profitable during times of declining shrimp prices. Semi-intensive culture produces lower effluent loads (Table 5) than intensive ponds. Indeed, where farmers use a water supply with limited water exchange and limited carrying capacity, semi-intensive farming is a more equitable use of that 'capacity' than intensive farms (Gavine and Phillips 1994). As a result, a number of countries, e.g., India, Vietnam, and Bangladesh, encourage semi-intensive shrimp culture (FAO-NACA 1994). However, experiences suggest that semi-intensive systems may still not prove sustainable if large areas of ponds are

developed and the carrying capacity of the environment is exceeded. In China, much of the recent collapse was in semi-intensive shrimp culture. In practice also, it is extremely difficult (impossible) to persuade farmers to remain at semi-intensive levels when they can see the immediate profits possible with intensive culture; this is true even when farmers know that what they are doing is unsustainable (Fegan 1994).

Methods can certainly be further developed to reduce the environmental impacts of more intensive shrimp culture systems. For example, as feed is the major source of self-pollution, good-quality diets can be used and excessive reliance on 'fresh' diets avoided. Feeding rates can be matched to shrimp requirements and the food conversion ratios improved. In temperate aquaculture, there has been a trend towards the use of highly digestible, 'low-pollution' diets (NCC 1990). The development of such diets, plus effective management of the ponds, reduce the pollutant loads and have long-term benefits for the shrimp farmer and the coastal environment.

Water management is also important. There is a trend towards recycle systems or minimal water use systems in Thailand (Table 4). Minimal new water is taken in for fear of taking in shrimp pathogens. Experiments have also been successful with no water exchange during grow-out in intensive shrimp ponds. The development of low water use systems has potential to reduce effluent impacts, provided water quality within the ponds can be controlled. These low water use systems will require more management skills among the farmers. Shrimp culture systems with minimal water use and controlled environments must be further studied and developed.

### **Treatment of Pond Effluents**

The treatment of effluents can reduce the adverse effects on the water quality in the receiving waters. Fish farmers in temperate regions have been treating farm effluents for some time. A major problem with treatment is the dilute but high-volume nature of aquaculture effluents compared with other forms of wastewater (Muir 1982). Cost-effective technology is now available in several temperate countries to reduce biochemical oxygen demand, suspended solids, nitrogen, and phosphorus in aquaculture effluents (Makinen et al. 1988, Henderson et al. 1989). No such technology yet exists for shrimp culture, but there has been considerable interest among researchers to develop suitable methods to treat shrimp pond effluents. The possibilities for treatment can be split into physical, chemical, and biological methods.

The physical methods include settlement and filtration. Various physical treatments to remove suspended solids and soluble organic carbon have been evaluated. A one-hectare settling pond is required to handle shrimp pond effluents of about 900 m<sup>3</sup>/day (Rubel and Hager 1979). Filtration is the best treatment to bring suspended solids down to less than 10 mg/l under various conditions, but the costs are prohibitive: for a 10-hectare pond in Hawaii, with effluent treated by screening and filtration (after which the water is reused), capital cost is US\$137,500/ha and annual operating cost is \$75,000/ha (Rubel and Hager 1980). Such costs are likely to limit the application of this technology in most Asian situations and other cheaper options need to be explored.

Settling ponds have greater potential and are now becoming more common in Asian shrimp farms, either to treat inflowing water or the effluent. In southern Thailand, one farm-level survey found that shrimp farms with a settling pond to treat inflowing water were on average more

profitable (Baht 380,956/ha-crop) than those without (Baht 185,725/ha-crop) (Office of Environmental Policy and Planning 1994). Government regulations in Thailand stipulate that farms with a pond area of over 8 hectares must have a settling pond not less than 10% of the farm area. These ponds have been successful in improving the water quality of pond effluents (Gavine and Phillips 1994).

Even so, there are some problems in applying settling pond technology. First is the cost, as settling ponds take land out of productive (grow-out) use. Second are the difficulties in digging ponds on small-scale farms. Third is that shrimp pond effluent, unlike that from intensive salmon culture, contains large amounts of phytoplankton. Settling ponds, advocated for removing solid wastes, are unlikely to be completely effective in treating the effluent released during normal operation because phytoplankton is buoyant and will not easily settle. However, settling ponds can be very effective in 'capturing' solid wastes during pond harvesting and cleaning.

The effluent during normal shrimp farm operation is rich in nutrients and phytoplankton and is potentially suitable for culturing fishes, mollusks, and seaweeds. Thus, 'biological' treatment may be used. There have been experiments to treat the wastewater produced by shrimp ponds during normal operations, using oysters *Crassostrea virginica* in Hawaii (Wang 1990) and the green mussel *Perna viridis* in Thailand (NICA 1992, Lin et al. 1993). It has been found that 1 kg of oysters can remove 12-15 grams of solid matter in the presence of suspended solids of 50-110 mg/l, but oyster treatment was not enough for the effluent to meet discharge criteria (S Zhang and JK Wang, personal communication). Experiments in Thailand show that green mussels can reduce biochemical oxygen demand, organic solids, and phytoplankton (NICA 1992). However, mussels are sensitive to salinity changes, which can cause mortality or reduce filtration rates. Mussels also produce feces and pseudofeces that contribute to sedimentation.

The seaweed *Gracilaria* is an attractive species to grow in polyculture with mussels in a biological treatment system because it can remove dissolved nitrogen and phosphorus, which are not absorbed by mollusks. *Gracilaria* culture has been carried out in shrimp pond effluents (Chandrkrachang et al. 1991), but the system has yet to be taken up on a wide commercial scale. Some species or strains of *Gracilaria* are sensitive to salinity fluctuations, light limitation in turbid waters, and smothering by solid matter and microbial growth. One advantage of *Gracilaria* is that it can be processed for agar as an additional source of income.

One alternative biological method is to use mangroves to treat shrimp pond effluent, either by retention of a mangrove buffer zone close to the shrimp ponds, or by replanting mangroves for the deliberate purpose of water treatment (Robertson and Phillips 1994, Table 3). Mangroves have been used successfully as a tertiary treatment for sewage in the United States, but care is needed to avoid overloading with nutrients and organic matter. Thus, there is potential for combining mangroves and semi-intensive or intensive shrimp culture in what could be a sustainable and environmentally sound integration (de la Cruz 1995).

The quality of effluent during harvest and pond cleaning is so poor that biological treatment will not be sufficient. It is necessary to develop alternative practices or methods. Shrimps must be harvested at the pond outfall without disturbing the pond sediments. Ideally, harvesting is followed by minimal sediment disturbance, drying, and liming to enhance oxidation of organic matter (Boyd and Fast 1992). If sediments must be disturbed, settling ponds may be used. Such potentially very damaging effluent should not be discharged into common water

bodies, but alternative uses must be found. In Thailand, there has been some interest in using pond sediment, rich in organic matter and nutrients, as an agricultural fertilizer. However, the sediment must be treated to remove salt, a process that also produces some effluent.

### **Integration of Shrimp Farming in Coastal Zone Management**

The environmental problems of the shrimp industry are not only the problems of individual farms, but often of a large number of farms built in areas with limited carrying capacity. Models have been developed to predict the capacity of coastal areas to support salmon cage culture (Makinen 1991, Barg 1992), but it remains to be seen whether similar approaches could be used to determine the long-term sustainable level of shrimp farming. Models or suitable guidelines to determine in a broad way the capacity of coastal environments to support shrimp culture would be useful to government planners, investors, and insurers, who could then assess the risks of environmental deterioration and plan accordingly.

Fast and Lester (1992) predicted that worldwide there will be more regulations to control the adverse effects of shrimp farming on the environment. In Thailand, regulations cover the siting of shrimp farms, waste treatment, and environmental monitoring (FAO-NACA 1994). In the United States, shrimp farms are subject to very strict effluent controls, which Hopkins (1992) suggests are threatening the industry. Primavera (1992) suggests that the government must give tax incentives to farmers operating waste treatment ponds or facilities.

Clearly, more effective regulations are needed to govern shrimp farming. It is important that all regulations are based on a clear understanding of the interactions between shrimp farming and the environment, so that the regulations are not unnecessarily restrictive, unrealistic, and unworkable. It is also important that regulations on the shrimp industry are set within the framework of a wider coastal management plan. Such an integrated plan must also protect shrimp farming from other sources of harmful effluents. In reality, the development of such a sound and equitable regulatory framework for planning and management of shrimp farming is still a long way off in many countries.

Shrimp farming is just one 'user' of the coastal environment in Asian countries. Shrimp culture can be seriously affected by polluting industries, and itself may have adverse effects on other coastal inhabitants. Thus, sustainability will likely depend on more effective farm planning, site selection, and management that carefully consider the carrying capacity of the environment and the needs of the other users of coastal resources. Shrimp culture can make an important contribution to the economies of many developing countries. Experience shows that a more effective approach to environmental management is required, one that integrates shrimp culture into the coastal environment in a much more sustainable manner.

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# **Recent Trends in Fish Diseases in Japan**

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## **Abstract**

Losses of cultured marine and freshwater fishes due to diseases averaged about 20,000 tons each year or 6% of the aquaculture production in Japan in 1980-1991. During this last decade, bacterial diseases have been responsible for most of the losses. Three trends are evident from epidemiological data. First, diseases caused by bacteria with multiple drug resistance are prevalent, and these are difficult to overcome by chemotherapy. Second, parasitic diseases and viral diseases that are practically impossible to cure are increasing. Third, some diseases seem to originate in juveniles (seed) imported from other countries. Further research should focus on: (1) improving dietary and environmental conditions, (2) giving the host animals resistance against disease through methods such as vaccination, and (3) developing diagnostic and disinfection procedures for epidemics. Active exchange of information is necessary to prevent, or alleviate the effects of, the spread of diseases through international export and import of juveniles.

## **Introduction**

The loss of cultured fish due to diseases averaged about 20,000 tons each year in 1980-1991 (14,000-17,000 tons of marine fish and 3,000-4,000 tons of freshwater fish), or 6% of the aquaculture production in Japan (Fig. 1). The rate of loss has gradually decreased perhaps due to the development of better culture techniques and preventive measures against epidemics.

Epidemiological studies have been conducted at the Nansei National Fisheries Research Institute since 1981 to determine the trend of incidence of marine fish diseases and to search for correlations between the disease, host fish, culture environment, and pathogens. These studies were done with researchers of prefectural fisheries experimental stations. Cases of diseases reported to the Institute increased from about 1,000 in 1981 to 3,500 in 1993 (Fig. 2).

This paper describes the recent trends of prevalent fish diseases in Japan and discusses some underlying causes and related issues.

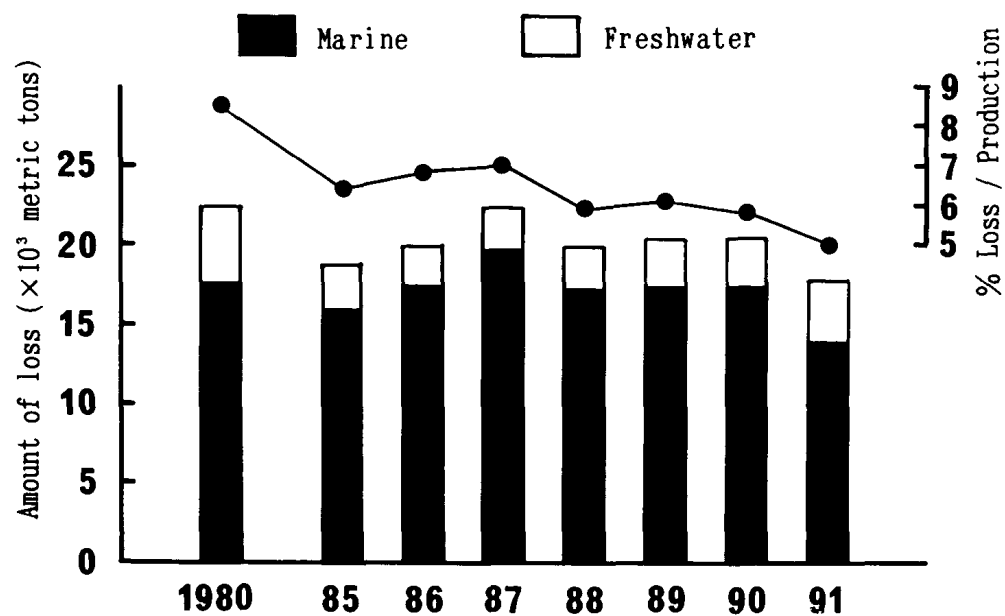


Fig. 1. Loss of aquaculture production in Japan due to diseases. Data from the Research Division, Fisheries Agency of Japan.

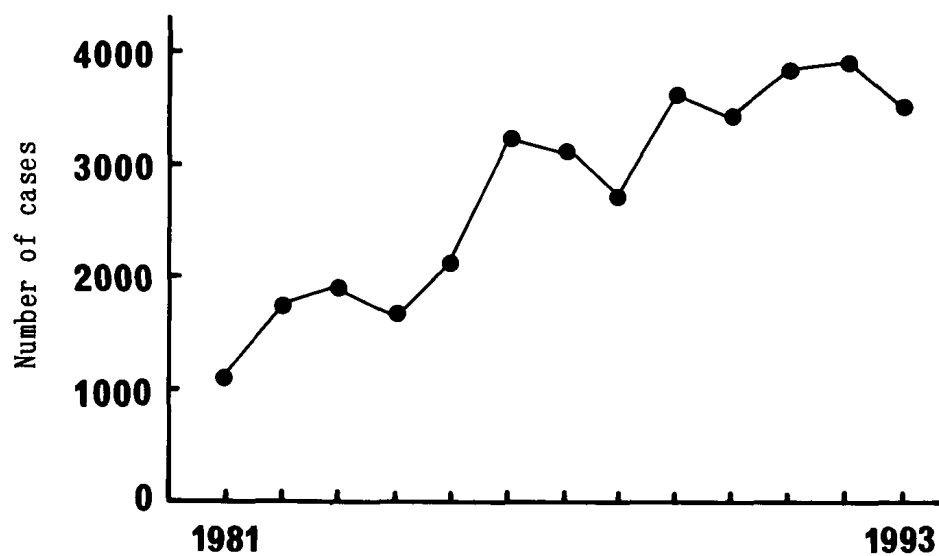


Fig. 2. Number of disease cases reported to the Nansei National Fisheries Research Institute from 1981 to 1993.

### Trends of Prevalent Fish Diseases

Ishioka (1992) analyzed the species-specific sensitivity to diseases, the seasonal changes in incidence of diseases, and the relationship between fish size and prevalence of disease. Data from 1981 to 1990 showed that deteriorating environmental quality and poor fish health led to situations favorable to pathogens.

Losses of freshwater and marine fishes due to diseases in 1991 are shown in Tables 1 and 2 together with the percent incidence of various diseases. The carp *Cyprinus carpio*, tilapia *Oreochromis niloticus*, and red sea bream *Pagrus major* appear to be less susceptible to diseases. But the flounder *Paralichthys olivaceus* and the puffer *Takifugu rubripes* are highly susceptible.

Table 1. Loss of cultured freshwater fishes due to diseases in 1991. Data from Research Division, Fisheries Agency of Japan.

Species	Production (tons)	Loss (tons)	Loss (%)	Disease	Incidence (%)
Eel <i>Anguilla japonica</i>	39,000	1,190	3.0	Edwardsiellosis	38.1
				Gill disease	34.5
				Complication	3.7
				Gill necrosis	3.5
				Beko disease	2.7
				Others	17.5
Salmonids <i>Oncorhynchus</i> spp.	20,000	1,230	6.1	Infectious hemato poietic necrosis	39.9
				Saprolegniasis	21.6
				Vibriosis	8.3
				Bacterial gill disease	7.7
				Furunculosis	7.7
				Others	14.8
Carp <i>Cyprinus carpio</i>	16,200	55	0.3	Gill necrosis	33.0
				Parasitic disease	9.1
				Others	57.9
Ayu <i>Plecoglossus altivelis</i>	13,900	1,370	9.9	Coldwater disease	46.1
				Glugeosis	24.8
				Mycotic granulomatosis	6.9
				Vibriosis	5.8
				Others	16.4
				Streptococcosis	84.4
Tilapia <i>Oreochromis niloticus</i>	5,600	37	0.7	Edwardsiellosis	12.4
				Gill disease	1.1
				Others	2.1

Table 2. Loss of cultured marine fishes due to diseases in 1991. Data from Research Division, Fisheries Agency of Japan.

Species	Production (tons)	Loss (tons)	Loss (%)	Disease	Incidence (%)
Yellowtails <i>Seriola</i> spp.	161,000	8,150	5.1	Streptococcosis	67.9
				Pseudotuberculosis	18.1
				Jaundice	6.0
				Complication	3.1
				Nocardiosis	1.0
				Others	3.9
Red sea bream <i>Pagrus major</i>	60,300	1,540	2.6	Iridovirus infection	29.2
				Bivaginosi	11.2
				White-spot disease	6.1
				Vibriosis	5.8
				Edwardsiellosis	2.9
				Others	44.8
Flounder <i>Paralichthys</i> <i>olivaceus</i>	6,500	1,090	16.7	Streptococcosis	25.6
				Edwardsiellosis	22.3
				Benedeniosis	11.3
				Complication	6.5
				Ascites	5.5
				Others	28.8
Puffer <i>Takifugu</i> <i>rubripes</i>	2,900	650	22.5	Kuchijirosho	27.7
				Kuchigusarebyo	16.8
				White-spot disease	12.2
				Complication	5.5
				Trichodinosis	3.8
				Others	34.0
Horse mackerel <i>Trachurus</i> <i>japonicus</i>	5,900	430	7.3	Vibriosis	53.6
				Streptococcosis	42.6
				Others	3.8

The trend of prevalence of fish diseases in 1993 is shown in Table 3. Bacterial diseases were most frequently reported in the yellowtail *Seriola quinqueradiata*, the purplish amberjack *S. purpurascens*, and the flounder. Parasitic and viral diseases were most frequent in red sea bream, the puffer, and the sea perch *Lateolabrax* spp.

With bacterial diseases, the prevalence of drug-resistant strains is the important problem. Parasitic and viral diseases are increasing; these are practically impossible to cure. In addition to these, some diseases originated from imported juveniles from abroad.

Table 3. Diseases reported among cultured fishes in 1993. Data from Nansei National Fisheries Research Institute.

Species	Number of cases reported	A	B	C	D	E	F	G	H	I	J
Yellowtail <i>Seriola quinqueradiata</i>	1,428	48.2	6.7	26.2	5.2	0.0	1.7	2.2	6.6	0.3	2.9
Flounder <i>Paralichthys olivaceus</i>	644	12.1	0.0	0.0	6.5	24.5	19.6	14.4	4.2	0.2	18.5
Purplish amberjack <i>Seriola purpurascens</i>	470	28.3	1.1	20.4	7.5	0.0	8.3	17.0	3.8	1.5	12.1
Red sea bream <i>Pagrus major</i>	320	0.3	0.0	3.8	5.9	12.5	5.6	19.1	15.9	5.9	31.0
Puffer <i>Takifugu rubripes</i>	218	0.5	0.0	0.0	6.9	0.0	11.4	37.1	9.2	6.9	28.0
Striped jack <i>Pseudocaranx dentex</i>	110	19.1	0.0	7.3	12.7	0.0	10.9	9.1	10.9	6.4	23.6
Sea perch <i>Lateolabrax</i> spp.	51	3.9	0.0	0.0	0.0	0.0	7.8	13.7	47.1	0.0	27.5
Goldstriped amberjack <i>Seriola aureovittata</i>	47	51.0	2.1	23.4	4.3	0.0	0.0	12.8	2.1	0.0	4.3
Schlegel's black rockfish <i>Sebastes schlegeli</i>	24	16.7	0.0	0.0	0.0	0.0	41.7	20.8	0.0	0.0	20.8
Striped beak perch <i>Oplegnathus fasciatus</i>	22	13.6	0.0	9.1	4.6	0.0	0.0	22.7	13.6	4.6	31.8
Dark-banded rockfish <i>Sebastes inermis</i>	21	33.3	0.0	0.0	9.5	0.0	4.8	38.1	0.0	0.0	14.3
Black sea bream <i>Acanthopagrus schlegeli</i>	17	0.0	0.0	35.3	5.9	0.0	29.4	23.5	0.0	5.9	0.0
Seven-banded grouper <i>Epinephelus septemfasciatus</i>	17	0.0	0.0	0.0	5.9	0.0	0.0	11.8	0.0	0.0	82.3
Other fishes	94	9.6	0.0	10.6	19.1	4.3	20.2	11.7	4.3	1.1	19.1

\* Diseases: A=Streptococcosis; B=Streptococcosis+Pseudotuberculosis (mixed infection); C=Pseudotuberculosis  
F=Other bacterial disease; G=Parasitic disease; H=Viral disease; I=Nutritional disease; and J=Others

### Prevalence of Drug-Resistant Bacteria

Among the bacterial diseases of cultured yellowtail, streptococcosis was responsible for the highest losses, and pseudotuberculosis ranked second (Table 2). Prevention of these diseases is therefore important for the successful culture of yellowtail. Multiple drug-resistant strains of *Pasteurella piscicida*, the causative bacterium of pseudotuberculosis, have been frequently isolated (Kim and Aoki 1993). The incidence of multiple drug-resistant strains of *Enterococcus seriolicida*, the causative bacterium of streptococcosis, has gradually increased in recent years (Fig. 3). Fish farmers now find it very difficult to overcome these diseases by chemotherapy.

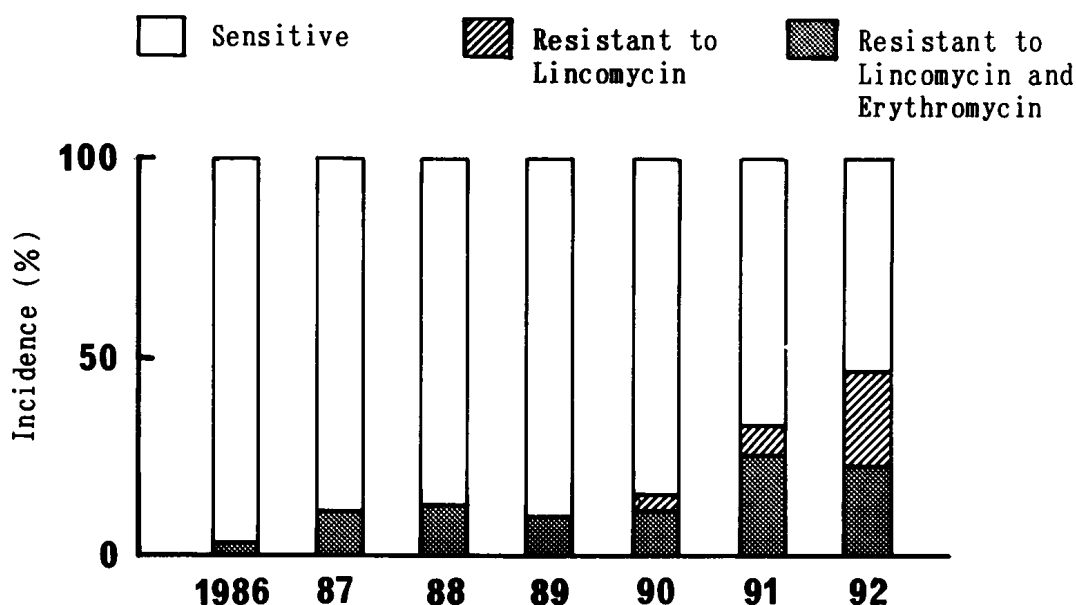


Fig. 3. Incidence of drug-resistant strains of *Enterococcus seriolicida* from 1986 to 1992. From Ehime Prefecture (1993).

The epidemiological surveys show a close relation between the increase of multiple drug-resistant strains and the indiscriminate use of chemotherapeutic agents in yellowtail culture. In an experiment to lower the drug resistance of *Enterococcus* bacteria, the drug macrolide was withheld for several months, after which the sensitivities of isolated bacteria to erythromycin were determined. The results showed that the incidence of drug-resistant strains became very low after drug use was stopped (Fig. 4).

Thus, we have to establish the proper use of chemotherapeutic agents in fish farms to prevent an increase in drug-resistant strains.

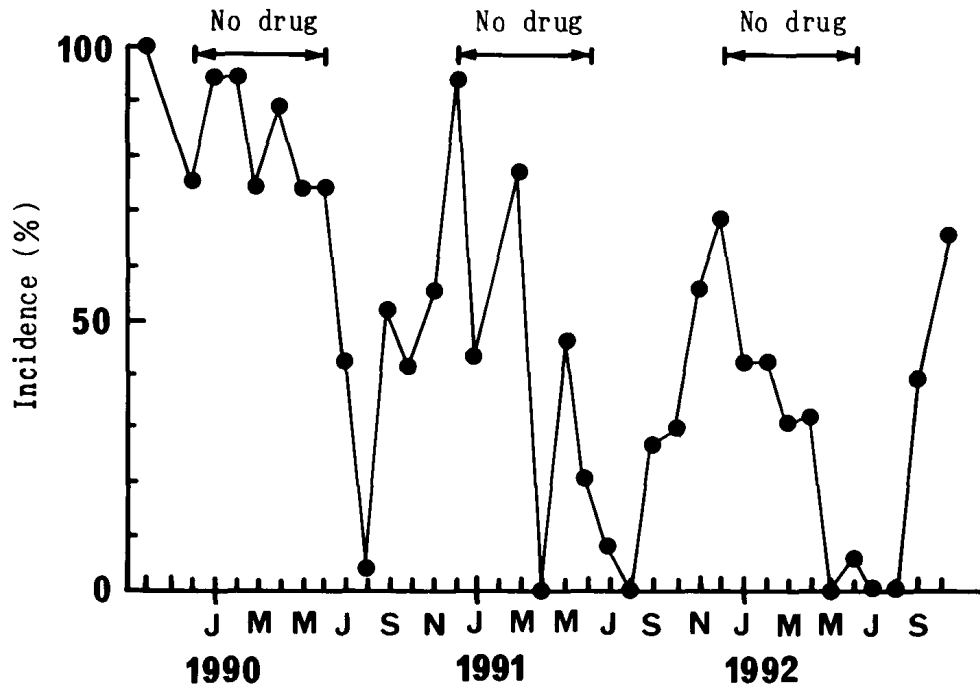


Fig. 4. Incidence of macrolide-resistant strains of *Enterococcus seriolicida* in a yellowtail farm where administration of the drug was stopped during the three periods shown by the bars on top. From Fukudome (1993).

### Increase in Parasitic and Viral Diseases

Parasitic and viral diseases are on the rise (Fig. 5). The parasitic diseases include benedeniosis and heteraxinosis in yellowtail, white-spot disease and bivaginosi in red sea bream, benedeniosis and trichodinosis in flounder, and white-spot disease, heterobothriosis, and trichodinosis in puffer (Table 2). White-spot disease, caused by the ciliate *Cryptocaryon irritans*, was first reported as an aquarium disease, became prevalent in many fish farms, and killed many fish species in recent years. Dense populations of fish in farms lead to very high numbers of parasitic animals.

In 1990, a new viral disease caused by an iridovirus affected the red sea bream in Shikoku Island (Inouye et al. 1992). Since 1991, this viral disease had spread to many red sea bream farms in western Japan and many fish died. Artificial infection experiments showed that the iridovirus is not so virulent. The fact that many red sea bream were killed by the iridovirus suggests that the fish were primarily weakened by some physiological or environmental factor.

Viral and parasitic diseases are difficult to cure with drugs. Only one pesticide, now used against the monogenetic trematode *Benedenia seriolae* parasitic on yellowtail, is legally allowed for marine fish. Thus, drastic changes are expected in the way fish farms are operated.

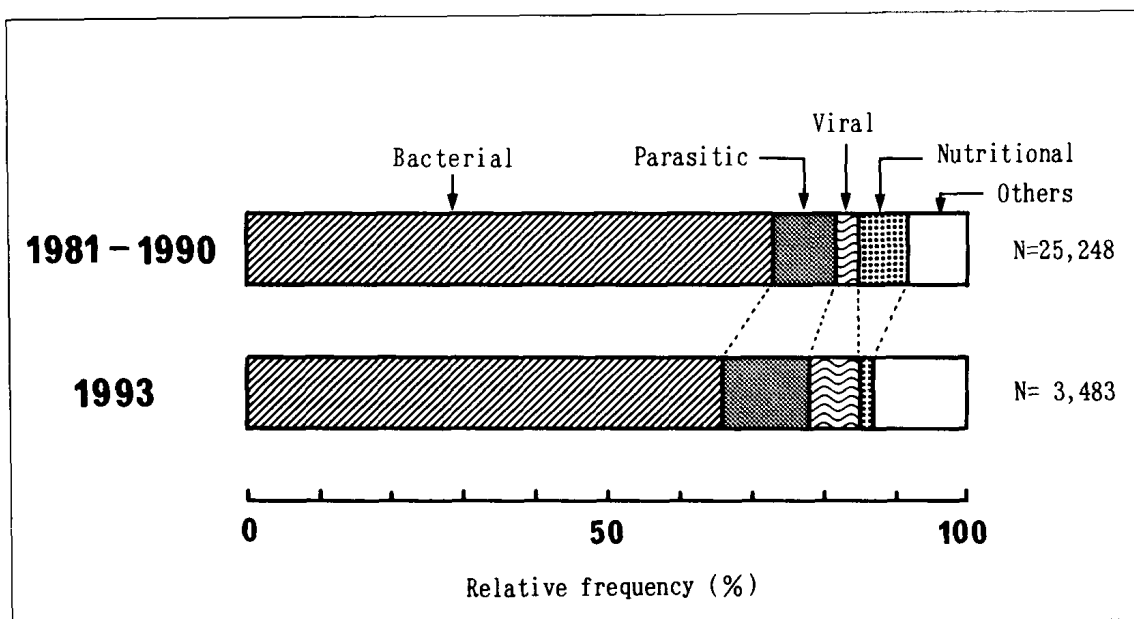


Fig. 5. Disease groups observed in cultured marine fishes. The frequencies of parasitic and viral diseases in 1993 have increased over those in 1981-1990. Data from Nansei National Fisheries Research Institute.

### Diseases from Abroad

The amounts of fish and shrimp juveniles imported from abroad have increased as cultured species have become more diverse. The species imported from abroad by the prefectures in western Japan in 1992 are shown in Table 4. Some of these species come from Taiwan and the Philippines. The imported juveniles of sea perch, purplish amberjack, the seven-banded grouper *Epinephelus septemfasciatus*, and the dark-banded rockfish *Sebastes inermis* make up much of the production of these species in Japan.

Imported stocks may have been the origin of some diseases, for example, epitheliocystis in red sea bream (Ototake and Matsusato 1987) and neobenedeniosis (caused by *Benedenia girellae*) in flounder. In 1993, mass mortality of cultured kuruma shrimp *Penaeus japonicus* occurred in many farms in western Japan due to rod-shaped nuclear virus (Takahashi et al. 1994, Inouye et al. 1994). Mass mortality occurred in all the shrimp farms that had imported the juveniles from China. The disease was transmitted horizontally from the imported shrimps to many shrimp farming areas (Nakano et al. 1994).

Imported fishes may easily become diseased due to the new environmental conditions. To avoid the risk of invasion of unknown pathogens in the future, juveniles for culture should be supplied from within the country. Unfortunately, import of juveniles will probably continue in response to the demand for cultured fish. Thus, there is an urgent need to take preventive measures against potential epidemics due to imported fish.



Table 4. Species of juvenile fish imported for culture in Japan in 1992. Data from Nansei National Fisheries Research Institute.

Species	Importing country
<i>Pagrus major</i>	Hongkong, Taiwan, China
<i>Acanthopagrus schlegeli</i>	China
<i>Lateolabrax</i> spp.	Hongkong, Taiwan, China
<i>Seriola quinqueradiata</i>	Hongkong, Taiwan, China, Korea
<i>Seriola purpurascens</i>	Hongkong, China, Korea, Viet Nam
<i>Seriola aureovittata</i>	Korea
<i>Epinephelus septemfasciatus</i>	Korea
<i>Epinephelus malabaricus</i>	Philippines
<i>Epinephelus awoara</i>	Hongkong
<i>Hexagrammos otakii</i>	China
<i>Sebastes inermis</i>	Korea
<i>Paralichthys olivaceus</i>	Korea
<i>Stephanolepis cirrhifer</i>	China
<i>Penaeus japonicus</i>	Taiwan

## Conclusion

Incidence of fish diseases depends on the condition of the host fish and the environment and on the presence of pathogens. Therefore, further efforts should be made to improve the dietary and environmental conditions to give the host animals resistance against disease. Activation of the defence mechanisms of the host animals through vaccination or immunomodulation should be investigated more intensively. To solve the problem of spread of diseases through international transfer of juvenile stocks, we need active exchange of information on fish diseases and the development of diagnostic, disinfection, and quarantine procedures.

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# **Health Management in Tropical Aquaculture Systems**

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## **Abstract**

Health management strategies are very important in aquaculture. In Asia, health management practices are broadly similar for the various aquatic species that are cultured. These focus mainly on maintaining the good health of the organisms throughout the life cycle. Good health management is based on an understanding of the interactions between the environment (water), the host, and the pathogens. In an ideal system, the three factors are balanced to offset a disease process. This balance is difficult to maintain in an intensive culture system and significant mortalities usually result. The outbreak of disease is thus related to poor health management. This paper deals with the health management practices applicable to the hatchery and grow-out stages of shrimp and fishes cultured in the tropics.

## **Introduction**

The main aim of a fish farmer is to optimize production and minimize inputs. To succeed, the farmer must practise good health management from the hatchery to the grow-out farms, and until the fish, shrimp, or mollusk is sold in the market or processed into value-added products.

Fish farming is more complex than terrestrial animal husbandry. This is because in the aquatic environment, the physical and chemical changes can be very unpredictable and rapid. The health of aquatic organisms depends on the water quality. Poor water quality can stress the organisms and make them more susceptible to disease-causing pathogens present in the water. Fish health management must thus be oriented towards reducing the stress factors and the risk of infection by potential pathogens.

A careful study of all routine work in the hatchery or pond complex will reveal that health management practices can be and must be incorporated at every stage of the operation. Trained personnel and good engineering design are required to ensure this. Many operations have failed in the past due to unqualified personnel or poorly designed systems. It is imperative that the

management of the operation be on a sensible and rational basis. Expensive foreign consultants hired to do the job often do not succeed because they do not understand local environmental conditions.

This paper discusses the health management practices that must be adopted in tropical aquaculture systems. Many of these practices have been refined over the years either by trial and error or more recently through scientific studies (Shariff et al. 1992).

## **Health Management in the Hatchery**

### **Water quality**

Good water quality is crucial in the hatchery and can be the deciding factor in its success. Most hatcheries treat the water before use, either with chemicals or with ultraviolet radiation to remove potential pathogens. In shrimp hatcheries, it is normal practice to pump the water from as far as possible at sea to ensure optimal water quality. Alternatively, water may be pumped through a sand filter bed. Hatchery operators unable to pursue these two options often pump water into large settling tanks and hold it there for 12-24 hours to allow the organic matter to settle or oxidize. Particulate matter may also be removed by filter bags, which come in various mesh sizes from 1 to 5  $\mu\text{m}$ . Water may then be treated with calcium hypochlorite at a minimum dose of 5 mg/l. Chlorine reacts rapidly with sea water by freeing bromine to form oxidative by-products such as bromoform and bromate (Mangum and McIlhenny 1975), so it is essential to aerate the water to remove the toxic residues. Baticados and Pitogo (1990) have shown that water treated with chlorine should be used within 6 hours or else the bacteria will multiply back to pre-treatment levels.

Many hatcheries use ultraviolet irradiation of water for rearing. Ultraviolet kills 98% of the water-borne pathogens (Clary 1978). It also reduces by 99% the levels of infectious hematopoietic necrosis virus (IHNV), *Oncorhynchus maso* virus (OMV), channel catfish virus (CCV), and *Herpesvirus salmonis* (Yoshimizu et al. 1986). The ultraviolet disinfection is nontoxic, does not affect water chemistry, and can be designed to suit any flow rate. Water to be treated must first be cleaned of particulate matter that otherwise hinders the transmission of ultraviolet and makes it ineffective.

The use of ozone is yet another way to remove pathogens. Yoshimizu et al. (in press) have shown that ozone at a dose of 0.5 mg/l for 15-30 seconds can remove 99.9% of *Vibrio anguillarum*, *Streptococcus* sp., *Aeromonas salmonicida*, *A. hydrophila* and *Escherichia coli* and inactivate 99% or more of hirame rhabdovirus, IHNV, and OMV. Ozone (O<sub>3</sub>) is formed with atomic oxygen when O<sub>2</sub> molecules are sufficiently excited to collide. Ozone is toxic to aquatic animals and ozonated water must be passed through activated carbon before it is used in culture tanks with animals. Besides removing pathogens, ozone also oxidizes some of the organic matter in the water.

### Sanitary measures and quarantine

A well designed hatchery must be fully enclosed. To prevent the introduction of potential pathogens via movement of personnel, a dip containing a disinfectant must be provided at the entrance to the hatchery. All who enter must first step into the disinfectant. Inside the hatchery, disinfectant dips must also be provided to treat nets and other equipment used in the culture tanks.

Any animal brought into the hatchery must be checked to ensure that it is healthy and has been purchased from a reliable source. Some hatcheries have a quarantine area to ensure that animals are disease-free, or if necessary, are treated for a given period. New animals are usually given a dip or bath in formalin (25-250 mg/l) to remove external parasites.

Feeds can also be a source of pathogens. For example, *Artemia salina* has been shown to carry *Vibrio harveyi* which can cause severe mortalities among shrimp larvae (Pitogo et al. 1992).

There are no treatments for viral infections. Oftentimes hatcheries cannot get virus-free broodstock, particularly tiger shrimp free from monodon baculovirus (MBV). However, the transfer of infectious agents to the eggs can be minimized by removing the parents after the eggs have been fertilized. The eggs and larvae of shrimps can also be washed with clean filtered sea water to reduce the incidence of MBV infection (Chen et al. 1992). However, in various fishes, the larvae survive better when they are looked after by their parents. Thus, it is always better to use parents that are free of pathogens.

When shrimp or fish larvae or juveniles are purchased, they are usually examined for health status, external parasites, and signs of diseases. MBV is a common viral infection and can be easily detected under fresh smears as viral inclusion bodies. However, there are still many hatcheries that do not screen the shrimps for MBV inclusion bodies. Other visual criteria may also be used to determine the health of larvae. Healthy fish exhibit bright body color, well spread fins, and active swimming. The guts are full of food, and the larvae have straight bodies and swim actively against the current when the water is spun around. One significant point to note is that a sick fish or shrimp does not feed.

### Routine procedures

Proper health management in the hatchery includes proper feeding regimes, sufficient water exchange and aeration, appropriate stocking densities, and maintenance of optimum temperatures. Excess feeds and feces increase the organic load and the concentrations of ammonia, nitrites, carbon dioxide, and bacteria. Acute mortalities can thus occur either due to the toxic environment or through secondary infections. Water quality must be maintained by frequent removal (siphoning) of wastes and regular exchange of water. Cleaning and handling of cultured organisms must be done with care and minimal disturbance. Sufficient aeration is essential to provide oxygen at all times. Water temperature in a hatchery must be maintained within an optimum range with the use of heaters or by enclosing the hatchery.

High stocking densities stress the animals and make them more susceptible to infections or other disorders. Overcrowding, increased oxygen consumption, and increased production of

metabolic wastes lead to deterioration of water quality. Unfortunately, hatchery operators stock at high densities to compensate for anticipated losses and thus get into a vicious cycle.

Any abnormal behavior of the fish or shrimp, particularly the inability to feed or swim, must be checked out immediately. A change in the behavior may indicate an adverse environment or an infection. The situation must be analyzed quickly and the appropriate action taken. In many situations, an incorrect diagnosis is made and inappropriate interventions are taken. Usually the first attempt to correct the situation is the 'shotgun' approach of adding chemicals or antibiotics. The problem may simply be poor water quality stressing the fish. In such case, the improvement of water quality allows the animals to feed and swim normally again.

Dead larvae and juveniles must be removed routinely. Removal of dead organisms is an effective way to prevent the spread of diseases.

Hatcheries must break cycle at regular intervals for a thorough clean-up. All tanks and floors must be disinfected and the filters back flushed and dried. The tanks are usually disinfected with either chlorine or iodine compounds or other oxidizing agents.

Transfer of shrimp postlarvae or juveniles from a hatchery to a pond is done in the early morning when there is not much difference in water temperature. For shrimp postlarvae, a sudden change of temperature of even 1°C can cause severe shock. Postlarvae for stocking must be selected to be of normal shape and size, particularly the rostrum and appendages. The abdominal muscle must be clear. Since MBV-free postlarvae are difficult to obtain, those with fewer inclusion bodies must be selected for stocking in ponds.

## **Health Management in Ponds and Cages**

### **Water quality**

In many large pond complexes, water is kept in large settling reservoirs (to reduce the organic and particulate load) before it is directed into ponds. Wild fish, crustaceans, and other potential disease carriers are kept out of the pond by large trap nets. Pond water is monitored regularly to detect changes at an early stage - before acute mortalities can occur. High phytoplankton and zooplankton blooms can reduce oxygen levels in a non-aerated pond, particularly at night. Algal blooms can also be followed by a sudden mass die-off due to nutrient depletion and other sudden changes in water quality.

In shrimp ponds, the water must be changed when the pH variation is more than 0.5 units per day, when there is a sudden increase in water transparency, or when a stable foam appears at the pond surface. To avoid shock to the shrimps, not more than 30% of the water may be changed in one day. Lime and fertilizer must be applied regularly to maintain the optimum condition of the pond.

Providing aeration is a common practice not only in intensive but also in extensive culture of species such as aquarium fishes that do not tolerate low oxygen levels. Ponds are aerated by paddle wheels, the placement of which is very important. Paddle wheels must be positioned so that there is a circular movement of water in the pond and the silt can gather at the pond center.

Eight paddle wheels are recommended for a one-hectare shrimp pond (Chanratchakool et al. 1994). Ponds receiving 6 hours of nightly aeration to keep dissolved oxygen above 4 mg/l gave an average catfish yield of 4,813 kg/ha compared to 3,659 kg/ha from unaerated ponds (Zhang and Boyd 1988).

Overstocking adversely affects the water quality in ponds and stresses the cultured animals. Suitable stocking densities depend on the local environment, number of farms in the area, design and structure of ponds, availability of equipment, seasonal variations in climate, desired market size, and the experience of the farm personnel (Chanratchakool et al. 1994).

