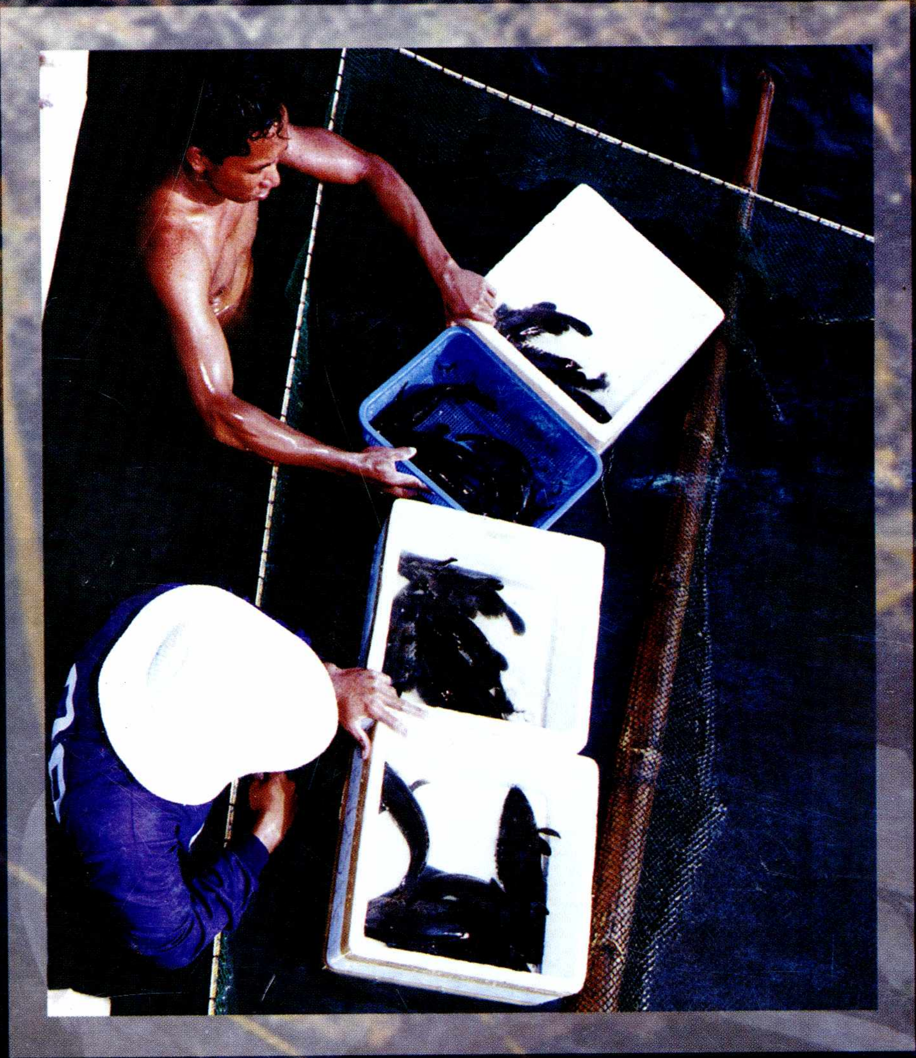
Responsible Aquaculture Development in Southeast Asia

Edited by Luis Maria B. Garcia



SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
AQUACULTURE DEPARTMENT

Responsible Aquaculture Development in Southeast Asia

Proceedings of the Seminar-Workshop on
Aquaculture Development in Southeast Asia
organized by the
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Luis Maria B. Garcia
Editor

SOUTHEAST ASIAN FISHERIES DEVELOPMENT CENTER
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On the Cover:
Harvest of pond-reared grouper

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FOREWORD

Globally, aquaculture development has been recently recognized as the fastest growing food-producing sector, contributing significantly to national economic development, global food supply and food security. This trend has been very apparent in Southeast Asia where fish is a staple in the people's diet. Increasing aquaculture production in the region appears to bridge the shortfall relative to the demand for fishery products that capture fisheries can, at present, no longer fulfill. However, this scenario of increased production did not materialize without a consequent trade-off impacting on environmental integrity, socioeconomic development and viability, and technological efficiency that ensure the sustainability of fish production.

The SEAFDEC Aquaculture Department has been aware of this scenario in the formulation of its three-year plans for research and development during the tri-annual Seminar-Workshop on Aquaculture Development in Southeast Asia (or ADSEA). The theme for ADSEA '99, "Responsible Aquaculture Development in Southeast Asia", is therefore timely. It comes at a time when SEAFDEC has adopted a new Strategic Plan, which adopts a regional approach in the formulation of programs of work in all its Departments. More importantly, since ADSEA '99 addresses responsible aquaculture development in the region, the results of this seminar-workshop could certainly serve as important inputs for the establishment of regional technical guidelines for implementing the global Code of Conduct for Responsible Fisheries, a major task that SEAFDEC is currently undertaking.

ADSEA '99 invited practitioners of aquaculture research and development in the region to define the status of technologies as these apply to major aquaculture systems. Researchers of the Aquaculture Department then presented an update of their aquaculture commodity-directed research, training, and extension activities since 1995. Together with the participation of representatives from the industry, the academe, government and non-government organizations, the workshops that followed identified and discussed issues and strategies relevant to aquaculture research and development in the region. The outputs of ADSEA '99 guided the Aquaculture Department in awarding priorities in its three-year research, training, and extension activities beginning in 2000. This volume documents the proceedings and the outputs of ADSEA '99. Hopefully, the contributions documented herein will translate to our common goal of attaining responsible food production and security through sustainable aquaculture.

Rolando R. Platon
Chief, Aquaculture Department
SEAFDEC

Panu Tavarutmaneegul
SEAFDEC Secretary-General

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BACKGROUND OF THE SEMINAR-WORKSHOP

The Seminar-Workshop on Aquaculture Development in Southeast Asia (ADSEA) is a series conducted every three years for the formulation of the three-year research and development plan of the SEAFDEC Aquaculture Department. It was conceived as a forum to assess the contribution of the Department to the development of aquaculture in the region. ADSEA was convened in 1987, 1991, and 1994. In 1997, in lieu of the regular seminar-workshop, a survey of aquaculture research and training needs was conducted and the result was the basis for the 1998-2000 research and training program of the Department. This seminar-workshop (ADSEA '99) reviewed the recent developments in aquaculture and provided a forum to discuss strategies to ensure further development of responsible aquaculture in the region. Specifically, ADSEA '99 1) assessed the progress and development of aquaculture technologies in the region, and research and development in the Department since 1995; 2) reviewed recent advances in sustainable and responsible aquaculture elsewhere in the world; and 3) identified strategies for sustainable and responsible aquaculture in the region. The contributions of selected participants during ADSEA '99 appear in this present volume.

ACKNOWLEDGEMENTS

The Governments of the Philippines and Japan provided financial support for the conduct of the Seminar-Workshop on Responsible Aquaculture Development in Southeast Asia (ADSEA '99). Led by the Organizing Committee Chairperson, Dr. Rolando Platon, and the Scientific Program Committee Chairperson, Dr. Clarissa L. Marte, the various working committees of ADSEA '99 spent a significant number of man-hours in planning the plenary and workshops sessions. All the participants and guests shared their experience and expertise to enliven the discussions, which eventually provided the material for formulating prioritized and specific areas for research and training to be undertaken by the SEAFDEC Aquaculture Department in the next three years. Mr. Augusto Surtida and the staff of the Training and Information Division prepared the layout of these proceedings.

Responsible Aquaculture Development for the Next Millennium

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Abstract

With the world population doubling in size from 3 to 6 billion people from 1960 to 1999 and currently growing at 1.33% per year (or an annual net addition of 78 million people), and expected to reach 7.3 to 10.7 billion by 2050 (with 8.9 billion considered most likely), there are growing doubts as to the long term sustainability of many traditional agricultural food production systems in being able to meet the increasing global demand for food. Nowhere is this more critical than within many of the world's developing countries, and in particular within those Low-income Food-deficit countries (LIFDC; currently representing over 62% of the world's population), which are net importers of food and lack sufficient earnings to purchase food to cover their basic dietary needs. Of the multitude of agricultural food production systems, aquaculture is widely viewed as being an important potential candidate capable of contributing to reductions in the shortfall in the terrestrial food basket. Aquaculture, the farming of aquatic plants and animals, has been the fastest growing food production sector for over a decade. Total global production from aquaculture more than tripled from 10 million metric tons (mmt) in 1984 to over 36 mmt in 1997, and production grew at an average compound rate of 11% per year since 1984. In contrast to traditional livestock food production systems, the bulk of global aquaculture is realised within developing countries (89.6% total) and LIFDCs (80.6% total).

Despite its good prospects and apparent potential for continued growth, the aquaculture sector has not been without its problems and critics. In particular, there have been concerns raised related to deficiencies in existing aquaculture legislation and planning methods, the use of certain farming practices, issues of resource use efficiency, disease treatment and control, environmental degradation, social welfare, and employment opportunities, etc. Although the majority of these are not unique to the aquaculture sector, it is imperative that these issues be addressed and resolved if the sector is to emerge into a major global food production sector in the next millennium.

In addition, the present paper reviews the origins and salient features of the FAO Code of Conduct for Responsible Fisheries (CCRF), and in particular of Article 9 of CCRF concerning aquaculture development. An overview is also presented of ongoing and planned initiatives concerning the implementation of the code. In particular, the paper attempts to consider the existing socioeconomic conditions of the majority of aquaculture producing countries within the Asian region, and the real basic need of identifying affordable and practical solutions to aid the development of the sector. Particular emphasis is placed on the need of government to provide an enabling economic and legislative environment and umbrella for the *sustainable* and *responsible* development of the sector, and the need for increased collaboration between the private and public sector organizations, and government engaged in all stages of the aquaculture development process.

Introduction

With the world population doubling from 3 billion people in 1960 to 6 billion in 1999, and currently growing at 1.33% per year (or an annual net addition of 78 million people), and expected to reach 7.3 to 10.7 billion by 2050 (with 8.9 billion considered most likely; UN Population Information Network, 1998 Revision of the World Population Estimates and Projections, http://www.popin.org/pop l998), there are growing concerns on the ability of many countries to meet their basic dietary needs. This is particularly so within many of the world's developing countries, and in particular within those Low-income Food-deficit countries (LIFDCs[1]; currently representing over 62% of the world's population; Table 1) which are net importers of food. In many cases, particularly in Africa, these countries cannot produce enough food to meet all their needs and lack sufficient foreign exchange to fill the gap by purchasing food on the international market. Unless concerted action is taken, the situation could deteriorate for many LIFDC's, where population growth is projected to outstrip gains in food production. In addition, the liberalization of the grain trade, under the Uruguay Round Agreement, is likely to increase food prices in the short term (FAO, 1999a).

Food Security, Malnutrition, and Poverty

For the purposes of this paper 'food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food

Table 1. **List of of Low-income Food Deficit Countries (LIFDCs) as of May 1998**

Afghanistan	Albania	Angola	Armenia
Azerbaijan	Bangladesh	Benin	Bhutan
Bolivia	Bosnia Herzegovina	Burkina Faso	Burundi
Cambodia	Cameroon	Cape Verde	Central African Republic
Chad	China	Comoros	Congo Dem Republic
Congo Republic	Cote d'Ivoire	Cuba	Djibouti
Ecuador	Egypt	Equatorial Guinea	Eritrea
Ethiopia	Ethiopia PDR	Gambia	Georgia
Ghana	Guatemala	Guinea	Guinea Bissau
Haiti	Honduras	India	Indonesia
Kenya	Kiribati	Korea DPR	Kyrgyzstan
Laos	Lesotho	Liberia	Macedonia
Madagascar	Malawi	Maldives	Mali
Mauitania	Mongolia	Morocco	Mozambique
Nepal	Nicaragua	Niger	Nigeria
Pakistan	Papua New Guinea	Philippines	Rwanda
Samoa	Sao Tome Pm	Senegal	Sierra Leone
Solomon Islands	Somalia	Sri Lanka	Sudan
Swaziland	Syria	Tajikistan	Tanzania
Togo	Tokelau	Turkmenistan	Tuvalu
Uzbekistan	Vanuatu	Yemen	Zambia

[1] Low-income Food-deficit countries, currently defined by FAO as nations that are 1) poor, with a net income per person that falls below the level used by the World Bank to determine eligibility for IDA assistance, which at present means that their net income amounts to less than US$1,505 per person, and 2) are net importers of food, with imports of basic foodstuffs outweighing exports over the past three years.

preferences for an active and healthy life' (World Food Summit, 1996). However, in the context of food security, it is also important to realize within individual countries and households that food is not always equally distributed. It follows, therefore, that to ensure nutritional well-being, every individual must have access at all times to sufficient supplies of a variety of safe, good quality foods. According to FAO (1999b), there are 790 million chronically undernourished people in the developing world who do not have sufficient food to eat (this being equivalent to more than the combined populations of North America and Europe). Moreover, it is also generally recognized that in those societies at peace, that poverty and marginalization are the root causes of hunger. Chronic food insecurity is the most prevalent in very poor countries whose populations are predominantly rural and largely dependent on agriculture for a living. In this context, it is important to remember that developing countries currently account for 4.4 billion of the total world's population of which one-third survive on less than US$ 1 a day (FAO, 1999b)

Overview of Global Aquaculture Production and Food supply

Of the different agricultural food production systems, aquaculture (the farming of aquatic plants and animals) is widely viewed as being an important domestic provider of much needed high quality animal protein and other essential nutrients (including n-3 fatty acids, vitamins, minerals and energy), particularly within China and many other Asian countries. Moreover, within many countries, aquaculture is also seen as an important provider of cash income and valuable foreign exchange earnings through the production of higher value cash crops for export, such as marine shrimp (Thailand, Ecuador, China), salmonids (Norway, Chile), eels (China, European Union or EU), carnivorous marine fish (China, Greece, Malaysia), turtles (China), molluscs (China, EU), and seaweeds (China, Philippines). In view of these positive characteristics, it is perhaps not surprising that aquaculture has been the world's fastest growing food production sector within agriculture for nearly two decades, exhibiting an overall annual growth rate of over 11.1% per year since 1984 (Fig. 1), compared with 3% for terrestrial farm animal meat production (Fig. 2), and 1.5% for landings from capture fisheries (Fig. 1). It is also important to mention here that aquaculture is similar to agriculture in the large diversity of animal and plant species cultured. For example, total aquaculture production in 1997 consisted of 121 finfish species, 45 mollusc species, 29 crustacean species, 13 aquatic plant species, and 4 miscellaneous species (FAO Fishstat Plus (AQUASTAT) Database, 1999).