### **Maintenance of pond bottom and net cages**

Feces, uneaten feed, and silt from incoming water accumulate on the pond bottom during the grow-out period. This high organic build-up is a source of hydrogen sulfide and also encourages disease-causing organisms to grow. Animals grown in ponds with well maintained bottoms usually show better feed conversion than those in poorly managed ponds. Poor pond bottom is indicated when shrimps have black or brown gills, external fouling, and damage to the appendages. Among fishes, fin rot is a common sign of a poor pond bottom. If pond bottoms are not managed, they can lead to the outbreak of disease and severe mortalities.

The pond bottom should be dried after harvest and prepared properly before stocking. It is often difficult to convince farm operators, especially those without a technical background, of the necessity to dry ponds. This is because ponds may sometimes take more than a month to dry and this can amount to a substantial opportunity cost, especially in shrimp farming where the earnings per hectare can be substantial. Drying the pond and removing the wastes manually or by machines are possible only during dry weather. Many farms still depend on dry weather to crack the pond bottom. Pressure pumps can be used to flush out wastes during any weather and is more convenient in places with lots of rain. However, pressure pumps carry out suspended wastes that pollute the receiving waters, and thus must be used carefully.

Once the pond has been cleaned, it must be flushed twice to get rid of debris and to stabilize the water pH. Then the pond is dried and limestone ( $\text{CaCO}_3$ ) or quicklime ( $\text{CaO}$ ) is applied to disinfect the pond bottom. After liming, ammonium sulfate can be applied at a rate of 10 g/m<sup>2</sup> in wet areas. The lime raises the pH and causes the fertilizer to release free ammonia ( $\text{NH}_3$ ) which kills any remaining fish or potential pest in the pond. Organic fertilizer is then added to encourage the growth of natural food organisms. Chicken or other manures must be completely dried before use as fertilizer. Animal manures have high levels of organic carbon and total nitrogen; when they decompose, they use up oxygen and produce hydrogen sulfide, methane, and ammonia.

In a cage culture system, the nets are frequently cleaned and dried in the sun. Excessive fouling of nets impedes the water movement through the cages and leads to deterioration of water quality.

### **Health monitoring**

The health status of the shrimps or fishes in ponds or cages can be easily monitored at feeding time. Healthy fish will immediately come to get the feed. To monitor shrimp feeding, a

net (about 1 m<sup>2</sup>) with a handful of feed is set at the bottom at feeding time. The net is lifted after one hour to check the feed consumption. Active feeding is an indication of healthy fish and shrimp.

## **Chemotherapy**

Antibiotics are commonly used in most hatcheries. Without the use of antibiotics and other chemicals, many hatcheries do not have good yields. However, it must be understood that the adverse effect of antibiotics can be felt only after several culture cycles when even high doses no longer prevent or control diseases. Failed runs usually lead to a temporary shutdown of the hatchery and frequently a change of ownership. One of the factors that caused the collapse of the Taiwan shrimp industry in the late 1980s was the heavy use of antibiotics (Liao 1989). The rampant use of antibiotics has also been linked to the development of resistant bacteria in the region (Baticados and Paclibare 1992, Aoki 1992, Supriyadi and Rukyani 1992).

Among the antibiotics and antibacterial compounds commonly used in aquaculture in Southeast Asia are oxytetracycline, sulphonamides, chloramphenicol, oxolinic acid, erythromycin, furazolidone, nitrofurazone, flumequin, and enrofloxacin (Baticados and Paclibare 1992, Aoki 1992, Supriyadi and Rukyani, 1992, Tonguthai and Chanratchakool 1992). Neomycin is commonly used when packing aquarium fishes. Other chemicals commonly used in the tropics are benzalkonium chloride, copper sulfate, dipterex, formalin, malachite green, methylene blue, potassium permanganate, trifuralin, and common salt.

The use of immunostimulants or enhancers is now being promoted, particularly in the farming of high-value shrimps and marine fishes (Raa et al. 1992, Sakai et al. 1992). Vaccines are also being developed for bacterial diseases like edwardsiellosis (Iida and Wakabayashi 1992).

In marine cage culture, the usual treatment for parasitic and bacterial diseases is by reversing the salinity. Juveniles infected with protozoan and monogenean ectoparasites or those with fin rot are dipped in freshwater for 15 minutes then returned to the cages. Reversing the salinity is particularly effective against myxobacteria, which can cause up to 100% mortality (Leong 1992). This treatment is also done on new arrivals. Therapeutic regimes for infected fish call for two or more treatments at weekly intervals.

There are still many farmers who use traditional methods to treat fish diseases. Tobacco plant stems are introduced into ponds for the treatment of Copepod (*Lernaea*) infection. Various natural herbs and products derived from plants are being used in China for the treatment of various fish diseases. However, these herbal or plant products are not readily available in southeast Asia. Sometimes these traditional methods do not work effectively because the correct dose is not known or not applied accurately.

## **Handling and Transport**

Careful handling of animals is crucial to high survival at all stages of the life cycle. Care must be taken to minimize stress during handling for sampling, treatment of diseases, and transport. Minor injuries on the body can lead to secondary infection with bacteria or fungi.



Fishes have natural protection - a mucus layer with antibacterial activity (Austin and McIntosh 1988), but any form of handling that removes the mucus layer leads to secondary infection. Anaesthetics at the correct dose allow easier and less stressful handling, but at an incorrect dose may kill the fish.

Live fishes and shrimps for market are usually transported in chilled water in insulated containers, preferably at night or in the early morning. The animals may also be transported in plastic bags in insulated containers. Recently, anaesthetics, ammonia-absorbing substances, and buffer solutions have been used in the transport of fish. To reduce metabolic activity and the production of feces, fishes are starved 12 hours before transport.

## **Nutrition**

Proper nutrition is essential for good health and optimal growth and reproduction of the cultured animal. Since the animals are raised under confined conditions, the diet must be well balanced and the essential vitamins and nutrients provided in the right proportions. Vitamin deficiencies can cause disease syndromes and deaths. Poor-quality 'trash' fish and other wet feeds can also lead to an increased susceptibility to bacterial infection.

Pelleted feeds must be stored in an appropriate facility to ensure that there is no loss of nutritive value. Most vitamins biodegrade with time, a process that is accelerated by high temperatures. Feeds must be purchased and used fresh. Feeds stored for more than three months lose their nutritive value and may become infected with fungi and other pathogens.

## **Conclusion**

There is room for further improvement of health management in tropical aquaculture systems. For example, the transfer of pathogens must be prevented by ensuring that fish for export or import are free of pathogens. Quarantine procedures must be stringently observed.

Indiscriminate use of antibiotics like chloramphenicol must be banned in aquaculture. Chloramphenicol is the only effective drug against typhoid fever, and its use in aquaculture may produce resistant typhoid bacteria. Similarly, absolute care must be taken in the use of hazardous drugs and chemicals such as malachite green. New health management technologies must be examined closely before being adopted or used. New technologies may have adverse effects on the environment in the short or long term. One example is the use of organochlorines to treat parasites; this chemical persists in the environment and also gets into the food chain and to the fish consumers.

Another important point in the use of chemicals in aquaculture is the withdrawal period. Scientists have to work out the withdrawal periods for different drugs used in tropical aquaculture. Most of the available data are for temperate Fishes and shrimps.

More work must be done to investigate locally available natural products that are environment-friendly and have high safety margins for fishes and shrimps. Vaccines that can be used as prophylactics must be developed.

Fish health scientists must frequently highlight their findings that apply to the aquaculture industry. Findings in scientific journals do not easily reach the people in the field. Scientists must use other forms of media to make the public aware of issues in fish health management, including the hazards of antibiotics, drug residues, and the transfer of diseases through transport and introduction of animals to new places.

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# **Transgenic Fish and Aquaculture**

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## **Abstract**

Transgenic fish species can be routinely produced by transferring foreign DNA into developing embryos via microinjection or electroporation. This technology offers an excellent opportunity for modifying or improving the genetic traits of commercially important fishes, mollusks, and crustaceans for aquaculture. Studies have shown that administration of recombinant fish or mammalian growth hormone (GH) to juvenile fish or oysters resulted in significant growth enhancement. Thus, it is possible to improve the growth rates of marine animals by manipulating GH or its gene. This paper reviews the results of studies to determine the efficacy of recombinant fish GH in improving the growth rates of fishes, mollusks, and crustaceans, and of gene transfer technology in producing fast-growing transgenic animals.

## **Introduction**

The worldwide harvest of fishery products traditionally depends upon the natural populations of fishes, mollusks, and crustaceans from fresh and marine waters. Due to the rapid increase in consumption of fishery products by the general public, as well as uncontrolled fishing and poor management, the total annual harvest has already approached the maximum potential of about 150 million tons as forecast by the US Department of Commerce. Accumulation of chemical pollutants in aquatic environments has further affected the fisheries production. A number of regions have experienced significant declines in the catches of important species such as salmon, striped bass, sturgeons, eels, jacks, mullets, mackerel, abalones, oysters and crabs (FAO 1986). Fishing fleets now travel great distances to exploit more productive areas. They have switched to alternative species and begun to employ a variety of sophisticated technologies. These developments have caused significant increases in fish prices.

In the past decades, many countries have turned to aquaculture to increase fish production. In 1992, the world production from aquaculture exceeded 17 million tons, about 32.2% of the total fisheries production (Csavas 1995). Thus, aquaculture has the potential to substantially meet the world demand for fishery products.

The success of aquaculture depends on: (1) complete control of reproduction and the life cycle, (2) excellent genetic background of the broodstock, (3) efficient detection and effective prevention of diseases, (4) thorough understanding of the optimal physiological, environmental, and nutritional conditions for growth and development, (5) sufficient supply of good quality water; and (6) innovative management techniques. By improving some of these factors, the aquaculture industry has already made impressive progress over the last several years. The application of molecular biology and biotechnology will further speed up the expansion of the industry. These applications include enhancing growth rates, controlling reproductive cycles, improving feed composition, producing new vaccines, and developing disease-resistant and hardier genetic stocks. Over the last several years, our laboratory and others have been searching for innovative strategies to increase fish production by applying the methods of contemporary molecular biology and biotechnology. In this paper, I will summarize results of our studies and those of many others to demonstrate the efficacy of modern biological techniques, including transgenic fish technology, in increasing the production from aquaculture.

### **Effect of Recombinant Fish Growth Hormone on Somatic Growth**

Thanks to the rapid advances in recombinant DNA technology, complementary DNA (cDNA) and the genomic sequence of growth hormone (GH) have been isolated and characterized for several fish species in recent years (Gill et al. 1985, Agellon and Chen 1986, Gonzales-Villaseñor et al. 1986, Momota et al. 1988, Watahiki et al. 1989). Our laboratory has prepared biologically active recombinant GH by expressing rainbow trout (rt) GH1 cDNA in *E. coli* cells (Agellon et al. 1988). Since rainbow trout GH molecule is highly hydrophobic, the resulting polypeptide synthesized in *E. coli* cells forms insoluble inclusion bodies, which are inactive but can be easily recovered by differential centrifugation. The protein is dissolved in a 100 mM Tris buffer pH 9.0 with 8 M urea. Renaturation of the recombinant hormone is carried out by slowly diluting the solution to 4.5 M urea and the protein concentration below 0.5 mg/ml while stirring gently at 40°C for 24 hours. The biological activity of the resulting hormone preparation is assessed by its ability to stimulate the uptake of radioactive sulfate into gill cartilage *in vitro* and the accumulation of insulin-like growth factor (IGF)-I in the liver *in vivo*.

Agellon et al. (1988) showed in a series of studies that application of this recombinant hormone to yearling rainbow trout resulted in a significant growth enhancement. After treatment with the recombinant rtGH for four weeks at a dose of 1 µg/g body weight each week, the weight gain among the hormone-treated rainbow trout was two times greater than among the controls. Significant length gain was also evident in hormone-treated animals. When the same recombinant hormone was administered to small juvenile rainbow trout by immersing them in GH-containing solutions, the same growth-promoting effect was also observed (Table 1; also Leong and Chen, unpublished results). These results are in agreement with those reported by Sekine et al. (1985), Gill et al. (1985), and others (Schulte et al. 1986, Sato et al. 1988a, 1988b, Moriyama et al. 1990). However, it is important to mention that the growth enhancement effect of the biosynthetic hormone was markedly reduced when more than 2 µg/g was applied to the test animals (Agellon et al. 1988). These results suggest that when the total amount of GH exceeds the maximal threshold level, homeostasis is disturbed and growth is affected.

Table 1. Effect of recombinant growth hormone (GH) treatment on the growth of young juvenile rainbow trout. Values are mean $\pm$ SE (n=15). Data from Agellon et al. (1988) with permission.

Treatment	Initial weight (g)	Final weight (g)	%Gain
Saline control	1.33 $\pm$ 0.6	3.94 $\pm$ 1.8	196
GH 50 $\mu$ g/l	1.29 $\pm$ 0.7	5.51 $\pm$ 1.6	327
GH 500 $\mu$ g/l	1.35 $\pm$ 0.7	5.30 $\pm$ 1.3	293

Groups of rainbow trout were subjected to osmotic shock in the presence or absence of recombinant GH. Weight was measured before and after 5 weeks of treatment. Final weights were not significantly different between the two GH treatments but both differed from the control.

Several years ago, Morse (1984) reported that bovine insulin and bovine GH enhanced the growth rate of California red abalone. Recently, Paynter and Chen (1991) found that dipping the spats or juveniles of the oyster *Crassostrea virginica* in solutions of recombinant rtGH polypeptide (10-100 nM) also resulted in significant increases in shell size, wet weight, and dry weight (Table 2). Oysters treated with recombinant rtGH, native bovine GH, or bovine insulin consumed more oxygen per unit time than controls. These findings suggest that recombinant fish GH can be used to enhance the growth rate of mollusks under intensive culture conditions. They further suggest that growth in mollusks may also be regulated by hormonal factors similar to mammalian GH and insulin-like growth factors (IGFs).

Table 2. Effect of recombinant rainbow trout growth hormone exogenously applied to oysters for 5 weeks. Values are means $\pm$ SE. Data from Paynter and Chen (1991), with permission.

GH conc. (nM)	Initial shell height (mm)	Final shell height (mm)	Total weight (mg)	Shell weight (mg)	Dry weight (mg)
0	8.14 $\pm$ 0.25	11.68 $\pm$ 0.27	206 $\pm$ 11	136 $\pm$ 8	6.10 $\pm$ 0.66
1	8.04 $\pm$ 0.27	11.74 $\pm$ 0.23	199 $\pm$ 9	131 $\pm$ 6	6.87 $\pm$ 0.66
10	8.72 $\pm$ 0.18	12.79 $\pm$ 0.27	244 $\pm$ 20	171 $\pm$ 11	9.42 $\pm$ 0.41
100	8.65 $\pm$ 0.32	13.00 $\pm$ 0.36	252 $\pm$ 13	189 $\pm$ 13	9.41 $\pm$ 0.74

In order to realize the potential of recombinant GH to enhance the somatic growth rate of cultured fish, a series of studies has to be conducted. These studies include: (1) route of hormone delivery, (2) effective dose of hormone, (3) regimen of hormone administration, (4) nutritional requirement, (5) effect of environmental factors, (6) effect of chronic and acute GH treatment, and (7) effect of fish GH on human consumers.

## **Transgenic Fish Harboring Growth Hormone Gene**

Although exogenous application of recombinant GH results in significant growth enhancement in fish, it may not be cost-effective. If new strains of fish producing elevated but optimal levels of GH can be produced, it would bypass many of the problems with exogenous GH treatment. Moreover, once these fish strains have been generated, they would be far more cost-effective than their ordinary counterparts because the fish would produce and deliver the hormone and transmit the enhanced growth characteristics to their offspring.

### **Gene transfer methodology**

Animals into which a segment of foreign DNA has been introduced and stably integrated into the host genome are called 'transgenic'. Since Constantini and Lacy's (1981) transgenic mice, many other transgenic animals including livestock and fishes have been constructed successfully (Palmiter et al. 1982, Gordon and Ruddle 1985, Hammer et al. 1985, Ozato et al. 1986, Dunham et al. 1987, Pursel et al. 1989, Chen and Powers 1990, Chen et al. 1993). These animals play important roles both in basic research as well as in biotechnology application. Various methods have been used to deliver foreign DNA into somatic cells and germlines of mammals and other higher vertebrates. The methods include direct microinjection, retrovirus infection, electroporation, calcium phosphate precipitation, and particle-gun bombardment. Direct microinjection of DNA into the male pronuclei of the fertilized eggs has been the prevalent method.

The microinjection method has been used to deliver foreign genes into several fish species in recent years. These include goldfish (Zhu et al. 1985), medaka (Ozato et al. 1986, Lu et al. 1992), rainbow trout (Chourrout et al. 1986), salmon (Fletcher et al. 1988), tilapia (Brem et al. 1988), zebrafish (Stuart et al. 1988), common carp (Zhang et al. 1990, Chen et al. 1993), and catfish (Dunham et al. 1992, Powers et al. 1991). In general, gene transfer in fish by microinjection is carried out as follows. Eggs and sperm are collected into separate dry containers. Fertilization is initiated by adding water and sperm to eggs and stirring gently. Eggs are water-hardened for various periods of time and then rinsed. Microinjection is done within the first two hours after fertilization. The equipment consists of a dissecting stereomicroscope and two micromanipulators, one with a microneedle for injecting DNA into the embryos and the other with a micropipette for holding the embryos in position during the injection. Since the male pronuclei of the fish embryos studied to date are not visible, the foreign genes are usually injected into the egg cytoplasm and the amount of the DNA injected into each embryo is in the range of one million copies or higher. In zebrafish and medaka, natural spawning can be induced by adjusting photoperiod and water temperature and newly fertilized embryos can be readily collected for microinjection. Within the first two hours after fertilization, the micropyle of the embryo is still visible under the microscope. The DNA solution can be easily delivered into the embryos with a microneedle through the micropyle (Stuart et al. 1988, Lu et al. 1992).

Although the microinjection method is successful in transferring foreign DNA into fish embryos, it is very laborious and time-consuming. There is interest in developing convenient mass gene transfer technologies for use in fish transgenesis. Among the mass gene transfer methods are particle-gun bombardment, electroporation, and those mediated by retroviruses, liposomes, or sperm. Electroporation is the most effective means of transferring foreign genes into fish embryos. This method uses a series of short electrical pulses that change the membrane permeability and thereby permit the entry of DNA molecules into embryos. Lu et al. (1992)

showed that the rate of foreign gene integration in transgenic medaka produced by electroporation was 20% or higher. Powers et al. (1992) recently reported a much higher rate of gene transfer in common carp and channel catfish with the same electroporator. The rate of transgene integration in transgenic medaka produced by electroporation was only slightly higher than that of microinjection, but it takes much less time to produce large numbers of transgenic fish by electroporation.

### **Transgenic fish harboring growth hormone gene**

Zhu et al. (1985) reported the first successful transfer into goldfish and loach of human GH gene fused to a mouse metallothionein gene promoter. According to Zhu (personal communication), the F<sub>1</sub> offspring of these transgenic fish grew twice as large as their non-transgenic siblings. Unfortunately, Zhu and his colleagues failed to present compelling evidence for integration and expression of the foreign genes in their transgenic fish. Recently, our laboratory as well as many other laboratories throughout the world have successfully confirmed Zhu's work by demonstrating that human or fish GH and many other genes can be readily transferred into embryos of a number of fish species and integrated into the genome of the host fish (for review, see Chen and Powers 1990). While several groups have demonstrated expression of foreign genes in transgenic fish, only Zhang et al. (1990), Du et al. (1992) and Lu et al. (1992) have documented that a foreign GH gene could be: (a) transferred to the target fish species, (b) integrated into the fish genome, and (c) genetically transmitted to subsequent generations. Furthermore, the expression of the foreign GH gene may result in enhancement of growth rates of both P<sub>1</sub> and F<sub>1</sub> generations of transgenic fish (Zhang et al. 1990, Lu et al. 1992).

In gene transfer studies on common carp and channel catfish, about 10<sup>6</sup> molecules of a linearized recombinant plasmid containing the long terminal repeat (LTR) sequence of avian Rous sarcoma virus (RSV) and the rainbow trout GH1 or GH2 cDNA were injected into the cytoplasm of one-, two- and four-cell embryos (Zhang et al. 1990, Chen et al. 1990, 1993, Powers et al. 1991, Dunham et al. 1992). Genomic DNA samples extracted from the pectoral fins of presumptive transgenic fish were then analyzed for the presence of RSVLTR-rtGH1-cDNA by PCR amplification, followed by Southern blot hybridization of the amplified DNA samples. About 35% of the injected carp embryos survived at hatching and about 10% of the survivors had integrated the RSVLTR-rtGH1-cDNA sequence (Zhu et al. 1985, Chen and Powers 1990, Chen et al. 1990, Zhang et al. 1990, Du et al. 1992, Lu et al. 1992). Southern-blot analysis of genomic DNA from several transgenic carps revealed that a single copy of the RSVLTR-rtGH1-cDNA sequence was integrated at multiple chromosomal sites (Zhang et al. 1990).

When an RSVLTR-csGH-cDNA construct was injected into catfish embryos, about 10% of the fish also turned out transgenic (Powers et al. 1991, Dunham et al. 1992). In microinjected medaka, 20-30% of the hatched individuals integrated the foreign gene, suggesting that DNA microinjected via the micropyle may have better access to the nucleus situated right beneath it (Lu et al. 1992).

### **Inheritance and Expression of Foreign Growth Hormone Gene in Transgenic Fish**

The patterns of inheritance of RSVLTR-rtGH1 cDNA in transgenic common carp were studied by fertilizing eggs collected from non-transgenic females or P<sub>1</sub> transgenic females with sperm samples of several sexually mature P<sub>1</sub> male transgenic fish (Chen et al. 1993). The DNA samples extracted from the resulting F<sub>1</sub> progeny were assayed for the presence of RSVLTR-rtGH1 - cDNA sequence by PCR amplification and dot-blot hybridization. The percentage of transgenic progeny resulting from nine matings were 0, 32, 26, 100 (4 progeny only), 25, 17, 31, 30, and 23. If each of the transgenic parents in these nine matings carried at least one copy of the transgene in the gamete cell, about 50-75% transgenic progeny would have been expected in each pairing. Of these nine matings, two sib lots, both control x P<sub>1</sub>, gave transgenic progeny as many as or more than expected. The other matings gave less than expected numbers of transgenic progeny. These results indicate that although most of these P<sub>1</sub> transgenic fish had RSVLTR-rtGH1 cDNA in their germline, they might be mosaics. Similar patterns of mosaicism in the germline of P<sub>1</sub> transgenic fish have been observed in many fish species studied to date (Ozato et al. 1986, Dunham et al. 1987, 1992, Stuart et al. 1988, Zhang et al. 1990, Lu et al. 1992).

If the transgene carries a functional promoter, some of the transgenic individuals are expected to express the transgene activity. Many of the P<sub>1</sub> and F<sub>1</sub> transgenic common carp produced rtGH at levels that varied about 10-fold (Zhang et al. 1990, Chen et al. 1993). Chen et al. (1993) recently detected rtGH mRNA in the F<sub>1</sub> transgenic carp with an assay involving reverse transcription, PCR amplification, and RNA dot-blot hybridization. Different levels of rtGH mRNA were detected in liver, eyes, gonads, intestine and muscle of the F<sub>1</sub> transgenic individuals.

### **Growth Performance of Fish Transgenic for Growth Hormone**

Since the site of transgene integration differs among the individuals in any population of P<sub>1</sub> transgenic fish, they should be considered as totally different transgenic individuals and cannot be directly compared for growth performance among themselves. Instead, the growth studies should be conducted in F<sub>1</sub> transgenic and non-transgenic siblings derived from the same family. Chen et al. (1993) evaluated the growth of F<sub>1</sub> transgenic carp in seven families. In these experiments, transgenic and non-transgenic full siblings were spawned, hatched, and reared communally under the same environment. Results showed that growth of F<sub>1</sub> transgenic individuals in response to rtGH1 cDNA varied widely. The seven trials showed that transgenics grew 20, 40, 59, and 22% faster, or 27, 15 and 2% slower than non-transgenic full siblings.

In three of the four families where F<sub>1</sub> transgenics grew faster than their non-transgenic full siblings, the highest and lowest body weights of the transgenics were larger than those of the non-transgenics. In the fourth family, the minimum but not the maximum body weight of the transgenics was larger than that of the non-transgenics. In two of the three transgenic families in which the transgenic siblings grew slower than the non-transgenics, the lowest and highest body weights of the transgenics were less than those of the non-transgenics. In the third family, however, one of the F<sub>1</sub> transgenics was the largest fish in the family. Since the response of the transgenic fish to the insertion of the RSVLTR-rtGH1 cDNA appears to be variable, as a result of random integration of the transgene, the fastest growing genotype will likely be developed by utilizing a combination of family selection and mass selection of transgenic individuals after the



insertion of the foreign gene. Among transgenic medaka carrying chicken b-actin gene promoter human GH gene construct, the F<sub>1</sub> transgenics grew significantly faster than the non-transgenic siblings (Lu et al. 1992).

In an effort to study the biological effect of elevated levels of IGF-I on somatic growth, transgenic medaka harboring trout IGF cDNA driven by carp  $\beta$ -actin gene promoter have been produced in our laboratory. Both P<sub>1</sub> and F<sub>1</sub> IGF-I transgenic medaka hatched two days earlier than their non-transgenic siblings. The P<sub>1</sub> transgenics also grew faster than the non-transgenics.

## General Conclusion and Prospective

Transgenic fish technology has great potential in the aquaculture industry. By introducing desirable genetic traits into fishes, mollusks, and crustaceans, superior transgenic strains can be produced for aquaculture. These traits include faster growth rates, improved food conversion efficiency, resistance to some known diseases, tolerance to low oxygen concentrations, and tolerance to extreme temperatures. Our laboratory and those of others have shown that transfer, expression and inheritance of fish growth hormone transgenes can be achieved in several fish species and that the resulting transgenics grow substantially faster than their non-transgenic siblings. This is a vivid example of the potential application of the gene transfer technology to aquaculture.

However, to realize the full potential of the transgenic fish technology in aquaculture or other biotechnological applications, several important scientific breakthroughs are required. These include: (1) more efficient technologies for mass gene transfer, (2) targeted gene transfer technologies such as embryonic stem cell gene transfer or ribozyme gene inactivation, (3) suitable promoters to direct the expression of transgenes at optimal levels during the desired developmental stages, (4) identified genes of desirable traits for aquaculture and other applications, (5) information on the physiological, nutritional, immunological and environmental factors that maximize the performance of the transgenics, and (6) safety and environmental impacts of transgenic fish. Once these problems are resolved, the commercial application of the transgenic fish technology will be readily attained.

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# **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)			Total
	Carp and other cyprinids	Tilapia and other cichlids	Others freshwater fishes	
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)						Total
	Milkfish	Sea bass	Snappers	Groupers	Mulletts	Others	
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	<i>Penaeus monodon</i>	Production (tons)		Total
		<i>P. merguensis</i> <i>P. japonicus</i>	Others	
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 *Eucheuma* 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	Oysters	Production (tons)			Total
		Mussels, clams	Cockles	Others	
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)		Total
	<i>Eucheuma</i>	<i>Gracilaria</i>	
Indonesia	110,000		110,000
Malaysia	-	-	-
Philippines	283,783	-	283,783
Singapore	-	-	-
Thailand	-	-	-
Vietnam	-	2,000	2,000
SEA total	393,783	2,000	395,783
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 quantitative 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					Average
	Indonesia	Malaysia	Philippines	Thailand	Vietnam	
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					Average
	Indonesia	Malaysia	Philippines	Thailand	Vietnam	
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					Average
	Indonesia	Malaysia	Philippines	Thailand	Vietnam	
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



## **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.

In spite 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. Farmers 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 farmers 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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# **Aquaculture in Indonesia**

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## **Abstract**

Indonesia has a long tradition in aquaculture, particularly in fresh water and brackish water. Most aquaculture is still in extensive systems with low productivity. Mariculture only started in the 1980s and contributes yet little to the total national production. Aquaculture has become increasingly important, particularly in supporting rural economies. The development of shrimp and prawn culture became a Government priority after trawl fishing was banned in 1980-81. With its strategic geographic position and enormous inland and coastal resources, Indonesia has good prospects in aquaculture.

## **Introduction**

Aquaculture in Indonesia is generally small-scale, with low technological inputs and high degree of dependence upon nature. Aquaculture covers freshwater, brackishwater, and marine culture. Freshwater and brackishwater culture have been practised for a long time, but mariculture or Seafarming just started in the early 1980s. More than 470,000 hectares of inland waters and 86,000 hectares of coastal waters are available for aquaculture. The total seed supply from open waters is estimated at 11.3 billion per year, consisting of 1.5 billion of milkfish, 800 million of shrimp, and 9 billion of freshwater fishes. Aquaculture has become important particularly in supporting the rural economy in Indonesia. In 1991, aquaculture made up 617,700 tons (Table 1) of the total fisheries production of 3,186,000 tons (FAO 1991, FAO 1993).

The development and management of fisheries, including aquaculture, are under the main auspices of the Directorate General of Fisheries, Ministry of Agriculture. Under PELITA V, the fifth Five-Year Plan (1989-1994), total fisheries production is projected to increase at 5.9% a year to reach 3,974,200 tons in 1993. Aquaculture in particular is expected to grow at a rate of 9.6% annually. In line with the government's current drive to promote non-oil exports, the development of fisheries is directed toward high-value seaweed, pearls, shrimps, crabs, and fishes such as tunas, sea bass, groupers, sharks, and ornamentals. The government encourages the private sector to invest in aquaculture and industrial fisheries; the industrial fisheries serve as development agents for small-scale fisheries. The objectives of fisheries development are:

- To increase production to meet domestic protein requirement, to provide raw materials for the processing industry, and to increase foreign exchange earnings through exports
- To increase the productivity of, and value-added products from, fisheries to improve the income of fishers and fishfarmers
- To expand employment and business opportunities
- To effectively improve the management of fisheries resources and the living environment

The national strategy for aquaculture development focuses on: (1) increasing the productivity of fishfarmers through improved technology, (2) increasing production through the intensification of culture in existing areas and expansion to new areas, and (3) diversifying towards species with high economic value. The aquaculture sector in Indonesia offers good prospects for investment. in coexistence with small-scale fisheries through the Nucleus Estate and Smallholder approach.

Table 1. Production from aquaculture in Indonesia in 1986 and 1991. Data from FAO (1993).

Species	Production (tons)	
	1986	1991
<i>Cyprinus carpio</i>	68,130	90,000
<i>Puntius javanicus</i>	22,877	28,000
<i>Osteochilus hasselti</i>	16,210	15,040
<i>Oreochromis mossambicus</i>	15,487	42,000
<i>Oreochromis niloticus</i>	8,487	12,200
<i>Osphronemus goramy</i>	3,938	4,130
<i>Trichogaster pectoralis</i>	1,414	2,500
<i>Helostoma temmincki</i>	4,988	5,800
<i>Clarias</i> spp.	886	4,000
<i>Anguilla</i> sp.	8	1,150
Other freshwater fishes	39,365	46,000
<i>Chanos chanos</i>	103,588	133,400
<i>Lates calcarifer</i>	798	2,000
Mugilidae	4,283	7,500
<i>Scylla serrata</i>	758	2,400
<i>Portunus</i> spp.	21	10
<i>Penaeus monodon</i>	15,424	70,560
<i>Penaeus merguensis</i>	13,575	18,000
<i>Metapenaeus</i> spp.	11,889	21,510
<i>Acetes japonicus</i>	929	1,500
Seaweeds	77,462	110,000
Total	410,554	617,700



## Freshwater Culture

Aquaculture in ponds, rice fields, cages, pens or floating nets is done by many fishfarmers, and running-water ponds and integrated fish culture systems are in operation in some places. The cultured fishes include common carp *Cyprinus carpio*, tawes *Puntius javanicus*, tilapia *Oreochromis mossambicus*, Nile tilapia *O. niloticus*, gouramy *Osphronemus goramy*, spotted gouramy *Trichogaster pectoralis*, kissing gouramy *Helostoma temmincki*, and nilem *Osteochilus hasselti*. The government has also encouraged the culture of the lele catfish *Clarias batrachus* and the lele dumbo or African catfish *Clarias gariepinus* imported from Taiwan in 1985. The Thai catfish *Pangasius sutchi* was also introduced to Indonesia some years ago, but only a few people are interested in culturing this species. The culture of giant freshwater prawn *Macrobrachium rosenbergii* has been developed in some places, particularly in the provinces of West Java, Central Java, East Java, and Yogyakarta.

Ricefields are usually stocked with the carps *Cyprinus carpio* and *Puntius javanicus*. When the common carps are about 100 grams each, they are harvested and stocked in running-water ponds and in cages, pens or floating nets in rivers, lakes, irrigation canals, dams, or reservoirs. Other species cultured in cages are the common carp *Cyprinus carpio*, gabus or murrel *Ophiocephalus striatus*, toman or murrel *O. microleptis*, and jelawat or carp *Leptobarbus hoevenii*. Small-scale cage culture is done in the provinces of West Java, Jambi, South Sumatera and Kalimantan. In 1990, the average production from freshwater aquaculture was greater than 1 ton/ha (Table 2).

Table 2. Freshwater culture in Indonesia in 1990 (Directorate General of Fisheries, Ministry of Agriculture, Indonesia).

Freshwater culture systems	Area (ha)	Production (tons)
Ponds	84,441	125,176
Rice fields	114,106	100,086
Cages	21	7,392
Total	198,568	232,654

FAO (1993) records a production of 250,820 tons of freshwater fishes in 1991.

To maintain the seed supply, the Directorate General of Fisheries has established *Macrobrachium* and fish hatcheries in several provinces. There are five *Macrobrachium* hatcheries, one each in West Java, Central Java, East Java, Yogyakarta, and Bali. There are 354 fish hatcheries covering 446 hectares — 18 central units under the Provincial Fisheries Service and 336 local units under the District Fisheries Service. The silver carp or mola *Hypophthalmichthys molitrix* and the grass carp *Ctenopharyngodon idella* have been successfully propagated in a government hatchery in Central Java and some juveniles have been distributed to other places. Besides the government hatcheries, private hatcheries in the country numbered 7,649 in 1988, covered about 1,622 hectares, and produced about 2 million young juveniles each year.

To support the development of freshwater aquaculture, the Government has established the Freshwater Fisheries Development Center in Sukabumi, West Java.

### Brackishwater Culture

In Indonesia, fish culture in brackishwater ponds, locally called *tambak*, started in the late 14th century. The existing *tambaks* as of 1990 total 276,442 hectares, 93% of these in Aceh, West Java, Central Java, East Java and South Sulawesi. From 1988 to 1990, the *tambak* area increased 3% annually. Until 1975, the main species cultured in the *tambak* was the milkfish *Chanos chanos*, and other species including penaeid shrimps were only by-products. Since 1975, the tiger shrimp *Penaeus monodon* and white shrimp *P. merguensis* have also become major crops, alone or in polyculture with milkfish. Fish farmers have adopted improved technology in the construction of their ponds. Water control structures such as sluice gates and irrigation canals are in place. Ponds are divided into several compartments depending on function and other requirements. Culture techniques have been improved as well. Ponds are prepared, pests are eradicated, manures and fertilizers are applied, young juveniles are stocked, and supplemental feeds are sometimes used.

The development of brackishwater culture is directed toward shrimp exports. The government prioritized the development of shrimp culture after shrimp catches declined due to the trawl ban in 1980 and the increasing population pressure in certain fishing areas. The total production from brackishwater ponds in 1990 was 272,000 tons, and about 30.3% were tiger and white shrimps (Directorate General of Fisheries, Ministry of Agriculture, Indonesia). Shrimps have become consistently the major source of foreign exchange — 30% in volume and 70% in value of the total fisheries export.

Based on the level of inputs and water management, extensive, semi-intensive, and intensive culture systems have been developed for shrimps. In the extensive system, the species under culture subsists on natural food grown with fertilizers. Pond water is changed with the tides. The stocking density is low and 1-2 crops are harvested per year depending on the condition of the site. The expected production is around 400-800 kg/ha-yr. In the semi-intensive system, higher stocking densities and supplemental feeds are used. Water pumps are used occasionally to increase oxygen levels. Two crops per year produce 1,000-2,000 kg/ha-yr. The intensive culture system is totally dependent on formulated feeds and on water pumps and paddle wheels. From two crops of shrimps a year, the total production is 5,000-8,000 kg/ha-yr.

The Brackishwater Aquaculture Development Centre in Jepara, Central Java was established to develop and support brackishwater aquaculture in the country.

The government strongly supports the development of *tambak*, particularly for small-scale aquaculture. The first Brackishwater Aquaculture Development Project, supported by the Asian Development Bank, includes the rehabilitation and construction of 280 km of primary and secondary canals serving 20,000 hectares of *tambak*. The project also provides credit to small-scale farmers. The Second Brackishwater Aquaculture Development Project established 10 Nucleus Estate and Smallholder *tambak* in Aceh, North Sumatera, South Kalimantan, East Kalimantan, and West Nusa Tenggara. Under the Fisheries Support Services Project supported by the World

Dank, about 600 kilometers of canals were rehabilitated to serve 18,000 hectares of *tambak* under intensive culture.

To support shrimp culture, the government will rehabilitate brackishwater canals, control the quality of fry and feed, control pests and diseases, develop post-harvest technology, improve the distribution and marketing mechanisms, and conduct training and extension in fisheries. These efforts will be supported by agro-industrial development (small-scale, medium, and rural industries).

## Mariculture

Indonesia has vast potential for mariculture or Seafarming. Fish farmers cultivate different marine species at very small scales in several places in the country, but mariculture contributes yet little to the total national production.

Fishes are cultured in pens and floating net cages in Tanjung Pinang (Riau Province), Belitung Island (South Sumatera), Serang (West Java) and West Nusa Tenggara. The cultured species are the grouper *Epinephelus coioides*, rabbitfish *Siganus javus*, and sea bass *Lates calcarifer*. The seaweed *Eucheuma* has been cultured in several places, especially in Bali, West Nusa Tenggara and Lampung. Some 89,568 tons of seaweed were produced from 747 hectares in 1990. In South Sulawesi, some farmers culture *Gracilaria* in brackishwater ponds that are not productive for shrimp culture. Pearl oysters are cultured in some places. A few years ago, the government also encouraged the culture of green mussels in provinces such as Jakarta, Lampung and Kalimantan. However, marketing problems were encountered and mussel culture has slowed down.

The technical development of mariculture is supported by Seafarming Development Center in Lampung.

## Research Needs in Aquaculture

Given the available resources, the level of technology applied, and the problems faced by the aquaculture industry, more research is needed in several problem areas.

### Freshwater culture

- Seed production and rearing of selected ornamental fishes
- Seed production and rearing of the tawes *Puntius javanicus*, marble goby *Oxyeleotris marmorata*, carps *Labeobarbus douronensis* and *Leptobarbus hoevenni*, catfish *Pangasius pangasius*, freshwater eel *Anguilla bicolor*, and featherback *Notopterus chilate*

### Brackishwater culture

- Seed production of milkfish
- Seed production and rearing of the white shrimp *Penaeus merguensis* and banana shrimp *P. indicus*

- Control of the pond environment
- Control and eradication of diseases and pests
- Land-use planning for *tambak* according to the technology level applied

### Mariculture

- Seed production of sea bass *Lates calcarifer*, rabbitfish *Siganus javus*, and grouper *Epinephelus tauvina*
- Formulation of artificial feeds
- Culture techniques for fishes, seaweeds, sea cucumbers, and mollusks

### Editors' Addendum

Among the papers that have been published during the past 20 years about Indonesian research and practices in aquaculture are listed below. Indonesian scientists write in Bahasa and there are not very many reports in English; those that are must be shared more widely.

Milkfish: Martosudarmo et al. (1976), Wiratno (1978), Padlan (1979), Poernomo and Singh (1982), Poernomo (1983), Chong et al. (1984), Prijono et al. (1988), Ahmad (1993)

Sea bass: Danakusumah and Ismail (1987), Kungvankij (1987), Martodusarmo (1987), Tiensongrusmee (1987)

Rabbitfishes: Ismael (1976), Ismael and Nuraini (1983), Waspada (1984), Diani et al. (1990), Kungvankij et al. (1990), Tacon et al. (1990)

Tilapia, carps, other freshwater fishes: Reksalegora (1979), Jangkaru and Djajadiredja (1979), Rifai (1979)

Seaweeds: Hatta and Purnomo (1994)

Integrated farming: Manik and Tiensongrusmee (1979), Sastroamidjojo (1993)

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# Recent Developments in Aquaculture in Japan

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Fukusho K. 1995. Recent developments in aquaculture in Japan, pp. 117-124. In: Bagarinao TU, Flores EEC (eds) Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines.

## Abstract

Aquaculture production in Japan in 1993 was 1,351,000 tons, 15.6% of the total fisheries production. About 93.6% came from mariculture and 6.4% from freshwater aquaculture. The per cent contribution of aquaculture to total production has increased in recent years but partly because marine fisheries, especially of sardine and pollack, have decreased. Aquaculture has reached a plateau, and decreased slightly between 1992 and 1993. Diverse marine and freshwater species are cultured in Japan — various fishes, crustaceans, mollusks, seaweeds, sea squirt, sea urchin, and others. Research and development in mariculture focus on finding substitutes for animal protein in feeds, improvement of fish quality, protection of the culture environment, use of offshore floating culture systems, and protection from diseases. Research in freshwater aquaculture has expanded to include recreational fishing, the propagation and preservation of endangered species, and the construction of fish ladders for salmonids and other migratory species.

## Introduction

The total production from fisheries and aquaculture in Japan has decreased in recent years. The total marine production was 8.49 million tons in 1993 (Table 1), only 66% of that in 1988 (12.85 million tons). This lower production was due to the significant decrease of the catches of the sardine *Sardinops melanostictus*, haddock *Theragra chalcogramma*, anchovy *Engraulis japonicus*, and squid *Todarodes pacificus* (Fig. 1).

Production from aquaculture has remained about the same or decreased slightly in recent years. The 1993 production from mariculture was 3% less than that in 1992; the freshwater production was 5% less (Table 1). The value of the production from aquaculture has increased to 700.4 billion yen (US\$1 = 100 yen), almost 27% of the total value of the production from the fisheries sector (Table 2).

Table 1. Production from marine and freshwater fisheries and aquaculture in Japan. Data from MAFF (1994).