Total global aquaculture production in 1997 (the latest year for which global information is available from FAO) was reported as 36 million metric tons (mmt; live weight equivalent; Figure 3) and valued at $ 50 billion, with production up by 6.2% since 1996 and more than doubling by weight since 1990 (Fig. 1). Moreover, aquaculture's contribution to total world fisheries landings has also more than doubled since 1984, with aquaculture increasing its share of total fisheries landings (includes both capture fisheries and aquaculture) from 11.4% by weight in 1984 to 27.6% in 1997 (Fig. 1).

At a species group level finfish contributed over half of total aquaculture production by weight in 1997 (18.8 mmt or 52.3%; Fig. 3), followed by molluscs (8.6 mmt or 23.8%) and aquatic plants (7.2 mmt or 20.1%). However, although crustaceans constituted only 3.6% of total aquaculture production by weight in 1997 (1.3 mmt), they represented 15.8% of total aquaculture production by value, with marine shrimp being the top aquaculture species group by value at $ 6.1 billion. The annual growth rates of the different major specific groups over the past decade is shown in Fig. 4, with most groups exhibiting double-digit growth rates over the period 1984 to 1997: finfish (12.8%, with production up by 11.6% since 1996), molluscs (11.9%, with production up by only 0.9% since 1996), aquatic plants (6.9%, with production up by only 1.0% since 1996), and crustaceans (15.7%, with production up by 6.7% since 1996).

In terms of per caput '*food fish*' supply from aquaculture (i.e., the production of farmed aquatic

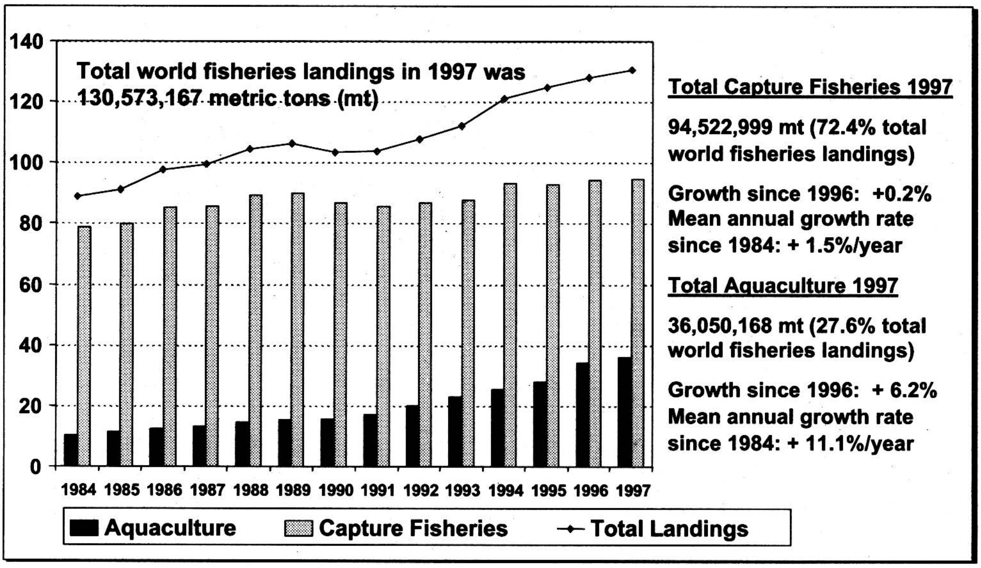

Figure 1. **Contribution of aquaculture to total world fisheries landings 1984 - 1997(FAO ,1999a)**

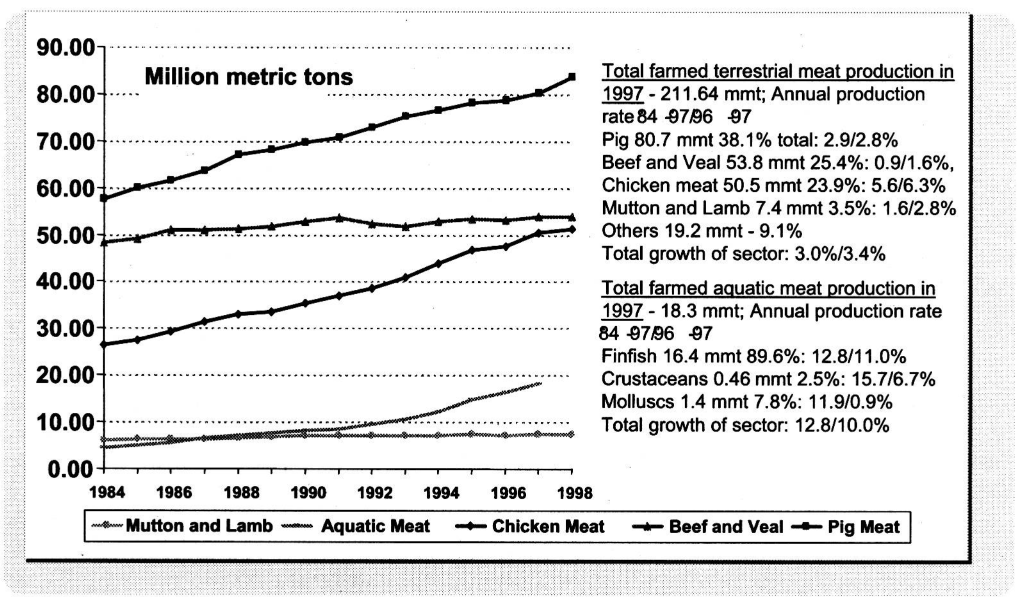

Figure 2. **Total global farmed terrestrial and aquatic meat production 1984-1998. FAOSTTAT Database (March 1999) / AQUACULT-PC Database (March 1999)**

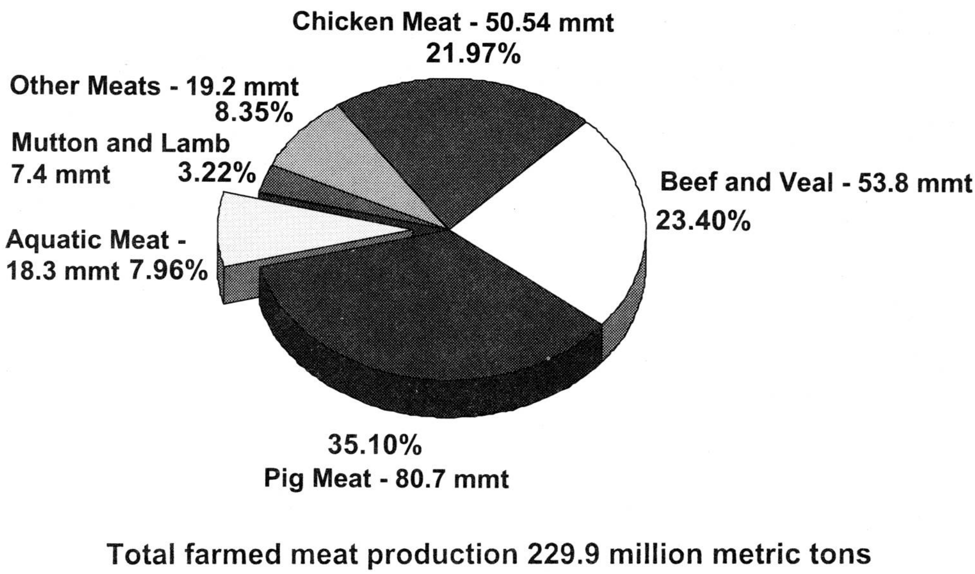

Figure 3. **Total world farmed aquatic and terrestrial meat production in 1997. (FAOSTAT/ AQUASTAT-PC Database, 1999)**

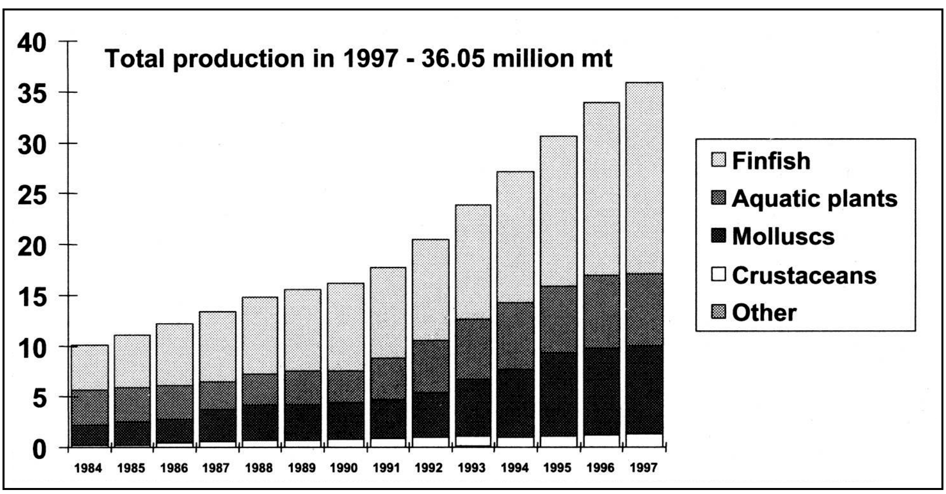

Figure 4. **Total world aquaculture production by major species groups 1984-1997. Growth of major species groups (expressed as % increase sl996 and compound growth rate for period 1984-1997): finfish 4.4 to 18.8mmt, 11.6% and 12.8 %/year; crustaceans 0.22 to 1.30 mmt, 6.7% and 15.7 %/year; molluscs 2.2 to 8.6 mmt, 0.9% and 11.9 %/year; aquatic plants 3.2 to 7.2 mmt, 1.0% and 6.9%/year; World total 10.1 to 36.0 mmt, 6.2% and 11.1 %/year (FAO, 1999a)**

finfish and shellfish on a whole live weight basis, and excluding farmed aquatic plants), global production has increased by 239% since 1984 from 1.45 kg to 4.92 kg in 1997, with supply growing at an average rate of 12.6% per year. By contrast, per caput food fish supply from capture fisheries has remained relatively static, increasing from 10.88 kg in 1984 to only 10.91 kg in 1997 and growing at an average rate of 1.75% per year or equivalent to the growth of the human population (1.75%) over the same period. On the basis of the above data, over 30% (31.1% in 1997) of 'food fish' consumed by humans in 1997, from a total average per caput food fish supply of 15.84 kg (up from 12.33 kg in 1984), is currently being supplied by aquaculture.

In terms of global animal protein supply, more '*food fish*' is consumed on a per caput basis than any other type of meat, with food fish representing 15.4% of global animal protein supply in 1996 (total global animal protein supply was 26.6g per caput in 1996), followed by pig meat (14.7%), beef and veal (13.5%), and poultry meat (12.8%). In general, people living within Asia and Africa (including LIFDCs) are much more dependent on fish as part of their daily diets than those people living in most developed countries and other regions of the world. For example, figures for 1996 show that while fish represent only 6.1% of total animal protein supplies in South America (Chile 10.3%, Ecuador 7.5%), 7.1% in North and Central America (USA 6.8%), 9% in Oceania (Australia 6.4%), and 9.8% in Europe (Norway 29.2%, Spain 17.0%), they provide 17.2% in Africa (Sierra Leone 63.4%, Ghana 59.1%, Gambia 53.4%, Guinea 47.4%, Congo Rep. 43.1%, Malawi 44.4%, Togo 43.5%, Senegal 38.3%, Cote d'Ivore 34.6%, Egypt 14.4%), over 27.1% in Asia (Maldives 80.5%, Korea DPR 68.3%, Indonesia 49.6%, Philippines 47.3%, Japan 47.2%, Sri Lanka 46.8%, Bangladesh 45.9%, Myanmar 43.7%, Korea Rep 40.2%, Thailand 36.1%, Malaysia 35.1%, Viet Nam 30.4%, Cambodia 28.4%, China 23.9%), and 23.0% within LIFDCs.

By economic country grouping, approximately 89.6% and 80.6% of total world aquaculture production in 1997 was produced within developing countries (32.3 mmt) and in particular within LIFDCs (29.02 mmt; Fig. 5). Whereas the developing countries' share of global aquaculture production has increased from 72.6% (7.37 mmt) in 1984 to 89.6% (32.3 mmt) in 1997, the share of production from developed countries has decreased from 27.4% (2.78 mmt) in 1984 to 10.4% (3.75 mmt) in 1997 (Fig. 5). Furthermore, aquaculture production within LIFDCs has been growing over 5 times faster (13.9% per year since 1984) than within developed countries (2.5% per year since 1984), with aquaculture production within developing countries displaying an average annual growth rate of 13.1% between 1984 and 1997.

By region, Asia produced over 90.9% of total aquaculture production by weight in 1997 (83.5% by value; production up 6.0% since 1996), followed by Europe (4.6%; production up 4.0% since 1996), North America (1.8%; production up 15.2% since 1996), South America (1.8%; production up 19.2% since 1996), Africa (0.3%; production up 0.9% since 1996), the former USSR area (0.3%; production up 5.4% since 1996), and Oceania (0.3%; production down 0.14% since 1996; FAO, 1999a). By country the top ten aquaculture producers in the world in 1997 were China (24.0 mmt, 66.6% world total), India (1.78 mmt), Japan (1.34 mmt), Korea Republic (1.0 mmt), Philippines (0.96 mmt), Indonesia (0.91 mmt), Thailand (0.57 mmt), Bangladesh (0.51 mmt), Viet Nam (0.49 mmt), and Korea DPR (0.49%). These top ten countries account for about 89.1% of total global aquaculture production (Table 2).

By environment, approximately 47.3% of aquaculture production was produced from inland waters in 1997, increasing from 3.6 mmt in 1984 to 17.0 mmt in 1997 at an average annual rate of 13.8% since 1984 (Fig. 6). The bulk of production from inland waters were from freshwater finfish species (86.5% in 1997; Fig. 7). By contrast, approximately 48.2% of aquaculture production was produced within marine waters in 1997, increasing from 5.9 mmt in 1984 to 17.4 mmt in 1997 at an average annual rate of 9.4% since 1984. The bulk of production from marine waters were in the form

Table 2. **Top twenty aquaculture producers in 1997**

Country	Production (metric tons)[a]	Production (% total world S)[b]	Growth (APGR 84-97, %/yr)[d]	Growth (increase 96-97, %)[e]	Total value (US $ 1,000)	Unit value (US $/kg)
1. China, mainland	24 030 313	66.6	+ 16.5	+8.2	23 549 193	0.98
2. India	1 776 450	71.6	+11.0	-0.4	1 975 418	1.11
3. Japan	1 339 861	75.3	+0.9	-0.7	4 706 068	3.51
4. Korea, Rep	1 040 280	78.2	+3.6	+16.0	1 204 957	1.16
5. Philippines	957 548	80.8	+5.9	-2.4	950316	0.99
6. Indonesia	911 610	83.4	+8.8	+3.5	2 240 482	2.46
7. Thailand	575 901	85.0	+ 14.3	+4.4	1 783 038	3.10
8. Bangladesh	512 738	86.4	+12.6	+14.0	1 370 199	2.67
9. Vietnam	492 000	87.8	+12.5	+ 19.7	1 118 040	2.27
10. Korea, DPR	489 321	89.1	-3.0	-37.5	307 745	0.63
11. USA	438 331	90.3	+2.5	+ 11.4	771 183	1.76
12. Chile	375 113	91.4	+37.0	+16.1	959 759	2.56
13. Norway	366 281	92.4	+24.7	+13.9	1 043 824	2.85
14. France	287 609	93.2	+3.4	+0.7	634 100	2.20
15. Taiwan, ROC	270 112	93.9	+0.8	-0.8	949 837	3.52
16. Spain	239 236	94.6	-0.3	+3.3	252 765	1.06
17. Italy	217 519	95.2	+7.0	+2.4	409 155	1.88
18. Ecuador	135 297	95.6	+ 12.3	+24.4	680 624	5.03
19. United Kingdom	129 715	95.9	+ 18.1	+18.0	426 829	3.29
20. Malaysia	103 360	96.2	+3.6	-5.6	215 226	2.08

[a]Total aquaculture production (includes finfish, crustaceans, molluscs, miscellaneous aquatic animals/ products, aquatic plants); [b] Accumulative total as % total world aquaculture production; [c]Per caput total aquaculture production; [d] Annual Percent Growth Rate (APGR) in production by weight between 1984 and 1997; [e] Percent change in production by weight between 1996 and 1997. FAO (1999a).

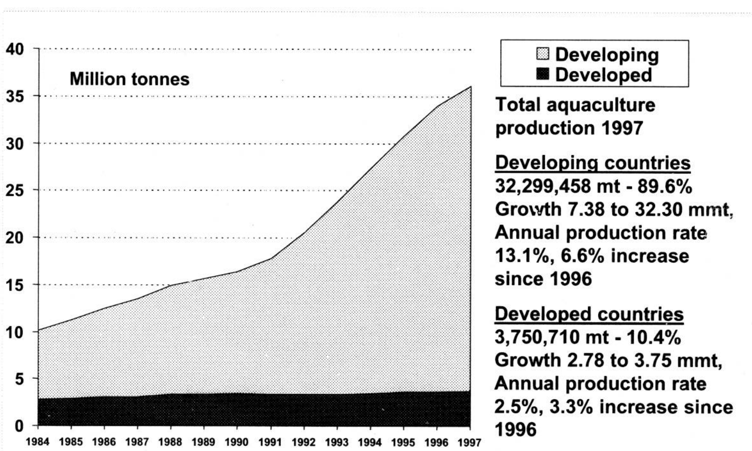

Figure 5. **Total world aquaculture production by major economic country groupings. FAO AQUASTAT-PC, FAO (1999a)**

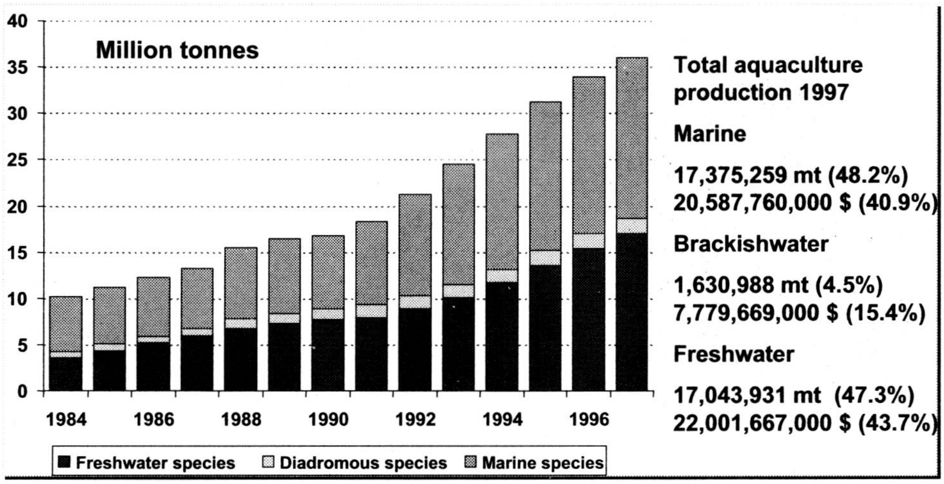

Figure 6. **Total world aquaculture production by aquatic environment. Growth expressed as % increase since 1996 and annual production rate for 1984-1997: freshwater 3.59 to 17.04 mmt, 10.7% and 13.8%; brackishwater 0.69 to 1.63 mmt. 0.4% and 7.4%; marine 5.88 to 17.37 mmt, 2.5% and 9.4%/year. (FAO, 1999a)**

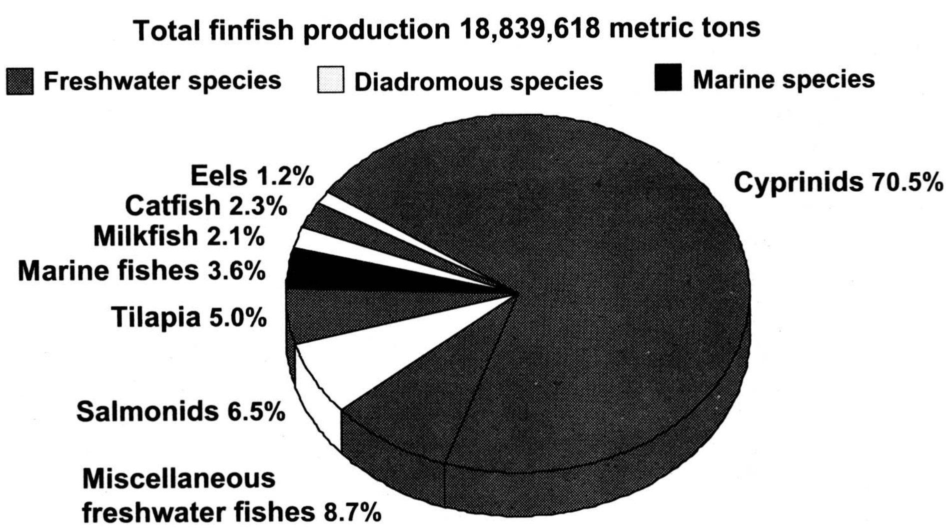

Figure 7. **Total finfish aquaculture production by major species groups in 1997. Values expressed as % by weight. (FAO, 1999a)**

of marine molluscs, aquatic plants (seaweeds), and marine crustaceans (FAO Fishstat Plus (AQUASTAT) Database, 1999).

Aquaculture, Food Security, and "Erap"

It is apparent from the above discussion that aquaculture currently makes an important contribution to the world's food supply, particularly within developing countries (including LIFDCs) and the Asian region. In this respect, it is extremely important to point out that the main factor driving the apparent high demand for fishery/aquaculture products within most developing countries and LIFDCs is their greater affordability to the poorer segments of the community, including the rural poor, compared with other animal protein sources. For example, the unit price of animal protein sources in Western Visayas (Philippines; the location of the current SEAFDEC meeting) was reported as beef 100 pesos/kg, pork 85 pesos/kg, chicken 70 pesos/kg, fish 60 pesos/kg, dried fish 120 pesos/kg, eggs 36 pesos/dozen, sardines 8.50 pesos/can, milk 35.5 pesos/pack (Cost of Living in Western Visayas for a family of six, Western Visayas Daily Informer, 15 October 1999; 40 Philippines pesos equivalent to 1 US $ at the time of this cost of living survey). Moreover, aquaculture can also effect food security by increasing income and thus enlarging the capacity to purchase food on the market place.

According to Kent (1995) if aquaculture products are to be used to strengthen the food security of the poor, the following guidelines should be considered;

- Funding for aquaculture for the poor should be increased;
- Aquaculture projects should do no harm to the food supplies of the poor;
- Existing aquaculture activities of the poor should be strengthened;
- The focus should be on low cost products favored by the poor;
- Production should be for local consumers;
- Community production should be encouraged; and
- Food security impacts should be monitored.

In addition to the above general guidelines, there is also an urgent need (in the opinion of the authors) for the further development and promotion of 'Environmentally Responsible Aquaculture Practices' (ERAP) to ensure the continued growth and sustainable development of the aquaculture sector, and its contribution to global food supply and food security in the next millennium.

Issues and Challenges to Sustainable Aquaculture Development

There is significant potential for continued expansion and growth of aquaculture and culture-based fisheries. Even in Asia, the full potential for further development has not yet been realized. Discussions during the recent Sessions of the FAO Committee on Fisheries stressed the increasingly important role of inland capture fisheries and aquaculture in fish production and in human nutrition and poverty alleviation in many rural areas, and emphasized enhancement of inland fish production through integrated aquaculture-agriculture farming systems and integrated utilization of small and medium size water bodies. Additional opportunities/strategies for further development and increased food production include, for example:

- intensification of production;
- specialization of production;
- rehabilitation of existing production facilities;
- improved fisheries enhancement methods;
- diversification of production;
- combining on-farm and off-farm activities.

Despite aquaculture's successes and considerable potential for continued growth and expansion, the sector has not been without its problems and critics. Although the majority of these issues are not unique to the aquaculture sector, and relate to the development of more environmentally sound and *responsible* farming practices, it is essential that these issues be addressed and resolved in a timely manner if the sector is to mature and sustain its rapid growth and to provide a positive image with the public and community at large into the next millennium.

As recalled by Dar (1999) on the occasion of the 1999 Ministerial Meeting on Fisheries, the major issues and challenges to aquaculture development that need to be addressed (although these may vary in severity from country to country) can be summarized as follows :

Weak institutional support and insufficient political recognition. At present, many of the decisions over developments affecting fisheries, aquaculture and aquatic environments are often made with little or no consideration of these sectors. Moreover, most fish producers suffer from the absence or inadequacy of defined rights to their specific practices, and institutional support, whether public or private. To address the issue of weak institutional support and insufficient political recognition, there is therefore a need to:

- develop comprehensive policies and associated institutional and legal frameworks in support of the sustainable development of aquaculture and culture-based fisheries;
- improve communication, cooperation and coordination among institutions, agencies and major stakeholders concerned with aquaculture and culture-based fisheries;
- strengthen institutional capacity to manage the sector and to expand the knowledge base in order to enable implementation of sustainable development policies and plans;
- enhance participation and consultation of all stakeholders (public and private) in the planning, development and management of aquaculture and culture-based fisheries, including the strengthening of community-based management of resources, support to non-governmental organizations and private sector associations (eg., groups of farmers, breeders, processors, traders, etc.), and the promotion among private sector groups of voluntary self-regulatory management schemes (eg., codes of practice, best management practices etc.); and
- promote 'enabling environments' in support of aquaculture development, including provisions for fair access to resources, mechanisms for conflict resolution, and ready access to information, credit and markets.

Need to enhance efficiency in the utilization of resources. At present, there is a global trend toward increasing competition between users or stakeholders, including both agricultural and non-agricultural sectors, for available resources, including land, energy/fossil fuels, water, and nutrient sources. Moreover, there is also a global trend within animal husbandry, including aquaculture production, toward intensification of farming systems and increased livestock/aquaculture production per unit area/time, as well as an increasing trend toward the vertical integration of animal and feed production systems so as to reduce risks and minimise production costs. To address these issues and enhance efficiency in the utilization of resources, there is therefore a need to:

- promote the further development of more environment friendly animal production systems and dietary feeding regimes;
- improve the efficiency of resource-use within animal production systems through the development of improved feed formulation techniques and/or through the selection of animal species feeding low on the food chain;
- reduce the dependence of animal production systems upon the use of potentially food-grade feed resources as nutrient inputs through the development and use of more sustainable non-food grade feed resources whose production can keep pace with the growth of the sector;

- improve efficiency in the use of water resources;
- improve site selection and allocation of land/space;
- improve selection and use of seed, broodstock, and feed/fertilizer and other inputs (chemicals, drugs, equipment);
- improve integration with other agricultural activities (e.g., irrigation, rice production, animal husbandry);
- promote the use of appropriate fish health management programs;
- promote the appropriate use of genetic resources and biotechnology;
- reduce the environmental impacts of aquaculture;
- avoid impacts on aquaculture resulting from aquatic pollution by non-aquaculture activities; and prevent impacts of aquaculture on aquaculture.