Sector	Production (tons)				
	1989	1990	1991	1992	1993
Marine					
Capture fisheries	9,899,700	9,570,010	8,515,100	7,771,500	7,224,000
Aquaculture	1,272,029	1,272,891	1,261,913	1,306,330	1,266,000
Total	11,171,729	10,842,901	9,777,013	9,077,830	8,490,000
Freshwater					
Capture fisheries	103,234	112,068	107,365	97,040	91,000
Aquaculture	98,535	96,851	97,367	90,762	86,000
Total	201,769	208,919	204,732	187,802	177,000
Total	11,373,498	11,051,820	9,981,755	9,265,632	8,667,000

Table 2. Value of the production from fisheries and aquaculture in Japan. Data from MAFF (1994).

Sector	Value of the production (billion yen)			
	1989	1990	1991	1992
Marine				
Capture fisheries	1,953.6	1,950.6	1,908.7	1,827.4
Aquaculture	567.2	609.3	639.6	612.4
Total	2,520.8	2,559.9	2,548.3	2,439.8
Freshwater				
Capture fisheries	64.7	65.0	68.0	68.5
Aquaculture	106.3	97.1	95.7	98.0
Total	171.0	162.1	163.7	166.5
Total	2,691.8	2,722.0	2,712.0	2,606.3



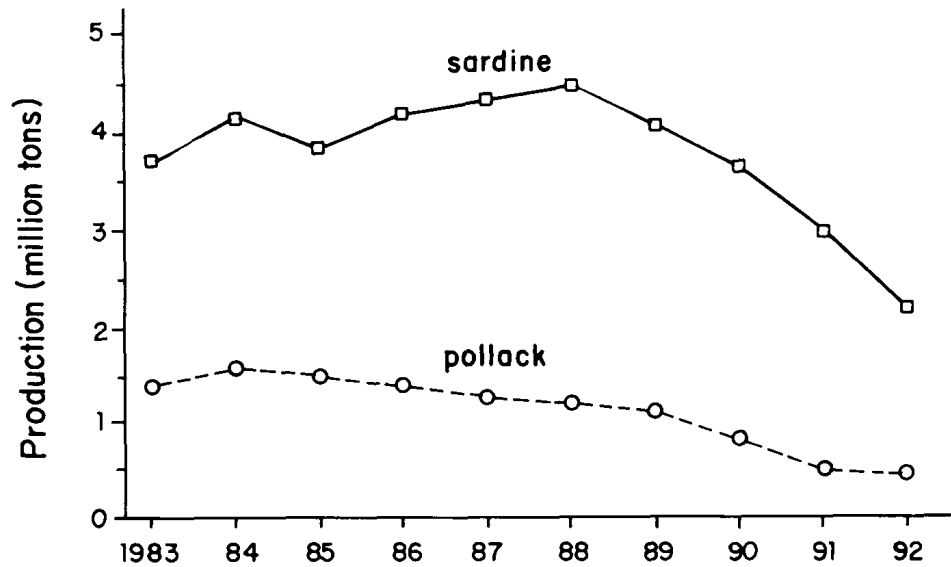


Fig. 1. Production from sardine and pollack fisheries in Japan. Data from MAFF (1994).

Technical developments in aquaculture in Japan have been earlier described by Mito and Fukuhara (1988), Umezawa (1994), and Kato (1994).

The lower production from aquaculture in recent years has been due to lower demand and consumption of fish as a result of bad economic conditions and greater import of fisheries products. Market prices of aquaculture products have also decreased as these have become ordinary daily dishes.

As in many other countries, self-pollution of aquaculture grounds has become a serious problem in Japan (Mito and Fukuhara 1988). Diseases have become very common (Sako 1995).

### Mariculture

Mariculture produced various species, mostly fishes, mollusks, and seaweeds (Table 3). In 1992, the oyster *Crassostrea gigas*, scallop *Patinopecten yessoensis*, and other mollusks contributed 454,336 tons; pearls from the oyster *Pinctada fucata* amounted to 69 tons. Contributions also came from the sea squirt *Cynthia roretzi* and the kuruma shrimp *Penaeus japonicus*.

Some 33 species of marine fishes are cultured in Japan, and the main ones are yellowtail *Seriola quiqueradiata*, red sea bream *Pagrus major*, coho salmon *Oncorhynchus kisutch*, flounder *Paralichthys olivaceus*, horse mackerel *Trachurus japonicus*, puffer *Takifugu rubripes*, and striped jack *Pseudocaranx dentex* (Table 4). A total of 263,503 tons were produced in 1993, less than in 1992. The production of yellowtail decreased, but those of red sea bream, flounder, horse mackerel, and puffer increased.

Table 3. Mariculture production in Japan. Data from MAFF (1994).

Group	1989	Production (tons)		1992
		1990	1991	
Fishes	235,126	255,506	267,794	263,503
Shrimp	2,813	2,636	2,491	2,187
Sea squirt	10,406	7,272	6,676	7,834
Oyster	256,313	248,793	239,217	244,905
Scallop	180,255	192,042	188,834	208,050
Other mollusks	1,456	1,486	1,340	1,381
Pearl	69	70	68	69
Seaweed	585,546	565,060	555,454	578,357
Others	45	26	39	44
Total	1,272,029	1,272,891	1,261,913	1,306,330

Table 4. Production of fishes from mariculture in Japan. Data from MAFF (1994).

Species	1989	Production (tons)		1992
		1990	1991	
Yellowtail	153,164	161,106	161,077	148,701
Red sea bream	45,536	51,636	60,127	65,950
Coho salmon	19,849	23,608	25,730	25,519
Flounder	4,283	6,039	6,515	7,128
Horse mackerel	6,655	5,863	5,889	7,161
Puffer	1,657	2,895	2,893	4,668
Striped jack	859	1,368	1,758	1,853
Black Porgy	129	136	117	118
Crimson sea bream	505	94	52	117
Filefish	45	67	177	99
Others	2,344	2,694	3,459	2,789
Total	235,126	255,506	267,794	263,503

The main seaweeds for culture are several species of *Porphyra*, *Undaria*, and *Laminaria*. The total harvest in 1993 was 578,357 tons (Table 5.)

Table 5. Production of seaweeds in Japan. Data from MAFF (1994).

Species	1989	Production (tons)		
		1990	1991	1992
<i>Porphyra</i>	403,290	387,245	403,363	382,805
<i>Undaria</i>	108,451	112,974	99,092	112,302
<i>Laminaria</i>	64,383	54,297	42,619	72,924
Others	9,422	10,544	10,380	10,326
Total	585,546	565,060	555,454	578,357

## Searanching

In addition to intensive mariculture, searanching has been conducted by national (Japan Seafarming Association), prefectural, city, and town fishermen's associations. Mass production of important species for stocking in coastal seas has been conducted since 1964 in Japan. About 80 species of aquatic animals are ranched with seed from hatcheries. Several ranched species such as the red sea bream, flounder, kuruma shrimp, blue crab *Portunus trituberculatus*, abalone, and scallop have contributed significant production.

Ocean ranching of salmon was started in 1888 and the national project has been carried out for more than 100 years now. The number of salmon *Oncorhynchus keta* juveniles that have been released in the ocean was 2.04 billion in 1992. The average rate of return to the mother river is nearly 3%, better than ten years ago.

Recent developments include the searanching of Japanese scallop in northern Japan, searanching of striped jack with seed that have gone through a conditioning procedure, and the acoustic habituation system for the red sea bream (Umezawa 1994).

## Freshwater Culture

Production from both inland fisheries and freshwater aquaculture has decreased since about 1990 to 90,762 tons in 1992 (Tables 1). The value of the aquaculture production was 64% greater than that of capture fisheries in 1989, but was only 43% higher in 1992 (Table 2). The main species for freshwater culture are eels *Anguilla* spp., carps *Cyprinus carpio* and *Carassius auratus*, rainbow trout *Oncorhynchus mykiss*, ayu *Plecoglossus altivelis*, and Nile tilapia *Oreochromis niloticus* (Table 6). A considerable amount of soft-shelled turtle and freshwater algae are also produced.

Table 6. Production from freshwater aquaculture in Japan. Data from MAFF (1994).

Species group	1989	Production (tons)		
		1990	1991	1992
Eels	39,704	38,855	39,013	36,299
Common carp	17,479	16,309	16,160	15,061
Crucian carp	1,236	1,191	1,210	1,079
Rainbow trout	15,596	15,395	15,127	14,480
Other trouts	4,292	4,677	4,870	4,905
Ayu	13,390	12,978	13,855	12,794
Nile tilapia	5,283	5,825	5,647	4,697
Other fishes	405	454	357	322
Soft-shelled turtle	743	799	764	763
Prawns	32	34	19	20
Mollusks	6	5	9	6
Pearl	0.9	0.7	0.7	0.2
Algae	368	327	335	333
Total	98,535	96,851	97,367	90,762

## Future Directions of Aquaculture

### Advancement of searanching technology and coastal resources management

With the institution of the 200-mile exclusive economic zone, it has become very important to preserve coastal fishing grounds and manage the fisheries resources. In order to advance searanching technology, the coastal ecosystems and their carrying capacities should be investigated. Fish behavior, populations dynamics, and genetic structure should be studied to provide the scientific basis for fisheries resources enhancement with cultured juveniles and for suitable laws in environmental protection.

### Development of seed production technology for new species

In Japan during the past 30 years, seed production technologies have been developed for several species of fishes, crustaceans, mollusks, seaweeds. For yellowtail, the technology for broodstock maintenance and induced spawning has been well developed. The supply of yellowtail juveniles for cage culture is assured, capture of wild seed is reduced, and recruitment of cultured yellowtail into natural habitats is possible through searanching.

Active research is going on in the seed production of bluefin tuna and other tunas, eels, groupers, spiny lobster, and bivalves with very high commercial value. 'Complete' culture (the entire life cycle under human management) would be possible if and when seed production

technology could be developed for these species. Technologies for bivalves and crustaceans are particularly needed.

### **Improvement of biological quality of cultured species**

There are three major ways to improve biological quality: (1) genetic breeding, (2) production of healthy seed for culture, and (3) addition of commercial value (color, meat quality, shape) to aquaculture products prior to marketing. Production of new races that grow faster and resist disease will be possible through genetic breeding and biotechnology (see Kato 1994, Chen 1995). Methods are being developed to produce juveniles with no deformities and with high stamina during handling, transport, and cage culture. Consumer preferences are being taken into consideration in the production and postharvest processing of cultured species. Scientific activity in these three fields is very high in Japan and important results have been obtained.

### **Use of defatted soybean meal for marine fish culture**

The sardine fishery has greatly declined in recent years and production of fish meal from this species has been reduced. Substitutes for fish meal in aquaculture feeds are urgently needed. The development of feeds with vegetable proteins is important. Defatted soybean meal has been found most effective and successful among the various protein sources tested; it can substitute for 30-40% of the fish meal in feeds for yellowtail (Shimeno et al. 1993a, 1993b). In the near future, marine fishes may be cultured with feeds made with vegetable proteins.

### **Development of offshore culture systems**

Self-pollution of cage culture sites in coastal waters is one of the barriers to further expansion of mariculture in Japan. Large-scale offshore floating cages have been tested. Successful development of this new culture technology will allow aquaculture to expand offshore and reduce pollution near shore.

### **Development of land-based and closed rearing systems**

For some species, land-based and closed rearing systems are feasible both technically and economically and are currently being tested.

### **Protection of the culture environment and prevention of diseases**

Active research continues on the carrying capacities of culture sites, pollution, red tides, amelioration of the culture environment, and prevention and control of diseases.

### **Recreational fishing**

About 20-30 million Japanese enjoy game fishing. But, current science and technology in fisheries and aquaculture are not for sport fishing, but for food supply. Studies in fish behavior, ecology and physiology would be useful in developing scientific sport fishing from searanching.

### Protection of endangered and migratory species

The propagation and preservation of endangered species is now high priority on the research agenda. For example, fish ladders are being developed to allow migrating salmon and other fishes to return to their home streams despite dams and other conversions.

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# Aquaculture in Malaysia

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## Abstract

Aquaculture in Malaysia is experiencing rapid growth. Total production in 1992 amounted to 79,699 tons valued at RM 207.4 million. These figures are 23% and 25% higher than the previous year's. Semi-culture of the cockle *Anadara granosa* was still predominant, contributing about 70% of the total output. Culture and production of the oyster *Crassostrea iredalei* is still insignificant. Sea bass *Lates calcarifer* constituted over 80% of the production from marine cages. Cage culture of grouper *Epinephelus* sp., snapper *Lutjanus* sp. and pompano *Trachinotus blochii* were also done in much smaller scale. The mangrove snapper *Lutjanus argentimaculatus* was recently spawned in captivity and larvae and juveniles were produced. In 1992, the tiger shrimp *Penaeus monodon* constituted about 87% of brackishwater pond production. Pond culture of the white shrimp *P. merguensis* and the mudcrab *Scylla* sp. is at the experimental stage. Red tilapia hybrid was the major freshwater species cultured in cages, with 1,486 tons harvested in 1992. Freshwater pond production was valued at RM 100.85 million, 22% of which was due to the eel *Anguilla japonica*. Production of freshwater ornamental fishes is also becoming significant. Other exotic species recently bred and cultured are the African catfish *Clarias gariepinus* and the pacu *Piaractus brachypomus*. The indigenous freshwater catfish *Mystus nemurus* and carp *Probarbus julleini* have recently been bred in captivity and cultured experimentally. Lately, there have been attempts to culture non-conventional species such as the bullfrog *Rana catesbeiana*, the soft-shell turtle *Trionyx sinensis*, and aquatic ornamental plants.

## Introduction

Development of aquaculture in Malaysia is relatively recent. The earliest beginnings can be traced to the turn of the century, but sizeable farms only began in the 1950s with the semi-culture of cockles and the culture of Chinese major carps in mining pools. Significant changes took place during the last two decades after the introduction of fish culture in marine cages in the

early 1970s (Chua 1979, Chua and Teng 1979, 1980), and more recently, the involvement of the corporate sector in commercial marine shrimp culture (Kuperan 1988).

The industry has grown rapidly in recent years. Production from aquaculture in 1992 was 79,699 tons valued at RM 207.4 million (Table 1). These figures are 23% and 25% higher than the corresponding figures the previous year. However, aquaculture contributes only 7% of the national fish production of 1,023,516 tons. Employment was also insignificant, as only 17,852 fish farmers were involved, 90% of whom were in freshwater aquaculture. Total pond area for aquaculture in 1992 was 8,360 hectares, 80% of them freshwater. In the same year, a total of 426,846 m<sup>2</sup> of cages were used, 93% of them for marine fish cages.

Table 1. Aquaculture production in Malaysia in 1992, by farming systems. Data from Annual Fisheries Statistics, Malaysia, 1992. US\$1=RM2.5

Fanning system	Area (ha)	Production (ton)	Value (RM x 1,000)
Cockle semi-culture	4,316	55,587	14,534
Mussel culture	4.7	1,493	629
Oyster culture	3.6	33	324
Marine cages	39.8	3,369	36,189
Brackishwater ponds	1,703	3,225	51,431
Freshwater ponds	5,598	14,162	97,618
Freshwater cages	2.9	484	3,403
Mining pools	1,059	1,346	3,227
Total		79,699	207,355

No less than 30 species are being cultured in Malaysia for food. In addition, hundreds of fish varieties are being bred and traded as ornamental organisms. The cockle *Anadara granosa* is the main aquaculture species in terms of production, but the tiger shrimp *Penaeus monodon* is the largest single contributor in terms of value.

### Cockle Culture

Cockle culture is the mainstay of Malaysian aquaculture in terms of output. Production of cockle in 1992 was 55,587 tons valued at RM 14.5 million (Table 1). This production was 16% higher than the previous year's inspite of a 24% drop in the total culture area. Cockle production areas are on the west coast of peninsular Malaysia, particularly in Perak, Selangor and Penang, which have extensive mudflats. The industry still depends on natural spatfalls for the supply of seed. Spatfalls occur throughout the year mainly in the above-mentioned states and only in smaller quantities in other areas. Spatfalls occur with two peaks in one year. The peaks differ slightly between regions but generally occur between December and April and between May and July (Ng, in press b). The yearly abundance and seasonal occurrence of spats vary for unknown



reasons. Cockle spats were abundant in 1985 (nearly 14,931 tons) but amounted to less than 1,800 tons in 1982-83 and only 3,481 tons in 1991 (Annual Fisheries Statistics, Malaysia, 1992).

The cockle culture method (Ng 1984, Broom 1985, Noordin 1988) has remained unchanged. Spats collected from the wild are spread over the culture beds. Present regulations stipulate that only spats larger than 6.4 mm may be collected from natural spatfall areas. The culture densities vary depending on the spat sizes. Stocks are culled after 3 months of culture. Optimum production is usually attained after a year of culture. Present regulations stipulate a minimum harvestable size above 3.2 cm. Average annual production is about 30 tons/ha.

Although cockle has been successfully bred in captivity (Kamal 1986), hatchery spat production on a commercial scale is not economical at the moment. Spat supply from natural sources is still abundant, but there has been a gradual decrease in the amount of spats in the last few years, and appropriate measures are necessary to protect natural spatfall areas.

The post-harvest quality of cockle has been improved through depuration. The Fisheries Research Institute has developed a pilot-scale depuration unit using UV radiation capable of reducing the bacterial load of cockles to below 20 cells per gram after 36 hours. A number of such depuration units have already been used by the private sector for mollusks in general.

## Mussel Culture

Culture of the green mussel *Perna viridis* also depends on natural spats. Major spat collecting areas are in the southwestern coast of peninsular Malaysia, in the southern states of Johore and Melaka. The main source of mussel seed in recent years has been Melaka. The season for spat collecting is normally between March and May. The techniques for mussel culture have hardly changed from those described by Choo (1983) and Noordin and Choo (1989). The mussels are mostly cultured in discarded trammel nettings hung from floating raft, rack or longline systems. Attempts to transfer the culture operations to other regions of the country have been technically successful, but the interest generated could not be sustained. Among the major reasons are the low marketability of mussels and the occasional problems with seed supply. There is no attempt yet to produce mussel spats in the hatchery due to the low economic return. Production in 1992 was a meager 1,493 tons (Table 1), less than the previous year's 1,563 tons. Efforts are being made to give added value to mussels by canning and processing.

## Oyster Culture

Oyster culture is a recent effort in Malaysia that started with experimental culture in Sabah. The Fisheries Research Institute under the Bay of Bengal Programme generated interest in oyster farming in peninsular Malaysia. Prior to this, oysters were collected and sold in the form of shucked meat that fetched a low price in the market. With the introduction of oyster culture, mainly of the *Crassostrea iredalei*, the oysters are marketed shell-on at significantly higher returns. Production of cultured oyster in 1992 was 33 tons valued at RM 0.3 million (Table 1). Other species being cultured include *C. belcheri* and *Ostrea folium*, both of which are mainly marketed as shucked meat. The sources of *C. iredalei* spats are some river estuaries in the northeastern coast of peninsular Malaysia. Spats of *C. belcheri* are found on the west coast.

Spats of *C. iredalei* can be produced in the hatchery at the Fisheries Research Institute, but the technology has not yet been taken up commercially. Present research on oyster seed production focuses on the development of remote setting techniques for the eyed larvae (TM Wong, personal communication).

### Marine Fishes in Cages

Culture of marine fishes in floating cages has rapidly developed since its introduction in the early 1970s. The production in 1992 was 3,369 tons valued about RM 36.2 million (Table 1). Marine cages are sited mostly near human settlements in Penang, Selangor and Johore. The last few years also saw a significant increase in marine cage culture in Kedah and Perak. Nonetheless, productivity is still low, with a national average of 8.5 kg/m<sup>2</sup> per year.

The sea bass *Lates calcarifer* is the main species cultured, constituting 81.5% of the total output (Table 2). The technology for sea bass seed production has been developed locally (Ali 1987a, 1987c) and there are a few hatcheries, but a significant number of small juveniles still has to be imported to meet the demand of the cage culture industry. The Malaysian government envisages the establishment of 330,000 m<sup>2</sup> or 8,250 units of marine floating cages for the culture of sea bass; production is expected to increase to 4,000 tons by year 2000 (Ali 1987b).

Other species being cultured in cages include the grouper *Epinephelus malabaricus* (Chua and Teng 1979, 1980) and the mangrove red snapper *Lutjanus argentimaculatus*. One problem in grouper culture has been vibriosis (Wong et al. 1979). Lately, cage culture of the golden pomfret *Trachinotus blochii* has been initiated by some farmers in southern peninsular Malaysia. There are at present a few local hatcheries for mangrove snapper and the grouper *Cromileptis altivelis*. Research on the propagation and seed production of mangrove snapper and grouper is ongoing at the Marine Fish Production and Research Center, Terengganu. *Epinephelus suillus* has been spawned in captivity, and larval rearing techniques are being refined (Doi et al. 1991).

### Shrimps in Brackishwater Ponds

The tiger shrimp *Penaeus monodon* constituted 87% of the 1992 production from brackishwater ponds and was valued at RM 46.3 million (Tables 1-2). The other pond-grown shrimp is *Penaeus merguensis*. Aquaculture production of shrimps has risen from 60 tons in 1984 to 2,963 tons in 1992, whereas marine landings have ranged from 81,627 tons in 1984 to 126,405 tons in 1992 (Annual Fisheries Statistics, Malaysia, 1992).

The grow-out technology for marine shrimps has not changed much from that described earlier (Ong et al. 1989). At present, most shrimp farms practise the semi-intensive system of culture with an initial stocking density of 10-20/m<sup>2</sup> giving a yield of 2-3.5 tons/ha-yr (Singh and Kamaruddin, in press). The prevailing production cost ranged RM 9-14/kg and the ex-farm price ranged RM 18-22/kg.

Table 2. Production of fishes and crustaceans from marine cages and brackishwater ponds in 1992. Data from Annual Fisheries Statistics, Malaysia, 1992. US\$1 = RM2.5

Culture system Species	Production (ton)	Value (RM x1000)
Marine cages		
<i>Lates calcarifer</i>	2,784	25,572
<i>Epinephelus</i> spp.	288	7,648
<i>Lutjanus</i> spp.	281	2,857
Others	16	112
Brackishwater ponds		
<i>Penaeus monodon</i>	2,820	46,260
<i>Penaeus merguensis</i>	143	2,917
<i>Scylla serrata</i>	71	586
Fishes	191	1,668
Total	6,594	87,620

At present, hatchery production of shrimp postlarvae is more than adequate to supply the local shrimp industry. There were 44 shrimp hatcheries producing 3.7 billion postlarvae in 1992 (Singh and Kamaruddin, in press). The local hatchery technology has not changed significantly and still depends on gravid females from the wild. The National Prawn Fry Production and Research Centre (NAPFRE) in Kedah is the only hatchery with a broodstock maturation program (using eyestalk ablation) for the production of nauplii. NAPFRE produced 80 million postlarvae in 1993 and proved that the nauplii were not different in quality from those spawned by wild broodstock (PC Liong, personal communication).

### Mudcrabs in Brackishwater Ponds

Crab fanning in Malaysia started in the 1970s but has not become attractive to fanners. Lack of juveniles is the major constraint. At least two species of crabs are being cultured: the brown mangrove crab *Scylla serrata* and the green sea crab *S. oceanica tranquebarica* (Liong and Subramaniam, in press). The green sea crab fetches a better market price and grows faster. The small juveniles for culture are obtained from the wild in Malaysia and also imported from other countries in the region. Crab juveniles have been successfully produced in the NAPFRE hatchery, but the cost of production is still high and hence, commercial seed production is not yet economically feasible.

Two distinct operations are involved in crab production. Culture involves rearing of juveniles for several months (during which crabs molt several times) to the harvestable adult stage. Culture in floating net cages results in low survival. Nowadays, crabs are cultured in 100-500 m<sup>2</sup> tidal ponds (Liong and Subramaniam, in press). The ponds are provided with adequate fencing to

prevent escape of the crabs. Continuous stocking is usually practised and 'trash' fish is used as feed. Culture period is normally 3-5 months and survival varies between 40 and 80%, depending on the initial stocking size, density, and duration of culture. Some farms use methods to induce molting because soft-shelled crabs fetch a better market price.

Fattening involves holding and feeding already big or adult crabs for short periods often to adjust to favorable market conditions. Crab fattening is done in cages placed in river estuaries or in ponds. Two types of cages are presently used: converted fish cages ( $3 \times 3 \times 1$  m) with wooden covers and smaller wooden-frame Netlon cages ( $2 \times 1.5 \times 0.6$  m). At present, there are less than 20 crab-fattening projects around the country (Liong and Subramaniam, in press).

The other pond-grown species are the mangrove snapper, sea bass, and grouper. There are also a few farms in Penang that culture milkfish *Chanos chanos* mainly as baits for tuna fishing.

### Freshwater Fishes in Cages

In Malaysia, freshwater cage culture is usually done in disused mining pools and reservoirs. Production in 1992 was 483.5 tons (Table 1) down from 574 tons in the previous year. Tilapia is farmed at semi-intensive to very intensive levels with production up to 300 tons/ha-yr (Ng, in press a). Red tilapia hybrid is the dominant species contributing 70% of the total output. Other species cultured in cages include the Javanese carp *Puntius gonionotus*, grass carp *Ctenopharyngodon idella*, and river catfishes *Pangasius sutchi* and *Mystus nemurus*. Commercial culture of *M. nemurus* in the Kenyir reservoir uses larvae and juveniles caught from the reservoir.

### Freshwater Fishes in Ponds

In terms of value, freshwater pond culture is the largest contributor to aquaculture production. In 1992, a total production of 14,162 tons was achieved with an estimated value of RM 97.6 million (Table 1). The increase in production over the previous year's was mainly due to greater pond area and greater average production per unit area.

The production of eel, *Anguilla japonica* increased from 442 tons in 1991 to 1,572 tons in 1992, making eels the largest single contributor to freshwater aquaculture in terms of value (Table 3). Commercial production of eel in Malaysia started in 1990 in a single 2,000-hectare farm on the east coast of peninsular Malaysia. The farm has 400 eel culture ponds about two hectares each and employs no less than 1,600 workers (Sukor, in press). The elvers are imported from East Asian countries and cultured either in monoculture or in polyculture with tilapia. The harvested eels are mainly exported, either live or processed, to Japan.

Various strains of tilapia contribute about 20% of the total production from freshwater ponds (Table 3). Tilapias, particularly the red tilapia hybrid, are also grown in concrete tanks under very intensive systems with aeration and supplemental feeding. Average tilapia production is about 15 kg/m<sup>2</sup> after 150 days of culture starting with 80 gram juveniles (Ng, in press a).

Table 3. Production of freshwater fishes and giant prawn, 1992. Data from Annual Fisheries Statistics, Malaysia, 1992.

Species	Production (ton)	Value (RM x 1,000)
<i>Anguilla japonica</i>	1,572	22,008
<i>Oreochromis niloticus</i>	3,145	20,814
Red tilapia	1,486	5,886
<i>Puntius gonionotus</i>	2,505	13,258
<i>Cyprinus carpio</i>	1,703	15,119
<i>Aristichthys nobilis</i>	1,222	2,792
<i>Ctenopharyngodon idella</i>	913	4,087
<i>Leptobarbus hoevenii</i>	481	3,710
<i>Oxyeleotris marmoratus</i>	115	2,610
<i>Clarias</i> spp.	904	3,341
Other fishes, ornamentals	1,852	9,099
<i>Macrobrachium rosenbergii</i>	94	1,526
Total	15,992	104,250

Chinese and Indian carps are mainly cultured in earthen ponds, mostly by small-scale operators using polyculture and integrated farming systems (Kechik, in press). The Chinese major carps, once the dominant group in freshwater aquaculture, are gradually being replaced by tilapias. Present-day extensive culture of Chinese carps is mainly confined to disused mining pools under the 'put-and-take' system. The Javanese carp *Puntius gonionotus* contributes 17.5% of the total output from freshwater ponds (Tables 1 and 3).

The marble goby *Oxyeleotris marmorata* is the largest freshwater eleotrid; it can grow to 2 kg and 50 cm total length. It is the most expensive freshwater table fish in restaurants in Malaysia, fetching retail prices of RM 20-50/kg, in contrast to carps and catfishes at RM 2-7/kg (Senoo et al., in press). Artificial seed production of the marble goby has been developed but not yet commercialized.

The last few years saw the introduction of many exotic species into the country, either intentionally or otherwise. The African catfish *Clarias gariepinus* and its hybrid with the local *C. macrocephalus* have become very popular among farmers due to their hardiness, ease of culture, high growth rates, and availability of fry. However, their market acceptability and price are low compared to those of the local *C. macrocephalus*. These catfishes are stocked in ponds at 5-20/m<sup>2</sup> and fed a floating pelleted diet with 18-24% protein, usually supplemented with chicken viscera, 'trash' fish, and rice bran (Thalathiah, in press).

Another exotic species that has generated some interest among farmers recently is the South American pacu *Piaractus brachipomus* (Zaini et al., in press). However, the culture of this species is regulated to prevent wrongful introduction into natural water bodies. Hence, pacu culture is small-scale, mainly for ornamental purposes.

### Breeding and Culture of Ornamental Fishes

Breeding and culture of ornamental fishes gained prominence in the 1980s with the establishment of farms particularly in southern peninsular Malaysia. The industry has grown rapidly ever since. There were about 18 farms in 1988 and 366 farms in 1993 (Ismail and Mazuki, in press). Of these farms, 311 were directly involved in fish breeding, 12 in the propagation of ornamental aquatic plants, and 43 in the production of live feed for aquarium fishes. The export of ornamental fishes has also increased in recent years. In 1989, a total of 79 million pieces worth RM 5.9 Million were exported. At least 166 varieties of fish were produced, with goldfish and Koi carp constituting 28.6%, barbs and danios 18.7%, and poeciliids 21.8%. Different states in Malaysia specialize in the production of particular ornamental fishes.

Despite the rich ichthyofaunal resource in Malaysia, most of the ornamental fishes that are bred are not indigenous. Lack of knowledge of the biology of indigenous species limits their aquaculture. To remedy the situation, research is being focused on the propagation of indigenous species. Recently, the indigenous and highly priced arowana *Scleropages formosus* was successfully bred in captivity by a private farm. This species is at present classified as endangered under CITES. Breeding and culture technologies are being developed for the indigenous carps such as *Tor tambroides* and *Probarbus julleini* and the river catfish *Mystus nemurus*.

### Breeding and Culture of Bullfrog and Terrapin

The breeding and culture of the fast-growing and highly marketable bullfrog *Rana catesbeiana* has been actively pursued in Malaysia (Lim, in press). Currently, there are at least 12 bullfrog farms in Malaysia producing about 80 tons of frog meat annually. Breeding is done in the farms. The culture ponds are 10-100 m<sup>2</sup> wide and 2-10 cm deep. The stocking density is about 50/m<sup>2</sup>. Mortality up to 30% occurs usually during the first 60 days of culture, mainly due to cannibalism. After 4 months of culture, the frogs attain the harvest size of 250-300 grams. The dressed carcass is normally packed and deep frozen for the market. At present, the entire production is absorbed by the domestic market, where the retail price of RM 20/kg is better than the export price. Domestic consumption of frog meat is about 400 tons annually. With better technical personnel and better feeds, Malaysia can meet the local market demand for bull frogs and even compete with India and Indonesia for the European and Japanese markets.

The culture of soft-shell turtle or terrapin *Trionyx sinensis* was introduced to Malaysia by Singaporean farmers about eight years ago. Now there are two well established terrapin hatcheries and a few small-scale grow-out farms in peninsular Malaysia (Heng, in press). Ponds are 200-1,000 m<sup>2</sup> with sandy bottom and specially constructed vertical concrete embankments or 'basking areas'. Stocking rates range 8-12/m<sup>2</sup> depending on availability of hatchlings. It takes about a year for the terrapins to reach the harvest size of 500-600 grams, with 'trash' fish and chicken offals as feed. Harvesting may be partial or complete. Terrapins are normally sold live in the local and export markets. Poor grade hatchlings are also sold for ornamental purposes. Terrapin culture has very good potential because of the increased demand in both local and overseas markets, but technical know-how is insufficient.

## Scope and Potential for Further Development

There is considerable potential for further expansion and development of aquaculture in Malaysia, both in terms of available resources and supporting infrastructure and services. Aquaculture is being accorded due recognition by the government and has been identified as one of the thrust areas for development under the New Agricultural Policy (1991-2010). By year 2010, aquaculture production is projected to reach about 200,000 tons and contribute about 15% to the total fish production annually. Shrimp culture and fish culture are expected to be the main areas of growth. Although cockle culture is still expected to be dominant, its percentage contribution is projected to decrease from 70% to about 20%. Rapid growth of oyster culture is foreseen.

The strategies for aquaculture development include:

- Development of new sites for the various culture systems

Availability of potential sites for aquaculture is well recognized. Efforts are now being made to identify and map these areas for future planning, especially in the formulation and subsequent alienation of 'Aquaculture Development Areas' (Tan, in press). Mapping is done through remote sensing and geographical information systems. One of the setbacks in the past has been the indiscriminate alienation of land, sometimes in conflict with the interests of aquaculture, and resulting in low success rates and discouragement in the industry. Through zoning, further development and better management of aquaculture will be facilitated.

Construction of dams for various purposes in recent years has presented a vast resource for freshwater aquaculture. Most of the reservoirs (total surface area about 100,000 hectares) are not optimally used for fish production. Present government policy encourages the use of marginal agricultural lands near the coasts for brackishwater pond culture. Research is also conducted to develop cage culture systems in more exposed coastal waters and cockle culture in deeper waters.

- Development of new culture systems and species

Malaysia has vast untapped ichthyofaunal resource. Research is needed to identify potential species for exploitation by the aquaculture industry. Introduction of new species adds impetus to aquaculture development. Demand for new varieties is very acute in the ornamental fish industry. Priority is being given to the indigenous riverine species such as *Tor tambroides*, *Probarbus julleini*, and *Mystus nemurus*.

Marine and brackishwater species such as the seaweed *Gracilaria* sp., sea cucumber *Stichopus variegatus*, golden pomfret *Trachinotus blochii*, and abalone *Haliotis* sp. have been identified for further research. In addition, research is being initiated on the application of biotechnological and genetic principles in the improvement of cultured species. Such efforts include production of gynogenetic, polyploid, sex-reversed, and transgenic fishes.

- Refinement of present technologies

Efforts are also focused on the refinement of present hatchery and grow-out technologies to make them more efficient and cost-effective. Among the objects of research are the hatchery technologies for marine fishes, oysters, and mudcrab, and culture technologies for mudcrab, white

shrimp, and the freshwater prawn. Further research is also needed for the development of artificial feed for marine fishes, biomanipulation of culture ponds, and handling and post-harvest technologies.

## Conclusion

The aquaculture industry in Malaysia is undergoing rapid development. Subsectors like marine cage culture and freshwater pond culture have grown tremendously. Shrimp culture and mussel culture need new impetus to move away from the present status. Inadequate supplies of larvae and artificial feeds, especially for marine fishes, require appropriate solutions. The future development of the aquaculture industry depends on effective fish health management. Overall, the outlook for further expansion of the Malaysian aquaculture industry is bright, but judicious planning, strong institutional support, and attractive credit and incentive schemes are still required.

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# Aquaculture in the Philippines

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## Abstract

Aquaculture is regarded as the most promising source of protein food in the years ahead. Milkfish and Nile tilapia are the major fishes now produced but groupers, sea bass, rabbitfish, red snappers, carps, and catfishes are grown by some farmers. The tiger shrimp is still the most important cultured crustacean, but white shrimps and mudcrabs also have great potential. Oysters and mussels are produced in considerable amounts. Mariculture of the seaweed *Eucheuma* is now a well established industry, and the pond culture of *Gracilaria* for agar extraction is beginning to take off.

## Introduction

Aquaculture is an important sector in Philippine fisheries and the most dynamic since the decline of marine fisheries starting 1976. The total fish production in the Philippines in 1992 was 2,625,607 tons — 41.3% came from coastal or sustenance fishing, 30.7% from offshore or commercial fishing, and 28% from aquaculture (Table 1). Fish production from the coastal zone decreased and the fish caught were of lower commercial value. Commercial fishing increased in production but existing fishing boats are old and small and lack modern equipment to explore the exclusive economic zone.

Aquaculture is a more controllable and manageable production system. From this sector, a yearly increase in production has been achieved (Table 1). In terms of value, aquaculture products contributed nearly 40% of P65.443 billion in 1992 (Table 2). Production from brackishwater ponds, from freshwater ponds, pens and cages, and from mariculture in different regions in the Philippines are shown in Table 3. In the export markets, cultured shrimps and seaweeds have been major winners since 1987. In 1992, the shrimp export was worth US\$211.448 million and the seaweed export \$18.953 million (Table 4). Employment in the aquaculture sector is estimated at 258,480 people (BFAR 1992).

Table 1. Volume of the fishery production in the Philippines, by sector, 1983-92.  
Data from BFAR (1992).

Year	Production (tons)			Total
	Aquaculture	Municipal	Commercial	
1992	736,381	1,084,360	804,866	2,625,607
1991	692,401	1,146,765	759,815	2,598,981
1990	671,116	1,131,866	700,564	2,503,546
1989	629,345	1,104,626	637,138	2,371,109
1988	599,554	1,070,195	599,995	2,269,744
1987	560,970	1,060,878	591,192	2,089,484
1986	470,893	1,072,361	546,230	2,089,484
1985	494,893	1,045,382	511,987	2,052,111
1984	477,887	1,089,046	513,335	2,080,268
1983	445,073	1,145,841	519,316	2,110,230

Table 2. Value of the fishery production in the Philippines, by sector, 1983-1992.  
Data from BFAR (1992). US\$1 = P25.

Year	Value of fish production (million pesos)			Total
	Aquaculture	Municipal	Commercial	
1992	25,986	22,656	16,801	65,443
1991	22,656	22,133	15,245	60,034
1990	20,467	19,300	12,411	52,178
1989	15,673	18,388	11,033	45,094
1988	15,213	16,633	10,272	42,118
1987	11,314	16,108	9,821	37,243
1986	10,832	17,251	9,248	37,331
1985	8,724	14,716	7,857	31,297
1984	7,266	11,863	6,521	25,650
1983	4,799	9,540	4,643	18,982

Table 3. Aquaculture production in the Philippines in 1992, by culture system, by region. Data from BFAR (1992).

Region	Total volume	Aquaculture production (tons)					Marine culture
		Brackishwater ponds	Ponds	Pens	Cages		
National Capital Cordillera	7,041 513	1,345 -	412	3,607 -	375 101	1,714 -	
Northwest Luzon	42,541	32,014	2,455	12	15	8,045	
Northern Luzon	3,336	1,095	1,672	-	495	74	
Central Luzon	112,927	78,418	33,220	50	629	610	
Southern Luzon	81,155	27,205	865	24,014	18,320	10,751	
Southeastern Luzon	15,660	6,816	207	-	8,427	210	
Western Visayas	115,519	110,716	810	-	-	3,993	
Central Visayas	30,980	11,495	-	-	-	19,485	
Eastern Visayas	15,771	3,699	142	36	90	11,804	
Western Mindanao	287,550	20,275	221	317	20	266,717	
Central Mindanao	5,487	4,772	561	-	-	154	
Eastern Mindanao	13,024	11,795	297	67	372	493	
Southern Mindanao	4,877	4,698	165	-	14	-	
Total	736,381	314,343	41,027	28,103	28,858	324,050	

Table 4. Quantity and freight-on-board value of the major fishery exports of the Philippines, by country of destination, 1992. Data from BFAR (1992).

Commodity Country	Quantity (tons)	FOB value (×1,000 pesos)	FOB value (\$ ×1,000)
<b>Shrimp/prawns</b>	23,623	5,347,417	211,448
Japan	17,897	4,068,924	161,056
USA	3,380	900,038	35,472
Korea	270	84,867	3,338
Others	1,626	293,588	11,582
<b>Tunas</b>	50,285	2,589,163	102,324
USA	10,944	494,019	19,512
Germany	9,967	483,540	19,059
Canada	6,492	363,462	14,395
Others	22,882	1,248,142	49,358
<b>Seaweeds</b>	22,756	480,398	18,953
United Kingdom	1,467	86,327	3,413
Denmark	3,663	67,370	2,673
France	3,724	61,380	2,416
Others	13,902	265,321	10,451

Developments in aquaculture in the Philippines, particularly environment-friendly mariculture and searanching, were reviewed by Aypa (1994), Delmendo (1994), Guerrero (1994), and Lopez (1994).

### Brackishwater Aquaculture

Brackishwater ponds range from small and simple water impoundments to huge excavations of complex engineering design. Most ponds are built on what used to be mangrove swamps. Estimates of mangrove areas converted to fishponds during 1950-1973 range from 1,000 to 24,000 hectares per year. Some 227,907 hectares of brackishwater ponds are in existence as of 1992, about 176,000 hectares used for milkfish culture and 25,000 hectares for tiger shrimp. A total of 314,343 tons were produced from brackishwater ponds in 1992.— 228,358 tons milkfish, 59,657 tons shrimps, and 26,328 tons of other species (BFAR 1992).

#### Milkfish

Most milkfish are produced in western Visayas, central Luzon, northwestern Luzon, southern Luzon, and western Mindanao. Producers of milkfish generally use the extensive culture method, with stocking densities of 3,000-7,000/ha, and production of about 350-500 kg/ha-yr. The semi-intensive culture method is now gaining interest among milkfish farmers. Higher stocking densities of 9,000-10,000/ha and use of supplemental feeds allow relatively high

production of 900-1,200 kg/ha-yr in the straight-run system. The modular culture system introduced in the Philippines in the 1970s by Yun-An Tang has been adopted by some large-scale farmers.

The National Bangus Breeding Program has had difficulty maintaining the caged broodstocks in good health, and the government has offered them for privatization at the price of P1,000 per year of age per fish. Seven stations had more than 500 breeders and most of these will soon be in private hands. With breeders now available and the milkfish hatchery technology already transferred, the shortage of milkfish seed may be solved. Recently, one importation from Taiwan was made because of an acute shortage of milkfish larvae from the wild.

### **Tiger shrimp**

In 1982, when there was demand for shrimps in the world market, many pond operators switched to shrimp production. Taiwanese feeds and shrimp farming technology and intense research in shrimp biology and hatchery techniques led to the rapid take-off of the shrimp industry. Milkfish ponds, sugarlands, ricelands, and coconut lands were converted into shrimp farms, many of them intensive systems. The use of feeds and pond aeration allowed high stocking densities. In areas where the Taiwanese method was not feasible, the extensive or semi-intensive systems were adopted for improved production. Thus, tiger shrimp production increased from 1,805 tons in 1982 to 59,657 tons in 1992 (BFAR 1992).