Responding to the demands by retailers, consumers and producers. With increasing global awareness and concern for the environment, the efficiency of resource use, the sustainability of different food production systems, and food safety, there are increasing demands of retailers and consumers for the production of greener, healthier and safer animal food sources for human consumption and consequently increasing demands by farmers and consumers for the development of national/internationally agreed standards and/or codes/guidelines for animal food production, including aquaculture production. To address these demands by retailers, consumers and producers, there is a need to promote human resource development and capacity building through:

- training, extension, education, and the transfer of appropriate technology;
- improved provision of and access to information;
- promotion of human resource development

The Code of Conduct for Responsible Fisheries (CCRF) and Aquaculture Development

Origins and basic contents of the CCRF

The FAO Code of Conduct for Responsible Fisheries originated at the International Conference on Responsible Fishing, held in May 1992 in Cancun, Mexico. Following this Conference and the 1992 United Nations Conference on Environment and Development (UNCED), FAO was requested by its member countries to draft an International Code of Conduct for Responsible Fisheries. Subsequently, many experts and representatives from governments, intergovernmental and non-governmental organizations participated in several FAO technical consultations and in the 1993 and 1995 Sessions of the FAO Committee on Fisheries for the purpose of the formulation of the Code.

The code draft documents received a broad consensus from the Member States of FAO and the final text was adopted by government representatives attending the 28th Session of the FAO Conference on October 31, 1995 (FAO, 1995).

The Code sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, while recognizing the nutritional, economic, social, environmental and cultural importance of fisheries, and the interests of all those concerned with the fishery sector.

The Code is based on relevant rules of international law, including those reflected in the 1982 United Nations Convention on the Law of the Sea, and incorporates the spirit of Agenda 21 and the 1992 Rio Declaration of the UN Conference on Environment and Development as well as the 1992 Convention on Biological Diversity.

The Code is non-binding in nature and will be implemented on a voluntary basis, although it contains certain provisions, which may be given or have already been given binding effect. An example of provisions which are already binding is the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, 1993.

The Code consists of five introductory articles, one article on General Principles, and six thematic articles (see Box 1).

Box 1. Contents of the Code of Conduct for Responsible Fisheries

1. Nature and Scope
2. Objectives
3. Relationship with Other International Instruments
4. Implementation, Monitoring and Updating
5. Special Requirements of Developing Countries.
6. General Principles
7. Fisheries Management
8. Fishing Operations
9. Aquaculture Development
10. Integration of Fisheries into Coastal Area Management
11. Post-Harvest Practices and Trade
12. Fisheries Research

http://www.fao.org/fi/agreem/codecond/codecon.asp

The Code is addressed primarily at *States*, that is, the Code stipulates actions to be taken by States, and their government authorities and institutions. However, it is also meant to address persons, interest groups or institutions, public or private, who are involved in or concerned with fisheries and aquaculture. In fact, in the case of aquaculture development, it is evident that responsibilities beyond the local farm level need to be shared by many players (FAO Fisheries Department, 1997). Providing an "*enabling environment*" for sustainable development in aquaculture, as in agriculture, is the responsibility of people in governments and their institutions, the media, financial institutions, pressure groups, associations, non-governmental organizations, as well as of social and natural scientists, manufacturers and suppliers of inputs, processors and traders of aquaculture products (Box 2.; see also FAO, 1999).

Box 2. Participants in the implementation of the Code of Conduct for Responsible Fisheries

- Government authorities/officials, policy-makers, planners and regulators
- Aquafarmers, producers, farm operators/workers, "aquaculture experts"
- Manufacturers and suppliers of aquaculture inputs
- Processors and traders of aquaculture products
- Consumers
- Banks and other financing institutions, investors, insurance companies
- Special interest and advocacy groups (professional associations, NGOs, others)
- Researchers, social and natural scientists
- International organizations (regional, global)
- Media
- others

Many aquafarmers, like most of their terrestrial counterparts, continue however to attempt solving problems on their farms while struggling with constraints such as inadequate access to resources, natural and financial, lack of institutional and legal support, or unavailability of appropriate information

(Barg *et al.,* 1997). In many cases, it is very difficult for aquaculture farmers to adapt their farming practices to new requirements. Nonetheless, in many cases there are obvious and significant advantages for the producers to improve their practices, most often in terms of increased productivity and efficiency, resulting in sustained profits, as well as in terms of environmental performance and public image. Most significantly, however, there are advantages which arise from recognized product quality and acknowledged “good practice”. Most producers recognize consumer demands as well as the requirements by retailers. It is therefore important that appropriate information on aquaculture is provided to consumers and to the public in general. Those trading aquaculture products as well as those supplying inputs required for aquaculture also have a role to play in providing such information to civil society.

Salient Provisions of the CCRF as Relevant to Aquaculture Development

The Code provides a range of provisions addressing important issues relevant to aquaculture. In addition to Article 9 “Aquaculture Development, which explicitly covers major aspects of aquaculture, there are also significant provisions in other sections of the Code having an important bearing on aquaculture and its general development context.

The following are a number of salient provisions, which are highlighted to provide examples of basic recommendations for possible important policies and actions which may be derived from the provisions of the Code.

Co-operation in implementation

The Code calls all those concerned and interested to collaborate in the fulfilment and implementation of the objectives and principles contained in this Code. Article 4 clearly highlights that not only States and their authorities should promote the Code but also all non-governmental organizations, which per definition also include private sector associations. Co-operation is sought and encouraged to facilitate the implementation of the Code, for example, as stated in following provisions:

CCRF 4.2. FAO, in accordance with its role within the United Nations system, will monitor the application and implementation of the Code and its effects on fisheries and the Secretariat will report accordingly to the Committee on Fisheries (COFI). All States, whether members or non-members of FAO, as well as relevant international organizations, whether governmental or non-governmental should actively cooperate with FAO in this work.

CCRF 4.4. States and international organizations, whether governmental or non-governmental, should promote the understanding of the Code among those involved in fisheries, including, where practicable, by the introduction of schemes which would promote voluntary acceptance of the Code and its effective application.

Special requirements of developing countries

In formulating and negotiating the Code it was recognized that many developing countries continue to face significant development problems, and that the special economic and social circumstances prevailing in these countries would need to be given due consideration. The Code therefore calls - in Article 5 - for efforts and measures to address the needs of developing countries, especially in the areas of financial and technical assistance, technology transfer, training and scientific co-operation. Special efforts should be undertaken particularly in the areas of human resource development.

General principles

There are six provisions under the *General Principles (CCRF Article 6)* that are of major significance for aquaculture matters:

The requirement to respect the environment, its goods and services, applies to both States as well as to all users of living aquatic resources. Special emphasis is given to the protection of critical fisheries habitats, and to the need to prevent impacts resulting from human activities.

CCRF 6.1. States and users of living aquatic resources should conserve aquatic ecosystems.

CCRF 6.8. All critical fisheries habitats in marine and fresh water ecosystems, such as wetlands, mangroves, reefs, lagoons, nursery and spawning areas, should be protected and rehabilitated as far as possible and where necessary. Particular effort should be made to protect such habitats from destruction, degradation, pollution and other significant impacts resulting from human activities that threaten the health and viability of the fishery resources.

The Code emphasizes not only all aspects of production of fish and fishery products, but also covers the requirement for responsible action in harvesting and post-harvest practices:

CCRF 6.7. The harvesting, handling, processing and distribution offish and fishery products should be carried out in a manner which will maintain the nutritional value, quality and safety of the products, reduce waste and minimize negative impacts on the environment.

High priority is given in the Code to consultation and effective participation of all interested stakeholders in decision-making, development of laws and policies and their implementation. Emphasis is also given to awareness raising, education and training.

CCRF 6.13. States should, to the extent permitted by national laws and regulations, ensure that decision making processes are transparent and achieve timely solutions to urgent matters. States, in accordance with appropriate procedures, should facilitate consultation and the effective participation of industry, fish-workers, environmental and other interested organizations in decision making with respect to the development of laws and policies related to fisheries management, development, international lending and aid.

CCRF 6.16. States, recognising the paramount importance to fishers and fish-farmers of understanding the conservation and management of the fishery resources on which they depend, should promote awareness of responsible fisheries through education and training. They should ensure that fishers and fish-farmers are involved in the policy formulation and implementation process, also with a view to facilitating the implementation of the Code.

International trade of aquaculture products continues to grow in importance. The Code clearly emphasizes the role of existing international trade agreements and highlights the important requirements for States to prevent the occurrence of negative impacts on trade, environment and societal demands.

CCRF 6.14. International trade in fish and fishery products should be conducted in accordance with the principles, rights and obligations established in the World Trade Organization (WTO) Agreement and other relevant international agreements. States should ensure that their policies, programmes and practices related to trade in fish and fishery products do not result in obstacles to this trade, environmental degradation or negative social, including nutritional, impacts.

The importance of aquaculture development and the potential benefits of aquaculture are well reflected in the General Principles of the Code. However, there is also a call for due consideration of environmental and social issues which may be associated with the development of aquaculture.

CCRF 6.19. States should consider aquaculture, including culture-based fisheries, as a means to promote diversification of income and diet. In so doing, States should ensure that resources are used responsibly and adverse impacts on the environment and on local communities are minimized.

CCRF Article 9 - Aquaculture Development

Article 9 of the Code contains provisions relating to aquaculture, including culture-based fisheries. Article 9 is divided into four sub-sections, which refer to responsible development both in areas of national jurisdiction (9.1) as well as within trans-boundary aquatic ecosystems (9.2), to the use of genetic resources (9.3), and to responsible practices at the production level (9.4).

Specifically, this Article includes requirements for appropriate legal and administrative frameworks, which are to provide for an “enabling environment” for the sustainable development of aquaculture (CCRF 9.1.1). Responsible development and management of aquaculture is emphasized, with special reference to advance evaluation of environmental effect, i.e., the requirements for environmental impact assessment and regular monitoring, which should be based on best available scientific information (CCRF 9.1.2 and 9.1.5). States are encouraged to produce aquaculture development strategies, to allow for appropriate use of resources shared by aquaculture and other activities, as well as to ensure avoidance of negative effects on the livelihood of local communities (CCRF 9.1.3 and 9.1.4).

With a perspective of addressing trans-boundary issues, the Code invites States to collect, share and disseminate data related to their aquaculture, and encourages co-operation on planning for aquaculture development at national and various international levels (CCRF 9.2.4). Special emphasis is given to development of appropriate mechanisms to monitor the impacts of inputs which are utilized in aquaculture including, for example, feeds, stocked organisms, equipment, chemicals, etc. (CCRF 9.2.5).

The selection, use, propagation, and movements of species is prominently addressed in the Code (a number of provisions under 9.2. and 9.3) and precautionary measures, such as the implementation of appropriate international and national codes of practice (CCRF 9.3.2 and 9.3.3), are advocated to avoid adverse effects on endemic biological diversity, as well as to prevent impacts of disease outbreaks. States are called on to promote steps to minimize adverse genetic, disease and other effects of escaped-farmed fish on wild fish (CCRF 9.3.1).

At the farm and local level (see CCRF 9.4.), the potential benefits of sustainable aquaculture development are well recognized, and States are called to promote responsible practices in support of rural communities and producers (CCRF 9.4.1). Enabling the participation of fish farmers is advocated in the development of appropriate practices. There is significant scope for assisting producers through appropriate human resource development activities, including training, extension and capacity building in general.

Other recommendations relate, in particular, to responsible selection and use of appropriate feeds, feed additives and fertilizers, including manures (9.4.3). Emphasis is also given to effective fish health management including safe use of chemicals (9.4.4). Provision CCRF 9.4.5 calls for the regulation of the use of chemicals that are harmful to humans and the environment. Avoidance of harmful effects on both human health and the environment are also the targets of provisions 9.4.6

which requires the judicious disposal of potentially hazardous wastes and 9.4.7 which demands good practices before and during harvesting, in order to ensure food safety, good quality and improved value of aquaculture products.

The Code and integrated coastal area management (CCRF Article 10)

It should be noted that the Code's provisions on Integrated Coastal Area Management (CCRF Article 10; see also FAO, 1996b) also have a bearing on aquaculture in general, and on coastal aquaculture in particular. Very broadly, these provisions recommend that the integration of fisheries (and aquaculture) into coastal area management should occur through the formulation of management plans, the provision and enforcement of appropriate environmental legislation, a transparent consultative process, and through monitoring the post-development impact. In the coastal management process, fisheries and aquaculture agencies should participate in decisions concerning the following:

- the planning and conduct of environmental impact studies;
- when permits for construction are being issued;
- whenever the drafting of laws and regulations are required; and
- in the spatial planning process (e.g., port development).

Fisheries and aquaculture agencies and sector representatives should also be full partners in interagency and interdisciplinary fora. CCRF Article 10 calls on States to ensure that representatives of the fisheries and aquaculture sector and fishing communities are consulted in the decision-making processes related to coastal area management and development.

The Code and post-harvest practices and trade (CCRF Article 11)

CCRF Article 11 deals with post-harvest practices and trade, and is also relevant to aquaculture. Responsible fish utilization is one of the main chapters of this article, claiming the consumer's' right to safe, wholesome and unadulterated fish and fishery products (see also FAO, 1998d). It refers to the work of the FAO/WHO Codex Alimentarius Commission and calls on States to promote the implementation of quality standards agreed therein. Those involved in the processing and marketing of fish and fishery products are encouraged to reduce post-harvest losses and waste, to improve the use of by-catch to the extent that this is consistent with responsible fisheries management practices, and to use resources such as water and energy, in particular wood, in an environmentally sound manner. The manufacture of value-added fishery products by developing countries is advocated and States are requested to ensure that domestic and international trade in fishery products accord with sound conservation and management practices. This latter remark points towards the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The Convention can limit, regulate and prohibit trade in these species and products there from if they are listed in one of the Annexes.

During the consultations leading to the CCRF, there was a debate of the FAO membership which was related to the remaining two chapters of Article 11 (Responsible International Trade, and Laws and Regulations relating to Fish Trade), and which was strongly influenced by the intention not to create clauses which would contrast with provisions issued under the Agreements leading to the Establishment of the World Trade Organization (WTO) and to make it clear that the formulation of trade rules is the prerogative of the WTO. The Code also states that policies and practices related to the promotion of international fish trade and export production should not result in environmental degradation or adversely impact the nutritional rights and needs of people for whom fish is critical to their health and well-being and for whom other comparable sources of food are not readily available or affordable. According to the Code, laws, regulations and administrative procedures applicable to international fish trade should be transparent, as simple as possible, comprehensible and, when appropriate, based on scientific evidence. They should be reviewed periodically and simplified without jeopardizing their effectiveness. In cases where regulations are changed, sufficient time should be allowed for preparing the implementation of the Code and consultation with affected countries would be desirable. In this connection the Code stipulates that due consideration be given to requests from developing countries for temporary derogation from obligations.

In summing up, the Code of Conduct for Responsible Fisheries was adopted by FAO Member Governments in 1995 and is considered as the practical foundation on which to establish sustainable fisheries and aquaculture in the future. The Code's structure and its different components correspond roughly to different groups of stakeholders (fishermen, managers, processors, traders, fish farmers, and scientists). The FAO Fisheries Department has been producing a number of Technical Guidelines to assist those concerned in the implementation and adaptation of the recommendations of the Code of Conduct (FAO, 1996a,b, 1997, 1998d). Such guidelines could be complemented as required by specific technical protocols, codes of practice, instruction manuals, best management practices, etc. General awareness on the existence and significance of the Code is growing, and its scope and purpose are becoming known to increasing numbers of persons and institutions involved in fisheries and aquaculture. However, the challenges of implementation of the Code's provisions in aquaculture can be significant, especially when considering the complexity of the issues and the diversity of aquaculture practices and people involved.

Due consideration should be given hereby to diversity of aquaculture species and species groups (finfish, crustacean, molluscs, aquatic plants) and systems utilized (e.g. extensive, semi-intensive, intensive, super-intensive systems). There are also varying purposes and contexts of aquaculture practice, for example, commercial aquaculture with significant focus on local, regional and international markets, and the very important practices of subsistence and household aquaculture for food security. The role of the various types of aquaculture in rural development, poverty alleviation and enhancing of food security can be significant.

Likewise there is significant diversity between aquaculture producers, as well as consumers of aquaculture produce, within countries, as well as between regions and economic status of countries, which is often related to different socio-economic circumstances in LIFDCs, developing and developed countries.

Selected Initiatives in Support of the Implementation of the CCRF

There are increasing numbers of initiatives aiming at the implementation of the CCRF. Selected examples of such initiatives are presented here, as they relate to aquaculture developments, and associated issues and themes of international interest or concern.

The FAO Bangkok Consultation on policies for sustainable shrimp culture and follow-up of related activities

The principal objective of this Consultation was to contribute to the preparation of guidelines containing policy options and methodologies for government policy-makers and, especially planners, to develop an appropriate incentive structure and regulatory and decision-making framework for the development of sustainable shrimp culture. The guidelines are in support of the implementation of the Code of Conduct on Responsible Fisheries including relevant provisions contained in its Article 9 "Aquaculture Development", and may facilitate the development of voluntary self-regulatory schemes implemented by farmer groups or industry associations.

The Consultation, held in December 1997 in Bangkok, Thailand, was attended by government delegates and observers from 12 countries of Asia and America accounting for about 90 % of the global production of cultured shrimp and including major consuming countries. Observers from 5 inter-governmental organizations (ASEAN, INFOFISH, NACA, SEAFDEC, World Bank) and from 4 international NGOs also attended, including Global Aquaculture Alliance (GAA), Greenpeace International, International Collective in Support of Fishworkers (ICSF), and World Wide Fund for Nature (WWF)

The main outcomes of the Consultation (FAO, 1998b) were produced in three working groups which addressed:

(1) the legal, institutional and consultative framework for sustainable shrimp culture,
(2) planning and regulatory methods and tools and economic incentive schemes for sustainable shrimp culture, and
(3) development of voluntary codes of practice for sustainable shrimp culture.

As stated in the report of the Bangkok Consultation (FAO, 1998b), "*The Consultation produced a broad consensus that sustainable shrimp culture is practised and is a desirable and achievable goal, which should be pursued. When practised in a sustainable fashion, shrimp culture is an acceptable means of achieving such varied national goals as food production, employment and generation of foreign exchange.*

Achievement of sustainable shrimp culture is dependent on effective government policy and regulatory actions, as well as the co-operation of industry in utilizing sound technology in its planning, development and operations. Noting that appropriate government responsibilities are outlined in Article 9 of the Code of Conduct for Responsible Fisheries, the Consultation recommended a range of desirable principles to be followed in the establishment of legal, institutional and consultative frameworks and regulatory policies for sustainable shrimp culture. It also noted that the Code provided an accepted baseline for the development of additional codes or guidelines applicable to shrimp culture.

The policy recommendations of the Consultation relating to legal, institutional and consultative framework for sustainable shrimp culture, planning and regulatory methods and tools and economic incentive schemes are significant (FAO, 1998b). Emphasis here is given to the recommended development of voluntary codes or similar self-regulatory instruments.

The Consultation concluded that codes of conduct, codes of practice and guidelines all have useful purpose and should be encouraged by FAO and others at various levels, e.g., local and national, and for various sectors, e.g., production, processing, input supplies, etc.. Voluntary codes can be useful instruments for reduction of government costs, to promote efficiencies, to provide protection and assurance to consumers and to producers alike, and most important, to help achieve sustainable operations. The Code of Conduct for Responsible Fisheries, particularly in its sections pertaining to aquaculture, provides an accepted baseline for development of additional codes or guidelines applicable to shrimp culture.

The Bangkok Consultation emphasized that contents of voluntary codes will vary depending on the objective of the developing entity. Codes appropriately could include:

- Provisions to better control disease;
- Provisions to govern use of drugs and chemicals;
- Provisions for record keeping to monitor various impacts of shrimp culture;

- Provisions for sound engineering practice and use of best practicable technology to achieve sustainability and effective operations with minimal impacts on the environment.
- Provisions to define sustainability with one possibility to seek intergenerational sustainability.
- There have been increasing efforts in recent years to develop such codes. Examples of "guiding principles " and "goals" of such codes are shown in Box 3.

Box 3. Guiding principles and goals of voluntary industry codes

Goals of the Code of Conduct for European Aquaculture, by Federation of European Aquaculture Producers (FEAP, 1999)

- to promote the responsible development and management of a viable European aquaculture sector in order to assure a high standard of quality food production while respecting environmental considerations and consumers' demands,
- to establish and recommend guiding principles for those in Europe who are producing live fish species through aquaculture,
- to establish a common base, through effective self-regulation, for sectoral responsibility within society and demonstrate the considerations of the production sector towards the fish it rears, the environment and the consumer.

Principles developed by Global Aquaculture Alliance (GAA, 1999):

- Cooperate with regulatory authorities
- Avoid environmentally sensitive sites
- Minimize impacts from water exchange
- Strive to improve feed use
- Avoid spread of disease
- Cooperate with research
- Benefit local community
- Strive for sustainability

Voluntary codes as well as best practice and other such guidelines are being developed by the private sector, often in co-operation with interested government agencies, not only for shrimp culture, but also in other aquaculture sectors, for example, for specific aquaculture commodities, such as mussels, trout, salmon, etc. or specific themes or issues, for example, on introduction and transfers of aquatic organisms, feed manufacturing, product hygiene and food safety, etc. A summary of potential benefits of developing and adopting codes of practice in aquaculture is given in Box 4.

Box 4. Potential benefits of developing and adopting codes of practice in aquaculture

- Public image can be enhanced through adherence to established and agreed norms and adequate self-regulation;
- Aquaculturists are in a better position to defend their interests, and to negotiate for rights and privileges against competing interests;
- Producers may form and strengthen producer associations and organizations when cooperating on such codes;
- Greater common understanding and agreement on specific measures which can be implemented to ensure sustainable aquaculture development;
- Roles and responsibilities of concerned agencies and interest groups can be properly identified and negotiated;
- Management can be improved and sustainability enhanced through cooperation on technical

Box 4 (Cont'd.)
information and training;
- Products may be labelled to inform consumers on adopted practices.

Specific reporting by Governments on implementation of the Code of Conduct for Responsible Fisheries in respect of sustainable shrimp culture

The 1997 Bangkok Consultation recommended that FAO specifically request governments of countries engaged in shrimp culture to report on progress in implementing the Code of Conduct for Responsible Fisheries in relation to shrimp culture activities to the FAO Committee on Fisheries (COFI) at its next and subsequent sessions. This is seen as a means of encouraging the use of the Code to achieve more quickly full sustainability and to maximize the benefits of shrimp culture. The Consultation recommended a range of possible areas for such reporting, and, in this regard, FAO was requested to develop appropriate criteria and indicators.

In pursuance of this recommendation, FAO held an expert meeting (FAO, 1998c) which prioritized a short-list of the criteria and indicators of sustainable shrimp culture, which could form the basis for regular reporting by countries to COFI. However, the group stressed that these criteria and indicators related to the national level and did not encompass farm-level and local-level indicators, which were inappropriate for the envisaged reporting exercise. The meeting concluded that it would be premature at this stage to request governments to report actual data on those indicators to the next session of COFI, 15-19 February 1999. Instead, it elaborated a questionnaire to allow governments to review and comment on the recommended indicators and on their present and future ability to acquire the related data and information.

The questionnaire elaborated by the ad-hoc expert meeting was sent by FAO to 30 governments of countries producing shrimp. The responses received indicate that the scope and coverage of data collection are improving as governments become more involved in shrimp culture management through licensing and regulatory measures including provisions for environmental impact assessments. The survey results indicate that responding governments regularly collect at present, or have firm plans to do so in the near future, data on many of the pertinent environmental issues associated with shrimp culture (Barg *et al*., 1999; FAO, 1999).

Only few countries referred specifically in their interventions to shrimp culture during COFI 1999. The primary reason was the very heavy agenda and severe time constraint, which the 23rd Session of COFI faced. Governments were required to consider and adopt three international plans of action, report on progress in the implementation of the Code of Conduct for Responsible Fisheries, and comment on certain highly debated issues such as eco-labelling of fish and fishery products. As a consequence, shrimp culture is not specifically mentioned in the meeting report (FAO, 1999b). However, it can be inferred from the report that governments do not wish to report in separate surveys or questionnaires on specific issues such as shrimp culture; instead all reporting related to progress in the implementation of the Code of Conduct including related action plans should be done within one biannual survey.

Assistance to Safe Trans-boundary Movement of Live Aquatic Animals

An important initiative in support of the implementation of the CCRF which is of significance to Asian aquaculturists and fish health management experts is the FAO Regional TCP Asia Regional Technical Co-operation Project (TCP/RAS/6714): Assistance to Safe Trans-boundary Movement of Live Aquatic Animals.

Owing to the seriousness of the recent outbreaks of disease in Asian aquaculture and the

Owing to the seriousness of the recent outbreaks of disease in Asian aquaculture and the significance of the losses incurred, the Asia regional importance of aquatic animal health management and the role of aquatic animal quarantine has simultaneously been recognized by NACA, the Network of Aquaculture Centres in Asia and the Pacific (NACA, 1996). On the request of their 15 member countries, NACA Governing Council has recommended the drafting and adoption of regional guidelines for health certification and quarantine of aquatic animals in the Asia-Pacific region. Responding to needs for the development and adoption of minimum aquatic animal health certification and quarantine guidelines and procedures for the Asian region, and the recommendation of NACA Governing Council, FAO in collaboration with NACA launched a Technical Cooperation Programme (TCP) project in early 1998.

Twenty-one governments are participating in the development of these technical guidelines which are also consistent with international legislation and agreements. Thus, they should be applicable not only to both participating and non-participating countries in Asia, but also to many countries in other parts of the world.

The purpose of the guidelines is to assist countries and territories in the Asian region with responsible international and within country movement of live aquatic animals. The technical guidelines are intended to facilitate trade and movement of aquatic species within and between regions with minimal or no intra- and international transfers/introductions of pathogens. It is also specifically provided to assist countries, territories and governments in Asia in the implementation of relevant measures contained in FAO's Code of Conduct for Responsible Fisheries and other relevant international agreements, where applicable to the region, including the OIE (Office International des Epizooties) and WTO/SPS (World Trade Organization/Sanitary Phytosanitary Agreement) measures. A comprehensive information system on aquatic animals pathogens and quarantine (Aquatic Animal Pathogen and Quarantine Information System - AAPQIS) is also being established in Asia, as a regional chapter of a global information system. FAO will extend this information system (AAPQIS) to the other regions of the world as an attempt to bring together inter-regional co-operation on aquatic animal quarantine and health certification (Subasinghe and Arthur, 1997; Subasinghe *et al.,* 1998 a,b).

Food Safety Issues Associated with Products from Aquaculture

There is growing consumer interest as well as some concerns related to food safety and food quality of aquaculture products. In 1997 an expert group meeting was organized jointly by WHO, FAO and NACA (FAO/NACA/WHO, 1999) to facilitate a review of food safety issues associated with products from finfish and crustacean aquaculture, to advise on the assessment of food safety hazards and risks, and on feasibility criteria, essential implementation requirements and recommendations for the control of priority hazards and risks. FAO is currently involved in revising the FAO/WHO Code of Hygienic Practice for the Products of Aquaculture under the auspices of the Committee on Fish and Fishery Products of the WHO/FAO Codex Alimentarius Commission.