The reduction in the demand and price of shrimps in the world market in 1989 was a great blow to the farmers who had invested much in shrimp culture. Production capacity was reduced to half and this greatly affected the shrimp farmers and the allied industries, like the hatcheries, feed millers, processors and exporters. Many shrimp hatcheries closed due to lack of customers. Recently, shrimp prices in the world market have increased again. But the shrimp farmers are now plagued with serious environmental problems like self-pollution, which causes diseases, poor growth, and high mortality.

A policy study by the Auburn University Team (1992) has come up with concrete recommendations for the sustained development of shrimp culture in the Philippines. In areas affected by water pollution, existing facilities for shrimp production must be redesigned. Reservoir ponds, biofilters or other means of effluent treatment must be integrated in the pond culture system.

### **Groupers, mudcrabs, others**

In 1992, some 26,328 tons of groupers, siganids, spadefish, sea bass, and mudcrabs were produced (BFAR 1992). Groupers have aroused the interest of fish farmers during the past two years. Grouper culture in ponds has been reported verbally at meetings, but documentation is lacking. One thing is clear — there is great demand for juvenile (seed) groupers in the export market. Studies on the breeding and larval rearing of groupers are being conducted, but successful hatchery production is still to be realized.

The mudcrab *Scylla serrata* is also in demand in the local and international markets. Small-scale fishfarmers buy or collect lean crabs and fatten them in cages or ponds divided into

compartments by nets or split bamboo. The crabs are fed 'trash' fish and harvested after 15 days or more.

## **Freshwater Aquaculture**

Table 3 shows the production from freshwater ponds, pens and cages in 1992, totalling nearly 98,000 tons, mostly from central, southern, and southeastern Luzon.

### **Nile tilapia**

Freshwater fish culture started in the Philippines in 1972 when the Nile tilapia was introduced. Now, the species is well established throughout the Philippines — in lakes, rivers and reservoirs, and fishponds. Nile tilapia is cultured in about 14,531 hectares of ponds and over 5,000 hectares of cages. Tilapia production in 1992 was 40,399 tons from ponds, 24,871 tons from cages, and 4,917 tons from pens (BFAR 1992). Tilapia cage culture is expanding to many lakes and reservoirs in the country and production is expected to increase.

As the tilapia industry grew, the demand for juveniles increased. Private hatcheries proliferated in addition to the government farms. In the absence of a broodstock development program, the genetic quality of Nile tilapia deteriorated and growth rates and fish sizes decreased.

The Bureau of Fisheries and Aquatic Resources (BFAR) collaborated with the International Center for Living Aquatic Resources Management and the Central Luzon State University Freshwater Aquaculture Center on a study funded by UNDP-FAO on tilapia genetic improvement in 1989-1992. Four tilapia strains from Ghana, Egypt, Senegal, and Kenya were imported and cross-bred with the existing cultured strains from Singapore, Thailand, Taiwan and Israel. After so many cross-breedings, a new strain has been produced, the so-called GIFT (genetically improved farm tilapia). Test culture of GIFT under different farming systems showed that it grows 60% faster than the ordinary Nile tilapia used by farmers. The GIFT strain is expected to replace the existing inferior strains. BFAR's tilapia broodstock development program will expand the production of GIFT in different outreach stations of the Department of Agriculture to cater to the needs of the farmers.

In Sampaloc Lake, Laguna, intensive tilapia cage culture with heavy feeding has resulted in eutrophication, oxygen depletion, and mass kills of cultured stocks (Santiago and Arcilla 1993).

### **Milkfish, carps, catfishes**

Milkfish is grown in about 18,000 hectares of pens in Laguna de Bay and 21,511 tons were produced in 1992 (BFAR 1992). Pollution, multi-use conflicts, and fish kills continue to be problems for the milkfish and tilapia industry in Laguna de Bay.

The production of carps, including the bighead carp *Aristichthys nobilis* and common carp *Cyprinus carpio*, from ponds and cages amounted to 4,615 tons in 1992 (BFAR 1992). The upgrading of carp species in the country is also being done by BFAR. Pure strains of common carps *Cyprinus carpio* were imported in May 1994 from Sukabumi (West Java) and from Madjalaya and are now being grown into breeders at BFAR in Tanay, Rizal.



The native catfish *Clarias macrocephalus* is becoming rare in the Philippines, probably due to loss of appropriate habitats and increasing pollution. Culture of the Thai catfish *C. batrachus* is well established in the country. In 1990-92, some farmers started the culture of the African giant catfish *C. gariepinus*. However, alarm was raised over the great likelihood that this carnivorous fish will escape into natural waters and decimate the local aquatic fauna. This alarm is justified. What is not justified is the fear that the African catfish will bite or eat people. Due to bad publicity, the catfish industry has suffered losses. But more and more farmers are growing African catfish.

### **Freshwater prawn**

Larval production and pond culture techniques for the freshwater prawn *Macrobrachium rosenbergii* are also being worked out by BFAR. Larval production and pond culture techniques are being worked out at the National Freshwater Fisheries Technology and Research Center in Muñoz, Nueva Ecija.

## **Mariculture**

### **Mollusks**

The oysters *Crassostrea iredalei*, *C. malabonensis* and *C. cuculata* have been cultured for a long time and the green mussel *Perna viridis* since 1950. All the harvest, about 30,000 tons in 1992 (Table 5), are marketed locally.

In recent years, there have been problems with red tides, and oyster and mussel farmers have suffered heavy losses. In 1993 alone, about P1 million worth of oysters and mussels in Manila Bay and in Maqueda Bay, Samar were affected by toxic algae, and some people died of poisoning. As a safeguard, BFAR and the Department of Health continuously monitor the cell counts of toxic algae in Manila Bay and immediately warn the public of any abnormal increase.

### **Seaweeds**

Mariculture of the seaweed *Eucheuma* is now a well established industry that produced 294,124 tons in 1992 (Table 5). Most *Eucheuma* farms are in central Visayas and Mindanao. Locally based seaweed processing plants are capable of producing refined and semi-refined forms of carrageenan that are used in many commercial products. *Eucheuma* farming and processing are a lucrative industry and *Eucheuma* ranks third among the country's fishery exports (Table 4).

The pond culture of *Gracilaria* for agar extraction is beginning to take off. BFAR is implementing a UNDP-FAO project to develop farming and processing technologies for *Gracilaria* species and to train government technicians and the families of coastal fishermen (Taw 1994). The project area covers coastal towns in eastern Sorsogon and Sorsogon Bay. Taxonomic studies identified 11 species of *Gracilaria* from Sorsogon, five of which have good potential for farming because of their fast growth rate and good-quality agar (Table 6).

Table 5. Production from mariculture in the Philippines, 1992. Data from BFAR (1992).

Region	Total	Production (tons)		
		Oyster	Mussels	Seaweeds
National Capital	1,714		1,714	
Cordillera	-	-	-	-
Northwestern Luzon	8,045	8,010	-	35
Northern Luzon	4	-	-	74
Central Luzon	610	507	103	-
Southern Luzon	10,751	892	5,418	4,441
Southeastern Luzon	210	134	53	23
Western Visayas	3,993	3,147	846	-
Central Visayas	19,485	-	-	19,485
Eastern Visayas	11,804	-	9,083	2,721
Western Mindanao	266,717	-	-	266,717
Central Mindanao	154	-	-	154
Eastern Mindanao	493	19	-	474
Southern Mindanao	-	-	-	-
Total	324,050	12,709	17,217	294,124

Table 6. *Gracilaria* species with good potential for farming and processing in the Philippines. Data from Taw (1994).

Species	Mean growth rate (%/day)	Mean gel strength (g/cm <sup>2</sup> )
<i>Gracilaria firma</i>	8.7	765
<i>G. fastigiata</i>	9.0	890
<i>G. changii</i>	9.0	963
<i>G. heteroclada</i>	6.2	968
<i>G. tenuistipitata</i> var <i>lui</i>	6.2	433

## Groupers

Grouper culture in floating net cages has been started in the recent years but juveniles are in short supply. Among the existing grouper cage culture projects are those of the Palawan National Agricultural College, the Philippine Human Resources Development Center in Lingayen, Pangasinan, and the Atlas Corporation in Bohol. Juvenile groupers are bought from fishermen and reared in net cages to marketable size or into breeders. Unless hatchery-reared juveniles become available, the grow-out culture of groupers will remain small-scale.

## Constraints and Problems

The aquaculture industry is growing at a fast pace. The problems of the industry in the Philippines and the rest of southeast Asia have been addressed by many of the studies conducted by the SEAFDEC Aquaculture Department, as summarized by Bagarinao and Flores (1995). Still there are problems. Fish farmers commonly complain about the following:

- Poor quality larvae and juveniles of tilapia, carps, and tiger shrimp, and stocks of *Eucheuma*

Continuous inbreeding of tilapias and carps has led to genetic deterioration and poor growth. Poor-quality shrimp larvae from infected broodstock (various diseases) die in large numbers. Genetic improvement of existing stocks of *Eucheuma* spp. is needed.
- Dwindling supply of tiger shrimp broodstock from the wild

Pond-reared broodstock must be produced and shown to be disease-free and effective spawners.
- Lack of larvae and juveniles for grow-out culture of milkfish and grouper

Production of larvae and juveniles in hatcheries is needed. Existing larval rearing techniques must be improved to increase survival. Larval nutrition must be studied.
- Low survival of grouper juveniles during transport

Appropriate handling techniques before, during, and after transport of grouper seed must be developed.
- High incidence of abnormalities in hatchery-produced milkfish fry

Milkfish culturists are biased against hatchery-bred milkfish with bent bodies and cleft gill covers. Such abnormalities must be reduced.
- High cost and poor quality of feeds for fishes and shrimps

Feeds make up 60% of the cost of shrimp production. Unless the price of feeds is lowered, the Philippines can not compete in the shrimp export market. Poor quality feeds settle at the pond bottom, pollute the water and soil, and adversely affect the cultured stock.
- Outbreak of diseases in shrimp grow-out ponds

Diseases such as luminous vibriosis and red spot disease, brought about by poor water quality, have become all too common. The occurrence and causative agents of shrimp diseases must be monitored in order to prevent and control them. Monitoring must be a continuous joint effort by the government, research institutions, and the industry.

- Lack of biodegradable pesticides to control snails in milkfish ponds

Since the government banned the use of the organotin pesticides Aquatin and Brestan, snail infestation in milkfish ponds became a serious problem.

- Impact of aquaculture drugs and chemicals on the environment and public health

Fish kills occur when toxic chemicals in sludge and effluents are released from culture ponds. Antibiotic-resistant bacteria pathogenic to people could develop as a result of the indiscriminate use of antibiotics in aquaculture.

- Lack of culture technologies for new species

Appropriate and economical technologies must be developed for the grow-out culture of grouper, sea bass, snappers, siganids, mullets, mudcrab, and white shrimps.

- Effective quarantine measures for new aquaculture species brought into the country

The introduction of exotic species into the country has been a problem and the government is now developing strict quarantine procedures.

- Pollution and environmental degradation

Domestic agricultural, industrial and aquaculture wastes cause pollution problems in the Philippines and other southeast Asian countries. Pollution control measures must be strictly enforced, or the problem will get worse. Erosion and siltation due to deforestation, agriculture, and urbanization cause serious problems on coral reefs, seagrass beds, and other aquatic habitats.

- Technology for recycling wastewater from intensive and semi-intensive farms

The use of biofilters like mussels, oysters, and seaweeds to cleanse aquaculture effluents must be further developed.

- Weak information exchange and networking in the marketing of aquaculture products

Overproduction causes prices in the export market to go down. A strong network and linkage must be forged among countries producing the same commodities in order to prevent overproduction, oversupply, and low prices in the foreign market.

- Lack of appropriate policies in aquaculture

A clearly defined legal framework for aquaculture is needed. Such policies and regulations must be based on thorough socioeconomic and technical studies.

## **Conclusion**

The future of aquaculture industry is bright, particularly in the marine areas where water quality is not heavily affected by pollution. Many freshwater bodies in Mindanao can still be harnessed for aquaculture. Expansion of brackishwater ponds is unlikely except in some areas in southern Mindanao where land and labor are relatively inexpensive and pollution is not yet too much a problem. Conversion of mangrove forests and swamps into ponds and other uses is strictly prohibited by law. The thrust of government and industry must be to intensify production in existing ponds through adoption of improved culture technologies, particularly for milkfish. Further success in aquaculture in the Philippines can only be assured if the problems and constraints facing the industry are resolved by research and appropriate technologies.

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# Coastal Aquaculture in Thailand

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## Abstract

Coastal aquaculture in Thailand has expanded rapidly in both area and production in the last decade. The important cultured species are the shrimps (*Penaeus monodon* and *P. merguensis*), sea bass *Lates calcarifer*, groupers *Epinephelus malabaricus* and *E. tauvina*, green mussel *Perna viridis*, horse mussel *Modiolus senhousenii*, blood cockles *Anadara granosa* and *A. nodifera* and the oysters *Crassostrea belcheri*, *C. lugubris* and *Saccostrea commercialis*. The total production from coastal aquaculture in 1991 was 230,444 tons, consisting of 70.3% shrimp, 28.8% mollusks, and 0.9% fishes. The seaweeds *Gracilaria* spp., pearl oysters, scallops, and abalones are cultured on a pilot scale in some places. Hatchery technologies have recently been developed for groupers, oysters, scallops, and abalones. Expanded aquaculture has had some adverse effects on the environment and has also suffered from the environmental changes and conflicts due to other sectors using the same water and other resources.

## Introduction

Thailand has about 2,600 km of coastline along the Gulf of Thailand and the Andaman Sea. The total fisheries production slightly increased during the last decade from 2.12 million tons in 1982 to 2.97 million tons in 1991 (Table 1). Capture fisheries made up 88% and aquaculture 12% of the total production.

The development of coastal aquaculture in Thailand focused on the black tiger shrimp, banana shrimp, mudcrab, sea bass, groupers, green mussel, horse mussel, blood cockles, and oysters. Culture techniques for these species have steadily improved. Production from coastal aquaculture grew from 36,900 tons in 1982 to 230,444 tons in 1991 (Table 1). The bulk (70%) of the production was from intensive shrimp culture but over the same period, mollusk and fish production also increased.

Table 1. Fisheries production in Thailand from 1982 to 1991. Data from Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand.

Year	Total	Production (×1,000 tons)			
		Capture Fisheries		Aquaculture	
		Inland	Marine	Freshwater	Coastal
1982	2,120.1	87.7	1,949.7	45.8	36.9
1983	2,225.4	108.4	2,055.2	47.0	44.8
1984	2,134.8	111.4	1,911.5	50.4	61.5
1985	2,225.2	92.2	1,997.2	75.2	60.6
1986	2,536.3	98.4	2,309.5	89.3	39.1
1987	2,779.1	87.4	2,540.0	89.8	61.9
1988	2,629.7	81.5	2,337.2	102.1	108.9
1989	2,740.0	109.1	2,370.5	91.7	168.7
1990	2,786.4	127.2	2,362.2	103.8	193.2
1991	2,967.7	136.0	2,478.6	122.7	230.4

To further promote fisheries in the country's economic development, the Government formulated a progressive fishery policy under the Seventh National Five-Year Plan (1992-1996). Under this policy, the coastal aquaculture sector was mandated to achieve the following:

- Undertake extensive propagation of brackishwater species
- Increase the production from coastal aquaculture by developing intensive culture techniques
- Use remote sensing and ground surveys in coastal zone development
- Develop effective techniques for sustainable utilization and conservation of coastal living resources

This paper reviews the status of aquaculture of different brackishwater and marine species, including some of the problems that further research may be able to resolve.

## Shrimp Culture

The shrimp culture industry in Thailand started to take off in 1986 and soon became the most profitable agribusiness venture. Shrimp production in 1982 was 10,091 tons from a culture area of 30,792 hectares; this increased to 184,884 tons from 72,796 hectares in 1992 (Table 2). The culture techniques and management vary according to the scale of operation (Potaros 1994).

The extensive culture system was in practice when shrimp culture began along the inner Gulf of Thailand. Most of the extensive farms are in mangrove areas. Farming depends on the natural seed supply and tidal water exchange. Ponds have sluice gates on the side to receive seawater, nutrients, and wild postlarvae (mostly *Penaeus merguensis* and *Metapenaeus* sp.) during high tide. The water in the pond is maintained at a depth of 50-60 cm. After 3-4 months, when the shrimps attain marketable size, the water is drained through the sluice gate during low



tide and the shrimps are trapped in a bag net. Before a new crop starts, the dikes are repaired and the ditch scoured. Farmers can raise two crops a year at yields of 187-375 kg/ha per crop.

Table 2. Shrimp culture and production in Thailand, 1982-92. Data from the Department of Fisheries, Ministry of Fisheries and Cooperatives, Thailand. US\$1 = Baht 25.

Year	Number of farms	Total area (ha)	Production (tons)	Value (million Baht)
1982	3,943	30,792	10,091	766
1983	4,327	35,537	11,550	950
1984	4,519	36,792	13,007	1,024
1985	4,939	40,769	15,841	1,348
1986	5,534	45,368	17,886	1,738
1987	5,899	44,770	23,566	3,449
1988	10,246	54,778	55,633	7,901
1989	12,545	71,166	93,494	11,072
1990	15,072	64,606	118,227	14,365
1991	18,998	75,332	162,070	19,834
1992	19,403	72,796	184,884	25,500

The semi-intensive culture system improves on the extensive by stocking shrimp postlarvae from hatcheries. In 1983, the Department of Fisheries succeeded in mass producing the postlarvae of the banana shrimp *P. merguensis* and tiger shrimp *P. monodon* in the hatchery and made up for the depleted natural supply. The semi-intensive farm is generally smaller, about 0.5-1.6 hectare, and includes a water reservoir pond from which water is pumped into the grow-out ponds. Pests, predators, and competitors of shrimp are eliminated with teaseed cake or rotenone root powder. Banana shrimps and black tiger shrimps are stocked at a density of 5-20/m<sup>2</sup>. Supplemental feeds are given. Yields are 375-625 kg/ha after a 4-month culture period.

The development of hatchery techniques in 1986 enabled the private sector to produce about 3,000 million shrimp postlarvae each year. This stimulated the shift from semi-intensive to Taiwan-style intensive shrimp farming. Intensive shrimp ponds vary from 0.16 to 1 hectare, about 1.5-3 meters deep, and are either rectangular or circular. Stocking densities range 30-60/m<sup>2</sup>. Intensive farms require high financial and technical inputs. Artificial diets and artificial aeration are absolutely necessary. Paddlewheels (electric or diesel motor-driven) and oxygen injectors are used. It is possible to grow 2-3 crops a year with 60-90% survival and yields of 5-10 ton/ha per crop. The national average yield surged from 0.39 ton/ha in 1985 to 2.15 ton/ha in 1991, at which time tiger shrimp made up 95.7% of total production (Csavas 1994).

The fishery census in 1993 showed 12,000 hatcheries producing more than 3,000 million postlarvae. Still, this supply does not meet the demand of the shrimp industry in Thailand. Also, the hatcheries depend on wild spawners, which are now in short supply. Thus, shrimp broodstocks must be developed.

With the rapid development of shrimp culture came various negative effects on the environment (Phillips 1995). In Thailand, 34% of cleared mangrove areas are now shrimp farms. Ponds were built even in unsuitable sites and more intensive culture methods were adopted. Farmers pushed their stocking densities to high levels to maximize the harvest. These profit-oriented practices eventually led to disease outbreaks. The first disease outbreak occurred in the intensive farms along the Inner Gulf of Thailand. More serious outbreaks spelled the end of shrimp culture in the Inner Gulf; many farms were abandoned. The farmers moved to the eastern and southern provinces and are now more aware of proper health management. Still, diseases persist. Antibiotics are widely used in Thailand and residues have been found in shrimp tissues (Saitanu et al. 1994).

Intensive shrimp farms discharge large quantities of effluents. To reduce the adverse impacts of shrimp culture, the Department of Fisheries issued various regulations. The total production ceiling is set at 200,000 tons a year. To control effluents, farms larger than 8 hectares are required to construct a wastewater oxidation pond with an area 10% that of the total water area of the farm. The biochemical oxygen demand of the effluents must not exceed 10 ppm. Legal action is taken by the government against farmers who discharge pond sediments. The government meanwhile has improved water flow in drainage canals and tributaries.

### **Mudcrab Fattening**

In 1986, the production of mudcrabs *Scylla serrata* amounted to 223 tons from 100 small farms, which disappeared when shrimp culture boomed (Csavas 1994). Nowadays, farmers prefer to fatten large but lean mudcrabs rather than culture small ones for a longer period. Mudcrabs are fattened in a pond surrounded by bamboo or netting to prevent the crabs from escaping. Fattening takes 10-20 days during which the mudcrabs are fed with chopped 'trash' fish.

The major constraints in mudcrab fattening are the short supply of mudcrabs and the high mortality in ponds due to cannibalism.

### **Fish Culture in Cages**

Total production of fishes from cages has improved over the years but is still lower than from mollusk culture (Table 3).

The sea bass *Lates calcarifer* is the most popular brackishwater fish cultured in Thailand. In 1973, the Department of Fisheries succeeded in artificial propagation of sea bass (NICA 1986) and now hatcheries produce about 30 million juveniles a year. Sea bass can be grown in earthen ponds, net cages, and pens (Kungvankij et al. 1986). The stocking rate is usually 20-40/m<sup>2</sup>. Net cages, usually 5x5x2 m, can be floating or stationary. The floating net cages are hung from wooden or bamboo frames kept afloat by styrofoam blocks or polypropylene tubs. Stationary net cages are fastened to wooden poles at the four corners and set in shallow waters with small tidal fluctuations. Farmers usually use chopped fresh 'trash' fish as feed. In 1991, about 1,461 cages were in operation and 1,650 tons of sea bass were produced.

The groupers *Epinephelus coioides* and *E. malabaricus* are the most popular marine fishes cultured in Thailand. At present, the culture sites are mostly in the east and southwest provinces. Groupers are cultured in net cages similar to those used for sea bass. Juveniles for stocking are collected from the wild. In 1991, about 355 tons of groupers were produced from 1,045 farms at yields of 300-400 kg/cage. In the near future, government and private hatcheries may be able to provide juveniles for stocking; larval rearing techniques are now being developed (Ruangpanit 1993).

Table 3. Production from coastal aquaculture of fishes and mollusks in Thailand from 1982 to 1991. Data from Department of Fisheries, Ministry of Agriculture and Cooperatives, Thailand.

Year	Fishes	Production (x 1,000 tons)			
		Blood cockle	Green mussel	Oyster	Horse mussel
1982	0.1	3.7	16.1	3.5	0.6
1983	1.2	7.1	18.7	3.4	0.6
1984	0.8	12.5	26.2	4.9	1.6
1985	0.7	12.4	25.9	3.5	0.4
1986	0.9	6.9	11.1	0.6	0.3
1987	1.5	9.6	23.9	1.5	0.8
1988	1.4	4.7	44.2	1.9	0.6
1989	1.8	12.8	58.7	1.4	0.0
1990	1.6	12.3	58.4	1.4	0.9
1991	2.0	26.4	35.5	3.3	1.1

### Mussel Culture

The green mussel *Perna viridis* is the most important mollusk cultured in Thailand the past 60 years (McCoy et al. 1988). The culture method developed from a stationary fishing gear, the bamboo stake trap. To collect mussel spats, bamboo poles or coconut palms are staked into the muddy bottom 4-8 meters deep. Another adaptation is to extend the wings of fish traps to collect mussel spat. The spats are left to grow on the stakes for 6-10 months until the mussels are marketable. The mussel culture areas are near the mouths of large rivers such as Bang Pakong, Chao Phraya, Mae Klong, and Tha Chin in the inner Gulf of Thailand. The culture area was expanded in 1979 by transplanting mussel spats to Pattani Bay in southern Thailand (Brohmanonda et al. 1988b). In 1991, mussel farms covered 300 hectares and produced 35,455 tons, less than during the previous three years (Table 3).

The horse mussel *Modiolus senhousenii* is also widely distributed throughout Thailand, in intertidal zones with water less than 3 meters deep and bottoms of mixed silt, sand and mud. The farmers collect 5-10 mm spats and transfer them to selected mudflats. After 8-12 months, the 2-3 cm mussels are harvested by dredging. The production of horse mussel in 1991 was

1,092 tons from 34 farms covering 80 hectares (Table 3). Horse mussels are sold for human consumption and as animal feed.

Green mussel culture in Thailand can be further developed. Basic scientific knowledge and information is needed regarding the biology of green mussel, how to fatten it, and when best to harvest it. Spat collection techniques using ropes or other material should be introduced. New culture methods such as the hanging-line method proven most efficient in Europe should be investigated for biological and economic feasibility in Thailand. Also, packaging techniques must be improved given that about 51% of the harvest is marketed fresh shell-on and the rest is processed into various forms (McCoy et al. 1988).

### Cockle Culture

The blood cockles farmed in Thailand generally inhabit nearshore or estuarine bottoms with fine mud. Suitable areas for cockle culture are sheltered bays with a river or canal to bring in plankton and other particulate food. The bottom slope must not exceed 15 degrees so that cockles are not moved by wind and wave action. Water depth must be 0.5-1 meter below mean sea level and the exposure period must not exceed 2-3 hours a day.

Culture of a local species of cockle, *Anadara nodifera*, began about 90 years ago in Phetchaburi Province (Tookwinas 1988). Cockle spats each 0.3-0.5 grams are still collected from natural settling grounds and stocked in selected areas 0.8-1.6 hectares wide at rates of 12-19 million spats per hectare. These 'farms' are fenced with bamboo poles 50 cm high to prevent the spats from being washed away. It takes about two years to reach the marketable size of 14-17 grams.

Cockles are highly favored in Thailand and the production of *A. nodifera* was not enough to meet the local demand. Thus, cockle farmers imported the spats of *A. granosa* from Malaysia beginning in 1973. About 20,000 tons are imported annually and cockle farming has developed considerably in places such as Satun, Nakhon Sri Thammarat and Surat Thani, where single farms may range 32-144 hectares in size. The culture method is similar to that in Malaysia (Tookwinas 1988). Production has varied during the past decade; in 1991, 260 farms covering 1,566 hectares produced 26,442 tons of blood cockles (Table 3).

### Oyster Culture

Oyster culture in Thailand dates back about 50 years (Brohmanonda et al. 1988a). The three species of oysters that are cultured are widely distributed along the coasts of Thailand. The east coast is the culture area for *Saccostrea commercialis* and the south coast mainly for *Crassostrea lugubris* and *C. belcheri*. The production has been low and variable during 1982-1992 (Table 3). In 1991, about 1,500 oyster farms occupied 768 hectares and produced 3,311 tons.

Oysters require hard substrates for attachment — wood, stones or rocks. Farmers use stones and branches to collect spats, which are then grown in shallow waters. The most suitable areas for oyster culture are river mouths that are protected by natural or artificial barriers against strong winds and waves. The salinity must not fall below 10-15 ppt for long periods and the water

must contain adequate nutrients for plankton production. Water depth must be 1-2 meters and the bottom must not be exposed for more than 2-3 hours a day during spring tides.

The traditional culture method is to use rocks as substrates for oyster spat settlement and let the spats remain on the rocks until they reach marketable size. The rocks are piled in groups of 5-10 and spaced in rows 50-80 cm apart. This method is extensively used in Chonburi and Chantaburi provinces. Some farmers now use concrete poles or tubes 15 cm in diameter and 40 cm high that are fitted on bamboo stakes driven into the bottom of the culture area. The poles or tubes are placed in rows about one meter apart. This method is widely used in Surat Thani province.

In another method, bamboo poles and wooden stakes 2-3 meters long are driven into the bottom to serve as spat collectors then culture structures. Stakes usually number 10,000-12,500 per hectare. This method is very similar to that for mussel culture; the only difference is that the oyster culture grounds are usually nearer shore. The hanging-line and tray methods are also used in mussel culture in some localities, depending on the substrate and the availability of materials. The culture period from spat to marketable oyster is 1.5-2 years.

The culture of the large oyster *C. belcheri* in Thailand has good potential, but the quantity of oyster spats from the wild is not sufficient for the needs of the oyster growers. The spat collection and culture techniques need to be improved and new ones developed. To improve the spat supply, the government established a mollusk hatchery in Prachuab Khirikhan in 1986. This hatchery can produce 500,000 oyster spats a year (Sahavacharin et al. 1988).

Mollusk culture in general is limited by the shortage of spats and suitable culture areas (McCoy and Chongpeepien 1988). Improved or new culture techniques are needed by the industry for oysters, pearl oysters, scallops, giant clams, and abalones. The demand for mollusks in both the domestic and the world markets must be expanded for the industry to grow further.

Pollution is a big problem. Water quality in the mollusk culture grounds has deteriorated due to sewage discharge, industrial effluents, and agricultural run-off. At present, no system exists for ensuring sanitation of mollusk products. At present, handling during harvest causes serious contamination. To solve this problem, farmers should decluster and clean the mollusks at the culture site where seawater is clean rather than at the landing sites where the water is generally polluted. The levels of heavy metals and bacteria must be kept within the international limits of acceptability (Phillips and Mutarasin 1985, Saitanu 1988).

## Seaweed Culture

*Gracilaria* and *Polycavernosa* are collected from natural beds or sea bass and grouper cages, dried, and sold to middlemen in Trat, Chantaburi, Songkhla, Pattani, and Trang (Csavas 1994). Most of the 60-200 tons collected each year is exported. At present, *Gracilaria* sp. is experimentally cultured in ponds or on net cages. The Department of Fisheries is examining the feasibility of mass propagating *Gracilaria* and other seaweed species. Experiments to grow *Gracilaria* in effluents from intensive shrimp ponds has shown initial success.

The main constraints in the expansion of seaweed culture in Thailand are the lack of domestic processing facilities and the low export prices.

## Experiments on Other Species

Experiments are underway to develop culture techniques for the red snapper *Lutjanus argentimaculatus*, starting with hatchery production of larvae (Doi and Singhagriwan 1993). Cage culture techniques for the local spiny lobsters (*Panulirus* spp.) were tested and found promising (Csavas 1994). The pearl oysters *Pinctada fucata*, *P. margaritifera*, *P. maxima*, and *Pteria penguin* are cultured in some places. Efforts are also underway to develop commercial culture of scallops (*Amusium pleuronectes* and *Chlamys senatoria*) and abalones (*Haliotis* spp.). Other species of interest are the cuttlefish *Sepia pharaonis*, the razor clam *Solen strictus*, and the grey mullet *Mugil cephalus*.

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# **Aquaculture in Vietnam**

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## **Abstract**

Aquaculture in Vietnam has gained momentum and now produces 370,000 tons of various aquatic commodities. Aquaculture includes shrimp culture in the Mekong Delta; fish culture in cages in rivers, reservoirs, and coastal waters; fish culture in ponds and lakes; mollusk culture in the northern provinces, culture of soft-shell turtle in some provinces, culture of the seaweed *Gracilaria*. In north and central Vietnam, aquaculture has increased the protein supply, the foreign exchange earnings, employment opportunities, and the living conditions of the people. Vietnam aims to develop aquaculture to produce more than 600,000 tons of aquatic products by the year 2000.

## **Introduction**

Vietnam has about 1.4 million hectares of water bodies suitable for aquaculture. Only about one-third of the surface area is used for aquaculture, now producing about 370,000 tons of fishes, crustaceans, mollusks, seaweeds, and turtles. Expansion has been rapid in brackishwater and freshwater areas. The contribution of aquaculture to the total annual fisheries production has increased from 307,000 tons in 1990 to 373,000 tons in 1993. With active measures and technical improvements, Vietnam aims at producing more than 600,000 tons of cultured aquatic products by the year 2000.

Farmers have paid special attention to shrimps, crabs, fishes and other species of high economic value (Table 1). In recent years, the traditional extensive culture method has been improved or upgraded to semi-intensive systems with the use of hatchery-produced larvae and artificial feeds.

Aquaculture has improved the protein supply, foreign exchange and export earnings, employment opportunities, and the living standards of the people in Vietnam.

Table 1. The aquatic species cultured in the northern, central and southern provinces of Vietnam.

Species	North	Central	South
<b>Crustaceans</b>			
<i>Penaeus monodon</i>	+	++	++
<i>Penaeus merguensis</i>	+	+	++
<i>Penaeus orientalis</i>	+		
<i>Metapenaeus ensis</i>	++	+	++
<i>Panulirus ornatus</i>	+	+	+
<i>Scylla serrata</i>	+	++	++
<i>Macrobrachium rosenbergii</i>	+		++
<b>Freshwater fishes</b>			
<i>Cyprinus carpio</i>	++	+	
<i>Ctenopharyngodon idella</i>	++	+	
<i>Aristichthys nobilis</i>	++	+	
<i>Hypophthalmichthys molitrix</i>	++	+	
<i>Cirrhina molitorella</i>	++	+	
<i>Puntius gonionotus</i>		++	
<i>Labeo rohita</i>	+		
<i>Ophicephalus spp.</i>			++
<i>Oxyeleotris marmoratus</i>			+
<b>Marine and brackishwater fishes</b>			
<i>Epinephelus ornatus</i>	+		
<i>Lates calcarifer</i>	+	+	+
<i>Seriola spp.</i>	+		
<i>Siganus sp.</i>			+
<b>Red seaweeds</b>			
<i>Gracilaria spp.</i>	++	++	
<i>Eucheuma sp.</i>		++	
<b>Mollusks</b>			
<i>Pinctada margaritifera</i>	+	+	+
<i>Pteria martensii</i>	+	+	+
<i>Chlamys nobilis</i>	+	++	+
<i>Arca granosa</i>	+	+	+
<i>Arca subcrenata</i>	+	+	+
<i>Meretrix spp.</i>	+	+	+
<i>Ostrea rivularis</i>	+	+	+
<b>Turtle</b>			
<i>Trionyx sinensis</i>	++	+	

++ Aquaculture well developed

+ Aquaculture limited

Most of the data in this paper were obtained from the reports my colleagues (Nguyen The Ann, Bui Dinh Chung, Pham Thuoc, Vo Van Trac) and I presented at the National Workshop on Environment and Aquaculture Development in Haiphong, Vietnam in May 1994. A report about the Haiphong workshop also appears in the NACA Newsletter 11(2): 1-3, 11 (Apr-Jun 1994).

## Shrimp Culture

Shrimp culture has developed rapidly and widely during the past decade. The area under marine shrimp culture was 30% greater in 1993 than in 1990. In 1993, about 200,000 hectares were used for shrimp culture and production was 40,000 tons. The Mekong Delta was the main area for shrimp culture with 170,000 hectares producing 33,000 tons.

The method of shrimp culture is mainly traditional extensive with average yields not more than 500 kg/ha-yr. The semi-intensive method is used in tiger shrimp culture in the Mekong Delta where ponds are 0.01-2 hectares in size. The average yield is 1 ton/ha-yr, but some ponds can obtain 1.5-2 tons/ha-yr. The area under semi-intensive culture is only 3,000 hectares.

There are now 238 shrimp hatcheries in Vietnam producing annually about 300 million postlarvae of different species (Table 2). This quantity met only about 10% of the demand of the farmers engaged in shrimp culture. Most of the hatcheries are in central Vietnam, from Qui Nhon to Phan Thiet. The postlarvae have to be transported to the Mekong Delta and some of the northern provinces of Vietnam.

Table 2. Development of the shrimp hatchery industry in Vietnam. Data from the Fisheries Bulletin, Ministry of Fisheries, Hanoi.

Year	Number of hatcheries	Postlarvae produced (million)
1986	16	3.3
1988	20	30
1989	45	200
1990	215	250
1991	215	300
1993	238	>300

## Mudcrab Culture

Culture of the mudcrab *Scylla serrata* is being developed in the northern provinces from Quang Ninh to Thanh Hoa as well as in the Mekong Delta plain. Crabs are grown mostly under semi-intensive conditions in small family-scale ponds. In bigger ponds more than 10 hectares, crabs are cultured with shrimps and the seaweed *Gracilaria*. Juvenile mudcrabs (body weight 50-70 grams) are collected mainly from the wild. Extensive crab culture can produce

100-200 kg/ha-yr and the semi-intensive method can yield 1,000 kg/ha-yr. Cultured crabs are sold mostly in Chinese markets at prices of VND 70,000-120,000/kg (about US\$7-10/kg in 1993).

### Freshwater Prawn Culture

Culture of the giant freshwater prawn *Macrobrachium rosenbergii*, either in monoculture or polyculture with rice, is also being developed in about 14,000 hectares of the Mekong Delta. In 1988, the production of freshwater prawn was about 5,000 tons. Two hatcheries produced postlarvae of the giant freshwater prawn.

### Fish Culture

Fish culture is being developed in ponds and lakes throughout the country. There are 78,000 hectares of freshwater bodies producing annually about 220,000 tons, at yields of 1.7-4 tons/ha-yr. The cultured freshwater species are the common carp, grass carp, bighead carp, and the Indian major carps (Table 1). There are 375 hatcheries supplying the farmers annually more than 5 billion juveniles of different freshwater fishes. In the northern provinces, hatcheries provide enough juveniles and no more are collected from the wild.

Fish culture in cages is being promoted widely in rivers, reservoirs, and coastal waters in Vietnam. The production from fish cages in the northern provinces was more than 6,000 tons in 1993. Each cage of 18-24 m<sup>3</sup> produced an average of 600-800 kg; after deducting all expenses, the net income was 50-60% of the total production cost.

Culture of the marble goby *Oxyeleotris marmoratus* in cages is being developed in rivers and reservoirs. The stocking density is 50-60 fish per cage and the yield is 400-600 kg from each cage after 8-10 months.

The marine fishes now cultured in cages are the grouper *Epinephelus ornatus*, the sea bass *Lates calcarifer*, yellowtail *Seriola* sp., and the white-spotted rabbitfish *Siganus* sp. The major difficulty in marine fish culture is the lack of juveniles for grow-out.

### Seaweed Culture

Due to increased market demand and improved culture technology, a rapid leap has been made in seaweed culture. The species being cultured in Vietnam are *Gracilaria asiata*, *G. blodgettii*, and *G. tenuistipitata*. Culture is mainly by extensive and improved extensive methods. The intensive method has been used recently but in small scale only. The improved extensive method yields 100-200 kg/ha-yr of dried seaweed. The semi-intensive ponds of 0.1-5 hectares yield 2-4 tons/ha-yr (dry).

*Gracilaria* production has gradually increased to about 2,000 tons dry weight in 1993. Depending on the market, the production has potential to increase in the coming years. *Gracilaria* is now used mainly for agar production for the domestic market; export markets are yet lacking.

Other seaweeds like *Eucheuma* and *Kappaphycus* have been cultured on experimental scale since 1992. Commercial culture of these species in Vietnam is expected in the near future.

### **Mollusk Culture**

Aquaculture of several species of mollusks is being developed in Vietnam (Table 1). Culture of freshwater and marine pearl oysters is now in the initial stage of development. Among the northern provinces, Quang Ninh has great potential for expanded aquaculture of clams, cockles and scallops in the tidal zones.

### **Turtle Culture**

The soft-shell turtle *Trionyx sinensis* is being cultured in some northern provinces. In Hai Hung, there are about 600-700 households involved in turtle culture. The other provinces with 300-400 households culturing the soft-shell turtle are Ha Noi, Ha Bac, Nam Ha, Ninh Binh and Ha Tay. The turtles are cultured in small ponds managed by individual families. The major consumers of soft-shell turtles are the Chinese. The selling price has increased to VND 280,000-350,000/kg in 1992-93.

### **Upgrading Aquaculture Technology**

The main directions of aquaculture development in the coming years are the following:

- Develop and apply suitable culture technologies.
- Apply appropriate culture technologies to aquatic species of high economic value to obtain more production.
- Conduct research to perfect and apply appropriate culture systems that ensure ecosystem balance and limit damage to the environment.
- Refine (hatchery) technology for artificial seed production to meet the requirement of fish and shrimp farmers.
- Develop health management measures (prophylaxis, prevention and treatment of diseases) for cultured species, and promote locally available drugs of plant origin rather than imported chemical drugs.
- Expand the supply systems of aquaculture services and goods such as feeds, seed, and drugs.
- Develop post-harvest processing to add value to aquaculture products.
- Conduct research on genetic selection techniques for important cultured species, and on the conservation of genetic diversity particularly among indigenous aquatic species.

The topography, climate, and ecosystems in Vietnam differ much between the southern and northern provinces. Therefore, the appropriate aquaculture technologies and species must be determined and applied accordingly.

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## **Editors' Addendum**

An informative account of the brackishwater integrated farming systems in Vietnam is given by de la Cruz (1995). Several papers in recent issues of *Naga*, the ICLARM Quarterly describe freshwater and brackishwater farming systems in Vietnam (Le 1992, Le 1994, Lin and Lee 1992, Nguyen 1993, Nguyen and Tran 1993, Nguyen et al. 1993, Le 1994, Truong et al. 1994).

A report about the Haiphong workshop also appears in the NACA Newsletter 11(2): 1-3, 11 (Apr-Jun 1994). In Vietnam, technologies have been developed for breeding and grow-out, including feeds and feeding, of major species. Lacking or inadequate are technologies for genetic selection, disease prevention, diagnosis, and treatment, and Seafarming. Most aquaculture areas were developed without adequate planning and without provision against ecological damage. Policies for aquaculture development lack an environmental approach. Activities in other sectors (agriculture, industries, energy generation, etc.) have caused harm to the water environment.

The Haiphong workshop ended with recommendations for the rational utilization of resources for sustainable aquaculture in Vietnam, one set each addressed to the farmers, to R&D institutions, to government, and to agencies for international cooperation.

### **For farmers:**

- Protect the water environment. Wastewater should be properly treated before discharge into common waterways.
- Interact closely with fishery extension workers.
- Invest in improved extensive, semi-intensive, or intensive culture methods, preferably for high-value species.
- Develop a proper plan for any aquaculture project based on a thorough site survey. Management plans and actual operations must include protection of mangrove forests and watersheds.
- Use drugs and chemicals in aquaculture properly.

### **For R and D institutions:**

- Strengthen the basic survey work to collect and process data needed to assess the status and potential of water bodies as basis for development planning.
- Conduct research on the interactions among resources, culture systems, and the environment in order to achieve sustainability.
- Conduct studies on the conservation and rehabilitation of genetic diversity, including rare or threatened species.
- Develop a national research program to reduce the risk of pollution in water bodies and to manage and treat wastes before these are discharged into water bodies.