Aquaculture-related aspects have also been addressed in the 1997 FAO Expert Consultation on Animal Feeding and Food Safety which generated a draft code of practice for good animal feeding (FAO/ESN, 1998). In addition, FAO's Fisheries Department has encouraged the preparation of Technical Guidelines on Good Aquaculture Feed Manufacturing Practice *(in preparation)*

Human health issues associated with the use of certain chemicals in aquaculture had been discussed in expert meetings such as for example, the Expert Meeting on the Use of Chemicals in Aquaculture in Asia (SEAFDEC/FAO/CIDA, in press) and for coastal aquaculture in general by GESAMP (1997). Important pioneer work on sound bases for drug and vaccine registration in the realm of aquaculture has been undertaken for the 1997 Workshop on International Harmonisation for Aquaculture Drugs and Biologics (Schnick *et al*., 1997). In this context, it is worth mentioning that WHO, jointly with FAO and Office International des Epizooties (OIE), will be developing a Code of Practice for prudent use of antimicrobials in livestock production (http://www.who.int/emc/diseases/zoo/meetings/code.html). The objective of this initiative is to develop recommendations relating to antimicrobial use in agriculture, including in particular livestock production and aquaculture, to:

- reduce the potential for the transfer of antimicrobial resistance to humans;
- preserve the efficacy of antimicrobials for humans and animals; and
- support human health and animal health

International Cooperation

Many activities in support of the implementation of the Code of Conduct for Responsible Fisheries benefit significantly from international cooperation and exchange among government agencies, stakeholder organizations, experts and institutions, and international organizations. A number of important considerations regarding Sustainable Aquaculture Development and the Implementation of the Code of Conduct for Responsible Fisheries have been presented by Dr William Dar to the Ministerial Meeting on Fisheries, held 1999 in Rome at FAO Headquarters[2]. These are summarized here as follows:

Important considerations

- There is an important commitment to promote aquaculture for food security and rural development (follow-up to World Food Summit Action Plan[3]).
- Article 5 of the Code of Conduct for Responsible Fisheries calls for due consideration of the Special requirements of developing countries and continued need for technical and financial assistance
- There is scope for the formulation of a Sub-Programme on Aquaculture Development within the Inter-regional Programme in support of the implementation of the Code of Conduct for Responsible Fisheries, as suggested by NACA during the 1999 Session of COFI.
- There is a need for continued regional cooperation, particularly through strengthened cooperation among regional organizations such as, for example, NACA, SEAFDEC, INFOFISH, and others in Asia. Significant opportunities exist also for inter-regional co-operation among countries of different regions.
- Continued support should be given to Regional Programmes on specialized themes such as, for example, Sustainable Aquaculture for Rural Development, and Development of Technical Guidelines on Quarantine and Health Certification, and Establishment of Information Systems for the Responsible Movement of Live Aquatic Animals (AAPQIS);
- Strengthened support may promote national and international initiatives aiming at the formulation and implementation of voluntary self-regulatory codes of practice, supported by technical guidelines and practical manuals;
- There is a growing need for technical review and agreement on international standards (for

[2] **Sustainable Aquaculture Development and the Code of Conduct for Responsible Fisheries,** *a presentation by William D. Dar, Ph. D., Secretary, Department of Agriculture, Republic of the Philippines, to the Ministerial Meeting on the Implementation of the Code of Conduct for Responsible Fisheries, Rome, 10-11 March 1999.* http://www.fao.org/fi/meetings/minist/1999/dar.asp

[3] *World Food Summit, 1996. Rome Declaration on World Food Security and World Food Summit Plan of Action. World Food Summit, 13-17 November 1996, Rome. Rome, FAO. 43 p.* http://www.fao.org/wfs/final/rd-e.htm

example, on food safety and quality, biotechnology and biosafety, environment, use of inputs, production practices, etc) which will require appropriate an intergovernmental global forum for discussion and consensus-building; and

- Consider suggestion discussed by COFI regarding the establishment of a COFI Sub-Committee on Aquaculture

In addition to the above key considerations, a number of ongoing or planned initiatives are reported here for general information. As a follow-up to the 1997 FAO Bangkok Consultation on Policies for Sustainable Shrimp Culture, an Expert Consultation on Best Practices and Institutional Arrangements in Shrimp Culture is being organized by FAO scheduled to be held in December 2000, to provide opportunity to interested governments, experts and concerned stakeholders to present and discuss experiences and options for sustainable shrimp culture practices and sector management. Among other matters, opportunity will be given to presentation of results of the ongoing WB/NACA/ WWF/FAO Programme on Shrimp Farming and the Environment. FAO is organizing an Expert Consultation on the Proposed Sub-Committe on Aquaculture of the Committee on Fisheries, which will be held during 28-29 February 2000 in Bangkok, at the FAO Regional Office for Asia and Pacific (http://www.fao.org/fi/meetings/cofi/cofi_aq/default.asp). A Conference on Aquaculture in the Third Millennium is being organized by NACA and FAO, and will be hosted by the Fisheries Department of the Government of Thailand in Bangkok during 20-25 February 2000 (http:// www.fao.org/fi/meetings/aq2000/default.htm). An Expert Consultation on Indicators of Sustainable Aquaculture Development, is being prepared by FAO in collaboration with the Institute of Aquaculture, Stirling University, and is expected to be held in November 2000, in Beijing, China

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Developments In Sustainable Shrimp Farming In Southeast Asia

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Abstract

In Southeast Asia, shrimp aquaculture has been practiced for many years and is a traditional coastal farming activity in several countries. The recent trend has been towards more intensive forms of culture resulting in a number of problems. However, experiences in the region suggest that shrimp farming can be socially, environmentally and economically sustainable and contribute to the production of food and alleviation of poverty in coastal areas, provided that appropriate management practices are adopted. Technical, economic, social and environmental issues have to be considered in the development and implementation of such management practices.

In the light of serious shrimp disease problems which have affected shrimp farming worldwide, and various environmental and social interactions, some have concluded that shrimp farming development in the region has not been completely sustainable. This paper provides background on the major sustainability issues and management strategies which need to be considered in the development of sustainable shrimp aquaculture. Good farm management practices such as farm siting, construction and design, seed quality, feed and fertilizer, water management, sediment management, shrimp health management practices, and efficient use of inputs and resources should be voluntarily followed and monitored. In order to maintain social harmony and minimize environmental impacts, integration of aquaculture into coastal area management as well as appropriate zoning, policies, regulations and legislation should be allowed for a balanced coastal development. Furthermore, active cooperation among farmers and their involvement in policy setting and planning for coastal development can contribute to better understanding of key issues and promotion of better management practices.

Fortunately, awareness and experience in sustainable management of coastal shrimp aquaculture in Southeast Asia is growing, and a number of local, national and regional initiatives are being taken to develop and implement improved management practices. At international levels, the FAO Code of Conduct for Responsible Fisheries Responsible Fisheries (CCRF), adopted in 1995 as a global inter-governmental consensus on the promotion of sustainable fisheries and aquaculture developments, provides a framework of basic principles and norms which all stakeholders concerned with shrimp culture can use as a common platform for better understanding, consultation and collaboration. Examples of recent efforts by NACA, in cooperation with FAO and other interested partners, in the implementation of the CCRF are given, and suggestions are provided to further promote the sustainable development of shrimp culture. A number of researchable issues on sustainable shrimp aquaculture are also reiterated for discussion in this seminar-workshop.

Introduction

FAO production statistics show that shrimp aquaculture expanded very rapidly in 1985-1995, averaging a 24.8% annual growth rate. Growth declined to only 8% per year in 1990-1995. But, since 1995, growth has been stunted due mainly to viral diseases, market issues, and environmental-related problems. In 1997, around 941,000 tons of shrimps and prawns valued at US$6.1 billion were cultured. Since 1991, cultured shrimps accounted for 27-29% of total shrimp production.

Global production of cultured shrimp and prawn continues to be dominated by Southeast Asia, which produced 504,769 tons accounting for 54% of global production in 1997 (Table 1). Thailand, the world's largest producer, saw its production decrease from a peak of 265,524 tons in 1994 to around 215,000 tons in 1997 because small shrimps were harvested in low or zero-water exchange culture system to minimize disease problems. The Philippines also reported similar decreases due to disease and reduction of stocking density. The growth of shrimp culture in Indonesia was interrupted by the local political situation and economic crisis. New countries such as Vietnam and Malaysia showed gradual increase in shrimp aquaculture outputs. Overall, shrimp production in Southeast Asia decreased by an average of 4.5% per year since 1995.

Thailand, Indonesia, Vietnam, Philippines and Malaysia dominate giant tiger shrimp (*Penaeus monodon*) aquaculture production, which is the major farmed shrimp species in these countries, making up around 52% or 83% of total global shrimp production and Southeast Asia production, respectively.

Table 1. **Shrimp production in Southeast Asia (in mt)**

	1992	1993	1994	1995	1996	1997
Brunei	2	4	5	10	27	57
Banana	-	-	-	-	-	-
Giant tiger	2	4	5	10	27	57
Other	-	-	-	-	-	-
Indonesia	141,586	138,578	132,406	145,216	151,086	158,480
Banana	21,779	29,167	23,860	31,676	28,822	31,800
Giant tiger	98,358	87,285	83,193	89,344	96,237	99,680
Other	21,449	22,126	25,353	24,196	26,027	27,000
Malaysia	2,963	3,994	5,858	6,779	7,501	9,519
Banana	142	57	69	66	89	139
Giant tiger	2,821	3,937	5,789	6,713	7,412	9,380
Other	-	-	-	-	-	-
Myanmar	1	3	3	5	7	8
Banana	-	-	-	-	-	-
Giant tiger	1	3	3	5	7	8
Other	-	-	-	-	-	-

Table 1. **(Continued)**

Philippines	78,396	95,816	92,647	90,491	78,067	41,610
Banana	760	230	378	346	709	687
Giant tiger	75,996	86,096	90,426	88,850	76,220	40,102
Other	1,640	9,490	1,843	1,295	1,138	821
Singapore	57	77	14	17	98	95
Banana	57	77	14	12	78	11
Giant tiger	-	-	-	5	20	20
Other	-	-	-	-	-	64
Thailand	184,884	225,515	265,524	260,713	224,836	215,000
Banana	4,752	3,285	3,000	1,814	1,827	1,700
Giant tiger	179,358	219,900	259,724	257,062	220,372	211,100
Other	774	2,330	2,800	1,837	2,637	2,200
Vietnam	37,800	42,000	45,000	52,000	65,000	80,000
Banana	7,560	8,400	9,000	10,400	13,000	16,000
Giant tiger	28,350	31,500	33,750	39,000	48,750	60,000
Other	1,890	2,100	2,250	2,600	3,250	4,000
Total	445,689	505,987	541,457	555,231	526,622	504,769
Banana	35,050	41,216	36,321	44,314	44,525	50,337
Giant tiger	384,886	428,725	472,890	480,989	449,045	420,347
Other	25,753	36,046	32,246	29,928	33,054	34,085

FAO Aquaculture Production Statistics, 1999

Definitions of Sustainable Development

There are a number of definitions of sustainability, although there are many different views on this topic. The commonly quoted FAO definition of "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 development conserves land, water, plant and genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (Barg, 1992).

In practice, sustainable development involves a consideration of technical, social, inter- and intra-generational equity, environmental, economic and institutional issues (Muir, 1996). With reference to aquaculture, management of sustainable development therefore requires attention of:

- Farming system and technology,
- Economic/financial sustainability,
- Social sustainability - social benefits, equity and interactions,
- Environmental sustainability - mainly interactions and use of major resources such as land, water, seed and feed, and
- Institutional and legal context.

Problems and Issues of Shrimp Farming

Diversity in the shrimp culture sector

Shrimp farms are commonly classified into extensive (low input systems characterised by low stocking densities, tidal water exchange and shrimp yields of less than 500 kg/ha/yr); semi-intensive (supplemental feeding, intermediate stocking, occasional pumping of water and yields of 1-2 tons/ha/yr); and intensive high stocking density formulated feeds, aeration and water pumping with yields of more than 2 tons/ha/yr). Farms may also be monoculture or polyculture (usually more common with low input systems); they may be operated as alternate cropping, involving one crop of shrimp followed by a harvest of another species (sea bass, milkfish) or crop (rice-shrimp alternate cropping systems in Vietnam). The farm size is also very variable, but shrimp farms in Southeast Asia are mainly small-scale.

Thus, an important consideration when discussing shrimp farming and its management is the diversity of farming systems in operation as well as their location, size, management and the people involved. Inevitably, with such diversity, most management decisions should be made based on a clear understanding of the diversity and practical circumstances at the local level.

Shrimp farming also supports a large number of associated "industries", including input suppliers (such as nauplii production, hatchery operators, manufacturers and suppliers of feeds, equipment, chemicals, pond construction, sediment removal, etc.) and people and businesses dealing with post-harvest handling and processing, distribution, marketing and trade. This diverse and sometimes fragmented structure of these sub-sectors has also to be considered in assessments of the nature of shrimp farming and its management (Fegan, 1996).

Economic significance

Shrimp farms generate considerable economic returns. Globally, it earns around US$6 billion yearly at farmgate prices, with the value increasing substantially as shrimp moves up the market chain to the consumer. In 1995, shrimp aquaculture production was estimated to be worth US$20 billion in Asia, with infrastructure investment in ponds alone around US$11.5 billion (ADB/NACA, 1998).

Poverty alleviation through income generation among coastal peoples is a critically important development objective (Islam and Jolley, 1996) to which shrimp and other forms of coastal aquaculture can contribute.

Social interactions: people involved, employment, and social impacts

A diversity of people from various backgrounds, social groups and traditions is involved in shrimp farming. Investment and economic output from shrimp generates considerable employment in developing (but also developed) countries from input suppliers (e.g. hatchery operations, feed sales), producers (farmers and farm workers) and in post-harvest and processing, including employment for women. Employment in distribution, marketing and trade is also significant. Exact numbers employed in shrimp farming are unknown. Some estimates suggest that globally around 1 million people may be involved, although this figure is probably an underestimate.

In Thailand, more than 150,000 people are directly employed in shrimp farming (Kongkeo, 1995), in addition to a large number involved in input supplies, support services, handling and processing of shrimp products.

Employment generated by shrimp farming can compare very favourably with some other agricultural and traditional activities in coastal areas. A survey (ADB/NACA, 1998) of around 5,000 diverse shrimp farms in Asia showed that intensive shrimp farming provided an average of 558 person-days/ha/yr. Semi-intensive shrimp farms provided a similar figure, but traditional/extensive farming systems had a much lower estimate of 192 person-days/yr. Even if multiple-use traditional activities are accounted, the employment potential of semi-intensive and intensive shrimp farming clearly compares well with traditional coastal activities such as rice, mangrove crab, and timber collection. Rice farming employment figures are commonly reported at around 200-250 person-days/ha/yr.

In Southeast Asia, small-scale farmers make up a major proportion of the shrimp farming/hatchery population, although there is a considerable variation among countries. A 1996 survey of 400 intensive shrimp farmers in Thailand showed that a majority of shrimp farmers were previously rice farmers or fishermen in rural areas. However, most investors from towns left their shrimp farming business since the golden age of shrimp farming has passed. Shrimp aquaculture can therefore contribute to diversification of employment opportunities in coastal areas. Such positive contributions to development among local people obviously need to be strengthened.

These positive aspects need to be set against the risk associated with calamities such as for example floods or shrimp disease, which, when they occur, can make such employment gains and other benefits short-lived. In some countries, concern has been raised about the distribution of benefits from shrimp farming (Olsen and Coello, 1995) and social conflicts have also sometimes arisen with other coastal resource users and communities as a result of rapid expansion of ponds (Bailey, 1988; Clay, 1996). Such issues have to be properly understood and ‘managed’ within the context of a management framework for sustainable shrimp aquaculture.

Environmental interactions

Environmental interactions of aquaculture in general arise from a wide range of interrelated factors including availability, amount and quality of resources utilized, type of species cultured, size of farm, farming systems management, and environmental characteristics of the farm site. These interactions arise because aquaculture relies heavily on environmental “goods” (e.g., water, feed ingredients, seed, etc) and “services” (e.g., coastal ecosystems for pond water discharge). Three issues arise from these interactions:

- aquaculture in general, and shrimp farming in particular, is highly sensitive to adverse environmental changes (e.g., water quality, seed quality), and can be seriously affected by aquatic pollution;

- aquaculture inevitably interacts with non-aquaculturists that rely on “commonly-shared” resources such as water and public land and may arise when formal and informal institutional, legal, and social structures are inadequate for conflict resolution and for allocation of resources among competing groups; and

- it is in the long-term interests of aquaculturists to work towards protection and enhancement of environmental quality. This raises interesting possibilities for aqua-farmers to work in partnership with communities and other groups with a mutual interest in protection of aquatic environments (Barg *et al.,* 1997), given that aquaculture needs good quality water and other natural resources.

They key environmental interactions of coastal shrimp culture are well known and are related mainly to the habitat and aquatic resources in shrimp aquaculture areas. Environmental impacts may arise through impacts on aquaculture, of aquaculture on the environment, and impacts of aquaculture on aquaculture. Perhaps less well known and documented is that coastal aquaculture, including shrimp culture, can contribute to environmental improvement, such as:

- Removal of nutrients and organic materials from coastal waters through seaweed and mollusc culture;
- An alternative source of employment for local peoples utilizing coastal habitats. For example, mixed aquaculture-mangrove systems can restore mangrove habitats in some countries (e.g., Indonesia's tambaks, Vietnam's mixed-farming systems);
- Mariculture providing an alternative to destructive fishing in coral reefs;
- Rehabilitation of fish stocks through stocking; and,
- Monitoring of environmental conditions

Management Strategies for Sustainability

Background

Management strategies for sustainability require consideration of a complex range of factors but generally require the consideration of strategies at different levels: (a) the farming activity (e.g., in terms of the location, design, farming system and operational management); and (b) the 'integration' of aquaculture into the developmental and environmental context characteristic of the specific coastal area in question.

Implementation of such management activities also implies human interventions at various levels, from the level of the farmer or investor to government policy. Because of the complex interactions of environmental, social and economic levels, an integrated view of coastal resource use, where shrimp aquaculture is but one activity among different economic and social uses, is essential.

Guidelines are already emerging for the improvement of management practices for shrimp aquaculture. In addition to efforts in the past (ADB/NACA, 1991; FAO/NACA, 1995), these include recent studies in Asia which produced the Regional Aquaculture Sustainability Action Plan (ASAP), prepared during the Regional Workshop on Aquaculture Sustainability and the Environment in Beijing, China in October 1995 (ADB/NACA, 1998), and the more global FAO Code of Conduct for Responsible Fisheries (CCRF) (FAO, 1995) and its associated Technical Guidelines FAO, 1997. In very broad terms, these initiatives identify management strategies at the level of:

- Technology and farming systems: The importance of appropriate farming technology/system and management of major inputs and outputs, with special attention to the major resources of feed, water, sediments and seed. Management actions taken at this level mainly involve the farmer and input suppliers.
- Adoption of integrated coastal area management approaches: The importance of integrating aquaculture projects within existing environmental (and social) systems in coastal areas is being increasingly recognised. This approach requires consideration of proper site selection and planning and management strategies, which allow allocation of resources among different coastal resource users. Management actions at this level are more complex and involve more 'players', including the farmer, other users of coastal resources, and government.

  Policy and institutional support: The importance of an unambiguous and supportive policy framework is strongly emphasised. Specific issues to be addressed may include aquaculture legislation, economic incentives and dis-incentives, public image, private sector and community participation in policy formulation, increasing the effectiveness of research, extension and information exchange. Management actions taken at this level are primarily the responsibility of government, although formulation of policy should also involve input from other 'stakeholders'. Policy decisions and their implementation play a strong role in influencing the management possibilities at the previous two levels.

Farm management practices

There are already a number of significant changes taking place in management practices at the farm level in several countries. The following are major management considerations for shrimp farming based on the ASAP and FAO's CCRF:

Farm siting: Many problems that have emerged with shrimp culture could be conveniently avoided by appropriately siting farms, which consider existing environmental suitability and social values and options for alternate uses. For example, problems associated with semi-intensive and intensive shrimp ponds in mangrove areas can be avoided by locating farms behind coastal mangrove belts (see Menasveta, 1997). Some of the constraints causing poor siting such as unclear land-use rights and others (see Fegan, 1996) should also be addressed. Mangrove land, for example, whilst widely recognised as a poor site for intensive shrimp pond development, may (in the past at least) have been more easily accessible because of lack of clear property rights and government incentives, which previously recognised mangroves as land of marginal value. Fortunately, there is increasing recognition that mangroves are not suitable sites for intensive farms, because of various risk factors (e.g., acidic soils, peaty and soft soils, etc). The cost of land in supra-tidal areas such as rice fields is higher, but the cost of construction for intensive ponds is much lower because heavy machines can be used efficiently. When shrimps are cultured in mangrove areas where water and soil contain high organic loads, disease problems always occur. In contrast, pond bottom in supra-tidal areas can be completely dried-out for efficient removal of the fouled bottom layer by heavy machines. Where farms are located behind mangrove areas, care is required to minimise potential salinisation impacts on surrounding lands through buffer zones, good farm construction and design (see below).

Farm systems development: Development of sound shrimp farming systems may enhance sustainability. Effluent from intensive ponds may be a useful source of nutrients and organic matter for mangroves, for instance. Integrated systems of farming freshwater fish, where aquaculture is integrated with agriculture, are recognized as environmentally sound systems given their efficient rates of conversion and recycling of nutrients and organic materials. There are many examples involving freshwater aquaculture, where pond water and sediments have been used to fertilize agricultural crops, thus eliminating the potential environmental impacts of effluent (see Edwards, 1993 for review). Such systems tend to be inherently more environmentally sustainable because they rely on more inputs from within the farming system, and therefore tend to have less demand for environmental 'goods' and 'services'. There are a number of advantages to diversification of systems, such as spreading the risk associated with monoculture among different crops and recycling of nutrients and organic matter.

Rice-shrimp farming is widely practiced in some parts of the Mekong delta in Vietnam, and in other delta areas in Asia. Such systems, which alternate rice farming in the rainy season with shrimp in the dry season (when there is salt intrusion), have been shown to be sustainable over long periods (Mekong Secretariat, 1992) and suffered less shrimp disease problems during recent white spot outbreaks (ADB, 1996). Alternate cropping between shrimp and fish has also been recommended on intensive farms. Mixed fanning systems have also been promoted in some areas. Integrated aquaculture-mangrove forestry (silvo-fisheries) offers one approach to conservation and utilization of the mangrove resource which allows for maintaining a relatively high level of integrity with the mangrove area while capitalizing on the economic benefits and poverty alleviation potential of brackishwater aquaculture (Fitzgerald, 1997). Indeed, silvo-fisheries have been used in mangrove replanting projects now being undertaken in Vietnam, Indonesia, and Philippines. These models should be further researched and mangrove-compatible systems promoted.

Intensive farming can be sustainable if well located and practiced with good management (e.g., incorporating some of the practices identified in this paper) since some intensive and semi-intensive shrimp farms have been operating in Asia for at least ten years. The opening up of ecologically-sensitive areas for extensive monoculture farming seems hard to justify given the large areas required for profitable farming and the low economic returns per unit area. Future development of shrimp farming systems is therefore likely to be towards more intensified systems, although perhaps not as intensive as in the recent past, and will necessarily have to give much greater attention towards 'management for sustainability'.

Farm construction and design features: Farm construction practices and design are important in the management of environmental interactions, and much can be done to mitigate environmental problems by adoption of appropriate practices in the construction and design of farms. To prevent conflicts with nearby rice farms, the ponds must be designed to have proper drainage system without interfering with freshwater canals. Pond embankments should be well compacted to prevent seepage of saline water into rice paddies. Saltwater intrusion can be avoided by siting farms on clay soil areas. The incorporation of water treatment ponds (as in the case of Thailand, where larger farms are now required by law to incorporate a settlement pond in farm designs) can help to reduce effluent load. Buffer zones between farms and surrounding land can also be used to minimise impacts on surrounding ecosystems, protect nursery grounds for aquatic life, and protect traditional activities. Mangrove buffer zones provide protection from storms, maintain traditional fisheries, and may even improve water quality (Macintosh, 1996). The water supply and drainage canals should be designed to reduce mixing of inflow and outflow waters and to adequately disperse effluents. To facilitate optimal water circulation in ponds, the pond shape for intensive culture systems should be square or round with an optimal size of 0.5-1.0 ha.

Selection of suitable species and seed: Shrimp culture in some countries also relies on wild shrimp post-larvae (Banerjee, 1993), leading to concerns about social and environmental impacts of shrimp seed collection. The increasing trend towards use of hatchery-reared shrimp helps reduce the reliance (and potential impact) on wild stock. The use of indigenous shrimp species would be preferable to introduced species, and genetic improvements may provide better stocks. Care needs to be taken not to impact on wild stocks with such practices, but protocols now being developed may help in this regard (e.g., FAO, 1997). Reduction in shrimp stocking densities has also been practiced, since farmers have now become aware that lowering of stocking densities can lead to more sustainable harvests. For example, farmers in Thailand are now reducing stocking densities in intensive farms and finding that profitability is maintained and the risk of disease reduced.

Appropriate feeds and fertilisers: Feed is required in intensive farming systems, where the amount used (and efficiency of use) and the type of feed becomes important. The amount of excess nutrient and organic matter can be significantly reduced by improved feeding practices, such as carefully controlled feeding and use of feeding trays (AAHRI, 1996). Surveys have also shown that food conversion ratio is less on small family-operated farms than on large-scale farms (CP News, 1994). Small farms are more efficient than large-scale farms run by workers due to the sense of belonging. There is increasing attention being paid to reduction in the use of fish meal in diets for aquaculture. The use of moist and fresh diets are known to be more polluting and wasteful of resources and tend to be less used on intensive farms in Asia, because of concerns over water pollution and introduction of shrimp pathogens. It can be expected that improved feeds (such as with more appropriate protein content) and feeding systems will be adopted over the next five years (Chamberlain, 1996), a move that could further reduce loadings of pond effluent.

Re-design of systems to provide for recycling of excess nutrients and organic matter in effluent into secondary aquaculture products (e.g., fish, mollusc) or even agricultural crops (Tookwinas, 1996) could also help increase the efficiency of resource use and make additional contributions to local food supplies (as well as reducing effluent loads to local coastal waters).

Fertiliser is generally required for plankton blooming during the initial stage while the stocked post-larvae mainly rely on natural feed. In low water exchange systems, the accumulated nutrient in pond will later serve as fertiliser.

Water and sediment management including effluent control: Various options for control of effluent loads in shrimp ponds which can be applied to reduce any impacts of effluents on surrounding waters, and keep any discharge within assimilative capacities of recipient water bodies. In Thailand, the generally practiced low water exchange system which was mainly developed for reducing the risk of introduction of shrimp pathogens, virus carriers and toxic particles released by nearby farms into the ponds, can dramatically reduce effluent loads. To maintain good water quality, circular water movement in Thai shrimp ponds is facilitated by heavy aeration to concentrate all the waste at the center of the pond rather than remaining spread throughout the pond bottom. This will cause the remaining bottom area clean which is necessary for low water exchange system. Although the quality of the existing pond water is poor when there is less water exchange, shrimp can gradually adapt to this condition. If there is heavy introduction of new water into the pond, it will cause high mortality to shrimp due to the sudden change in water quality (chemical, biological and physical). This low water exchange system has been used to expand shrimp farms into areas with little access to seawater.

If ponds are located in unavoidably polluted or disease-prone areas, particularly along rivers and canals, a closed (zero water exchange) system should be developed. This system has reservoirs, which later serve as water treatment ponds. After settlement in the reservoir, the incoming water is chlorinated to eliminate some pathogens and virus carriers. Waste water from grow-out pond is pumped into this treatment pond where organic loads and silt will settle in and phytoplankton and zooplankton are consumed by introduced fish and bivalves, e.g. tilapia, mullets, milkfish, green mussels or oysters, acting as bio-filter. The clear surface water is allowed to overflow into the supply canal where heavy aeration is applied so as to eliminate toxic gases before pumping back into the grow-out pond. This system is not suitable in open-sea areas where salinity is usually high due to increased evaporation.

The closed system is also used for *Penaeus monodon* culture in freshwater, particularly in areas accessible to estuarine waters. If the soil is still salty, the salinity of stocked freshwater at the depth of 30 cm in grow-out ponds will rise to about 5 ppt within 1-2 weeks. Otherwise, pathogen-free hypersaline water (150-200 ppt) from salt farms should be transported by truck and subsequently diluted to 5 ppt in the grow-out pond. After seed stocking, freshwater is gradually added to fill the pond to the desired level. Because of a nearly five-fold dilution and the absorption of sodium chloride by the bottom soil, the final salinity will become nearly 0 ppt, which is not harmful to the surrounding environment. The stocking density is reduced to $20/m^2$ so that shrimp can grow to the size of 20-25 g within 3 months. Freshwater will stunt the shrimp only after 100 days of culture period. This 3-month culture will force the farmers not to pollute their ponds as the amount of feed is much less than 4-5 months. Another advantage of this technique is that yellow head and white spot viruses hardly occur in freshwater. However, the long-term impact on the environment needs more careful study.