- Improve existing technologies and develop new and progressive ones, particularly in:
  - \* breeding marine fishes and other high-value species
  - \* intensive culture with emphasis on health management
  - \* development of vaccines and drugs
  - \* feed formulation and production
  - \* genetic selection for high yields

**For government:**

- Take rapid action to provide clear and precise guidelines for the application of the Law on Protection of the Environment, Ordinance on Protection and Development of Fishery Resources, and the Veterinary Ordinance. Provide details and specific rules and regulations on the following:
  - \* management, protection, and development of aquatic genetic materials
  - \* management and sustainable use of water bodies
  - \* epidemiology and veterinary monitoring of aquatic products
  - \* registry and management of seed production and culture practices
- Refine the policies that promote sustainable aquaculture.
- Increase support for R and D institutions.
- Support research that helps in formulating an updated multi-sectoral plan, which will include key areas and ecosystems, and which will become the basis for guidelines to investors and farmers regarding environmentally sustainable culture systems.
- Mobilize investments in upgrading of the agro-fishery infrastructure and technical services system for the industry.
- Establish an effective network of fish inspection and fishery environment control.
- Improve the fishery extension system and develop a program geared to closer community participation.
- Support the establishment of protected areas for the conservation of biodiversity.

**For agencies of international cooperation:**

- Assist Vietnam in formulating a national program for the development of sustainable aquaculture.
- Assist in identifying and establishing protected areas for biodiversity conservation.
- Coordinate with scientists and research centers in developing appropriate, environment-friendly technologies in aquaculture.
- Assist in training specialists in genetic selection, environmental management, protection of resources, and in planning and policy formulation for sustainable aquaculture.
- Exchange information and experience in the organization and operation of fishery extension, fishery inspection, management and control of water resources, and fish health services system.

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# Research on Marine and Freshwater Fishes

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## Abstract

Most of the fish research at SEAFDEC AQD in 1992-1994 was on milkfish. Studies were conducted on year-round spawning through hormonal or environmental manipulation; optimum lipid and protein levels and ration size for captive broodstock; and the influence of spawner age on reproductive performance. The economics of hatchery operations, alone or integrated with broodstock as a commercial enterprise, was assessed. Mass production of larvae was refined with the use of commercial or SEAFDEC-formulated larval diets. Alternative rearing schemes in large tanks and ponds were tried. Hatchery-produced and wild-caught larvae were compared in terms of growth and production in experimental nursery and grow-out ponds. Supplemental diets for brackishwater grow-out culture were formulated.

Studies on broodstock management of grouper *Epinephelus* spp. included lipid enrichment of the diet and hormonal induction of sex inversion. Seed production techniques were developed but survival rates were low. Grouper culture was found economically feasible in experimental ponds with 'trash' fish as feed.

The mangrove red snapper *Lutjanus argentimaculatus* was successfully induced to spawn with injection of human chorionic gonadotropin. Initial larval rearing trials were successful but survival rates must be improved.

Hormonal manipulation of spawning of the Asian sea bass *Lates calcarifer* allows seed production during most of the year. Photoperiod manipulation leads to maturation of females, but not males, beyond the natural breeding season (April-November). Nursery rearing of 9 mm juveniles is feasible in floating net cages with night lights that attract food zooplankton. The requirements of sea bass for lipid, protein, carbohydrates, and essential amino acids were determined.

In the rabbitfish *Siganus guttatus*, weekly injections of luteinizing hormone releasing hormone analogue (LHRHa) sustains milt production for three weeks. Thyroid hormones injected into broodstocks improved the growth of larvae to day 7.

Induced spawning techniques for the Asian catfish *Clarias macrocephalus* were refined by determining the seasonal responsiveness to

LHRHa and pimoziide injections and testing for pheromonal induction of spontaneous spawning. The optimum insemination rate was determined and egg hatchability was enhanced by removal of the adhesive coat before incubation. Several practical diets for catfish during grow-out culture were tested against 'trash' fish.

The broodstock management for bighead carp *Aristichthys nobilis* was studied. Cage-reared juveniles from cage-reared broodstock showed the best growth. To improve the reproductive performance, the broodstock diets were supplemented with vitamins A, C, and E.

Research on tilapias focused on genetics and strain selection. Several strain testing procedures for Nile tilapia were evaluated in their efficiency to detect economically important strain differences. Reference lines were developed from two existing red tilapia strains to measure and reduce the effects of uncontrolled nongenetic variables in strain evaluation experiments with Nile tilapia. The tolerance of two Nile tilapia strains to heavy metals was similar when gauged by the 24-hour and 96-hour lethal concentration and by fish growth, survival, and reproductive performance. In a separate study, four strains of red tilapia showed generally higher seed production when reared in tanks than in cages. Improvements in the feed and feeding management for Nile tilapia were also studied.

Intensive tilapia farming and feeding have led to oxygen depletion and fish kills in Sampaloc Lake. To rehabilitate the lake, it is imperative to reduce the farming area from 30 to 6 hectares; stop the use of commercial feeds; and remove the water hyacinths and other debris. Fish kills in Laguna de Bay have also become serious in recent years, and a review of the occurrences, losses, and possible causes is currently being conducted. Studies on the epizootic ulcerative syndrome of snakeheads in Laguna de Bay have yet to pinpoint the pathogen. Skin lesions in tilapias in several ponds and lakes in the country were found to be due to bacteria.

## Introduction

Growth and expansion of marine and freshwater fish culture is necessary in view of the rapid decline in world fish catch and the degradation of the aquatic environment. The SEAFDEC Aquaculture Department has conducted studies on the artificial propagation, nutrition and feed development, farming and socio-economics, health management, and the environmental impact of culture of several fishes. These studies aim to develop aquaculture techniques that would be sustainable ecologically, economically, and socially. This paper reviews recent (1992-1994) studies on cultured fishes at SEAFDEC AQD.

## Studies on Milkfish *Chanos chanos*

### Ecology

The systematics, genetics, distribution and life history of milkfish was fully detailed by Bagarinao (1994). The natural life history of milkfish is one of continual migration. Adults are

large, long-lived, pelagic, and schooling. They spawn offshore near coral reefs and small islands. The eggs and larvae are pelagic and larger than those of most marine fishes. Larvae over 10 mm long and 2-3 weeks old (the 'fry') move inshore by passive advection and active migration. Passing through shore waters and surf zones, these larvae enter shallow-water depositional habitats such as mangrove swamps, where they metamorphose and settle for a few months as juveniles. Some juveniles may enter freshwater lakes (if available) where they grow into sub-adults but do not mature sexually. Both small juveniles and large sub-adults return to sea when they reach the size limit supportable by the habitat. Little else is known of the population dynamics of wild milkfish. To ensure that milkfish (and other fishery species) continue to support human populations, there must be a conscious effort to protect, manage, and rehabilitate coastal habitats and resource systems.

### **Broodstock development**

Reproduction of milkfish broodstock in concrete tanks and floating cages has been fully documented. Milkfish broodstock 9-10 years old spontaneously mature and spawn in concrete tanks 150-200 m<sup>3</sup> in capacity and 2 meters deep (Emata and Marte 1994). From April to November 1991, the different stocks spawned 19-36 times and total egg collection ranged from 8.5 to 12 million (Table 1). As holding facility for milkfish broodstock, concrete tanks are a feasible alternative to floating cages, with no resulting difference in reproductive performance.

Various milkfish stocks in floating cages (24-59 fish per cage, various ages, from either wild-caught or hatchery-bred larvae) had annual egg production ranging from 0.27 to 21.55 million in 1986-1991 (Emata and Marte 1993). The different stocks spawned 5-51 times a year, and averaged from 50,000 to 956,000 eggs per spawning. Older broodstocks from 1978-1981 larvae showed consistently higher annual egg production and number of spawnings. Broodstocks derived from wild-caught or hatchery-bred larvae were not different in reproductive performance (Table 2). Further studies confirmed that broodstock origin (wild or hatchery-bred larvae) does not affect reproductive performance, but that 11-14 year old broodstocks spawned more eggs than 9-year old ones (AC Emata, unpublished).

Milkfish broodstock in floating cages incidentally eat their own spawned eggs (Toledo and Gaitan 1992). The mean number of spawned eggs at the water surface significantly declined one hour after spawning and very few eggs were recovered 4 hours later. Eggs were found in the guts of spawners 5 hours after spawning. Thus, spawned eggs should immediately be collected to prevent egg cannibalism by spawners.

Current studies aim for year-round spawning, increased egg production, and improved egg and larval quality. Off-season spawning was attempted through hormonal implantation. In female milkfish, serum estradiol and testosterone levels are positively correlated with gonadosomatic index and oocyte diameter (Marte and Lam 1992). Testosterone levels were significantly higher in males with moderate amounts of viscous milt than in those with milt that were either scanty and viscous, or abundant and fluid. A single implant of slow-release capsules of estradiol (for females) or 17 $\alpha$ -hydroxyprogesterone (for males) resulted in earlier maturation and spawning than of the unimplanted control fish (Marte and Emata, unpublished). Maturation and spawning occurred in March, still within the natural breeding season (March to October). Attempts to induce off-season spawning of tank-reared broodstock through photoperiod manipulation also failed as fish did not spawn during the off-season (AC Emata, unpublished).

Table 1. Reproductive performance of 1981, 1982a, and 1982b milkfish broodstocks in concrete tanks in 1991. Most values are means±standard error. Modified from Emata and Marte (1994).

Broodstocks	Total egg collection (million)	Daily egg collection (×1,000)	Total spawnings	Viable eggs (%)	Hatching rate (%)	Normal larvae (%)	Survival (%) from hatching to 21-23 d to 21-23 d
1981	10.4	290±40	36	79±3	63±5	81±4 (5 runs)	31±9 20±9
1982a	12.0	230±30	53	81±4	55±5	79±3 (9 runs)	27±5 23±9
1982b	8.5	530±50	19	76±5	59±6	69±5 (3 runs)	30±5 8±5
Overall	31.0	300±30	108	82±2	62±3	81±2 (17 runs)	29±4 17±3

Table 2. Reproductive performance in successive years of milkfish broodstocks raised from 1980 wild-caught or hatchery-produced larvae. Modified from Emata and Marte (1993).

Year	Number of fish	Number of spawnings	Total egg collection (million )	Daily egg collection ( $\times 1,000$ ) <sup>d</sup>	Egg viability (%) <sup>d</sup>
<b>From wild-caught larvae 1980</b>					
1986	50	27	13.2	490 $\pm$ 100	-
1987	36	24	15.0	730 $\pm$ 130	84 $\pm$ 3
1988	36	19	7.1	400 $\pm$ 60	84 $\pm$ 4
1989	39 <sup>a</sup>	17	4.1	240 $\pm$ 70	83 $\pm$ 4
1990	39	23	8.3	380 $\pm$ 90	92 $\pm$ 3
1991	31 <sup>b</sup>	26	16.5	560 $\pm$ 150	96 $\pm$ 1
<b>From hatchery-bred larvae 1980</b>					
1986	34	27	16.7	640 $\pm$ 160	-
1987	34	46	21.6	440 $\pm$ 60	84 $\pm$ 3
1988	34	33	18.3	540 $\pm$ 80	90 $\pm$ 2
1989	26	6	5.7	940 $\pm$ 330	80 $\pm$ 7
1990	26	10	4.7	450 $\pm$ 140	97 $\pm$ 1
1991	24 <sup>c</sup>	4	1.3	310 $\pm$ 220	98 $\pm$ 1

a Three spawners were added to the stock

b Sampling in Nov 1991 showed 19 females, 9 males, 3 undetermined

c Sampling in Nov 1991 showed 12 females and 12 males

d Mean $\pm$ standard error

Breeding studies require identification of individual specimens. Visual implant tags were used to tag milkfish at the adipose tissue on the operculum; these tags allowed faster tagging (less than one minute), had higher retention rate and longer retention time, did not cause infections, and were easily readable (Emata and Marte 1992).

Dietary factors (proteins, lipids, vitamins) known to influence egg and larval production and quality of fish broodstock were also evaluated. Cage-reared broodstock fed diets with 36% protein at 4% body weight daily had higher egg production, mean number of eggs per spawning, and spawning frequency than broodstocks fed diets with 36% protein at 2% ration or 42% protein at 2 or 4% ration (CL Marte, personal communication). In a later study, the same broodstock fed diets with 6% lipid at a 4% ration produced the highest total number of eggs and the highest mean number of eggs per spawning. However, they did not differ from broodstocks fed diets with 6% lipid at 2% ration nor 10% lipid at 2 or 4% ration in terms of the frequency of spawning, the quality and sizes of eggs and larvae, and larval survival (CL Marte, personal communication). Present and future studies will test lower dietary protein (24 and 30%) and vitamin supplements to further refine the broodstock feed.

## Seed production

Agbayani et al. (1991) showed that an integrated milkfish broodstock and hatchery enterprise is not economically attractive (i.e., has negative net present value and negative internal rate of return) up to the 15th year. These results were based mostly on theoretical Figures. The economics of milkfish hatchery operations, alone or integrated with broodstock, was reassessed in collaboration with operators of commercial hatcheries in Panay Island (LMB Garcia, personal communication). A milkfish hatchery would be profitable if the cost of milkfish eggs or newly hatched larvae does not exceed P6,000 per million (US\$1=P25). However, an integrated broodstock and hatchery operation has low profit margins. If the hatchery depends on just a small number of broodstock that can not produce enough eggs, the facilities become underutilized and the operation fails.

Morphological abnormalities occur in 2-17% of hatchery-produced milkfish larvae and become obvious at day 35 (GH Garcia, personal communication). These deformities of the opercular bones (exposing the gills) and of the branchiostegal rays and membrane are similar to the shortened operculum of teleosts fed diets deficient in vitamin C (Halver et al. 1975). The causes of these deformities in milkfish are being studied. Trials were made to enrich food organisms with vitamin C and highly unsaturated fatty acid, or their combination, but these enriched foods did not enhance growth and survival nor get rid of the deformities of milkfish larvae (RSJ Gapasin, personal communication). Another study will look at vitamin C supplementation of the broodstock diet as a way to minimize if not eliminate the deformities in the offspring.

Mass production of milkfish larvae was refined with the use of commercial or SEAFDEC-formulated diets for shrimp larvae (MN Duray, personal communication). The larval feed Nosan R-1 (Nosan Kogyo, Japan) could replace up to 50% of the rotifer requirement. Either Lansy A-2 (Artemia Systems, Belgium) or the carageenan-microbound diet (c-MBD, SEAFDEC AQD) could replace half of the requirement for *Artemia* nauplii. Total replacement of the natural food organisms with formulated larval diets gave poor results.

Practical diets were formulated and tested for milkfish larvae (IG Borlongan, personal communication). Two diets were found effective as supplement or partial replacement of natural food organisms. These practical diets could reduce the capital requirements for natural food production in hatcheries.

Whole-body concentrations of the thyroid hormones thyroxine  $T_4$  and triiodothyronine  $T_3$  were measured in different stages of milkfish larvae to determine their role in early development (Jesus 1994). The hormone levels surged during metamorphosis. Information like this may lead to a design of an appropriate protocol for thyroid hormone treatment to improve growth rates and yields of milkfish.

The bacterial load in the hatchery system during routine operations was assessed in order to develop health management techniques for milkfish and other fishes in the hatchery (R Duremdez-Fernandez, personal communication). The chemotherapeutant nifurpirinol was shown to be toxic to milkfish (Tamse and Gacutan 1994).

Alternative rearing schemes for milkfish larvae were tested. Larval rearing in large concrete tanks and earthen ponds with fertilizers applied to encourage plankton blooms) were tried for milkfish, but survival rates were only 2-5% (CL Marte, personal communication).

The concept and practicalities of a multi-species hatchery were described by Duray (1994) to guide shrimp hatchery owners who want to venture into seed production of milkfish and other fish species.

### Grow-out culture

Hatchery-produced milkfish larvae reared in brackishwater nursery ponds for 45 days had higher mean body weight but lower survival than wild-caught larvae (EM Rodriguez, personal communication). However, no such difference was found after another 45 days in grow-out ponds. In this study, 13% of the hatchery-produced larvae had opercular deformities.

Semi-intensive milkfish culture requires supplemental diets. The energy and protein requirements, food intake, and the effects of dietary protein and ration size have been determined (Sumagaysay 1993, 1994). Growth of milkfish is correlated with food consumption and is higher in the presence of supplemental feed than on natural food alone (Table 3). Among fish grown on natural food alone, food consumption and growth during the wet season (average salinity 22 ppt) are higher than during the dry season (32 ppt) (Sumagaysay 1994). A supplemental diet with 25% protein was as good as one with 36% protein. A further study showed that a supplemental diet with 24% protein given at 4% of body weight per day is optimal for milkfish growth, production, and profitability in ponds (Sumagaysay, in press).

Table 3. Weights, growth, and daily ration (mean±standard error) of milkfish fed natural food and supplemental diet. Initial weight of fish, 5.5 grams. Modified from Sumagaysay (1993).

Diet	Day	Weight (g)	SGR <sup>a</sup> (g/d)	Daily ration per fish (g/d)	(kcal/d)
Natural Food	42	35.2±2.0 <sup>a</sup>	3.8±0.2 <sup>c</sup>	0.4±0.3 <sup>a</sup>	0.6±0.4 <sup>a</sup>
	76	57.0±0.4 <sup>b</sup>	1.4±0.1 <sup>ab</sup>	0.7±0.1 <sup>ab</sup>	1.4±0 <sup>a</sup>
	96	76.6±0.8 <sup>b</sup>	1.2±0.4 <sup>a</sup>	0.7±0.2 <sup>ab</sup>	1.4±0.4 <sup>a</sup>
Supplemental feed	42	32.3			
	76	71.6±3.4 <sup>b</sup>	2.4±0.4 <sup>bc</sup>	1.4±0.5 <sup>a</sup>	5.9±2.2 <sup>a</sup>
	96	116.4±5.4 <sup>c</sup>	3.1±0.3 <sup>c</sup>	4.8±0.4 <sup>b</sup>	19.7±0.7 <sup>b</sup>

SGR, specific growth rate

For each column, values with the same superscripts are not significantly different. Daily ration was calculated from gastric evacuation rates.

Snails like *Cerithium* and *Telescopium* compete with milkfish for food in brackishwater ponds. Organotin pesticides like Aquatin and Brestan have been banned in the Philippines as in many other countries, and environment-friendly ways to eliminate pond snails must be found. Rice straw piled up 15 cm thick on pond bottoms with snails can be burned to kill the snails (Triño et al. 1993).

Occasional mass kills of milkfish in brackishwater ponds have been attributed to low dissolved oxygen in the morning, or to acid pond water due to sulfates washed from the dikes by rains. Sulfide, a toxin produced by sulfate-reducing bacteria in sediments, was also examined as a possible cause of mass kills. In bioassays in flow-through seawater with different sulfide concentrations, 200  $\mu$ M (=6.4 mg/l) total sulfide was found lethal for 50% of juvenile milkfish after 8-24 hours (TU Bagarinao, personal communication).

### Feed development

The requirements of juvenile milkfish for fatty acids and essential amino acids are now known (Borlongan 1992a, 1992b, Borlongan and Coloso 1993, Coloso et al. 1992). Milkfish grown in sea water differ in the lipid and fatty acid composition of the tissues than those grown in fresh water (Borlongan and Benitez 1992). The total polyunsaturated fatty acids, especially  $\omega$ -3, were higher in seawater than freshwater milkfish. The nutrient requirements of milkfish are shown in Table 4 as summarized by FDS (1994).

Inexpensive and locally available leaf meals of swamp cabbage *Ipomoea aquatica*, sweet potato *I. batatas*, ipil-ipil *Leucaena leucocephala*, cassava *Manihot esculenta*, or their combination were tested as protein sources of diets for milkfish (Borlongan and Coloso 1994). About 15% of fish meal protein may be replaced with proteins from all leaf meals, except ipil-ipil, without any change in the growth, feed conversion ratio, and survival of milkfish in ponds.

The levels of several minerals in milkfish tissues and in sea water were measured as a step toward determining the dietary mineral requirements (GG Miñoso, personal communication).

## Studies on the Grouper *Epinephelus coioides*

Editors' note: The grouper that has been called *Epinephelus suillus* in many studies and publications of the SEAFDEC Aquaculture Department and that called *Epinephelus tauvina* in other reports from Kuwait, Singapore, and Thailand should be correctly referred to as *Epinephelus coioides* (Doi et al. 1991; Heemstra and Randall 1993).

### Broodstock development

Spontaneous spawning of wild-caught grouper in concrete tanks produced large numbers of eggs; however, egg and larval quality varied widely (Toledo et al. 1993). Efforts were made to improve egg quality and hatchability by enriching the 'trash' fish with cod liver oil or a commercial emulsion of highly unsaturated fatty acids. However, broodstock fed lipid-enriched diets had lower egg production, spawning frequency, fertilization rates, and hatchability (GF Quinitio, personal communication).



Table 4. Summary of known nutrient requirements of milkfish *Chanos chanos*, Nile tilapia *Oreochromis niloticus*, and Asian sea bass *Lates calcarifer*. Modified from Feed Development Section (1994; see original references therein).

Nutrient	Requirement (% of dry diet or % of protein)		
	Milkfish	Nile tilapia	Asian sea bass
<b>Protein<sup>a</sup></b>			
For larvae	40	35	43
For juveniles	30-40	25-30	
Protein:energy ratio	44	-	50
<b>Essential amino acids<sup>b</sup></b>			
Arginine	5.2%	2.2	3.6
Histidine	2.0	1.7	
Isoleucine	4.0	3.1	
Leucine	5.1	3.4	
Lysine	4.0	5.1	4.5
Methionine + Cysteine	2.5 (cys 0.8)	3.2 (cys 0.5)	2.4 (cys 0.7)
Phenylalanine + Tyrosine	4.2 (tyr 1.0)	5.5 (tyr 1.8)	
Threonine	4.5		3.8
Tryptophan	0.6	1.0	0.5
Valine	3.6	2.8	
<b>Lipid<sup>a</sup></b>	7-10	6-10	10
<b>Essential fatty acids<sup>a</sup></b>			
PUFA ( $\omega$ -3)	1-1.5%	-	0.5
PUFA ( $\omega$ -6)	-	0.5	0.5
<b>Carbohydrate<sup>a</sup></b>	25	25	20-25
<b>Digestible energy (kcal/kg)</b>	2,500-3,500	2,500-4,300	

<sup>a</sup> Requirement as % of dry diet; <sup>b</sup> Requirement as % of protein  
PUFA, polyunsaturated fatty acids

Among cage-reared groupers, spermiating males were observed in February-September and females with mature oocytes were found in July-November (GF Quintio, personal communication). Natural sex inversion was observed when a 7.8 kg fish had mature oocytes in July but spermiated in August. Differences in body size appeared to induce sex inversion: the larger of two females in a 2x2x3 meter deep cage became male and the smaller one remained female. Further studies will determine if this practical sex inversion technique can be used widely in aquaculture.

Induction of sex inversion through hormonal implants is also important because male groupers are scarce and natural sex inversion takes time. In one study, 17 $\alpha$ -methyltestosterone (MT) induced spermiation of larger groupers (1.2-1.6 kg) 5 months after treatment (Tan-Fermin et

al. 1994); however, these fish reverted back to being female 8 months after MT withdrawal (Table 5; Tan-Fermin 1992a). In another study, sex inversion of 3-year old cage-reared females was also induced by MT (4 mg/kg) or MT+LHRHa (20 µg/kg) implanted bimonthly, or MT injected biweekly (CL Marte, personal communication). Fish left untreated, or given only bimonthly LHRHa implants, or the hormone vehicle, remained female. The optimum MT dose and duration of treatment and the fertilizing capacity of milt from sex-inversed fish have yet to be determined.

### **Seed production**

Larval rearing trials initially examined the food and feeding biology of grouper larvae (MN Duray, personal communication). Then mass production trials were made. Larvae fed small rotifers (screened with a 90 µm mesh net) had higher growth and survival than larvae fed unscreened rotifers. Survival and growth after three weeks were improved by a high *Anemia* ration (3/ml each day) and by the commercial diet Lansy A-2. Further studies will define hatchery production techniques that ensure high survival.

### **Grow-out culture**

Wild-caught juvenile groupers stocked in brackishwater ponds at a density of 6,000 per hectare and fed 'trash' fish *ad libitum* for 5 months grew to mean body weights of 400 grams with 88% survival (I Bombeo-Tuburan, personal communication).

The fishery for juvenile grouper at Sapien Bay, Capiz was studied. Most of the juveniles were *Epinephelus sexfasciatus* and *E. coioides* collected with artificial shelters ('bonbon') in July-September (NB Solis, personal communication).

### **Health management**

Bacterial infections due to *Vibrio* sp. occur among wild-caught juvenile and adult groupers held in concrete tanks (Lavilla-Pitogo et al. 1992). It is recommended that methods of grouper collection, handling, and transport be improved such that injuries, crowding, and stress are avoided and the fish do not succumb secondarily to bacterial infections.

## **Studies on the Snapper *Lutjanus argentimaculatus***

Thirteen species of snappers of the genus *Lutjanus* were found year round (with a peak in May) in the markets in Iloilo (Cheong et al. 1992). The most common and abundant were *Lutjanus vitta*, *L. gibbus*, and *L. argentimaculatus*. Juveniles of the mangrove red snapper *L. argentimaculatus* are commonly found in mangrove areas and thus probably amenable to pond culture (TU Bagarinao, personal communication).

### **Broodstock development**

Mangrove red snapper broodstock (1.8-4.9 kg BW) raised from wild-caught juveniles in floating net cages were found sexually mature from March to November (AC Emata, unpublished data). Broodstock held in concrete tanks were sexually mature only in May-October. A mature male and a female (2.5-4.9 kg) given a single intramuscular injection of human chorionic gonadotropin (1,500 IU/kg body weight) spawned 0.5-1.2 million eggs within 32-40 hours (Emata

Table 5. Stage of gonad development in the protogynous grouper *Epinephelus suillus* (20 individuals) during treatment with various doses of  $17\alpha$ -methyltestosterone and 8-9 months after withdrawal of treatment. Modified from Tan-Fermin (1992).

Methyltestosterone (mg/kg fish)	Fish weight (kg)	Stage of gonad development			After treatment 8-9 months
		3 months	6 months	8-9 months	
0	0.7	primary oocytes, gonial cells			
0	1.4	spermatogenesis			
0	1.5	not sacrificed			
0	1.3	not sacrificed	milt at 5 months	primary oocytes, gonial cells	with cannulated eggs
0		not sacrificed	not sacrificed	not sacrificed	with cannulated eggs
0		not sacrificed			with cannulated eggs
0.5	0.8	primary oocytes, gonial cells			
0.5	1.5	spermatogenesis			
0.5	1.5	not sacrificed			
0.5	0.8	not sacrificed	milt at 5 months	primary oocytes, gonial cells	with cannulated eggs
1.0	1.0	primary oocytes, gonial cells			
1.0	1.2	spermatogenesis			
1.0	1.5	not sacrificed			
1.0	0.6	not sacrificed	cannulated milt	primary oocytes, gonial cells	with cannulated eggs
1.0		not sacrificed	not sacrificed	not sacrificed	with cannulated eggs
5.0	1.2	spermatogenesis			
5.0	1.6	spermatogenesis			
5.0	0.8	not sacrificed	spermatogenesis	not sacrificed	with cannulated eggs
5.0		not sacrificed	not sacrificed	not sacrificed	with cannulated eggs
5.0		not sacrificed			

et al. 1994). Egg viability ranged 65-80%. Rematuration of cage-reared broodstock occurred monthly for 5-6 consecutive months.

### Seed production

Larval rearing trials on mangrove red snapper concentrated on feeding management (MN Duray, personal communication). The larvae increased rotifer consumption during growth and began to feed on *Artemia* nauplii on day 22. Rotifers may be supplemented with the commercial diets Nosan R-1 or Frippak, but survival at day 21 was only 3% on average. Larvae fed *Artemia* nauplii at a higher ration of 3-4/ml per day had better growth and survival.

## Studies on the Asian Sea Bass *Lates calcarifer*

### Broodstock development

Wild-caught juvenile sea bass grown in floating cages mature spontaneously, the males at 2-2.5 years and the females at 3-4 years of age (Toledo et al. 1991). A stock of 13 females and 28 males in a floating cage spawned 26 times from June to October, with monthly egg collection ranging from 393,000 to 60 million. Spawnings were mostly during the first or the last quarter moon periods.

Manipulation of the reproductive cycle with LHRHa treatment was studied further. Spontaneous spawning of sea bass in floating net cages followed a semilunar cycle, but LHRHa induced spawning any day during the lunar cycle (Garcia 1992). Alternative LHRHa delivery through rectal intubation or oral administration turned out unsatisfactory (LMB Garcia, personal communication).

Milt dilution may be induced by LHRHa treatment; a single LHRHa (40 µg/kg BW) injection reduces the sperm count 12-36 hours after injection (GH Garcia, personal communication). However, such injection must be given to males not later than 24 hours after injection into females.

Tank-reared broodstock kept under constant 8, 12, or 16 hours light all spawned spontaneously throughout the natural spawning season (May-November) but not during the off season (AC Emata, unpublished). However, females with mature oocytes and males with scanty milt were observed in December-March under the short and normal photoperiod. Females with mature oocytes were found in January-March under the long photoperiod.

### Seed production

Nursery rearing of sea bass in illuminated cages was found feasible for juveniles of initial size about 9 mm but not for the smaller nor larger ones (Fermin et al. 1994a, 1994b). Among the natural plankton attracted to the cages by the night light, copepods comprised 67-90% of the diet of the test juveniles. Growth and survival increased with zooplankton density, which was highest at a light intensity of 300 lux. This promising nursery technique will be further refined.

The cladoceran *Moina macrocopa* was tested as an alternative live food for sea bass in the nursery (Fermin and Bolivar 1994, Ganzon-Naret and Fermin 1994). Conditions for the mass production of the cladoceran *Diaphanosoma celebensis* were determined. This cladoceran had higher reproductive rate when fed *Tetraselmis tetrahele* than when fed rice bran, rice straw extract, bagasse extract, and baker's yeast (MR de la Peña, personal communication). Actual production and use of cladocerans as food for larger sea bass (and other fish) larvae have to be conducted under hatchery conditions.

Sea bass (30 days old) stocked at 5/m<sup>2</sup> in brackishwater nursery ponds grew well on a ration of 'trash' fish alone or in combination with commercial feeds (Triño and Bolivar 1993).

The weight-specific ammonia excretion rate in sea bass is higher in fresh water than in sea water and is largely unaffected by prolonged starvation (Almendras 1994).

### **Feed development**

A practical diet for sea bass is in the making (Table 4). Sea bass juveniles fed diets with 20% carbohydrates and 12% lipid, and 42.5% protein level showed the highest weight gain of 6.4x and feed conversion ratio of 1.22 after 12 weeks (MR Catacutan, personal communication). The *in vitro* protein digestibilities of raw or processed leguminous seeds (white and black cowpeas, green and yellow mungbeans, rice bean, and soybean) were determined preparatory to their possible use as protein and energy sources in seabass diets (PS Eusebio, personal communication).

## **Studies on the Rabbitfish *Siganus guttatus***

### **Broodstock development**

Male rabbitfish given weekly LHRHa injections showed greater sperm production and greater amounts of expressible milt up to 3-4 weeks than control males injected with saline (Garcia 1993).

### **Seed production**

The physiological role of thyroid hormones in early development was studied by Ayson and Lam (1993). Rabbitfish spawners were given T<sub>4</sub> injection. Levels of thyroxine T<sub>4</sub> and triiodothyronine T<sub>3</sub> in maternal plasma, eggs, and yolk-sac larvae increased following the injection. Apparently T<sub>4</sub> was converted into T<sub>3</sub> by the spawner. At day 7, larvae from spawners given T<sub>4</sub> at doses of 10 and 100 µg/g body weight survived and grew better than those from spawners given 1 µg/g.

The salinity tolerance of rabbitfish eggs and larvae indicates that 14-37 ppt sea water is suitable for the period from spawning to 24 hours after hatching (Young and Dueñas 1993).

## Studies on the Asian Catfish *Clarias macrocephalus*

### Broodstock development

The Asian catfish spontaneously matures but does not spawn in captivity. Hormonal manipulation of reproduction is necessary to ensure a steady seed supply. In one study, oocyte maturation and ovulation was induced 15-16 hours after injection of 0.01-0.10 µg LHRHa + 1 µg pimozone per gram body weight (Tan-Fermin 1992b). Injection of 0.05 µg LHRHa + 1 µg pimozone per gram body weight and stripping of eggs 16-20 hours later is a reliable method to obtain high rates of ovulation, fertilization, and hatching (Table 6).

To further refine the breeding technique, the standard LHRHa-pimozone treatment was tested at different times of the year. Ovulation was 100% before (Apr-May) and at the peak of the natural spawning season (Jul-Sep), but only 80% at the end (Oct-Dec) and 60% during the off season (Jan-Mar) (JD Tan-Fermin, personal communication).

Table 6. Effect of a fixed dose of pimozone with various doses of LHRHa on egg production, fertilization, and hatching rates (mean±standard error) of gravid catfish *Clarias macrocephalus*. Modified from Tan and Emata (1993).

Date of experiment	Treatment		Egg production (eggs/g fish)	Fertilization rate (%)	Hatching rate (%)
	LHRHa (µg/g)	Pimozone (µg/g)			
Jun 1990	0.10	1	47.4±5 <sup>a</sup>	90±4 <sup>a</sup>	39±3 <sup>a</sup>
	0.05	1	67±10 <sup>a</sup>	84±7 <sup>a</sup>	51±22 <sup>a</sup>
	0.025	1	53±3 <sup>a</sup>	75±12 <sup>b</sup>	48±45 <sup>a</sup>
	0	1	65	39	0
	0	0	-	38	1
	0	-	40	36±10 <sup>c</sup>	1b
	-	0	40±4 <sup>a</sup>	39	0b
Aug 1990	0.10	1	82±4 <sup>a</sup>	87±4 <sup>a</sup>	58±4 <sup>a</sup>
	0.05	1	77±4 <sup>a</sup>	90±4 <sup>a</sup>	79±1 <sup>b</sup>
	0.025	1	79	71	46
	0	1	-	-	-
	0	0	-	-	-
	0	-	-	-	-
	-	0	-	-	-
Sep 1990	0.05	1	96±6	97±1	69±5
	0	-	-	-	-

For LHRHa, the 0 dose means 0.9% sodium chloride. For pimozone, the 0 dose means 1:9 dimethylsulfoxide and propylene glycol.

For each experiment, means with the same superscript under each column are not significantly different.

The pheromones etiocholan-3 $\alpha$ -ol-17-one glucuronide, 11 $\beta$ -hydroxyetiocholanolone glucuronide, or their combination were used to induce spontaneous spawning of hormone-treated catfish. Release of gametes was not observed even 30 hours after injection (LMB Garcia, personal communication).

Artificial fertilization techniques were also refined. Fertilization and hatching rates were highest when 25-50  $\mu$ l of milt was diluted 3.5x in saline solution and mixed with 2.5-10 grams of stripped eggs (MV Tambasen-Cheong, personal communication). The variability in hatchability of eggs was also addressed by testing chemical washes to remove the adhesive egg coat. Eggs washed with saline, tannin, or their combination had higher hatching rates (17-23%) than those washed with water alone (control, 10%) (JD Tan-Fermin, personal communication).

### **Feed development**

Juvenile catfish fed *ad libitum* four practical diets with 38% protein had mean weight gains of 120-200% after 36 weeks, whereas those fed 'trash' fish and practical diets had a weight gain of 61% (CB Santiago, personal communication). Although the catfish were relatively small, some females already had mature gonads at harvest.

## **Studies on the Bighead Carp *Aristichthys nobilis***

Cage-reared broodstock were fed diets with or without supplemental vitamins A, E, and C (CB Santiago, personal communication). Assessment of reproductive performance was inconclusive as fertilization and hatching rates and larval production from three spawning trials were variable within and among treatments.

The commercial production of bighead carp in hatcheries around Laguna de Bay relies only on several broodstocks. Purchasing and exchanging breeders among hatcheries is a common industry practice that can lead to problems like inbreeding and negative selection. Thus, the breeding management techniques of three commercial hatcheries were assessed based on growth performance of juveniles. Juveniles were obtained from spawns of broodstocks grown in either ponds, cages, or reared in cages and conditioned in ponds prior to induced spawning. These juveniles were then reared in either cages or laboratory tanks. Growth after 90 days was best among cage-reared juveniles from cage-reared broodstock (AE Gonzal, personal communication).

Mass production of the freshwater rotifer *Brachionus calyciflorus* for culture of bighead larvae was studied. Mean population density and intrinsic growth rate was highest when the rotifer was cultured in *Scenedesmus* + chicken manure extract (SF Baldia, personal communication). The rotifer did not survive in filtered lakewater, green water, yeast, and chicken manure extract.

## **Studies on the Nile Tilapia *Oreochromis niloticus* and Red Tilapia**

### **Genetics**

Several strain testing procedures for Nile tilapia in small to medium-size experimental facilities were evaluated for their efficiency to detect economically important strain differences

(ZU Basiao, personal communication). Size grading or having a common starting size among genotypes detected true strain differences better than mixed-size grading. Initial size differences resulted in apparent growth depensation under experimental conditions but growth compensation in rice-fish farms.

Three tilapia strains (Israel, NIFI, CLSU) were evaluated for growth performance under restricted feeding (Romana-Eguia and Eguia 1993). Growth was retarded by restricted feeding in all three strains but it differed significantly among strains. The Israel strain was the best.

Two Nile tilapia strains (NOT, CLSU) were evaluated for their resistance to heavy metal exposure. In one study, the growth, survival, and reproductive performance of two Nile tilapia strains were not affected by a two-month exposure to a sublethal mixture of zinc, cadmium, and inorganic mercury (Cuvin-Aralar and Aralar 1993). In both strains, 88-99% of the metal burdens were eliminated after two months in metal-free water (Cuvin-Aralar 1994). Full-sib juveniles (one month old) from nine families of the NIFI and commercial Nile tilapia strains showed similar tolerance to inorganic mercury (ML Cuvin-Aralar, personal communication).

Two hybrid reference lines were developed from existing red tilapia strains to measure and reduce the effects of uncontrolled nongenetic (environmental) variables in experiments that evaluate Nile tilapia strains (MR Romana-Eguia, personal communication). Variation in the growth data of Nile tilapia strains was indeed lowered when either of the two red tilapia hybrid reference lines was used as a covariate.

The reproductive performance of four red tilapia strains held in cages or in tanks at a stocking density of 12 females and 4 males per cage or tank was also assessed. Cage- or tank-reared broodstocks of the NOT red tilapia had higher egg and larval production than the other strains (MR Romana-Eguia, personal communication). In all strains, seed production was generally lower among cage- than tank-reared broodstock.

### **Feed development**

A tilapia diet has been developed by AQD (Table 4). This diet supplemented with 5% soybean oil as lipid source resulted in better reproductive performance of Nile tilapia broodstock than diets with corn oil, cod liver oil, or a cooking oil made from coconut oil (Table 7; Santiago and Reyes 1993). It is not necessary to add oil to tilapia diets, but if desired, soybean oil is the best among the vegetable oils tested. In another study, it was found that free essential amino acids in muscle did not consistently confirm amino acid requirements (Santiago and Lovell 1994).

Feeding management methods for Nile tilapia are being developed to minimize feed wastes. In one study, juvenile tilapia fed diets with 25% protein for 7 weeks had a higher weight gain than those given an 18% protein diet throughout, or alternate feeding of 18% and 25% protein diets (CB Santiago, personal communication).

### **Fish health**

Skin lesions have recently been observed among Nile tilapia. In a brackishwater pond in Oriental Mindoro, incidence of skin lesions was highest (51%) in July when chloride, alkalinity, and water hardness were highest (FP Palisoc, personal communication). *Acinetobacter* was the



Table 7. Spawning and juvenile ('fry') production of Nile tilapia fed diets with supplemental oils for 24 weeks. Modified from Santiago and Reyes (1993).

Dietary treatment	Number fish that spawned	Spawning frequency per female <sup>a</sup>	Number of juveniles per spawning <sup>b</sup>	Total juveniles per spawner <sup>c</sup>
Control diet (no oil added)	2/5	1.8	526	1,078
+ Cod liver oil	1/5	0.4	18	18
+ Corn oil	3/5	1.6	646	1,586
+ Soybean oil	5/5	3.4	603	1,865
+ Coconut oil-based cooking oil	3/5	1.8	647	1,856
+ Cod liver oil and corn oil	3/5	1.2	594	1,593
Soybean meal diet	4/5	1.4	539	775

<sup>a</sup> Mean for all females

<sup>b</sup> Mean for spawnings with viable juveniles

<sup>c</sup> Mean for females that spawned

most dominant bacteria isolated from infected fish. Tilapias in Lake Sebu in South Cotabato also developed skin lesions in January to March. These skin lesions must be studied to develop appropriate health management methods.

### Studies in Lake Ecology

Monitoring of the dissolved oxygen in Sampaloc Lake in Laguna indicated a progressive depletion of oxygen in the subsurface waters due mainly to the wasted feeds from intensive tilapia farming (Santiago and Arcilla 1993). Only the top one meter of the lake water has oxygen at 3 mg/l or greater and can presently support fish. The current levels of total ammonia (3 mg/l) and sulfide (5 mg/l) are already toxic. Fish kills in Sampaloc Lake have become frequent. To save the lake from imminent biological death, it is imperative to: (1) reduce the farming area from 30 to 6 hectares, (2) stop the use of commercial feeds, and (3) remove the water hyacinths and other debris.

Fish kills in Laguna de Bay have been recorded since 1932 but have become more serious in recent years. The SEAFDEC Aquaculture Department is presently conducting a review of the occurrences, losses, and possible causes of fish kills (AE Santiago, personal communication).

Ecological and microbiological studies on the epizootic ulcerative syndrome of snakeheads in Laguna de Bay indicate that low temperature is a predisposing environmental factor, but have yet to pinpoint the primary causative pathogen (Cruz-Lacierda and Torres 1994, FP Palisoc and GD Lio-Po, personal communication).

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# Research on Crustaceans

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## Abstract

Crustacean research at the SEAFDEC Aquaculture Department during the last three years focused mostly on the tiger shrimp *Penaeus monodon*. Studies were done along six problem areas: (1) developing spawning techniques for captive broodstock, (2) defining physico-chemical levels tolerable by larvae or postlarvae, (3) finding alternative feeds or fertilizers for extensive culture, (4) reducing the cost and evaluating the quality of formulated feeds for semi-intensive culture, (5) preventing and controlling disease, and (6) documenting the chemicals used in shrimp culture and their effects on the environment. To reduce feed costs, substitutes for expensive feed components were screened and the specific nutrient requirements of tiger shrimp during culture were determined. A few studies were made on other crustaceans. The vitellogenin levels during maturation of the white shrimp *P. indicus* were measured. The digestibility of feedstuffs was also tested in the white shrimp. Culture techniques are being developed for the mudcrab *Scylla serrata* in ponds, pens, and cages.

## Introduction

Studies were conducted in 1992-1994 on three crustacean species: the tiger shrimp *Penaeus monodon*, the white shrimp *P. indicus*, and the mudcrab *Scylla serrata*. The mudcrab was identified during ADSEA '91 as the top priority crustacean for research and the white shrimp as another alternative species for grow-out in ponds. However, most of the research at AQD still focused on the tiger shrimp, the most important commercial species and the one beset with many problems.

## Studies on the Tiger Shrimp *Penaeus monodon*

### Breeding

Quinitio et al. (1993) correlated the ovarian development with the morphological changes of the genitalia during the first maturation of female tiger shrimp. They identified two stages, the primordial germ cell and the chromatin nucleolus stages, during the earlier phase of maturation, in

addition to the four later stages seen by Tan-Fermin and Pudadera (1989). Females mate only when the thelycum is fully developed (Quinitio et al. 1993).

A most critical problem in tiger shrimp hatchery production today is the lack of spawners. Tan-Fermin (1991) compared ablated pond-reared adults, ablated wild-caught adults, and unablated wild spawners in terms of growth and reproduction. Ablation enhanced maturation but led to the retention of bigger and more advanced oocytes. Thus, ablated females released fewer eggs than unablated wild spawners. The results also suggested that ablation may induce growth simultaneous with maturation in pond-reared but not in wild-caught broodstock.

Primavera and Caballero (1992a) found that unablated females reared in low-intensity green light, or ambient light under black cover spawned the most eggs. The number of spawns increased 14-17x with ablation. In wild-caught males, unilateral ablation increased the number and spike length of sperm cells and reduced the percentage of abnormal sperm (Gomes and Primavera 1993). Ablation may thus help improve the sperm quality in pond-reared males — if these behaved like the wild males. The effect of captivity on the sperm quality of wild and pond-reared tiger shrimps is currently being studied (ET Quinitio, personal communication).

Growth and secondary sexual characteristics were studied in pond-reared broodstock. Primavera and Caballero (1994) found that joining of the petasma, presence of sperm in spermatophores in males, and sperm in the thelycum of females were first noted in shrimps 26-28 mm in carapace length. Morphometric changes and gonadal development in pond-reared broodstock are currently being studied further.

A study by Millamena et al. (1993) showed that polyunsaturated fatty acids reach very high levels during, and may have a significant role in, the maturation of ablated females. The role of carotenoids in the reproduction of pond-reared tiger shrimp was determined by comparing diets with or without astaxanthin (MPY Pangantihon, personal communication), or carotenoid-containing foods such as mussel meat, crab meat, and *Artemia* in combination with a pelleted broodstock diet (ET Quinitio, personal communication). In both studies, maturation, spawning, and hatching rates were very variable and not significantly different among treatments.

## Hatchery

Physiological studies were undertaken to define the optimal rearing conditions for tiger shrimp larvae and postlarvae. Optimal salinity ranges were determined by bioassays. Of the larval stages, the nauplii show the most limited salinity tolerance. Only 50% of nauplii subjected to a salinity 4 ppt lower than the spawning salinity develop into protozoa (Parado-Esteva et al. 1993).

Ammonia and pH also affect larval growth and survival in tiger shrimp (Noorhamid et al. 1994). Almendras (1994) used ammonia excretion as an index of the tiger shrimp's physiological state when transferred to different salinities or different pH. Ammonia excretion temporarily but significantly increases after abrupt transfer from seawater to lower salinities, and decreases at higher salinities. Change in pH similarly altered ammonia excretion. High pH has a more lethal effect than low environmental pH; 40% of the postlarvae transferred to high pH started dying after 2.5 hours (Almendras 1994).

Water management techniques in the hatchery were compared in terms of the survival, growth, and development of tiger shrimp larvae (Parado-Esteva, unpublished).

The economics of shrimp hatcheries was studied by Agbayani et al. (1994). The hatchery business was less profitable in 1991 than in 1985 due to the low market price of postlarvae (Table 1). In 1991, medium-scale hatcheries (100-300 tons in water capacity) registered the highest economic returns. Small hatcheries less than 100 tons in capacity and large hatcheries more than 300 tons were more vulnerable to changes in market prices and other natural factors such as diseases, typhoons, supply of spawners, and price decreases. High survival rates improved cost efficiency in hatchery operations.

### Grow-out culture

Nursery rearing of postlarvae in ponds is still practised by extensive shrimp growers. Rodriguez et al. (1993) demonstrated that nursery rearing can also be done in 'hapa' nets installed in the pond. With feeding, postlarvae can be stocked at higher densities in hapa nets without sacrificing growth and survival.

Chicken manure, rice hulls, and sugar mill wastes were tested as fertilizers in extensive shrimp ponds. In terms of growth and survival of tiger shrimps, boiler ash (derived from burned bagasse from sugar mills) was a more efficient fertilizer than chicken manure (Subosa 1992).

The aquatic weeds *Ruppia maritima* ('kusay-kusay') and *Najas graminea* ('digman') commonly found in extensive ponds were shown to provide both food and shelter for shrimps (Primavera and Gacutan 1989). The assimilation efficiency of shrimps for *Ruppia* was higher than for *Najas* and significantly higher in males than in females (Catacutan 1993). In another study, shrimps grown in ponds with *Ruppia* and with plankton had better survival and growth than those in ponds with filamentous green algae (Bombero-Tuburan et al. 1993).

Farm-made feeds are occasionally used to supplement the natural food in the pond. Bombero-Tuburan et al. (in press) studied the feasibility of using the golden apple snail *Pomacea canaliculata* or 'kuhol', a common pest in rice culture, as feed for tiger shrimp. 'Kuhol' given in combination with corn or cassava resulted in good production and size-frequency distribution of shrimps.

Pesticides are used in extensive shrimp ponds to eliminate unwanted species that compete with the shrimps for food, oxygen, or space. Some pesticides cause mortalities or toxin-related abnormalities such as the soft-shell syndrome. The tolerance of juvenile shrimps to two commonly used pesticides in ponds, saponin in teaseed cake and rotenone in derris root, was determined in laboratory bioassays (Cruz-Lacierda 1993). Both pesticides were proven safe at the concentrations customarily used in ponds, 0.4 ppm purified rotenone and 15 ppm crude saponin. Significant mortalities and soft-shelling occurred only at concentrations greater than 1 ppm rotenone or 100 ppm saponin (1 ppm=1 mg/l).

Pond snails are often very difficult to eliminate. They are usually just handpicked since inorganic molluscicides also cause soft-shelling in shrimps. Burning rice straw piled 15 cm thick at the pond bottom effectively gets rid of snail species (Triño et al. 1993).

Table 1. Comparative technical and economic indices of small, medium, and large shrimp hatcheries in Panay in 1985 and 1991. Data from Agbayani et al. (1994). US\$1=₱25; 1 peso = 100 centavos.

Indices	1985			1991		
	Small	Medium	Large	Small	Medium	Large
Number of hatcheries	10	17	11	97	40	15
Stocking rates (larvae/liter)	50	50	50	17	17	15
Number of runs/year	10	10	10	4	6	8
No. of good runs	10	10	10	3	4	6
No. of bad runs	10	10	10	1	2	2
Survival rates (%)	10	10	10	10	16	11
Production ( $\times$ 1,000 postlarvae)	560	1,600	18,000	1,688	5,452	6,977
Investments (pesos)	350,000	2,754,600	4,513,852	244,387	561,111	826,216
Prices (centavos)	30	30	30	8	11	10
Revenues (pesos)	168,000	1,600,000	5,400,000	144,094	619,596	672,709
Earnings above variable cost (pesos)	285,816	1,170,152	5,393,439	34,186	220,526	107,879
Net income (pesos)	309,600	1,208,000	3,927,000	(9,732)	122,381	(25,739)
Variable cost per fry (centavos)	12	10	9	5	6	7
Total cost per fry (centavos)	13	12	10	8	8	9
Return on investment (%)	90	41	74	-4	22	-3
Return on working capital (%)	562	643	1338	30	279	35
Net present value (pesos)	781,800	1,338,000	9,000,000	105,251	460,885	292,369
Benefit/cost ratio	1.5	1.1	1.4	1.2	1.3	1.1
Internal rate of return (%)	123	29	55	52	100	63



Primavera (1993) compared the different shrimp farming systems in terms of resource use, effluents, economics, and effects on the environment. Semi-intensive shrimp culture is ecologically and economically more viable than extensive or intensive culture and is recommended for sustainability of the industry in the Philippines.

Searanching or restocking of juvenile shrimps back in the wild is being planned by SEAFDEC AQD. One initial study has been done on the tagging of shrimps since the success of searanching can only be evaluated by monitoring the performance of released animals. Primavera and Caballero (1992b) showed that streamer tags do not cause immediate mortality in 2 or 7 month old tiger shrimps in tanks, but significant mortality occurs after 6-8 weeks of tagging.

### Feed development

Feeds account for 50-60% of total expenses in semi-intensive shrimp culture. Thus, many AQD studies were directed towards lowering the cost of feeds for tiger shrimp. Three major approaches were tried: (1) determination of the nutrient requirement and optimal levels for tiger shrimp, (2) screening of substitutes for expensive feed components such as fish meal and imported binders, and (3) finding alternative sources of protein or lipids.

The requirement of tiger shrimp for threonine is 1.45% of the diet or 3.5% of dietary protein (Millamena et al., in press). Postlarvae also showed best growth and survival on diets with arginine at 4.6% of dietary protein and with valine at 5.8% of dietary protein (OM Millamena, personal communication).

Catacutan and Lavilla-Pitogo (1994) found that 50-100 ppm ascorbic acid or 100-200 ppm phosphated ascorbic acid, a more stable derivative, is needed for good growth and survival of juveniles. These levels improve the structure of the hepatopancreas of shrimps infected with monodon baculovirus. Nevertheless, pond studies indicate that there is no need to include vitamins in shrimp diets for semi-intensive culture as sufficient vitamins may be supplied by the natural food in ponds (Triño et al. 1992).

Fish meal is not just expensive; it also competes with human consumption of fish and is ecologically inefficient in that it adds one step to the food chain of cultured animals. Thus, there is a great need to find less costly or more abundant sources of protein. Lactic yeast and fish protein concentrate were tested and found to be good alternative sources of protein (Millamena, in press). Leaf meals such as those from kamote *Ipomoea batatas*, kangkong *I. aquatica*, malunggay *Moringa oleifera*, and papaya *Carica papaya* were tested as partial replacement for fish meal (VD Peñaflorida, personal communication).

Various legumes were also tested as protein sources and methods were developed to remove toxic components and increase digestibility. *Leucaena leucocephala* or 'ipil ipil' was shown to be a promising substitute for fish meal, but its use is limited by the presence of mimosine, an anti-nutritional factor (Pascual and Catacutan 1990). Peñaflorida et al. (1992) found that soaking for 24 hours was a practical and effective method to remove mimosine from mature 'ipil-ipil' leaves. Eusebio (1991) found that dehulling increased the digestibility of rice bean, but not of cow pea used in diets for tiger shrimps. Dehulling removes the tannins that occur mostly in the seed coats.

Wheat flour is commonly used as binder in feeds. It is relatively expensive because wheat is not locally grown. Since carbohydrates from red seaweeds may also have similar binding quality as flour, meals from *Kappaphycus* and *Gracilaria* were tested as binders for shrimp diets. It was found that *Gracilaria* can be used at 10% of the diet weight to replace 67% of the wheat flour (VD Peñaflorida and NV Golez, personal communication).

Alternative lipid sources were also tested. Cod liver oil, soybean oil, and corn oil proved to be good sources of lipid, but beef tallow, pork lard, and coconut oil resulted in poor growth and survival of tiger shrimp (Catacutan 1991).

Juvenile tiger shrimps tolerate fat oxidation or malonaldehyde levels equivalent to 828 mg TBA/kg diet (PF Subosa, personal communication; TBA is thiobarbituric acid, an indicator). The effects of antioxidants and storage conditions on feed quality were studied. It was found that antioxidants need not be added to freshly prepared feeds that are used within 1-2 months and stored at 28-30°C (Bautista et al. 1992). Under such conditions, shrimps fed diets without antioxidants survive and grow as well as those fed diets with antioxidants, and the feeds without antioxidants show no significant signs of deterioration. However, inclusion of the antioxidant butylated hydroxytoluene in feeds stored up to 4 months improves the growth rate of juvenile shrimps (PF Subosa, personal communication).

Some shrimp diseases may be due to fungal toxins formed during deterioration of feeds in storage. A survey revealed that commercial shrimp 'finisher' feeds in the Philippines had aflatoxin B<sub>1</sub> levels ranging from 'not detected' to 120 µg/kg, and most feeds contained 10-40 µg/kg (Bautista et al. 1994). Studies then determined the tolerance of tiger shrimp to fungal toxins in deteriorating feeds. Pre-adult tiger shrimp (17 grams) tolerate aflatoxin B<sub>1</sub> up to 52.3 (µg/kg without any change in growth, but histopathological changes already appear at 26.5 µg/kg aflatoxin B<sub>1</sub> (Bautista et al. 1994). Similarly, 5 gram juveniles tolerate up to 50 ppb aflatoxin B<sub>1</sub> (Bautista and Subosa, in press).

## Diseases

Luminescent vibriosis is a common fatal disease caused by the bacterium *Vibrio harveyi* that invades shrimp hatcheries. Lavilla-Pitogo et al. (1992) studied the sources of *V. harveyi* in tiger shrimp hatcheries. To determine whether the disease can be controlled by environmental manipulation, Lavilla-Pitogo (personal communication) determined the tolerance of *V. harveyi* to various temperatures, pH, and salinities. The bacteria were found to be tolerant of a wider range of conditions than tiger shrimp larvae or postlarvae. Elimination of the natural microflora enhanced the survival of *V. harveyi* in hatchery tanks and the presence of the diatoms *Chaetoceros* and *Skeletonema* effectively controlled it (CR Lavilla-Pitogo, personal communication).

Studies were also conducted on the role of *Vibrio* spp. in the etiology of red disease syndrome (E Tendencia, personal communication) and the incidence and etiology of the swollen hind-gut syndrome (CR Lavilla-Pitogo, personal communication) in tiger shrimps.

Numerous drugs and chemicals are used to control diseases in aquaculture in the Philippines (Baticados and Paclibare 1992). Another survey found that about 40 chemical and biological products are used in intensive shrimp farms (Primavera et al. 1993). Table 2 shows these products. Both studies strongly recommend that medically important antibiotics not be used

in aquaculture because antibiotic-resistant strains of human pathogens may develop. Government is urged to regulate both the use of bioactive compounds and the disposal of pond wastes.

Table 2. Chemical and biological products used in hatcheries and grow-out ponds of the shrimp *Penaeus monodon* in the Philippines. Modified from Primavera (1993).

Product	Use	Remarks
<b>Therapeutants</b>		
Chloramphenicol	Antibacterial	Commonly used in hatcheries; added to feeds by some farmers
Doxycycline	Antibacterial	Used as hatchery bath
Erythromycin	Antibacterial	For necrotic shell and gill diseases; also for spawner disinfection
Formalin	Fungicide, parasiticide	Used as bath or added to pond system
Malachite green	Parasiticide, antifungal	Against shell and gill diseases; for disinfection of eggs
Nitrofurans (furazolidone, nifurpirinol)	diseases; Antibacterial, fungicide	Disinfection of spawners; may cause deformities in larvae
Oxolinic acid	Antibacterial	Added to grow-out feeds
Oxytetracycline	Antibacterial	Added to feeds or to ponds directly
Rifampicin	Antibacterial human tuberculosis	Used in hatcheries; prescribed for
Sulfa drugs	Antibacterial	Added to feeds
Trifluralin	Antifungal (Treflan)	Agricultural herbicide used in hatcheries
<b>Disinfectants</b>		
Calcium sulfide and calcium hypochlorite commercial bleach		Widely used in hatcheries
EDTA	Chelates heavy metals	Hatchery use
Iodine compounds	For disinfection	Used against shell-related diseases
Laundry detergent	For disinfecting eggs	
Alkyl benzyl dimethyl ammonium chloride	Antibacterial, antifungal	Used for soil and water treatment
Benzalkonium chloride	Antibacterial	Also used to induce molting
Dodecyl dimethyl ammonium bromide	Antibacterial, antifungal	

Table 2 Continued.

Product	Use	Remarks
<b>Soil and water treatment</b>		
Bacteria-enzyme preparations	Decomposition of organic matter	Used in the wastewater treatment industry
Lime Ca(OH) <sub>2</sub> CaCO <sub>3</sub> CaO	Traditional pond inputs Increases pH, disinfects	Also used to induce molting
Potassium permanganate	Oxidizer and detoxifier	
Zeolite	Absorbs toxic gases	For water quality maintenance
<b>Pesticides</b>		
Ammonium sulfate	Piscicide	Used with burnt lime
Chelated copper	Algicide, antibacterial	Also used to induce molting
Teaseed powder, crumble, flakes	Piscicide	Widely used in ponds; also used to induce molting
<b>Plankton growth</b>		
Chemical fertilizers urea (45-0-0) and monoammonium phosphate (16-20-0)	Traditional pond inputs	
Organic fertilizers dried chicken manure, others	Traditional pond inputs	
Nutrient mixes		May be mixed with fertilizers
<b>Feed additives (two or more may be combined in one product)</b>		
Calcium, other minerals		
Vitamin C, others		
Enzymes		
Hormones		
Fatty acids		
Protein extracts		
Chicken eggs (binder)		

Tiger shrimps may also be exposed to heavy metals in addition to the chemicals listed in Table 2. Juveniles were found able to detoxify and remove copper and lead by granule formation and excretion; thus, tiger shrimps, like other decapods, are not suitable for biomonitoring of heavy metal pollution (Vogt and Quintio 1994).

## Ecology

The role of mangroves as shrimp nurseries for juvenile shrimps is currently being studied (J H Primavera, personal communication). A riverine mangrove and an island mangrove were selected as study sites. The shrimp populations at the two sites include *Penaeus merguensis*, *P. monodon*, *P. latisulcatus*, *P. semisulcatus*, and at least four *Metapenaeus* species. These shrimps usually lie hidden during the day and emerge to feed at night. Carbon isotope ratios showed that mangrove detritus is not the primary food source of juvenile shrimps at the two sites (JH Primavera, personal communication).

### Studies on the White Shrimp *Penaeus indicus*

The white shrimp is commonly harvested as an incidental species from tiger shrimp ponds. Larval rearing is like those of other penaeids, but the reproductive physiology has not been studied. Techniques for the grow-out of white shrimp have not been established, thus its monoculture is not widely practised. The white shrimp was identified as a priority species for research during ADSEA '91.

Quinitio and Millamena (1992) correlated the levels of vitellogenin, a female-specific protein in the hemolymph, with gonad maturation stage. The vitellogenin level is low during the immature stage, increases gradually, and reaches a peak during the mature stage.

The number of eggs spawned by white shrimps from the wild was found to increase with spawner size (CT Villegas, personal communication). Selective breeding studies on shrimps have been started.

Pond grow-out of white shrimp is a problem because of its slow growth and low survival upon reaching the size range 11-15 grams. A feed is being developed for white shrimp, starting with a study of the digestibility of 21 locally available plant protein sources. Mungbean was well digested by white shrimp enzymes *in vitro*, but resulted in low survival and growth when included in formulated diets (PS Eusebio, personal communication). Papaya leaf meal was as digestible as shrimp head meal and Peruvian fish meal.

### Studies on the Mudcrab *Scylla serrata*

The mudcrab has very high market potential and many farmers have ventured into culturing or fattening them. Samonte and Agbayani (1991) demonstrated that culture of mudcrab has a short payback period of 1-2 years. Juvenile crabs stocked at 5,000/ha gave a 133% return on equity, 66% return on investment, and very promising in terms of other discounted indicators. Stocking densities of 15,000/ha and 20,000/ha were not economically feasible (Samonte and Agbayani 1991).

Techniques for grow-out culture of mudcrabs in ponds, pens, and floating cages were tested (AT Triño, personal communication). The abundance and size distribution of juvenile mudcrabs in mangrove and non-mangrove areas in northern Panay were studied (NB Solis, personal communication).

The SEAFDEC Aquaculture Department will undertake collaborative studies with the Australian Centre for International Agricultural Research and the Bribie Island Research Institute on seed production, the main bottleneck in mudcrab culture. Different feeding and water management schemes will be tested for broodstock and larvae.

## Recommendations

Research on broodstock development of tiger shrimp, including genetic selection, must continue until an adequate supply of good quality spawners is assured. The cost of tiger shrimp production must be lowered, either through cheaper feeds or more efficient culture techniques. Disease prevention and control remain crucial to success. But even more important is to address the interaction between aquaculture and the environment. Environment-friendly methods of producing tiger shrimp are imperative. The negative effects of shrimp culture on the environment must be prevented, and ameliorated, otherwise, diseases will continually threaten the future of the shrimp industry.

Seed supply seems to be the main problem in the expansion of mudcrab aquaculture. Thus, research in mudcrab breeding and larval rearing must be pursued. Nutritional studies must also be conducted to develop feeds for mudcrabs in pond culture.

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# Research on Seaweeds and Mollusks

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## Abstract

Research on seaweeds focused on the carrageenan-producing *Kappaphycus alvarezii* and the agar-producing *Gracilaria* spp. Growth of *K. alvarezii* was better on horizontal lines than on vertical or cluster lines from bamboo rafts. All morphotypes (brown green, and red) grew faster at 50 cm than at 100 cm below the water surface, but the green morphotype showed better carrageenan properties. A socioeconomic survey of *K. alvarezii* farming in Panagatan Cays, Antique revealed that a farmer has an average annual production of 3 tons/ha (dry) with the fixed bottom and hanging longline methods.

Three species of *Gracilaria* in natural beds in Iloilo showed monthly variations in biomass and agar quality; *G. heteroclada* had the highest biomass and gel strength. When this species was grown in tanks, growth and agar sulfate content were influenced by the interaction of light, salinity, and nutrients. Enriched and unenriched stocks of *G. heteroclada* differed in agar quality. When *G. heteroclada* was grown with the tiger shrimp *Penaeus monodon* in extensive ponds, the highest growth rate and production were obtained at the seaweed stocking density of 250 g/m<sup>2</sup>; this was in November when average water temperature, transparency, and salinity were low. Salinity tolerance varies among *Gracilaria* species.

Oyster (*Crassostrea iredalei*) and mussel (*Perna viridis*) farming in Western Visayas were assessed in 1992 in terms of the culture methods, socioeconomics, marketing, and profitability. A more localized survey of oyster and mussel farming was conducted through rapid rural appraisal in two coastal towns in 1993. A farmer-participatory study followed in 1994 for the culture of oysters, mussels, seaweeds, and rabbitfishes in a river mouth in Dumangas, Iloilo. Green mussel, brown mussel (*Modiolus metcalfei*), and seaweeds transplanted to Dumangas from Capiz have reproduced. In another study, the green mussel was tested as a biological filter in tiger shrimp ponds; shrimps stocked with mussels grew better than those without.

A nationwide survey on the *Placuna placenta* fishery in 1993 showed 27 remaining 'kapis' beds; many others have been depleted due to excessive gathering, pollution, siltation, and trawling. Broodstocks are being developed to produce 'kapis' seed for grow-out and restocking. For the first time at AQD, adult donkey-ear abalone *Haliotis asinina* from the wild spawned naturally in laboratory tanks. Juvenile abalones can be successfully grown on *Gracilaria* or abalone diet.

## Introduction

Six seaweed genera were prioritized for research at AQD during the ADSEA meeting in 1991: *Eucheuma*, *Kappaphycus*, *Gracilaria*, *Gelidiella*, *Porphyra*, and *Sargassum*. But the studies conducted in 1992-1994 focused only on *Kappaphycus* and *Gracilaria*. Among mollusks, the slipper oyster *Crassostrea iredalei*, green mussel *Perna viridis*, window-pane oyster *Placuna placenta*, pearl oysters *Pinctada* spp., and the abalones *Haliotis* spp. were ranked as top priorities for research. No studies on *Pinctada* were proposed during the period.

Studies on the growth, production, carrageenan quality, and proximate composition of the different morphotypes of *Kappaphycus alvarezii* were done to ascertain the best strain for cultivation and for use as feed ingredient. Simple economic analysis allowed comparison of the profitability of the various methods of cultivation. Studies on *Gracilaria* aimed at selecting the best species or strain for culture and agar extraction. Growth under various culture conditions was assessed together with salinity tolerance and agar quality.

Oyster and mussel farming and the fishery for windowpane oyster were assessed to determine problems and recommend ways for improvement. The green mussel was tested as a biofilter in an effort to develop a technology for cleaning effluents from intensive shrimp ponds. Another major effort was to artificially propagate the windowpane oyster and the local abalone for grow-out culture or restocking in areas where these species have been depleted.

## Studies on *Kappaphycus alvarezii*

### Chromosome number

Samples of *Kappaphycus alvarezii* from Panay and Guimaras islands were examined for chromosome counts with an aceto-iron-haematoxylin-chloralhydrate stain. At late diakinesis stage, the chromosome count was  $n=32$  and the chromosomes were bar-shaped and 3  $\mu\text{m}$  long (H Yabbu, personal communication).

### Socioeconomics of farming

Located west of Caluya Island, Antique, Panagatan Cays is an incomplete atoll with a shallow reef flat 1,300 hectares wide. Panagatan was colonized six years ago by seaweed planters from nearby islands including Mindoro and Panay. About 15-20 hectares are now used for seaweed culture. A survey of the farming practices of *K. alvarezii* planters was conducted in November 1993 and May 1994 to determine the status, production, and problems of seaweed farming in the

area (Hurtado-Ponce, unpublished). November is the peak of the planting season and May is the harvesting season of seaweeds in the Philippines. Some 43 seaweed planters (72% of all planters in Panagatan) were interviewed with a structured questionnaire. Seaweed farming is the main livelihood of 93% of the people in Panagatan; fishing is done mainly for home consumption.

Individual planters farm areas of 280-17,500 m<sup>2</sup> at stocking densities of 0.5 kg/m<sup>2</sup>. Most farmers (79%) plant two morphotypes (brown and green), and 70% use a combination of the fixed bottom method and the hanging longline method of culture. An initial investment of P2,500 (US\$1 = P25) can provide a monthly income of P2,600. Seaweeds are harvested after 45 days of culture and used to seed larger areas. After another 60-90 days, the seaweeds are totally harvested and dried. From three to six harvests are made in one year. Yearly production ranges 0.3-12 tons/ha. Farmgate prices range P4.50-7.50/kg. During the peak season (March-May), 100-150 tons of dried seaweeds are sent to Cebu on big sailboats. Epiphytes, grazers, typhoons, and thallus whitening were the major problems reported by the farmers.

### **Experimental cage culture**

*Kappaphycus alvarezii* seedlings were cultured in cluster, vertical, and horizontal lines inside floating cages tied to a bamboo raft (Hurtado-Ponce 1994). Juvenile groupers (*Epinephelus* sp.) were stocked in the cages to control grazers. After 45 days, the seaweeds on the horizontal lines showed the highest specific growth rate (5.3% per day) and production (1204-1533 g/m line). After 120 days of culture, 68% of the groupers survived and reached mean weights of 297 grams.

### **Carrageenan properties**

Three morphotypes (brown, green, and red) of *Kappaphycus alvarezii* were grown 50 cm and 100 cm below the water surface then examined for carrageenan properties and proximate composition (Hurtado-Ponce, in press). When grown at 50 cm deep, the green morphotype was significantly different from the brown and red in all carrageenan properties except sulfate content (Table 1). When grown at 100 cm deep, the green morphotype differed only from the brown. The three morphotypes did not differ in proximate composition, except in ash content and nitrogen-free extract.

## **Studies on *Gracilaria***

### **Stock assessment in Iloilo, Panay Island**

The influence of some environmental factors on biomass and agar quality was studied for 12 months in *Gracilaria changii* from Guimbal, *G. rubra* from Concepcion, and *G. heteroclada* from Estancia and Zarraga (Pondevida 1993). For all species, the biomass varied monthly but no correlation was found between biomass and temperature, pH, turbidity, nutrients, and salinity at different study sites. However, phosphate was positively correlated with the biomass of *G. heteroclada* in Estancia, and rainfall was negatively correlated with the biomass of *G. changii* in Guimbal and *G. heteroclada* in Zarraga.

Table 1. Carrageenan properties of three different morphotypes of *Kappaphycus alvarezii* grown at two depths. Values are means $\pm$ SE (n=2). Data from Hurtado-Ponce (in press).

Water depth Morphotype	Yield (%)	Gel strength (g/cm <sup>2</sup> )	Gelling temp. (°C)	Melting temp. (°C)	Viscosity (cps)	Sulfate (%)
<b>50 cm</b>						
Brown	8.5 $\pm$ 2.7	1.0 $\pm$ 0	4.3 $\pm$ 0.5	30.0 $\pm$ 1.5	23.0 $\pm$ 2.0	20.6 $\pm$ 0.9
Green	4.7 $\pm$ 0.6	131.0 $\pm$ 8.0	17.3 $\pm$ 1.3	67.5 $\pm$ 0.5	34.5 $\pm$ 1.5	15.2 $\pm$ 0.4
Red	10.8 $\pm$ 0.3	7.5 $\pm$ 4.5	8.6 $\pm$ 1.6	46.5 $\pm$ 0.5	25.5 $\pm$ 0.5	15.7 $\pm$ 0.3
<b>100 cm</b>						
Brown	7.5 $\pm$ 0.3		3.0 $\pm$ 0	69.0 $\pm$ 0.7	30.0 $\pm$ 2.0	34.5 $\pm$ 1.5
22.2 $\pm$ 0.7 Green	4.8 $\pm$ 2.4	56.5 $\pm$ 11.5	12.7 $\pm$ 1.5	47.5 $\pm$ 0.5	28.0 $\pm$ 0	15.7 $\pm$ 0.2
Red	11.6 $\pm$ 1.3	64.0 $\pm$ 11.0	13.9 $\pm$ 0.1	53.5 $\pm$ 0.5	24.0 $\pm$ 1.0	15.9 $\pm$ 0.9

### Experimental tank culture

*Gracilaria heteroclada* was grown in fiberglass tanks in enriched or unenriched seawater at stocking densities of 500, 1000, and 2000 g/m<sup>2</sup> (Hurtado-Ponce, unpublished). Pulses of 2 mM NH<sub>4</sub>Cl and 0.2 mM KH<sub>2</sub>PO<sub>4</sub> were provided for 12 hours at night. Growth was significantly higher at the stocking density of 500 g/m<sup>2</sup> in both enriched and unenriched seawater.

In another experiment, *G. heteroclada* was grown in outdoor or indoor tanks, at either 15, 25, or 35 ppt salinity, and with or without 5.58 µM urea enrichment (Pondevida 1993). Seaweeds at 15 ppt in outdoor tanks with urea enrichment grew significantly better than the rest. Thus, *G. heteroclada* is tolerant of low salinity.

Tank-grown *G. heteroclada* was transplanted to Dumangas for farming (Hurtado-Ponce, unpublished). After two months, the farmers were able to harvest and sell the seaweed. The presence of unwanted algae was a problem.

The salinity tolerance of four other species of *Gracilaria* (*G. changii*, *G. fastigiata*, *G. firma*, and *G. tenuistipitata*) from Sorsogon was tested in concrete tanks (SR Ferrer, personal communication). Preliminary results show that salinity tolerance and growth rates differ by species.

### Pond culture with tiger shrimp

The tiger shrimp *Penaeus monodon* was stocked at 2,500/ha and 5,000/ha together with *Gracilaria heteroclada* planted at 250, 500, and 750 g/m<sup>2</sup> in the 'rice-planting' method and at 500 g/m<sup>2</sup> in the longline technique. During the 5-month culture period, growth and production of the seaweed varied monthly and with the seaweed stocking density. Highest average growth rate (3.1% per day) and production (873 g/m<sup>2</sup>) of *G. heteroclada* was obtained at the stocking density of 250 g/m<sup>2</sup> during November when average temperature was 29.5°C, salinity was 24 ppt, water transparency was 74%, and water depth was 83 cm (Hurtado-Ponce, unpublished).

### Agar quality

Species of *Gracilaria* grown under different conditions were tested for agar quality. Wild stocks of *G. heteroclada* from Estancia and Zarraga yielded agar of higher gel strength than *G. changii* and *G. rubra* (Pondevida 1993). Harder gels are highly priced in the international agar market. Agars with gel strength of 600 g/cm<sup>2</sup> or more are considered bacteriological grade agar.

Salinity affected the gel properties of *G. heteroclada* grown in outdoor or indoor tanks, with or without urea enrichment. Seaweed grown at 25 ppt produced agar with significantly higher gel strength and gelling and melting temperatures but lower agar yield and sulfate content than those at 15 and 35 ppt (Pondevida 1993).

Several studies were done to manipulate and possibly improve the gel properties of *G. heteroclada*. Seaweed grown at a density of 2,000 g/m<sup>2</sup> in tanks with enriched seawater produced agar with significantly higher gel strength, and higher gelling and melting temperatures than those grown at 500 and 1000 g/m<sup>2</sup> (Hurtado-Ponce, unpublished). In unenriched seawater, gel properties did not vary with stocking densities.

The two species *G. heteroclada* and *G. changii* have gel strengths of more than 600 g/cm<sup>2</sup> and are thus of potential commercial importance. Two methods of alkali treatment were tested on these species (de Castro 1993a). In Treatment I, the seaweeds were pretreated with either 1, 3, or 5% NaOH for 30-60 min at 85-90°C. In Treatment II, crude extracted agar was treated with either 5, 10, or 15% NaOH for 3 days at room temperature. Significant differences in gel strength were found (Table 2), but either alkali treatment may be used for *G. heteroclada* and *G. changii*. Treatment II is a modification of the standard method used for *Polycavernosa* spp. in Thailand; it can be used for reprocessing of crude agar extracted at the village level.

The agar yield and gel strength of *G. heteroclada* cultured in cages at different depths (25, 50, and 100 cm) varied monthly. Seaweeds grown at 25 cm deep had higher agar yields and gel strength (TR de Castro, personal communication).

Table 2. Gel strength (mean±SE) of two *Gracilaria* species under different alkaline treatments. Data from de Castro (1993a).

Treatment	NaOH (%)	Duration	Gel strength (g/cm <sup>2</sup> )	
			<i>G. heteroclada</i>	<i>G. changii</i>
I	1	30min	463 ± 4.2	379 ± 8.9
	3	30min	516 ± 1.6	538 ± 7.9
	5	30min	642 ± 11.9	574 ± 5.5
	1	60 min	632 ± 8.7	357 ± 1.3
	3	60 min	568 ± 4.6	644 ± 3.4
	5	60 min	444 ± 3.2	414 ± 4.8
II	5	3 days	439 ± 3.3	783 ± 5.3
	10	3 days	639 ± 11.9	469 ± 4.9
	15	3 days	542 ± 5.6	657 ± 16.6

### Studies on Oyster *Crassostrea iredalei* and Green Mussel *Perna viridis*

#### Socioeconomics of farming in western Visayas

The socioeconomics, technical status, marketing, and profitability of oyster and mussel farming in Western Visayas were assessed in a 1992 survey (GPB Samonte, personal communication). Oyster and mussel farms are located among fish capture devices in rivers and bays. About 73% of the oyster farmers and 81% of the mussel farmers have farms with areas less than 1,000 m<sup>2</sup>. Oyster and mussel farming in western Visayas is dependent on the natural spatfall — almost year-round for oysters, but seasonal for mussels. Four methods are used to culture oysters: stake (most common), bottom, rack hanging, and raft hanging; the raft method is the most cost-efficient. Mussels are cultured on stakes, at the bottom, and on rafts; the stake method

is the most cost-efficient. Unpaid owner and family labor is an essential input in oyster and mussel farms. The production costs are minimal and affordable by small-scale fishermen. Mussel farmers had higher net farm income than oyster farmers. Oyster and mussel farmers belong to the marginalized sector of society. The average mussel or oyster farmer in the study was 44-45 years old, married with 5-6 children, and had an elementary education, 8-9 years of farming experience, and a household income of P20,500-28,700 in 1990 (US\$1 = P25). Farmers have no legal claim to the farm lots; most of them own their houses but not their home lots.

A localized technical and socioeconomic assessment was made of oyster and mussel culture in Binaobawan, Pilar, Capiz and Lakaran, Dumangas, Iloilo in 1993. Rapid rural appraisal was conducted to determine the condition of the resources and the livelihood and socioeconomic situation of the villagers, particularly the oyster and mussel farmers (WG Gallardo, personal communication). Fishing is the major livelihood in both villages. In Lakaran, all residents are engaged in oyster fanning by the rack hanging method. In Binaobawan, 77% of the villagers are engaged in oyster and mussel fanning; oysters are cultured by the bottom method and mussels by the platform method. Production of oysters in Binaobawan could be increased by adapting the method used in Lakaran.

Market-size green mussels and the brown mussel *Modiolus metcalfei* were transplanted from Capiz to Lakaran for culture by the oyster farmers there (KG Corre, personal communication). Five months after transplantation, spats of green mussels were found attached to nearby bamboo poles and oyster and mussel shells.

### **Green mussels as biological filter in shrimp ponds**

Work in Thailand and elsewhere have suggested that shrimp pond effluents may be cleaned by biological filters such as filter-feeding mollusks and nutrient-absorbing seaweeds. Green mussels were tested as biological filter in ponds with tiger shrimps stocked at 5/m<sup>2</sup>. The mussels prevented excessive growth of phytoplankton and an increase in suspended solids. Water transparency was higher in shrimp ponds with green mussel than those without. After a 98-day culture period, shrimps in ponds with mussels had significantly higher body weight than those without mussels, but survival and production were not significantly different (KG Corre, personal communication).

## **Studies on the 'Kapis' *Placuna placenta***

### **Fishery**

A nationwide survey of the windowpane oyster or 'kapis' fishery was conducted to assess the present status (WG Gallardo, personal communication). There are 27 'kapis' beds in the Philippines, six of which are the major sources. 'Kapis' stocks are declining and most beds are already depleted due to excessive gathering, pollution, siltation, and trawling. 'Kapis' shells support an open access fishery; anybody can gather shells by handpicking in shallow areas, compressor diving in deeper areas, and dredging. To prevent the depletion of the 'kapis' resource, several measures are recommended: establishment of sanctuaries, ban on trawling and other destructive fishing methods, strict enforcement of existing regulations, community-based fishery

management, and further research on seed production, restocking, and transplantation (WG Gallardo, personal communication).

### Seed production

To provide 'kapis' seed for grow-out and restocking, broodstocks are being developed for eventual spawning and seed production in the hatchery (JM Ladjá, personal communication). Wild-caught 'kapis' were induced to spawn after intragonadal injection of 1 ml of 2 mM serotonin solution. The larvae developed to early pediveliger stage. 'Kapis' broodstocks kept in tire rays at a river mouth showed more mature gonads than those held in laboratory tanks. Broodstocks fed a 3:1 combination of the microalgae *Isochrysis galbana* and *Tetraselmis tetrahele* developed more mature gonads than those fed a 1:1 combination (JM Ladjá, personal communication).

### Studies on the Donkey-Ear Abalone *Haliotis asinina*

Studies on the reproductive biology of the local abalone were initiated in 1993 on specimens collected from Panagatan Cays, Antique (EC Capinpin, personal communication). As of May 1994, the 150 specimens collected had shell lengths of 4.8-9.6 cm. The specimens ranged in gonad development from immature to fully mature.

Abalones collected from Panagatan Cays were maintained in fiberglass tanks for spawning and seed production trials. Since March 1994, abalones have spawned continuously on a semilunar cycle (M Hosoya, personal communication). Juvenile abalones ranged 1.5-2 cm after three months.

Juvenile abalones were reared for 120 days in plastic baskets inside fiberglass tanks with flow-through seawater. They were fed *Gracilaria heteroclada*, *Kappaphycus alvarezii*, or a commercial diet for Japanese abalone. Growth of the local abalone was best on *Gracilaria* and worst on *Kappaphycus* (EC Capinpin, personal communication).

### Conclusion

Studies at the SEAFDEC Aquaculture Department have focused on the biology, culture, and agar quality of several *Gracilaria* species. Growth and production of *Gracilaria heteroclada* are higher in tanks than in ponds. Nutrient enrichment during the culture period enhances growth and improves agar quality. Salinity tolerance varies by species. Alkali treatment of the raw material improves agar quality.

Oyster farming and mussel fanning are important livelihoods for marginal fisherfolk in many towns in western Visayas. Income for the fisherfolk could be improved with government and private support, in terms of policy, credit, culture and post-harvest methods, and infrastructure. Green mussel is a potential biofilter in intensive shrimp ponds. The local abalone is relatively easy to spawn and rear in the laboratory. Seed production of the windowpane oyster may soon be feasible.



## Editors' Addendum

The following other papers on seaweeds and mollusks were published by SEAFDEC AQD researchers during the past three years:

- Culture of *Gracilaria*: Lavilla-Pitogo (1991), Hurtado et al. (1992c), de Castro and Guanzon(1993),
- Culture of *Kappaphycus*: Hurtado-Ponce (1992a), Samonte et al. (1993)
- Biology and gathering of seaweeds: Luhan et al. (1992), Hurtado-Ponce et al. (1992a, b), Hurtado-Ponce(1993)
- Post-harvest processing of seaweeds: Hurtado-Ponce (1992b, c), de Castro (1993b, c, d)
- Biology of *Placuna placenta*: Gallardo et al. (1992)

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# **Community Fishery Resources Management in Malalison Island, Philippines**

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Agbayani RF. Community fishery resources management in Malalison Island, Philippines, pp. 209-219. In: Bagarinao TU, Flores EEC (eds) Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines.

## **Abstract**

The Community Fishery Resources Management Project, launched in 1991 in Malalison Island, Philippines is a development-oriented research project integrating biology, economics, sociology, engineering, and public administration. The general objective is to support, and learn from, the collaboration of people's organization, biologists, and social scientists in applying community-based techniques in fishery management. During Phase I, the Project concentrated on community organizing, institution building, and the introduction of seaweed farming as alternative livelihood. Studies were made on the marine resources of the island, the traditional boundaries and territorial use rights, the economic utilization of resources in the island, and the cultivation techniques for seaweeds. Phase II started in 1994 with the implementation of the territorial use rights in fisheries and the test deployment of prototype concrete artificial reefs. Phase II includes impact assessment (environmental, social, and economic), institutional arrangements in fishery co-management, ethnographic studies, economics of Seafarming techniques, and management of fishery cooperatives.

## **Introduction**

The Community Fisheries Resource Management (CFRM) Project was launched in Malalison Island off western Panay, Philippines in 1991 by the SEAFDEC Aquaculture Department with support from the International Development Research Centre of Canada. The CFRM Project addresses two main issues: the degradation of coastal resources and the poverty of fisherfolk (Lacanilao 1989). Declining productivity in marine ecosystems is caused primarily by the conversion of mangroves swamps to ponds, destructive fishing practices, and siltation due to forest denudation. SEAFDEC AQD felt the need to undertake socially oriented developmental research focusing on the issues of poverty and marine resource degradation.

Research conducted under CFRM is development-oriented and multi-disciplinary. Biological studies are integrated with economics, sociology, enterprise management, public

administration, and engineering to accomplish community-based resource management. Fishery co-management through community self-regulation of fishery resources is an alternative strategy to 'top-down' policy-making (Hviding and Jui-Larsen 1993, Pomeroy 1993). The active involvement of the community and the legal support of the local and national government in the protection of fishery resources make possible sustained harvests. The CFRM Project provides the poor fisherfolk of Malalison opportunities to improve their livelihood and quality of life through appropriate interventions such as community organizing and institution building, alternative livelihood, territorial use rights in fisheries, deployment of concrete artificial reefs, and searanching.

Malalison was selected from among five candidate sites on the basis of socioeconomic and biophysical criteria. Socioeconomic criteria included income and dependence on fishing, (destructive) fishing practices, use of credit for fishing activities, potential for alternative livelihood, and presence of a non-government organization in the locality. The biophysical criteria evaluated were the presence of live coral cover, other hard substrate, seagrass beds, mangroves, water 10-30 meters deep, and protection from the southwest monsoon.

Figure 1 shows a topographic-nautical map of Malalison Island. Under the CFRM Project, socioeconomic and biological studies were conducted to obtain baseline data about Malalison's natural resources and the user community.

### **Socioeconomic Situation**

A demographic census taken at the start of the project showed 74 households with an average of 5-6 members (SV Siar, personal communication). About 72% of the households lived below the poverty level of P2,500/month as defined by the National Economic Development Authority, and 52% earned less than P1,250/month (US\$1=P25). Income from fishing accounted for 60-100% of the total income of 65% of the households. About 49% of the households had 1-2 working members, and another 42% had 3-4 working members. Among the household heads, 84% reported fishing and related occupation (net mending, fish vending, boat making) as their main livelihood. The rest of the household heads were engaged in swine-raising, construction work, coconut-lumber making, or farming.

The educational attainment of the household heads in Malalison was very low (SV Siar, personal communication). About 72% reached various grades in elementary school, 15% had two years secondary education, and 5% had three years of college. Of the only two college graduates, one is the incumbent barangay (village) captain.

Malalison has a young population: in 1991, 68% were younger than 30 years, 19% were 30-50 years old, and only 13% were older than 50. The population increased from 431 in 74 households in 1991 to 485 in 94 households in December 1994, a 3% annual growth rate. This is higher than the national growth rate of 2.1% estimated by the National Census and Statistics Office.

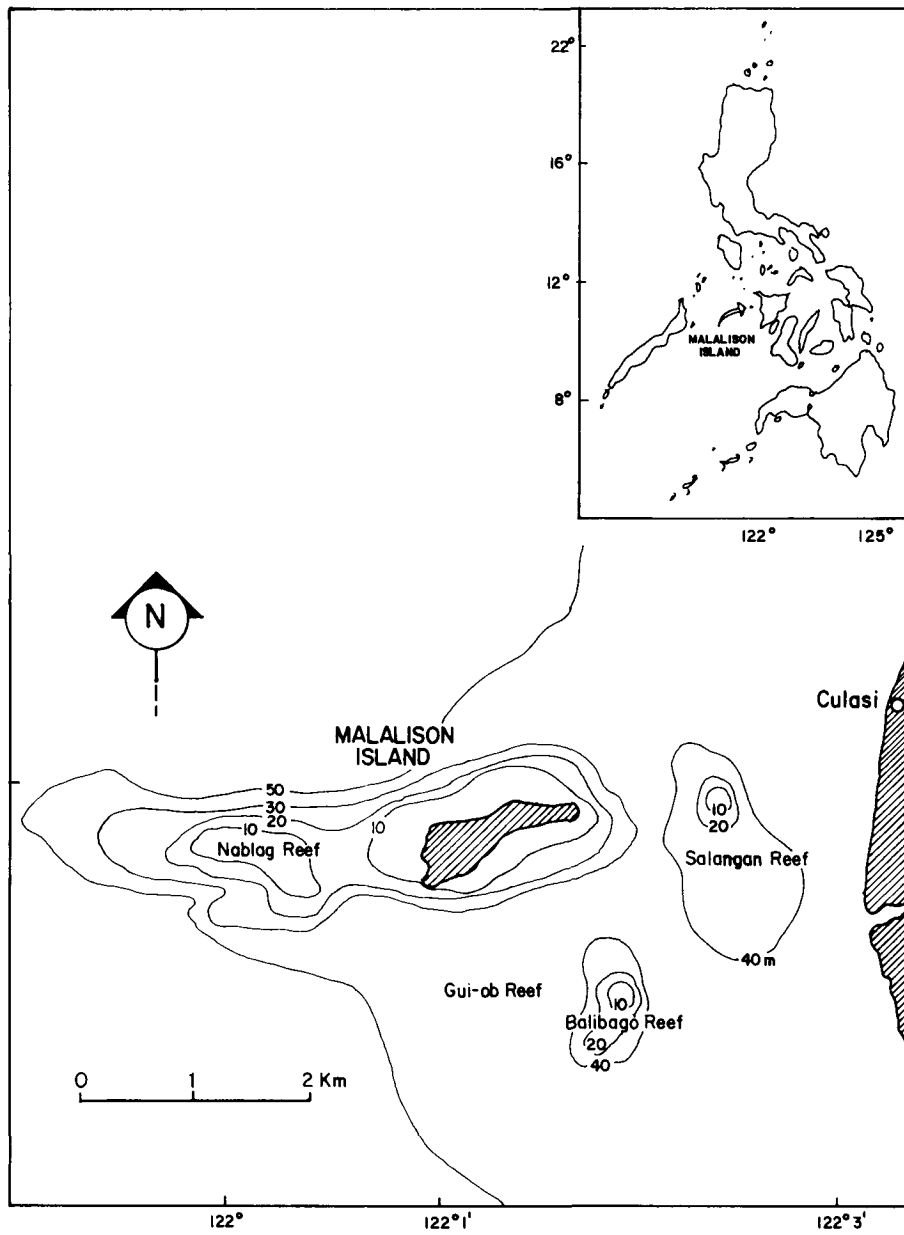


Fig. 1. Map of Malalison Island, showing the major reefs.

## **Economic Utilization of Resources**

An agro-fishery village transect was prepared with rapid rural appraisal techniques (Conway 1989, Lamug 1989) to determine the land and marine resources, economic activities, agricultural and fishery products, problems, and opportunities in Malalison. The transect was divided into coral reefs, lowland rice fields, upland, village, and nearshore. Some of the economic opportunities identified were capture of ornamental Fishes from the coral reefs, vegetable farming and salt-making near the rice fields, planting of fruit trees in the uplands, establishment of a cooperative-managed consumer store in the village proper, and seaweed farming near shore (Agbayani and Siar 1994).

The waters around Malalison are a shared resource. In 1992, the Malalison waters supported a population of 6,820 in 1,364 households in 16 coastal barangays in Culasi and nearby Batbatan Island (SV Siar, personal communication). Commercial (large-scale) fishers from other provinces have also encroached on the waters of Malalison to the disadvantage of the municipal (small-scale) fishers. Of the 74 households in Malalison, 37% have non-motorized boats and 22% own motorized boats. Hook-and-line is the most common fishing gear, followed by spears and nets. Women and children gather mollusks, sea urchins, sea cucumbers, and other reef products.

Because of the monsoon winds in July-November, fishing is seasonal in Malalison, particularly among the fishers using spears and hook-and-line. Lack of alternative income sources during the off-season has forced fishers to use efficient but destructive fishing methods to maximize the catch during the peak season (SV Siar, personal communication). Blast fishing was rampant during the 1980s until the initiator and source of dynamite died in 1991. Malalison fishers now allege that fishers from other islands and provinces do blast and cyanide fishing around the island. The Malalison version of the 'muro-ami' (locally called 'duldog'), introduced by Japanese fishermen before World War II, became a source of conflict both within and outside the island. 'Duldog' has been prohibited since 1986, but the ban has been commonly ignored. Overfishing and destructive fishing practices have degraded the marine resources, particularly the coral reefs around the island.

The small-scale reef fisheries in Malalison have been described and the yield of the coral reefs was estimated at 5.8 tons/km<sup>2</sup>-yr (Amar et al. in press). A two-year survey (Apr 1992 to Mar 1994) documented the average monthly catch, sales, net income, number of fishing hours per day and fishing days per month of 38 fishers using different gears (Table 1; Agbayani, unpublished data). In year 2, the average monthly catch of net fishers and hook-and-liners decreased by 17-25% due to fewer fishing days per month and also because of the substantial decrease in 'duldog' fishing as a result of the active information campaign in year 1 and the social pressure among the fisherfolk. Sales and net income increased due to the higher value of the species caught in year 2.

## **State of Living Marine Resources**

The living marine resources in Malalison were assessed during 1991-1994. Many species of mollusks, echinoderms, and other invertebrates are found in Malalison, and many are used as food or sold for additional income. Five species of seagrasses and 74 species of macrobenthic algae were recorded around Malalison (CL Marte, personal communication). The biomass of these benthic plants was highest in March-May.

Table 1. Average fishing effort, catch, and income of 38 Malalison fishers in April 1992-April 1994 (Agbayani, unpublished).

Gear	Fishing (d/mo)	Fishing (h/day)	Catch (kg/mo)	Sales (pesos/mo)	Net income (pesos/mo)
<b>Year 1</b>					
Spear	16	5	38	935	886
Net	11	6	53	1107	916
Hook & line	15	6	28	808	725
<b>Year 2</b>					
Spear	12	5	39	1154	984
Net	10	6	44	1148	1042
Hook & line	11	8	16	949	825

Over 120 species of corals in 49 genera were found in nine sampling stations around the island (CL Marte and YH Primavera, personal communication). Coral reef cover was 5-15% on the southeast (Kawit and Talisay) and 29-58% on the northeast side (Amihanan) (Fig. 1). The fish census along 50-meter transects at the 10-meter depth contour showed over 70 species (LMB Garcia and EC Amar, personal communication). The highest number of fish species (85) was seen in Amihanan and the highest standing biomass (67 t/km<sup>2</sup>) in the southwest side (Nablag).

### Causal Model of Poverty

The fisherfolk are among the poorest of the poor in developing countries like the Philippines. Their incomes almost exclusively depend on the fishery resources adjacent to their village. Such is the case of the Malalison fisherfolk. In order to improve the social and economic conditions of a poor fishing community, developmental projects like CFRM must examine the causes of such poverty.

During the past three years of immersion in the community, the CFRM research team built a causal model of poverty in Malalison (Fig. 2). A causal model is a simplified representation of reality; it is a communication tool for use in identifying the causes and mechanisms of a problem under consideration (Eusebio et al. 1991). Such models are often site-specific and may be changed or improved during the course of a project. The causal model of poverty in Malalison has been discussed in several meetings and workshops in and outside Malalison and SEAFDEC AQD in order to reach a consensus.

The direct causes of poverty in Malalison are: (1) the degraded condition of marine and land resources, (2) limited livelihood opportunities, (3) low educational attainment of the island residents, and (4) lack of people empowerment. The marine and other natural resources have been degraded because of the high rate of use, high population growth, destructive fishing practices, and poor enforcement of fishery laws and regulations.

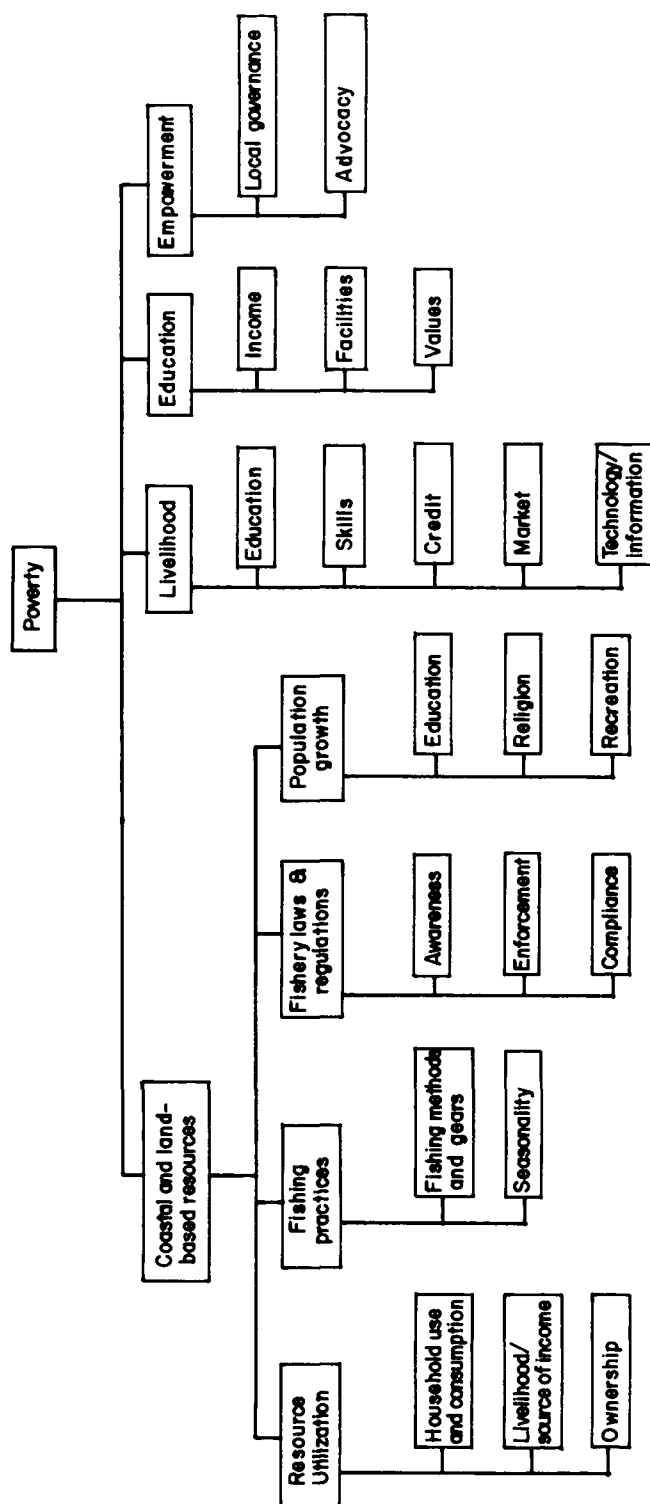


Fig. 2. Causal model of poverty in Malalison Island, Philippines.



The direct causes of the high population growth are the low educational attainment of household heads, the religious prohibition against artificial birth control, the lack of recreational facilities in the island, and the tendency to view children as workers, caregivers, or insurance against adversity. High population growth is thus both an effect and a cause of poverty.

Lack of alternative livelihood is another direct cause of poverty in Malalison. Residents lack education, skills, information, and technology. Lack of credit prevents or limits other economic activities. The inability to access the market for non-traditional products, e.g., shellcraft has prevented the community from pursuing some alternative livelihood.

Low educational attainment limits the ability of the Malalison fisherfolk to understand and properly use their resources, do business, learn new skills, get what they want, and rise above poverty. The children are unable to go to school because of lack of funds and educational facilities on the island, and because many parents undervalue education.

The passive posture of the fisherfolk in managing the coastal waters is due to the 'top-down' strategy of policy formulation and implementation (Agbayani and Hurtado-Ponce 1993). The fisherfolk are not educated about their natural resources and are not trained in local governance and policy advocacy.

### **Logical Framework of the Interventions under CFRM**

Research and development projects such as CFRM require a conceptual model or logical framework to focus on the effects of interventions on the resources and on the socioeconomic status of the target beneficiaries. In 1991, several development interventions were formulated for Malalison (Fig. 3). Foremost was the social preparation through community organizing and institution building to empower the fisherfolk. The community was to be encouraged to lobby for territorial use rights in fisheries. Seafarming and other livelihood were to be introduced to improve incomes. Artificial reefs were to be deployed to increase underwater habitats and increase fisheries production. Finally, searanching was to be done also to improve the fisheries.

Effective evaluation of the CFRM Project requires identification of realistic environmental, social, and economic indicators (Ramos and Garcia 1993). These qualitative and quantitative indicators allow us to determine whether project objectives are met, and if not, to analyze the reasons for the failure so that corrective steps can be made. Analysis of the impact of CFRM will use the following indicators:

#### **Social and economic**

- Active participation of FAMI members in the organization
- Self-reliance of FAMI as an organization, e.g., in financing livelihood projects and making representations with government agencies on their own
- Elimination of illegal fishing
- Increased incomes
- Diversified income sources
- Higher average education of the children
- Increased knowledge

- Improved job skills
- Better health

Environmental

- Increase in fish stocks and other fishery species
- Regeneration of corals
- Conservation of seagrass beds
- Reforestation of the uplands

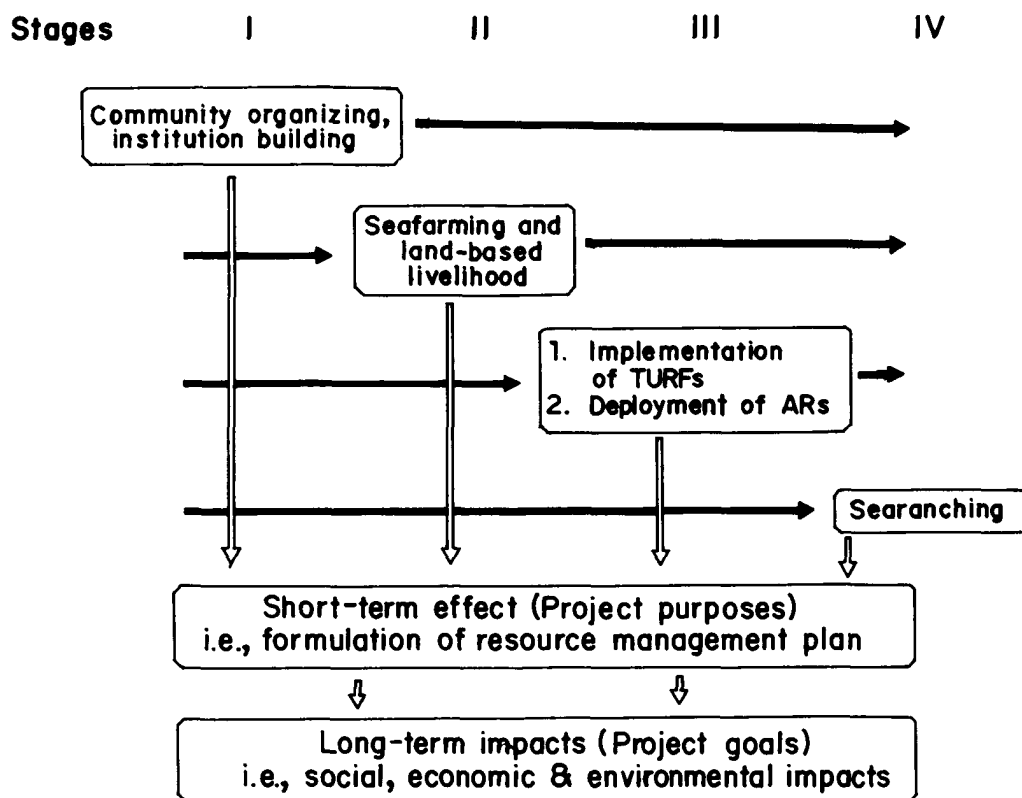


Fig. 3. Logical framework of the developmental interventions under CFRM in Malalison Island, Philippines.

## Community Organizing

Community-based resource management hinges on the formation of a strong and sustainable fishers' association. In 1991, the Fishermen's Association of Malalison Island (FAMI) was organized with the support of the Culasi municipal government. PROCESS Foundation, Inc., a non-government organization was tapped to facilitate the community organizing and the training of FAMI members since 1991. At first, coordination between PROCESS and SEAFDEC AQD was ineffective but this was soon corrected. The problem now is that FAMI members expect too much too soon in terms of improved livelihood and incomes under (CFRM (Agbayani and Siar 1994).

A Resource Management Committee has been created comprising representatives of different groups of fishers (hook-and-line, net, and spear), the local government units and concerned agencies, SEAFDEC AQD, and PROCESS Foundation. FAMI is expected to: (1) improve enforcement of fishery laws through self-regulation and vigilance, (2) stop illegal fishing, (3) develop skills in alternative livelihood, and (4) improve access to appropriate technology.

FAMI's plans, targets, accomplishments, and gaps are assessed in annual seminar-workshops. At these workshops, the FAMI members assess and evaluate the strengths, weaknesses, opportunities of, and threats to, the CFRM Project.

## TURFs in Malalison

Resource ownership is a burning issue in resources management. The open access character of a resource leads to uncontrolled and destructive exploitation and environmental deterioration (Ostrom 1990, Oakerson 1992). As a management strategy, the granting of territorial use rights in fisheries (TURFs) to a community provides them a sense of ownership of, and responsibility for, the fishery resource (Lacanilao 1989, Siar et al. 1992, Bojos 1992, Garcia 1992, Fellizar 1992).

The Local Government Code of 1991 includes the policy delegating the local government units and peoples' organizations to manage their own resources. *"Municipalities have the exclusive authority to grant fishery privileges in the municipal waters (15 km from the coastline) and impose rentals, fees, or charges."*

The Culasi Sangguniang Bayan (Municipal Council) passed Municipal Ordinance No. 5-90 designating a 1 km<sup>2</sup> area between Malalison and Culasi as a TURFs area. This version of the ordinance was questioned by the Provincial Council of Antique because of its 'class' character, i.e., the ordinance favors the Malalison community over other communities and sectors in the town of Culasi. There is also a need to recommend to the municipal government a modification of the ordinance: the actual TURFs area in Malalison waters must be specified.

The Resource Management Committee will prepare a resource management plan that defines the rules and rights of the members of the community in the use and management of the resources in the TURFs area. Effective implementation of TURFs will help ease the fishing pressure and ultimately increase the catch and income of *individual* fishers, if not the total for all fishers.

## Artificial Reefs and Searanching

Prototype concrete artificial reefs or ARs were deployed in Guiob (Fig. 1) in May 1994 (CL Marte, personal communication) to test the technical feasibility in terms of design, strength, and deployment with local labor. At the initiative of its members, FAMI will declare Guiob as a fish sanctuary where no fishing will be allowed. ARs in a fish sanctuary will help rehabilitate the coral reefs and lead to increase in fish stock. Full deployment of concrete ARs will be done at selected sites in 1995, taking into consideration the biophysical characteristics and the socioeconomic effects on the resource users. As a complementary strategy, searanching of appropriate species in the ARs will increase the fish stocks.

## Seaweed Farming and Other Livelihood

FAMI cooperated with SEAFDEC AQD researchers in culture trials with the seaweed *Kappaphycus*. Seaweed farming was generally successful in terms of production, profit, and FAMI management. FAMI also revitalized a consumer store in the island. Management of the enterprise, particularly of the finances, was improved.

## Conclusion: CFRM to 1997

The CFRM project will continue the capacity-building activities of FAMI members during the next three years. Needs assessment by the FAMI members will guide the types of training activities to be undertaken. The sustainability of the community-based approach to coastal resource management will depend largely on the capacity of the fisherfolk organization to implement the provisions of the resource management plan. The supportive roles of government, non-government institutions, and other stakeholders as co-managers of the resource will greatly influence the success of community-based resource management.

Economic activities will be both marine- and land-based and will be determined by the FAMI members. Capture of coral reef fishes with environment-friendly techniques was suggested during the last assessment forum as another potential livelihood as the demand for marine aquarium fishes continues.

Research will focus on the analyses of the social, economic, institutional, and environmental impacts of the development interventions.

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# **Training and Information Dissemination at SEAFDEC AQD**

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## **Abstract**

The SEAFDEC Aquaculture Department (AQD) is mandated to develop human resources and to disseminate and exchange information for aquaculture development in the region. In 1991-1994, a total of 294 participants attended 23 sessions of nine training courses. Many others participated in AQD's student practicum, internships, and summer work programs. AQD conducted seminar-workshops on aquaculture development in southeast Asia, fish breeding, feeds and feeding, and training needs. Information materials (newsletters, a monograph, two extension manuals, leaflets, and videos) were produced based on research at AQD. To assist fishfarmers and other sectors of the local aquaculture industry, AQD conducted on-site or outreach seminars, and provided resource persons during fairs and exhibits, seminars, and consultative meetings. The AQD Library is open to all users; in addition to the collection of printed materials, a CD-ROM reader is now available for fast retrieval of bibliographic information from computerized databases like ASFA.

## **Introduction**

The SEAFDEC Aquaculture Department (AQD) exists to develop and promote aquaculture in southeast Asia. One mandate of AQD is to develop human resources and disseminate and exchange information in aquaculture. Since its establishment in 1973, the Department has received trainees from SEAFDEC Member Countries (Thailand, Malaysia, Singapore, Philippines) and other countries for short-term training courses. AQD has conducted scientific conferences and seminar-workshops to disseminate aquaculture science and technology. AQD researchers and information specialists have also packaged the relevant information into monographs, extension manuals, newsletters, and video programs.

### Training Program

Six short-term training courses were offered at AQD in 1991-1994 (Table 1) in accordance with the recommendation of the 1991 Seminar-Workshop on Aquaculture Development in Southeast Asia (ADSEA '91). Three additional training courses were conducted by AQD in collaboration with the Network of Aquaculture Centres in the Asia-Pacific and the UP-V Brackishwater Aquaculture Center. Sixteen Iranians and one Pakistani attended the training course in Aquaculture Engineering. Nine Bangladesh nationals sponsored by the Government of Bangladesh attended the Shrimp Culture course, and two Pakistanis took the course in Brackishwater Aquaculture Management and Operation. A total of 327 government workers and aquaculture technicians completed the 25 sessions of training courses in 1991 to 1994 (Table 1).

Table 1. Participation in the SEAFDEC AQD training courses.

Training Course	Number of sessions	Number of participants			
		1991	1992	1993	1994
Fish Nutrition	3	12	13	12	
Marine Fish Hatchery	5	16	30	13	13
Fish Health Management	4	14	14	14	15
Aquaculture Management	4	14	18	18	18
Shrimp Hatchery	3	17	12		14
Culture of Natural Food	2	13		8	
Aquaculture Engineering	2			17	1
Shrimp Culture	1				9
Brackishwater Aquaculture Management & Operation	1				2
Total	25	86	87	82	72

These 'hands-on' courses were 10-20% lectures and 80-90% laboratory and practical work. The resource persons included the Department's professional staff of 63 Ph.D. and M.Sc. degree holders, faculty from the University of the Philippines in the Visayas (UP-V) and the UP Marine Science Institute, and experts from other research institutions and the private sector. The training facilities include fish and shrimp hatcheries, various laboratories, a feed mill, and audio-visual lecture rooms.

ADSEA '94 recommended that two courses be offered again: Freshwater Aquaculture (phased out in the 1980s) and Coastal Aquaculture (formerly Brackishwater Pond Culture).

AQD also offered practicum training for graduating students in fisheries and related fields to satisfy the 400 hours requirement. The training provides students practical experience in aquaculture to supplement their theoretical orientation in school. Students assist in ongoing



research and verification studies at AQD. In 1991-94, 124 graduating students from various schools did their practicum at AQD.

Table 2 shows the number of trainees by country of origin and sponsoring agency. SEAFDEC AQD provided fellowships to 165 trainees from member countries.

Table 2. Participation in SEAFDEC AQD training courses by home country and sponsoring agency, 1991-1994.

Country	Number of participants by sponsor			Total
	SEAFDEC AQD	World Bank	Govt or Private	
Philippines	68		99	167
Thailand	49			49
Malaysia	38		6	44
Singapore	3			3
Vietnam	7			7
Iran			18	18
Bangladesh			10	10
Nigeria		5	1	6
Sri Lanka			4	4
China		3		3
Hongkong			3	3
Pakistan			3	3
Kenya			1	1
Egypt			1	1
Indonesia			3	3
Saudi Arabia			2	2
India			2	2
Papua New Guinea			1	1

The SEAFDEC AQD fellowships are funded by the Government of Japan.

Internships in fish and shrimp hatchery, feed development, chemical analyses, disease diagnosis, plankton culture, and other laboratory work were also arranged for various individuals and groups. Sixty-four trainees from the government and the private sector in the Philippines, one from Australia, and one from Sri Lanka undertook internship at AQD. Ten students also undertook the Summer Science High School Internship.

Pursuant to the directive of the Philippine President, a Summer Work Appreciation Program was implemented by AQD in collaboration with the Department of Labor and Employment. This program engaged 227 out-of-school teenagers in productive endeavors at AQD.

To improve the training program of AQD, a survey of aquaculture training needs in the Philippines was initiated. The survey will be extended to other countries in the region.

### Seminar-Workshops

Five seminar-workshops were held by AQD in 1991-1994 to disseminate and share research findings. These well attended conferences were:

- Aquaculture Development in Southeast Asia (ADSEA '91)
- Aquaculture Workshop for SEAFDEC/AQD Training Alumni (1992)
- Breeding and Seed Production of Cultured Fishes in the Philippines (1993)
- Nutrition and Feeds (1994)
- Aquaculture Development in Southeast Asia (ADSEA '94)

AQD also conducted outreach or on-site seminars, participated in national fairs and exhibits, and provided resource persons in non-AQD seminars and consultative meetings.

### Library and Documentation

Researchers, teachers, students, and aquaculture practitioners avail of the excellent resources of the AQD Library. Acquisition of information materials in aquaculture and related subjects is constantly being intensified through purchases, subscriptions, gifts and exchanges, and requests from donor agencies. Library holdings as of 30 June 1994 include 11,733 monographic volumes, 6,188 pamphlets, 2,633 SEAFDEC publications, and 4,050 bound journal volumes. A CD-ROM reader is now available for fast retrieval of bibliographic information from commercial databases like the Aquatic Sciences and Fisheries Abstracts.

### In-House Publications

Two monographs, three extension manuals, two conference proceedings, two compilations, and other reports were published by AQD in 1991-1994.

- |  |      |
|--|------|
| • Biology of Milkfish ( <i>Chanos chanos</i> Forsskal)   | 1991 |
| • Seaweeds of Panay  | 1992 |
| • AEM No. 19 Prawn Hatchery Operations   | 1991 |
| • AEM No. 20 Management of Milkfish Broodstock   | 1992 |
| • AEM No. 21 Feeds and Feeding of Milkfish, Nile Tilapia,<br>Asian Sea Bass, and Tiger Shrimp        | 1994 |
| • Proceedings of the Aquaculture Workshop<br>for SEAFDEC AQD Training Alumni                         | 1993 |
| • Aquaculture Development in Southeast Asia and Japan<br>and Prospects for Seafarming and Seafarming | 1994 |

• Collected Abstracts of Research Publications (1987-90)	1991
• Collected Abstracts of Research Publications (1991-93)	1994
• Annual Report 1991	1992
• 20 Years of Research & Development: An Anniversary Souvenir Volume	1993
• 1992-93 SEAFDEC/AQD Report: R&D for Sustainable Aquaculture	1994
• Caring of Milkfish Larvae (Video)	1992
• Oyster and Mussel Farming in Western Visayas (Video)	1993
• Rapid Rural Appraisal (Video)	1994

Volumes 13-15 of the quarterly newsletter *SEAFDEC Asian Aquaculture* came out in 1991-93. This newsletter features news in aquaculture, as well as short versions of papers published by AQD researchers originally in primary journals, as well as news in aquaculture.

Volumes 9-12 of the bimonthly newsletter *Aqua Farm News* came out in 1991-1994. AFN is a technology-oriented package focusing on specific topics, including the following recent ones:

Vol. 9	Sea bass: the profitable alternative Grow-out culture management for freshwater finfishes Integrated fish farming Why artificial reefs? Coastal aquaculture: environmental issues What you should know about seaweeds
Vol. 10	Marine ornamental fish Filipino crabs Farming lapulapu Mollusc culture Aquaculture and its human elements Snappers: worthy of aquaculture?
Vol. 11	Small is beautiful Milkfish breeding Tilapia culture Policing fisheries Catfish culture
Vol. 12	Farming the sea Alternative development Conserve biodiversity Hatchery systems Sigamid culture GATT issues in agriculture



# **The SEAFDEC Aquaculture Department at 21: R&D for Sustainable Aquaculture**

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## **Abstract**

This paper reviews the research output of the SEAFDEC Aquaculture Department (AQD) over the past 21 years of its existence. These realized studies are compared with the priority problem areas recommended for research by international or regional seminar-workshops convened by AQD in 1983, 1987, 1991 and 1994. Between 1976 and 1994, AQD researchers produced 554 publications, including 274 in journals indexed by the Institute for Scientific Information, 122 in other journals, and 158 in conference proceedings. Another 82 publications from work done outside AQD were authored or co-authored by AQD researchers, mostly during their graduate programs. In addition, AQD published 21 extension manuals and 14 technical reports and monographs by AQD researchers, and co-published two other monographs by non-AQD researchers. AQD's major contributions have been the technologies for tiger shrimp seed production, grow-out culture, feeds, and disease control; milkfish seed production and feeds; rabbitfish seed production; and tilapia feeds and strain selection. Communication and two-way feedback among AQD researchers and representatives of the aquaculture industry and the SEAFDEC Member Countries must be improved to fine-tune AQD research. In the late 1980s, AQD started redirecting some of its research towards environmental problems in aquaculture. Much of the near future will be spent implementing research imperatives in sustainable and responsible aquaculture.

## **Introduction**

After two decades, it is time for the SEAFDEC Aquaculture Department (AQD) to take stock and evaluate the past and present, and stride into the 21st century with greater resolve and a clearer focus: the continued promotion of aquaculture within the context of sustainable development. Various authors (GESAMP 1991, Pullin 1993, Csavas 1995, McManus 1995, de la Cruz 1995, Phillips 1995) have made important recommendations regarding how sustainable and responsible aquaculture may be achieved, and Chua (1993) has laid down some policy guidelines

and management strategies for aquaculture within the framework of integrated coastal zone (and watershed) management.

Now more than ever, it is important to improve strategic planning in aquaculture and to give more attention to asking the right questions to be attacked through research (Davy 1991). One approach towards this goal is a historical review of research and development (in a given sector, or a country, or by an institution), as there often is value in looking back and trying to learn from past experiences. The evolution of research systems in relation to development objectives, particularly better definition at the starting point of research, must be given the attention that it deserves in aquaculture and fisheries.

AQD's research and other operations as it turned a decade old were reviewed by Lacanilao (1983). Another opportunity for a historical review presents itself now, after ADSEA '94, the third Seminar-Workshop on Aquaculture Development in Southeast Asia and 21 years into AQD's existence. ADSEA was conceived about a decade ago as a means to assess the contribution of the SEAFDEC Aquaculture Department to the development of the aquaculture industry in southeast Asia. ADSEA meetings were convened by AQD in 1987, 1991, and 1994. These were attended by representatives of SEAFDEC Member Countries, the academe, the private sector, and government agencies. ADSEA '94 was also attended by representatives from Vietnam and Indonesia, and ADSEA '91 and '94 by invited scientists who presented reviews of special topics. The constraints in aquaculture in different countries in the region were identified during the workshops, then the country representatives prioritized the species and problem areas for AQD research. Thus, these meetings ended with lists of recommendations and priorities, which became the basis of the three-year plans of AQD.

Before ADSEA '87, AQD had also convened the International Milkfish Workshop Conference in May 1976, the Second International Milkfish Aquaculture Conference in October 1983 (Juario et al. 1984), and the First International Conference on the Culture of Penaeid Prawns/Shrimps in December 1984 (Taki et al. 1985), all in Iloilo. Later seminar-workshops were held to discuss aquaculture manpower training (Villegas et al. 1993), and research and development in fish breeding and seed production, and in feeds and feeding. In addition to these formal meetings, AQD holds yearly round-table dialogues with aquaculturists, researchers, and government administrators in the Philippines. The stated aim is always, in effect, to review and then fine-tune AQD's research.

It is thus of academic and practical interest to see how the research output of AQD scientists has matched the needs of the aquaculture industry as identified during the various meetings. This paper shows the relation between recommended and realized research at AQD and the resulting contribution of AQD to aquaculture development. The result of the analysis may be used to decide whether AQD has lived up to its research mandate. This paper also spells out some of the new directions that AQD has taken or will take in support of sustainable aquaculture.

### **AQD's Research Output**

Since its establishment 21 years ago, AQD has become a well recognized aquaculture research institution, not only in the region but the world over. A large number of studies were proposed (e.g., 754 studies between 1974 and 1982) but the results of those from AQD's earlier

years went unpublished, or became in-house reports with no external peer review (Lacanilao 1983). A better measure of AQD's research accomplishment is not the number of proposed studies but the number of publications from completed research. Between 1976 and 1994, AQD researchers produced 554 publications, including 274 in journals indexed by the Institute for Scientific Information (ISI), 122 in other journals, and 158 in conference proceedings. Another 82 publications from work done outside AQD were authored or co-authored by AQD researchers, mostly during their graduate (theses) programs. In addition, AQD published 21 extension manuals and 14 technical reports and monographs by AQD researchers. AQD also co-published key monographs on the milkfish industry (Librero 1976, Smith 1981).

The 554 publications were tallied by year, aquaculture commodity, and research topics. Figure 1 shows the breakdown of these publications by year, together with the subset of papers published in ISI-covered journals. The difference between the two curves represents the papers in other journals and in proceedings. A peak number of proceedings papers were produced in 1986 due to the First Asian Fisheries Forum held in Manila, Philippines in 1985 (Maclean et al. 1986). The publications have slowly increased over AQD's lifetime as our scientists 'matured' and more research studies were completed. The sharp increase in ISI-covered papers in 1990 was due to a rethinking (with incentive) among AQD researchers: that stringent peer review and verification of research results among scientists is a necessary first step for the development of aquaculture technology. Publication of scientific papers in ISI-covered journals is preferable over the production of 'grey literature' in conference proceedings and in-house reports (Bagarinao 1994a).

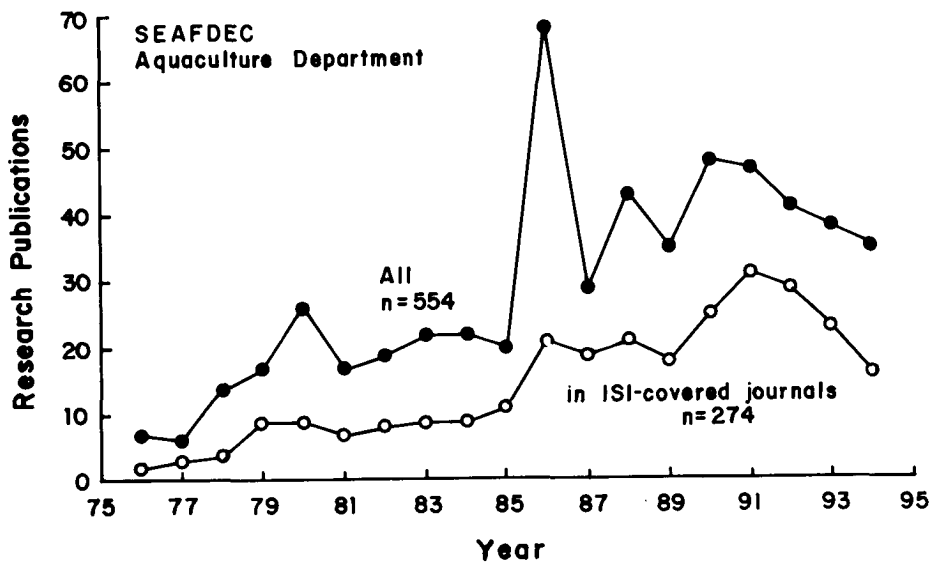


Fig. 1. Number of AQD publications from 1976 to 1994.

The tally includes research conducted at or by AQD in part or whole. The researchers of the SEAFDEC Aquaculture Department are mainly Philippine nationals, mostly with M.Sc. degrees. Others affiliated with AQD include some Japanese researchers assigned to AQD by the Japan International Cooperation Agency, or who hosted AQD researchers in their laboratories in Japan. Several others were Europeans or Americans who collaborated with AQD researchers on some AQD-based project.

The number of publishing AQD scientists (Ph.D., M.Sc, or B.Sc. with publications) increased from five in 1976 to 47 in 1986 and varied from 25 to 35 in 1987-94. The publishing scientists produced an average of 1.3 papers a year. The number of AQD researchers increased from 4 in 1974 to 83 in 1982 and has varied between 57 and 68 during the last seven years. The annual publication rate varied from 0.18 to 0.92 during 1976-94 when all researchers were considered.

So, AQD is reasonably good at producing scientific papers. AQD's research is generally of the 'applied' type, mostly targeted at developing aquaculture technologies, such as in breeding, hatchery, nursery, grow-out, feeds, and health management. But, even applied research does not necessarily translate to technology, much less to aquaculture production. The impact of AQD's scientific papers in terms of aquaculture production is difficult to show (and the assessment of the economic benefits of AQD's research and development is not the purpose of this paper). Indeed, research benefits may be difficult to prove (Nature 359: 173-174, 1992) and yet the perils of accountability in science are only too real (Aiken 1992). What can be shown is whether AQD's scientific papers addressed the problems brought to AQD's attention during the various seminar-workshops such as ADSEA.

### **How Relevant Were the Studies?**

By 'relevant' we mean done at the right time in answer to identified needs. Ideally, research should also be 'appropriate,' meaning done to develop technologies that are environment-friendly, socially equitable, culturally sensitive, and sustainable. To get some idea of relevance, the topics of the publications were compared with the lists of recommended research topics and priority species from the Second International Milkfish Aquaculture Conference (Juario et al. 1984), ADSEA '87 (Juario and Benitez 1988), and ADSEA '91 (Lacanilao et al. 1994). Taki et al. (1985) did not produce a list of recommendations. These topics were tabulated by year periods preceding and following the major conferences. From proposal to published scientific paper may take just 1-2 years but usually longer; this lag time must be borne in mind when comparing recommended versus realized research.

The First Annual Report 1973 defined AQD's research activities, which were restated in the 1981 Annual Report to include:

- Production of adequate supply of quality seeds
- Improvement of culture techniques including water quality management practices
- Formulation of low-cost feeds and propagation of natural food organisms
- Control of pests, predators, and diseases
- Improvement in the design of aquaculture facilities
- Socio-economics of aquaculture
- Aquatic pollution in relation to aquaculture



AQD's research started with programs on crustaceans, milkfish, and Seafarming (mollusks). Research then moved on to tilapia and other freshwater fishes, to herbivorous and carnivorous marine fishes, and to seaweeds. It must be noted that since the beginning, environmental problems related to aquaculture were part of the research mandate of AQD.

### Research on Shrimps

The research program for tiger shrimp started with induced spawning for seed production in the hatchery, with concurrent studies on the biology and ecology of various life stages in the wild (Santiago 1977, Primavera 1978, Motoh 1985). Before the 1984 shrimp conference, intense research was already underway in broodstock development, hatchery techniques, grow-out in ponds, feed development, and in diseases and chemical use (Table 1). Work on broodstock, feeds, and diseases intensified following the shrimp conference and the ADSEA meetings.

ADSEA '87 prioritized tiger shrimp as No. 1 and called for the development of: (1) captive broodstock, (2) economically feasible diets for grow-out, broodstock, and larvae, (3) refined hatchery and nursery techniques, (4) techniques for disease prevention and control in the hatchery, (5) water management methods for ponds. All these needs, except (5) were addressed by AQD's research (Table 1). The technologies follow often slowly from the research.

Table 1. The number of publications by AQD researchers on various research topics concerning tiger shrimp.

Research topics	Number of papers					Total
	1976- 1980	1981- 1984	1985- 1987	1988- 1991	1992- 1994	
Broodstock management	9	3	3	8	5	28
Spawning	3	1				4
Hatchery	2	4		4		10
Larval development	2					2
Nursery			1		1	2
Grow-out	3	3	3	5	3	17
Feeding habits	1	2				3
Nutrient requirements		2	3	4	1	10
Digestive physiology			3	1	1	5
Feed development	5	3	2	6	1	17
Feed storage				1	2	3
Diseases	4		2	6	1	13
Tolerance limits	1		3	2	4	10
Chemical use	2	1	3	3	2	11
Biology, tagging	1			1	1	3
Environment				1	4	5
Total	33	19	23	42	26	143

ADSEA '91 prioritized tiger shrimp as No. 2 and called for more specific research on: (1) restocking of juveniles or adult shrimps in identified sanctuaries, (2) comparison of the performance of larvae from wild spawners, and from ablated and unablated broodstock, (3) a standard set of criteria for fry quality, (4) genetic selection, (5) health management, and (7) ecological effects of intensive shrimp culture. An ongoing Ph.D. thesis aims to identify suitable natural habitats for restocking or searching of tiger shrimps (JH Primavera, personal communication). Captive broodstock and larval quality are being studied, but genetic selection has not been done. AQD researchers have continually monitored and studied new diseases in shrimp hatcheries and ponds (Table 1). Health management has become more crucial in recent years, and AQD has properly emphasized preventive measures such as sanitation rather than chemotherapy, which is often hazardous to shrimp, farm workers, and consumers. Primavera (1993 and earlier papers) has documented the ecological effects of intensive shrimp farming in both scientific and layman media.

ADSEA '94 has again placed tiger shrimp No. 1 priority for AQD research (see Priorities and Recommendations, page 251). The recommended research topics are basically the same as in ADSEA '91, but with additional imperatives to understand and manage the environment (including soil, water, carrying capacity, feed and chemical inputs, and effluents) within and surrounding the culture ponds. A clear call has also been made for aqua-silviculture technology to rehabilitate abandoned ponds. If these environmental studies could be carried out by AQD, they would be great leaps forward in making shrimp culture sustainable.

### Research on Other Crustaceans

Even before the tiger shrimp industry became a roller-coaster enterprise, both government and the private sector called for the development of culture methods for other shrimps and other crustaceans of export potential. AQD researchers did some work on other *Penaeus* shrimps, on the mudcrab *Scylla serrata*, and the freshwater prawn *Macrobrachium rosenbergii* (Table 2; also see AQD Annual Reports 1975 to 1983). ADSEA '87, '91, and '94 called for the development of broodstocks, hatchery techniques, feeds, grow-out culture, and disease control methods. But it seems that AQD researchers already have their hands full with research on tiger shrimps and various fishes. A collaborative research program with the Australian Centre for International Agricultural Research may provide just the incentive to continue the mudcrab studies started in 1977.

*Artemia* has been and still is in great demand as fish food in aquaculture. AQD has collaborated with the *Artemia* Research Centre of the University of Ghent, Belgium, in the development of culture techniques for, and uses of, *Artemia* (Table 2).

Table 2. The number of publications by AQD researchers on various topics concerning crustaceans other than tiger shrimp.

Species Research topics	Number of papers				Total
	1976- 1980	1981- 1987	1988- 1991	1992- 1994	
<b><i>Scylla serrata</i></b>					
Disease	1				1
Grow-out economics			1	1	2
<b><i>Penaeus japonicus</i></b>					
Life cycle			1		1
Feeding	3				3
<b><i>Penaeus indicus</i></b>					
Spawning		2	2		4
Larval development		1			1
<b><i>Penaeus merguensis</i></b>					
Larval development	1				1
Parasites	1	2			3
<b><i>Macrobrachium rosenbergii</i></b>					
Grow-out		1			1
Diseases		1			1
<b><i>Artemia salina</i></b>	4	5	1	1	11

### Research on Milkfish

AQD's research program on milkfish also started with induced spawning of wild adults, simultaneous with studies on the life history and ecology of the species, and the economics of the milkfish industry (Librero et al. 1976, Vanstone et al. 1977, Chaudhuri et al. 1978, Liao et al. 1979, Kumagai and Bagarinao 1979, Senta et al. 1980, Smith 1981). In the early 1980s, studies were started on nutrition and feed development, and on diseases and tolerance to toxicants (Table 3). Following the spontaneous spawning of milkfish broodstock in floating cages starting in 1980 (Lacanilao and Marte 1980, Marte and Lacanilao 1986), hatchery operations became possible and larval rearing techniques were developed over the years.

The 1983 milkfish conference recommended various studies in (1) induction of gonad maturation and spawning, (2) nutrition and feed development, (3) environmental physiology and fish health, (4) fry collection and handling, (5) culture methods, and (6) economics of the industry. Much work was done and published in research areas 1, 2, and 3 but not in the others (Table 3). Studies in milkfish grow-out techniques and economics were conducted at AQD in the early 1980s but only a few of these were published and only much later (e.g., Baliao et al. 1987, Agbayani et al. 1989).

Table 3. The number of publications by AQD researchers on various research topics concerning milkfish.

Research topics	Number of papers					Total
	1976- 1980	1981- 1984	1985- 1987	1988- 1991	1992- 1994	
Broodstock management		1	1	2	2	6
Endocrinology		1	2	1	3	7
Spawning	5	1	6	2	2	16
Hatchery			3	4	1	8
Larval development			3	1		4
Fry collection, storage	3	1	4			8
Nursery	1		4	3		8
Grow-out		1	1	9	1	12
Nutrient requirements	1	1	3	4	4	13
Digestive physiology		4	11	3	2	20
Feed development			1	3	1	5
Diseases, parasites	1	2	5	1		9
Tolerance limits		3	2	3	3	11
Biology	2				1	3
Ecology	4	3	4	1		12
Genetics		1		2		3
Total	17	19	50	39	20	146

Studies on fry collection were discontinued when it was more or less decided that the indigenous technology was already highly developed. Also, efficient collection techniques contribute to depletion of fishery resources - billions of larvae and juveniles of other fishes and crustaceans are captured with milkfish but these are killed either incidentally or intentionally. The 1983 conference recommended that the various species that occur with milkfish larvae be used in aquaculture where possible. One study was done to identify these other species (Bagarinao and Taki 1986), but this was not followed up.

ADSEA '87 placed milkfish No. 7 among the priority marine and brackishwater fishes for research by AQD, behind sea bass, grouper, red snapper, golden snapper, mullet, and rabbitfish. The recommendations for milkfish were to (1) refine broodstock management, (2) assess the economics of hatchery systems, (3) develop practical diets for the different life stages or phases of culture, and (4) develop methods of disease prevention and control. Diseases have not been much of a problem in milkfish, but active research was conducted and is continuing in the first three areas (Table 3).

Sometime in the late 1980s, there grew a perception that brackishwater pond culture was responsible in large part for the loss of mangroves (and for social inequities) in the Philippines and thus should not be further expanded or promoted. There was a retreat from pond studies and AQD

closed down its pond culture station in Leganes in 1990. The idea was that AQD should focus on research, such as in seed production and nutrition, that could not be easily done by the private sector, and then conduct pond studies in collaboration with private pond owners or with fisheries schools that have ponds. AQD has successfully carried out some studies with the University of the Philippines in the Visayas and with the Department of Agriculture in Iloilo, but has to strengthen its ties with the local pond operators to be able to implement the research imperatives of ADSEA '91 and '94.

Milkfish was ranked No. 2 priority by ADSEA '91. In addition to those of ADSEA '87, a few more imperatives were added. As abnormalities were found among hatchery-reared milkfish, priority was placed on the refinement of breeding and larval rearing techniques and on the assessment of the performance of hatchery larvae in grow-out systems. Studies on the bioenergetics of milkfish and on the nutrient cycles in ponds were also called for. The Representative of Japan asked AQD to study the population genetics (races and stocks) of milkfish, and the factors affecting recruitment and survival in the wild, sort of a continuation of the ecological research at AQD in the early years. A recent review paper put together the existing information on milkfish genetics and life history (Bagarinao 1994b) and can serve as a springboard for future studies.

Milkfish became No. 1 priority species after ADSEA '94 (see Priorities and Recommendations). Emphasis continues for broodstock development and management, and for hatchery refinement and economic assessment. Feeds and diseases no longer appear on the research agenda, but genetics does. Milkfish pond culture has again become a concern for research, particularly the grow-out of hatchery-bred fish, eradication of snail pests, survey and improvement of culture techniques, bioenergetics and nutrient cycles, and integrated farming. AQD has entered into a Memorandum of Understanding with the University of the Philippines in the Visayas to collaborate on pond studies. Although AQD does not favor conversion of mangrove areas to new ponds, it recognizes that brackishwater pond culture is an important reality in the Philippines, Indonesia, Thailand, and other parts of southeast Asia.

### **Research on Rabbitfishes and Mullet**

AQD studied other herbivorous brackishwater and marine fishes in order to diversify southeast Asian aquaculture. In 1980, trials were made in the spawning and larval rearing of the mullet *Mugil cephalus* at AQD (MN Duray, personal communication). The mullet project did not get off the ground and only one paper ever came out (Baticados and Qunitio 1984). Likewise, AQD started in 1981 a research program on *Siganus* in the wake of Lam's (1972) review and the later studies on rabbitfish biology and culture. Work on spawning and larval development (Avila 1984, Juario et al. 1985, Bagarinao 1986, Duray 1986, Hara et al. 1986a) eventually produced a hatchery technology for *S. guttatus* (Hara et al. 1986b).

Unfortunately, the pond operators in the Philippines are not much interested in rabbitfishes and mullets. It seems that the market for these fishes is limited and there is not much profit incentive to develop the grow-out technology. ADSEA '87 ranked mullet No. 5 and rabbitfish No. 6 priorities among the marine and brackishwater fishes for AQD research. The development of hatchery techniques, feeds, and disease control methods were called for. During 1988-91, AQD continued research on rabbitfish spawning, larval physiology, hatchery techniques,

and feed development (Table 4). AQD maintained broodstocks of *Mugil cephalus* but otherwise did not do any prescribed research on mullet.

Table 4. Number of publications by AQD researchers on various topics concerning rabbitfishes, mullets, sea bass, groupers, snappers.

Species Research topics	Number of papers			Total
	1984-1987	1988-1991	1992-1994	
<b><i>Siganus guttatus</i></b>				
Spawning	2	2	1	5
Hatchery	4	2		6
Larval physiology	5	2	2	9
Feed development		2		2
<b><i>Mugil cephalus</i></b>				
Parasite	1			1
<b><i>Lates calcarifer</i></b>				
Spawning	2	8	1	11
Hatchery		4		4
Larval development	4	1	1	6
Nursery		1	5	6
Nutrient requirements		1		1
Feed development		2		2
<b><i>Epinephelus coioides</i></b>				
Spawning	1		1	2
Sex inversion			2	2
Hatchery		2		2
Grow-out		2		2
Disease			1	1
<b><i>Lutjanus argentimaculatus</i></b>				
Spawning			1	1
Inventory			1	1

Similar research needs were identified during ADSEA '91, but with clear imperatives to develop broodstocks and grow-out culture techniques. Also called for were the inventory, taxonomy, and screening of rabbitfishes and mullets suitable for culture. For rabbitfishes, the following were to be assessed: natural stocks, markets, socioeconomics of the industry, and feasibility of searanching. Only three papers on rabbitfish came out after ADSEA '91. AQD does not have the manpower to address the research gaps in the biology and culture of rabbitfishes and mullets when these are low in priority. Even when AQD acknowledges that it is a good idea to develop the aquaculture of herbivorous fishes, some sort of 'market forces' drive even the type of research that gets undertaken.

Thankfully, the expectations for rabbitfishes and mullets have been scaled down during ADSEA '94 (see Priorities and Recommendations). It remains to be seen whether even these studies could be conducted in the next few years.

### **Studies on Sea Bass, Groupers, and Snappers**

The sea bass *Lates calcarifer*, groupers *Epinephelus* spp., and snappers *Lutjanus* spp. are now increasingly produced by aquaculture throughout most of southeast Asia. Seed production techniques were easily developed for sea bass (NICA 1986) and are in the making for groupers and snappers (Doi et al. 1991, Doi and Singhagraiwan 1993, MN Duray, personal communication). The earliest AQD research on sea bass and grouper were on spawning and larval rearing (Harvey et al. 1985, Bagarinao and Kungvankij 1986, Kungvankij et al. 1986).

ADSEA '87 ranked sea bass, grouper, and red snapper as priority species 1-3. Hatchery techniques, feeds, and disease control were the major needs to be addressed for grouper and snappers, but hatchery techniques were no longer a problem for sea bass. The papers that came out of AQD following ADSEA '87 were mostly on sea bass spawning, hatchery, and feed development; only a few papers were on grouper hatchery and grow-out (Table 4).

Grouper rose to No. 1 priority, snapper No. 3, and sea bass No. 4 after ADSEA '91. Among the recommended studies on groupers and snappers were: (1) inventory and taxonomy, for identification of species suitable for aquaculture, (2) development of broodstock and breeding techniques, (3) culture techniques in the hatchery, nursery, and grow-out, (4) feed development, and (5) health management. Studies on sex inversion among protogynous groupers were also deemed a priority. Sea bass research was to focus on induction of off-season spawning, broodstock management to control sex inversion, feed development, health management, refinement of hatchery, nursery, and grow-out techniques, and on economics and marketing. The papers after ADSEA '91 were on sea bass spawning and nursery; grouper spawning, sex inversion, and disease; and red snapper inventory and spawning (Table 4).

Perhaps the major doubt raised about the development of grouper, snapper, and sea bass culture is the carnivorous nature of these species, and thus the need for 'trash' fish, or fish meal for high-protein diets, for the nursery, grow-out and broodstock phases. This constraint is more serious for less developed countries such as the Philippines where there is no such thing as 'trash' fish and even small fish are eaten by people living along the coasts. Because culture of these species is capital-intensive, it can only be done by a few moneyed concerns and the profits accrue only to a few. Still, cage culture of these species is well established in most of southeast Asia and AQD is mandated to address the research needs.

ADSEA '94 recommends research on broodstock development and breeding, hatchery rearing, grow-out culture, feed development, and health management for grouper, snapper, and seabass, in that order. AQD will focus mostly on the seed production of groupers and snappers during the next few years.

### **Research on Tilapias**

The aquaculture of Nile tilapia, particularly intensive cage culture with feeding, quickly became established in southeast Asia during the 1980s. AQD established its freshwater aquaculture

station in Binangonan in Laguna de Bay in 1978 and the earliest research were on tilapia breeding (Annual Reports 1978 to 1980) and feeding and nutrition (Pantastico and Baldia 1979, Santiago et al. 1982). More papers mostly on cage culture and nutrition and feeds came out between 1982 and 1987 (Table 5). ADSEA '87 placed red tilapia as No. 1 priority and other tilapias as No. 4 among freshwater Fishes for AQD research. The recommended studies were to select strains, refine hatchery techniques, and develop feeds for nursery and grow-out. The papers that came out in 1988-1991 answered these imperatives but for Nile tilapia (Table 5).

Table 5. The number of publications by AQD researchers on various research topics concerning tilapia, bighead carp, and catfish. The Binangonan Freshwater Station of SEAFDEC AQD was established in 1978.

Species	Number of papers				Total
Research topics	1979-1983	1984-1987	1988-1991	1992-1994	
<i>Oreochromis niloticus</i>					
Genetics		2	3	2	7
Hatchery	1	1	3		5
Grow-out		5	3		8
Nutrient requirements	2		2	2	6
Feeding	2	3	4	1	10
Salinity tolerance				2	2
Diseases		3			3
Pollution				3	3
<i>O. mossambicus</i>					
Feeding	1				1
Chemical use			1		1
<b>Red tilapia</b>					
Feeding			1		1
<i>Aristichthys nobilis</i>					
Spawning			4		4
Hatchery		2	4		6
Nutrient requirements			2		2
<i>Clarias macrocephalus</i>					
Spawning			1	2	3
Hatchery			1		1

Nile tilapia became top priority and red tilapia No. 4 after ADSEA '91. Selective breeding was considered important for both, but concern also arose about the ecological effects of new strains. As intensive cage culture and feeding caused eutrophication and fish kills in lakes, there came calls to improve feeding techniques and management, and to develop or verify tilapia culture techniques in brackish and marine waters. The papers that came out after ADSEA '91 were



on strain comparisons, broodstock nutrition, and the effect of tilapia culture on the environment (Table 5).

The ADSEA '94 priorities for tilapia research are mostly the same as before but studies on bioenergetics, health management, and sustainability of culture have also been recommended. Tilapia culture contributes considerably to the fish supply, and ways must be found to make it compatible with the environment and with other water uses.

### Research on Carps and Catfishes

Carp studies at AQD began with supplemental feeding of the rohu *Labeo rohita* and common carp *Cyprinus carpio* and on spawning and culture of bighead carp *Aristichthys nobilis* and silver carp *Hypophthalmichthys molitrix* (Annual Reports 1979 to 1985, Pantastico et al. 1986, Tabbu et al. 1986). Carps were first spawned by AQD researchers in Laguna de Bay in 1983 and the juveniles were made available to fishpen and cage operators in the lake (Fermin 1988). By 1987, there were about 16 private carp hatcheries around Laguna de Bay.

ADSEA '87 considered carps (grass carp) as No. 5 priority among freshwater fishes and called for refinement of hatchery techniques. Ten AQD papers in 1988-91 were concerned with spawning, hatchery, and nutrition of bighead (Table 5). ADSEA '91 and '94 called for more studies on bighead carp: broodstock management, genetic improvement, feed development, and disease control. More research on bighead carp have yet to be finished.

ADSEA '87 ranked catfish as No. 3 priority for research; the needs were for refined hatchery techniques, feeds for nursery and grow-out, and selected breeds. A research program on the native catfish *Clarias macrocephalus* was started and papers on spawning and hatchery techniques have already come out (Table 5). ADSEA '91 and '94 considered catfish No. 2 priority and echoed the earlier recommendations, together with the development of grow-out culture techniques and genetic characterization of *C. macrocephalus*.

In addition, there has been a lot of concern about the ecological effects of the introduction and rapid establishment of the African catfish *C. gariepinus* in the Philippines. SEAFDEC AQD is expected to study and monitor these effects.

### Research on Mollusks

Mollusk research at AQD started early under the Seafarming Program and 46 studies were proposed between 1975 and 1982 (Lacanilao 1983). Many of these studies were described in the Annual Reports 1977 to 1985, but only 10 publications came out between 1978 and 1987 (Table 6), starting with Yap (1978) and Young (1980).

ADSEA '87 considered the mussel *Perna viridis*, slipper oyster *Crassostrea iredalei*, cockle *Anadara* spp., and the windowpane oyster *Placuna placenta* as top priorities for research. The R&D needed for these species were similar: resource assessment, spatfall forecast, evaluation and refinement of grow-out techniques, transplantation, depuration, product development, and hatchery techniques. ADSEA '91 produced an even more ambitious list of research topics for priority mollusks (ten species). Between 1988 and 1994, socioeconomic studies on oyster and

mussel farming were conducted, mussels were tested as biofilter in shrimp ponds, and the windowpane oyster and the donkey-ear abalone *Haliotis asinina* were spawned in the laboratory. Otherwise, AQD researchers were focused on fishes and shrimps.

The abalone has been placed top priority by ADSEA '94. Resource assessment, refinement of hatchery techniques, and development of grow-out techniques are called for. Indeed, AQD should shift more effort into mollusk research as mollusk mariculture can be profitably carried out by small-scale fishermen and has less adverse effects on the environment.

Table 6. The number of publications by AQD researchers on topics concerning mollusks and seaweeds.

Species Research topics	Number of papers				Total
	1978- 1983	1984- 1987	1988- 1991	1992- 1994	
<b><i>Perna viridis</i></b>					
<b><i>Modiolus metcalfei</i></b>					
Fanning			1		1
Biology	1	1			2
Depuration		1			1
Red tide		1			1
<b><i>Crassostrea iredalei</i></b>					
Fanning		1			1
Biology		2			2
Sanitation		2	1		3
<b><i>Placuna placenta</i></b>					
Biology	1				1
Broodstock				2	2
<b><i>Haliotis asinina</i></b>					
Spawning				1	1
<b><i>Gracilaria</i></b>					
Biology				1	1
Natural stocks			1	2	3
Farming			1	2	3
Agar				7	7
Disease				1	1
<b><i>Kappaphycus</i></b>					
Fanning				2	2

## Research on Seaweeds

AQD set up a Mollusk and Seaweed Program in 1983 but few studies were initiated. Seaweeds (*Gracilaria*, *Porphyra*, and *Eucheuma*) were recommended for research by ADSEA '87, and AQD responded by promptly organizing a seaweed team. ADSEA '91 placed *Eucheuma* and *Gracilaria* as the top two of five priority species. Most AQD research was on *Gracilaria* farming and agar characterization (Table 6). This focus is correct because the *Gracilaria* industry is still undeveloped and agar is more versatile and potentially more profitable than carageenan from *Eucheuma*. ADSEA '94 called for more studies on *Gracilaria* and *Kappaphycus* (see Priorities and Recommendations).

## Research on 'Non-Commodities'

Table 7 shows the number of AQD publications about non-commodity topics and those that bear on environmental issues. Many studies on the limnology, biology, and socioeconomics of Laguna de Bay and other lakes in the Philippines were described in Annual Reports 1977 to 1982, and others on aquaculture engineering in Annual Reports 1980 and 1982. AQD has the potential to carry out more studies of the environmental type: biodiversity conservation, pollution, socioeconomics, and sustainable culture techniques. Environmental studies in aquaculture were not officially recommended by ADSEA '87 and ADSEA '91, but a few such studies were carried out by AQD (e.g., Cuvin-Aralar 1990, Santiago and Arcilla 1993). ADSEA '94 recommended many such studies, but it remains for the AQD researchers to include environmental concepts in their mainstream (breed, seed, feed, diseases, production) studies.

Table 7. Number of publications of AQD researchers on 'non-commodity' topics.

Research topics	Number of papers				Total
	1976-1980	1981-1987	1988-1991	1992-1994	
Taxonomy	6	6		1	13
Fishing gears	1	2			3
Natural food	1	4	6	1	12
Aquaculture engineering		8			8
Mangroves		1	1	3	5
Polyculture		5	2		7
Red tide		3			3
Epizootic ulcerative syndrome		1		1	2
Laguna de Bay		1	1	1	3
Heavy metals			5	3	8
Algae in wastewater		2			2
Socioeconomics				2	2

## AQD's Contribution to Aquaculture Development

AQD has filled some of the information gaps in southeast Asian aquaculture, as shown in the previous section, but still has to address many more. AQD's major contributions so far have been the technologies for tiger shrimp seed production, grow-out culture, feeds, and disease diagnosis; milkfish seed production and feeds; rabbitfish seed production; and tilapia feeds. In recent years, the advances AQD made in milkfish seed production have apparently been overtaken by Taiwan and Indonesia, which both now have well established milkfish hatcheries run by the private sector (Liao 1993, Ahmad 1993, S Kumagai, personal communication).

AQD's training program has been going since 1974 and has produced a large number of technical personnel who have gone into the aquaculture business by themselves or have helped direct further aquaculture R&D by their governments (Primavera 1988, Villegas et al. 1993, Villegas 1995). AQD has also developed its own research manpower over the years, having sent most of its staff for graduate studies. These new Ph.D. holders have taken over the AQD research leadership from the pioneer administrators.

### AQD in Context

AQD's research accomplishments must be viewed in context, in relation to the development of aquaculture in southeast Asia and Japan. AQD was established in 1973, quite recently by many standards. Brackishwater pond culture in the Philippines and Indonesia started probably four centuries ago, mariculture in Japan about ten centuries ago, and freshwater fish culture in China as early as 3,000 years ago (Herre and Mendoza 1929, Lin et al. 1980, Davy 1991). Earlier developments were slow and unsystematic; most advances were made during the last century and particularly after the Second World War. Most other countries in Asia also have had some form of aquaculture for a long time. For example, Malaysia started carp culture in mining pools in the 1900s, shrimp culture in ponds in the mid-1930s, and cockle culture in 1948 (Liong et al. 1988). In Thailand, sea bass has been produced from ponds for 50 years and has been artificially propagated in hatcheries and cultured in cages since 1973 (Sirikul et al. 1988). Years before the ADSEA '87 seminar-workshop recommended them for AQD research, grow-out culture systems for *Epinephelus*, *Lutjanus*, *Macrobrachium*, *Clarias*, and *Oxyeleotris* (marble goby) were already established in Thailand, Malaysia, and Singapore (Sirikul et al. 1988, Liong et al. 1988, Cheong 1988) and for the seaweed *Eucheuma* in the Philippines (Camacho and Macalinlag-Lagua 1988).

AQD's role in aquaculture research and development has been shared by many R&D organizations, including government agencies, universities, the International Center for Living Aquatic Resources Management, the Asian Institute of Technology, and the Network of Aquaculture Centres in Asia-Pacific. The governments and universities of most Asian countries have undertaken research to solve the technical constraints in their own aquaculture sectors. Aquaculture research has been going a long time in Japan as well as in the other Asian tiger economies (Davy 1991, Lee et al. 1993, Chou 1994).

### The Communication Gap

Through the ADSEA seminar-workshops and other meetings, as well as its newsletters, extension manuals, and other publications, AQD has dutifully disseminated aquaculture

information (Villegas 1995). But there seems to be gaps between what is written, what is understood, and what is transferred and used. One 'problem' may be that AQD researchers write and lecture in English, whereas the foreign trainees, the farmers, and the other users of information are not all well versed in this language. Another may be that AQD produces extension materials based on research results, but otherwise does not have a strong hand in the on-site extension of technology, believing this to be more the function of government line agencies.

An unmistakable communication gap exists even among the participants of ADSEA. During each ADSEA, AQD researchers reviewed the advances in the biology and culture of various species. However, none of the country representatives (except those from the Philippines) related these advances (or the lack thereof) to their needs, at least not in the country papers they wrote for the three ADSEA proceedings. In addition, none of the country representatives in later ADSEAs referred to their own compatriots' country papers in earlier ADSEAs. It is as if the country representatives did not make any connection with each other, nor with the AQD researchers. There may be various reasons for this communication gap but the result is unfortunate: incomplete feedback. AQD researchers do their best to address the problems as identified by the country representatives. But the country representatives do not indicate whether their problems have been sufficiently addressed by AQD, and whether or not their research needs have actually changed from one representative to the next (or from one ADSEA to another). Obviously, the connection must be made if both AQD and the SEAFDEC Member Countries are to realize fully the goals of the ADSEA meetings, as well as AQD's mandates.

A clear example of this communication gap within the ADSEA experience is what happened to the overview papers of Rabanal (1988, 1994). In his ADSEA '87 paper, Rabanal (1988) discussed in many paragraphs the production constraints and the prospects for growth and expansion of the aquaculture industry in southeast Asia. But the official ADSEA '87 recommendations hardly reflected these constraints; Juario and Benitez (1988) published a list of recommendations in outline form — in phrases with mere keywords and without enough context — such that the recommendations probably meant slightly different directions to different researchers. Unfortunately, this outline was probably what AQD researchers consulted when they chose their research topics for the years that followed. The same constraints and others were identified again by Rabanal (1994) and again not reflected in the (unpublished) official ADSEA '91 recommendations. Similar constraints in shrimp and carp culture have still been noted by Kutty (1995) during ADSEA'94.

The communication gap is otherwise much reduced between AQD researchers and the Philippine representatives, for obvious reasons. The proximity allows the government agencies (Department of Agriculture and Department of Science and Technology), the academe (including the University of the Philippines), and the private sector in the Philippines to pick up new findings from, and report new problems to, AQD both during the ADSEA seminar-workshops and especially during the local yearly round-table discussions. These yearly discussions invite feedback and suggestions from the industry practitioners, but are often prefaced with the caveat that what AQD can do for the Philippines is limited by what has already been programmed for southeast Asia based on the previous ADSEA.

## **The Redirection of AQD**

The Aquaculture Department of the Southeast Asian Fisheries Development Center now faces the challenge of generating innovations in aquaculture that will assure a reliable supply of animal protein, and at the same time protect the environment and improve the quality of life of marginalized farmers and fishermen. Like many other organizations worldwide, SEAFDEC AQD was a product of its time and has evolved with the changes of the times. AQD started out as a production-oriented development organization and, in response to the realities and needs of the 1990s, has turned into a research and development institution concerned with the environment and committed to sustainable aquaculture and sustainable development.

Historically, this transformation at AQD was marked by the assumption of the Office of the Chief by Dr. Flor Lacanilao in 1981-1982 and 1986-1992. He infused AQD with his ideas of aquaculture development that is environment-friendly and socially equitable, and of aquaculture research that passes peer review at the level of the international scientific community. AQD is set on continuing in this direction.

### **Recommendations for Aquaculture and the Environment**

During ADSEA '87, Camacho and Macalinlag-Lagua (1988) recommended research on 13 topics, which were general enough to apply to southeast Asia, were well grounded in sound aquaculture (and ecological) principles, and already pointed the way towards sustainable aquaculture, even without any reference to the buzzwords from the 1987 Brundtland Report. AQD has addressed about half the recommendations (on breeding and seed production, nutrition and feed development, and disease control). But the following research needs have been mostly overlooked: grow-out technologies (aside from feeds); post-harvest handling, processing, and marketing; maintenance of environmental quality at culture sites; and stock assessment of fishery resources to complement fish dispersal activities.

Calls for environmental studies were made by the country representatives during ADSEA '87. Pollution in Johore Strait and acid sulfate soils in shrimps ponds were the problems in Malaysia (Liong et al. 1988). Singapore also reported poor water quality and plankton build-up in ponds, and water stagnation and oxygen deficiency in cage farming sites (Cheong 1988). In the Philippines, the pollution and use conflicts in Laguna de Bay made headlines, and mollusk culture suffered from environmental deterioration (red tides), displacement by housing and industry, and inadequate sanitation (Camacho and Macalinlag-Lagua 1988). Among the aquaculture problems in Japan were: (1) pollution due to use of 'trash' fish as feed, (2) red tides that badly affected yellowtail culture, (3) predators, fouling animals, oxygen deficiency, and slow growth of mollusks in culture grounds, and (4) conservation of suitable farming grounds (Mito and Fukuhara 1988).

### **Seafarming and Searanching**

The 1991 ADSEA seminar-workshop was convened specifically to examine the prospects for Seafarming (or mariculture) and searanching in southeast Asia and Japan. The idea was that aquaculture development should move in the direction of the open seas as inland and nearshore waters have become polluted or subject to conflicting claims and uses. Of course, Japan is already way ahead in both Seafarming and searanching (Umezawa 1988) but Thailand, Singapore, and Malaysia also have well developed mariculture (Sungkasem and Tookwinas 1994, Chou 1994,

Kechik 1995). Mariculture in the Philippines produces seaweeds and mollusks on a commercial scale, and marine fish culture in cages is mostly experimental or small-scale (Delmendo 1994). Recently, milkfish pens have been set up in shallow waters in Cavite inside Manila Bay (EEC Flores, personal observation); this new development may reduce the controversial pen culture operations in the much-abused freshwater lake, Laguna de Bay.

A consensus has not been reached regarding Seafarming as a solution to some of the environmental problems of and from aquaculture. The environment-aquaculture issue is very complicated and Seafarming and searanching may themselves cause some ecological problems (Munro 1994). Sustainable development of Seafarming and searanching calls for careful planning, and investments must take into account environmental, biotechnological, and socioeconomic considerations (Chong 1994). After ADSEA '91 (and even before), some AQD research shifted towards the development of Seafarming and searanching. AQD in collaboration with the International Development Research Centre (Canada) launched in 1991 what came to be called the Community Fishery Resources Management Project. This Project included in the proposal the Seafarming of seaweeds, mollusks, and fishes, and the searanching of snappers and other reef fishes at Malalison Island (Agbayani 1995).

### **Sustainable and Responsible Aquaculture**

The theme for ADSEA '94 was "Sustainable Aquaculture Development" and everybody seemed to have joined the bandwagon. But the reality seems to be that 'the right hand does not know what the left hand is doing.' Of course, the private sector always has pushed and will push for aquaculture development that turns a profit. But even the public sector, the academe, and AQD itself are not internally consistent about which R&D contributes to sustainable aquaculture. For example, the propagation and monoculture of a 'super strain' of fish increases the risk of total crop failure in case some 'super disease' strikes. Also, the culture of highly priced carnivorous fishes that require 'trash' fish or fish meal can not be easily justified nor considered sustainable. Such inconsistencies and the inertia involved in the redirection of R&D attest to the very real difficulties with the implementation of sustainable aquaculture.

Strategies for R&D for sustainable aquaculture were discussed during ADSEA '94. The principles of sustainability must be incorporated in all phases of the R&D, from planning to monitoring, to reporting. Sustainability issues must guide feed development and feeding management, the use of drugs and agro-chemicals, and the development of culture techniques for chosen species. Research must also address cross-commodity, multidisciplinary and multisectoral problems such as socioeconomics, marketing, equity, legislation, and policy. Research, training, and development institutions at different levels must strengthen collaborations, but divide the work and minimize duplication, to accomplish projects and solve problems more efficiently. Technology packages for small farmers, especially on environmentally compatible culture techniques, must be developed by AQD. AQD was asked to strengthen its role as extension agents of improved technologies, e.g., by continuing to provide resource persons for the extension programs of the Philippines' Bureau of Fisheries and Aquatic Resources. Information dissemination for aquaculture practitioners and the general public must be improved to promote a balanced public opinion, and must include environment education related to sustainable aquaculture.

Csavas (1995) recommends some FAO guidelines for countries and research institutions to take to achieve sustainable and responsible aquaculture. We strongly urge that these recommendations (pages 10-11) be seriously considered when planning, implementing, and managing aquaculture R&D or enterprises.

## Conclusion

In the future, AQD's regular meetings with representatives of the aquaculture sectors in southeast Asia must work at better communication and two-way feedback. These extramural consultations must be followed (or preceded) by intramural discussions not only of research results, but of concepts and new directions. AQD must continue to shift some of its resources to more research in sustainable farming systems and environmental problems in aquaculture.

This review paper and the ADSEA '94 proceedings add more to the voluminous stacks already published by national and international organizations on research directions, priorities, coordination, collaboration, and information dissemination in aquaculture development, which now highlight environmental concerns, social equity, and gender issues. Aquaculture and fisheries gatherings in the future should not merely echo what had been said and written before, but really work on concrete measures to address the issues and concerns already raised. Large congresses, such as the Asian Fisheries Forum held every three years, often hold small-group workshops or symposia. These groups can be directed to work on specific issues and come up with concrete action programs to be implemented by specified organizations. Such action programs are a better output of meetings than printed proceedings!

AQD will encourage and organize small-group meetings of aquaculture scientists, practitioners, and government representatives to tackle specific problems and implement specific solutions. A small meeting in November 1995 is being organized by SEAFDEC AQD and the Food and Agriculture Organization to address the problem of chemical abuse in aquaculture.

Let us all stop talking and start concretizing sustainable and responsible aquaculture. The next ADSEA should, hopefully, be an occasion for comparing success stories.

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# ADSEA '94 Priorities and Recommendations

## Marine and Brackishwater Fishes

### 1. Milkfish *Chanos chanos*

- Refinement of broodstock management through nutrition and manipulation of age stocks
- Induction of maturation and spawning through hormonal control of puberty and photoperiod manipulation
- Refinement of hatchery techniques for high larval survival
- Elimination of deformities in hatchery-produced larvae
- Verification and economic assessment of hatchery and nursery techniques transferred to private cooperators
- Improvement of brackishwater pond culture
- Survey of pond culture practices in relation to production
- Integrated fanning of milkfish
- Studies in bioenergetic and nutrient cycles in brackishwater ponds and freshwater pens
- Development of biodegradable molluscicides for brackishwater ponds
- International collaboration for adaptation and transfer of hatchery and grow-out techniques
- Genetic studies

### 2. Grouper *Epinephelus coioides*

- Refinement of broodstock management and breeding techniques
- Studies on reproductive biology and endocrinology
- Improvement of hatchery and nursery techniques with alternative live food and water management
- Studies on sources of wild seed
- Improvement of holding and transport techniques for wild juveniles
- Determination of nutrient requirements
- Development of feeds for nursery and grow-out
- Health management
- Documentation and improvement of existing culture techniques
- Economics of monoculture and polyculture

### 3. Mangrove red snapper *Lutjanus argentimaculatus*

- Refinement of broodstock management and breeding techniques
- Refinement of hatchery rearing techniques
- Development of nursery and grow-out culture techniques
- Feed development

### 4. Asian sea bass *Lates calcarifer*

- Broodstock management to control inbreeding
- Development of artificial feeds

- Health management
- Refinement of polyculture system with tilapia
- Socioeconomic studies for market and product development

**5. Rabbitfish *Siganus guttatus***

- Refinement of broodstock management
- Feasibility studies for searanching
- Market study and socioeconomic assessment of existing industry
- Cage culture as alternative livelihood
- Collation of traditional knowledge on rabbitfish biology, fishery, and culture

**6. Striped mullet *Mugil cephalus***

- Broodstock development
- Adoption and refinement of hatchery techniques
- Development of grow-out culture techniques

**7. Marine ornamental fishes**

- Development of breeding techniques
- Improvement of techniques for capture, holding and transport of wild fish

**Freshwater Fishes**

**1. Tilapias (Nile, red, others )**

- Selective breeding
- Synchronization of spawning
- Refinement of hatchery management
- Methods for quality assessment of juveniles
- Improvement of feeding practices
- Bioenergetics studies
- Sustainable grow-out culture systems
- Control of ectoparasite infestations

**2. Native catfish *Clarias macrocephalus***

- Refinement of induced maturation and spawning
- Studies on reproductive biology and endocrinology
- Refinement of hatchery and nursery techniques
- Feed development for nursery and grow-out
- Development of grow-out culture techniques
- Genetics of *Clarias macrocephalus*
- Ecological impacts of the introduced Thai and African catfishes

**3. Bighead carp *Aristichthys nobilis***

- Broodstock management and genetic improvement
- Feed development for broodstock and juveniles

**Crustaceans**

**1. Tiger shrimp *Penaeus monodon***

- Restocking of juveniles in suitable areas
- Development of pond-reared broodstock
- Improvement of larval quality through nutrition
- Genetic characterization of local strains
- Impact of pond culture on the environment
- Quantification of pond degradation through soil quality analysis
- Characterization of successful ponds
- Aqua-silviculture for rehabilitation of abandoned ponds
- Substitution of fish meal in shrimp feeds
- Improvement of feeds and feeding methods
- Collation of data on pesticides, antibiotics and other chemicals in shrimp culture
- Efficacy tests for vaccines and immunostimulants
- Health management
- Studies on the sustainability, constraints, social equity, and other implications of the Comprehensive Agrarian Reform Program

**2. Mudcrab *Scylla serrata***

- Development of broodstock and hatchery techniques
- Development of grow-out culture techniques (polyculture, culture in mangrove areas, feeding)

**3. *Penaeus indicus*, *P. merguensis*, *Metapenaeus* spp.**

- Improvement of grow-out culture techniques

**Mollusks**

**1. Abalone *Haliotis asinina***

- Resource assessment
- Refinement of spawning and hatchery techniques
- Development of grow-out culture techniques

**2. Window-pane oyster *Placuna placenta***

- Spatfall forecasting
- Development of hatchery techniques

- Development of grow-out techniques
- Transplantation or stocking in depleted areas
- Product development

**3. Oysters *Crassostrea* spp.**

- Spatfall forecasting
- Evaluation and refinement of culture technology
- Transplantation and transfer of culture technology
- Product development

**4. Green mussel *Perna viridis***

- Use as biofilter in semi-intensive and intensive shrimp ponds

**Seaweeds**

**1. *Gracilaria* spp.**

- Inventory of *Gracilaria* species and selection of highly productive cultivars with high-quality agar
- Development of hatchery technology
- Genetics and creation of seedbank
- Monoculture and polyculture in ponds
- Use as biofilter in semi-intensive and intensive shrimp ponds
- Product utilization, e.g., as feed ingredient
- Village-level processing of semi-refined agar
- Socioeconomic studies in seaweed-dependent communities

**2. *Kappaphycus alvarezii***

- Genetic studies for strain selection
- Economics of the raft culture method (vertical and horizontal lines)
- Development of seed production technology
- Identification of suitable farming areas
- Follow-up studies on "ice-ice" phenomenon
- Village-level processing for semi-refined carageenan

**Community Fishery Resources Management**

- Integrated seafarming: seaweeds, abalone, siganids, snappers
- Monitoring of artificial reefs and fish sanctuary
- Biological assessment of marine resources in Malalison
- Socioeconomic studies: resource use conflicts, costs and benefits, decision criteria
- Institutional arrangements and policy studies