Culture in full-strength seawater with high water exchange system is the most suitable technique for shrimp farms along the coast where farm effluent can be completely drained out to the open sea. In the past, these farms faced a major problem of stunted shrimp caused by high salinity and clear water. In fact, high salinity (over 40 ppt) will affect shrimp only during the juvenile stage when they mainly consume zooplankton, which are not available in normal high salinity and clear water. Heavy fertilization with minimal water exchange during early stage is required so as to increase natural food for shrimp juvenile. Bacterial infection and pond bottom deterioration caused by overblooming of phytoplankton also hardly occur under such high salinity conditions.

Management strategies for effluent need also to be carefully balanced against discharge targets, to avoid unnecessary costs. Nutrient and organic matter concentrations in effluent are highest during shrimp harvesting and subsequent cleaning of ponds, when effluent quality can be very poor due to disturbance and release of material previously bound to the sediment. Effluent targets could be met in many circumstances by concentrating management efforts in the treatment of harvest water and sediment. A significant proportion of nutrients and organic material is tied up in bottom sediments, and consequently some countries have placed restrictions on indiscriminate discharge of shrimp farm sediments (FAO/NACA, 1995). Sediments also have potential as a useful fertiliser. There is increasing interest in the use of bio-filtration, including wetland-mangrove habitats in appropriately located sites on the farms (Robertson and Phillips, 1995).

Physical removal of pond sludge is a major operation in Thai shrimp farming to eliminate silt, organic matter, pathogens and virus carriers, toxic gases such as ammonia, hydrogen sulfide and methane accumulated in the pond bottoms from previous crops. During the dry season, the fouled layer of the pond bottom is scraped off by bulldozer and dried on the pond dikes or removed by excavator to dry in a reserved area nearby. During the rainy season when heavy machine is not practical, sludge can be removed in suspension by high-pressure hoses and then pumped to a settlement pond to avoid contaminating the water supply.

There are numerous other options for bio-filtration, including the use of molluscs, seaweeds, finfish ponds. Recent studies have also been made with the use of halophytes for treatment of saline aquaculture effluent, such as *Suaeda* sp. and *Salicorna* sp., succulent marsh plants which can be used as fodder for some livestock.

Whilst various research have focused on various aspects of intensive pond effluent treatment, it is also becoming clear that controlling effluent loads released to the coastal environment requires a 'holistic' type of approach. This should be based on the understanding of the local farming systems, properly defining problems (if any), and development of locally appropriate solutions (Smith and Masters, 1996; Boyd, 1997) depending on individual farming systems or location of specific environmental concerns.

Shrimp health management practices: Shrimp diseases are a major manifestation of the lack of sustainability in all types of shrimp culture (Chamberlain, 1996). Farm and shrimp health management practices favoring hygienic measures, and the safe and effective use of therapeutants and other chemicals need to be developed. The adoption of the systems approach which gives emphasis on management of conditions which lead to disease and reduced chemical use is also being promoted - a potentially "win-win" situation which may be both profitable and can minimize environmental costs. The development of captive broodstock for major farmed shrimp species and programs for their genetic improvement should result in farmers having better quality shrimp post-larvae free of and/or resistant to specific pathogens. Specific pathogen-free seed or high health shrimp post-larvae or low pathogen seed is also showing promise. Pruder et al (1995) emphasized that sustainability and farm profitability can be achieved by integrating high health shrimp seed with disease control and appropriate farm management practices.

Key Issues to Minimize Environmental and Social Impacts

Pond rehabilitation

The area of "abandoned" or unproductive shrimp farms is controversial and poorly defined, but there is increasing interest in rehabilitation of some farming sites, and recognition that such efforts may contribute to sustainability (e.g. mangrove replanting, meeting social objectives, contributing to re-employment). In the Philippines, mangrove areas released by the government for large areas of extensive ponds, are being reverted to public land and reforestation, as well as various forms of aquaculture. In some localities, intensification of shrimp farming in the best ponds of a farm might allow some of the ponds sited in former mangrove areas to be returned to mangrove. There may also be opportunities for extensive farms on mangrove land to replant part of the farm, and intensify the remaining pond area. This is an area of increasing interest (Stevenson and Burbridge, 1997).

Coastal area management

The concept of 'integration' can be extended to the integration of aquaculture farms into the coastal area, a concept that is given increasing attention as a result of pressures on common resources in coastal areas arising from increasing populations combined with urbanization, pollution, tourism and other changes (Sorensen, 1997). Integrated coastal management (ICM) is a process that addresses the use, sustainable development and protection of coastal areas, and according to GESAMP (1996) "comprehensive area-specific marine management and planning is essential for maintaining the long-term ecological integrity and productivity and economic benefit of coastal regions". There have already been considerable efforts within countries as well as internationally to address economic, social and environmental problems being experienced in a wide range of coastal areas. Few of these efforts address aquaculture specifically, but nevertheless aquaculture (and shrimp farming in particular which requires coastal land) has some considerable benefit to participating in such activities.

ICM involves a participatory and strategic planning process that spans issue identification and assessment, public education and stakeholder consultation, selection of issues to be addressed, geographic focus and activities to address issues, formulation and adoption of a management plan, and capacity building within the public sector for implementation. Roles and responsibilities for planning and implementation of ICM need to be clearly delineated. An institutional structure for ICM typically contains distinct but clearly linked mechanisms for: (i) achieving interagency coordination at the national or regional level (e.g., through an inter-ministerial commission, authority of executive council); and (ii) providing for conflict resolution, planning and decision-making at the local level (Tobey and Clay, 1997). Tobey (1997) indicates ICM can be made operational through:

- land use zoning and buffer zones;
- regulations, including permitting to undertake different activities;
- non-regulatory mechanisms, such as incentive-based measures, technical assistance and extension, voluntary agreements and adoption of Best Management Practices;
- construction of infrastructure;
- conflict resolution procedures;
- voluntary monitoring; and
- impact assessment techniques.

The integration of shrimp farming into coastal area planning and management has been the subject of considerable interest and it is recognized that this is an important step which will contribute to sustainability. However, practical experience in implementation for aquaculture is limited, which is in large measure because of the absence of adequate policies and legislation and institutional problems, such as the lack of unitary authorities with sufficiently broad powers and responsibilities. Integration of aquaculture into integrated coastal management is a subject area which will receive more attention in the future as practical experience of ICM in general improves (for a critical review of experiences in ICM, see Sorensen, 1997). A recent GESAMP working group has also looked into this aspect and developed some strategies for integration of aquaculture into integrated coastal management planning (U. Barg, FAO, Rome, personal communication).

An important principle of ICM is adoption of participatory approaches. In inland areas, aquaculture is commonly practiced on privately owned land, often in well-established agricultural farmland. Coastal aquaculture in contrast is often developed close to (or sometimes) on public land or water, leading to increased risk of conflicts with other coastal resource users (Bailey, 1988). The problems are likely to be most serious where there are traditional community-based uses of common property resources, large coastal populations and/or aquaculture operations, and other development interests (e.g., tourism), as large "consumers" of environmental "goods" and "services" in relation to existing resource availability. In such situations, effective formal or non-formal conflict resolution and the participation of concerned 'stakeholders' in planning of balanced resource use for aquaculture and other uses is necessary to avoid or resolve conflicts between shrimp farmers and other users of common property. Rubino and Wilson (1993) emphasize that procedures for resolving conflicts between aquaculturists and other marine or public water resource users may also promote public acceptance of coastal aquaculture in general.

Experience with coastal fisheries management in general shows that failure to include coastal residents in natural resource management can lead to lack of community compliance resulting in resource depletion and conflicts, particularly when government capacity to enforce laws and regulations is limited. A promising approach to this problem may be "co-management", which involves the cooperation of the local community in establishing and enforcing local management rules with the support from government (Pomeroy, 1994). The co-management approach has proved useful for community-based management of some coastal capture fishery resources, but the devolution of ownership and management of resources to local people and communities should be explored for coastal aquaculture.

Davy (1991) emphasized the importance of local ownership and management of coastal resources considering that "trends in the development of fisheries (including aquaculture) in Japan indicate that only through ownership or a system of fishery rights is there a satisfactory foundation for future development". More attention should be given to explore and develop such local community-based development strategies. As pressures on coastal resources inevitably increase with expanding populations, or accelerating resource extraction rates, the further development of mechanisms for effective conflict resolution and apportioning of resources between all types of coastal aquaculture and other sectors will become increasingly more important components of sustainable aquaculture management.

There are already examples where cooperation among individual shrimp farmers can also help improve management of common resources for sustainability. For example, the farmers' association in Surat Thani and in Chantaburi in Thailand coordinate the timing of pond intake and discharge, thus avoiding some of the problems associated with self-pollution of water supplies (Phillips and Macintosh, 1997). The association is also now active in replanting of mangroves in coastal areas. Farmer associations can also provide more effective means of voicing individual farmer concerns and aspirations and are being promoted in several countries. NACA is also in the early stages of establishing a regional farmers association in Asia, to promote such coordinated activities.

Aquaculture zoning

Zoning of land (and water) areas for certain types of aquaculture development may also be another strategy for 'integrating' aquaculture into coastal areas. It may help in controlling environmental deterioration at the farm level, and in avoiding adverse social and environmental interactions. In Malaysia, government policy is to identify specific coastal aquaculture zones, compatible with existing land use patterns. In Korea, Japan, Hong Kong and Singapore (FAO/NACA, 1995), there are well developed zoning regulations for water -based coastal aquaculture operations (marine cages, molluscs seaweeds). Zoning can also be designed in ways to encourage multiple use if appropriate, following agreed allowable and non-allowable uses, promoting optimal and balanced coastal resource use. Zoning for aquaculture may be particularly beneficial for small-scale shrimp farmers, who can be provided with proper water supply/drainage infrastructure, avoiding the ad hoc water supply and drainage systems resulting from uncoordinated development of individual farms (ADB/NACA, 1996).

Aquaculture legislation

Government regulations are an important component of management in supporting aquaculture developments, maintaining environmental quality, reducing negative environmental impacts, allocating natural resources between competing users and integration of aquaculture into coastal area management. Regulation of aquaculture, often (but often also one of the traditional users) recognised as a 'newcomer' among many traditional uses of natural resources, has commonly been conducted with an amalgam of fisheries, water resources, agricultural and industrial regulations (Rubino and Wilson, 1993). It is becoming increasingly clear that specific regulations governing aquaculture may be necessary (Howarth, 1995; Howarth, 1996), not least to protect aquaculture development itself. "Constructive aquaculture policies and regulations can accentuate the benefits of cooperation and head off potential problems" (Rubino and Wilson, 1993). This also strongly emphasised in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995; FAO, 1997).

Regulation of aquaculture is a particularly intricate exercise due to the interdependency of the activity upon the state of aquatic environment in which it is conducted and the use of a wide range of environmental "goods" and "services". Land and water, in particular, may already be governed by various "non-aquaculture" laws and regulations developed for other purposes (Howarth, 1996). Rubino and Wilson (1993) and Howarth (1995) provide more information on some of the key issues to be considered in legislation.

Environmental impact assessment

Environmental impact assessment (EIA) can be an important legal tool and the timely application of EIA (covering social, economic and ecological issues) to larger scale coastal aquaculture projects can be one way to properly identify environmental problems at an early phase of projects, enabling proper environmental management measures (which will ultimately make the project more sustainable) to be incorporated into project design and implementation. Sri Lanka, Indonesia and Malaysia already have some EIA regulations covering development of large-scale shrimp culture, but more widespread and effective use of EIA may be worthwhile.

A major problem with EIAs is that they are difficult (and generally impractical) to apply to smaller-scale shrimp farm developments and cannot take account of the potential cumulative effects of many small-scale farms. Such problems, which can seriously influence sustainability because of the effect of self-pollution and inter-farm spread of shrimp pathogens, can only be solved through an integrated coastal management approach and more regional level environmental assessments.

Environmental quality standards

A number of countries have adopted various environmental quality standards to control environmental effects of shrimp aquaculture, including the effects of pond effluent on receiving waters. Such standards are notoriously difficult to monitor and enforce (one of the reasons being the large number of farms, often spread over large geographical areas, and limited capacity and time for monitoring). In any event, to be ecologically effective, water quality standards for effluent should be set based on the farm type and environmental quality objectives for receiving waters. In view of such difficulties a more practical approach may be the design and implementation of "best management practices" which for the purposes of maintaining desired environmental quality may include such issues as management techniques such as more efficient feed and feeding methods and reduced stocking densities, reduced water use, effluent treatment and reuse through settlement ponds, and responsible disposal or re-use of pond sediments.

Shrimp culture often suffers from water pollution caused by other industries (FAO/NACA, 1995). Thus, attention should be given to water pollution controls in other sectors, rather than concentrating on shrimp culture alone. Water quality management should be part of a comprehensive integrated approach to environmental management in coastal areas. Whilst adoption of more integrated approaches would greatly benefit the protection of environmental quality and coastal aquaculture also, unfortunately, such approaches are relatively rare in many areas.

Some On-going Asia Regional Initiatives

There are a number of ongoing regional initiatives which are providing support and development cooperation in dealing with some of the above management issues.

Asia regional quarantine and health certification

On the request of NACA member countries, NACA and FAO are cooperating on the drafting and adoption of regional guidelines for health certification and quarantine of aquatic animals in the Asia-Pacific region, based on regional circumstances but also consistent with international legislation and agreements. Thus, they should be applicable not only to both participating and non-participating countries in Asia, but also to many countries in other parts of the world.

Capacity building and technical guidelines to support the application of the CCRF to shrimp aquaculture

NACA and FAO are working on a project entitled Technical Guidelines and Capacity Building for the Application of the Code of Conduct for Responsible Fisheries to Shrimp Aquaculture (Phase I) designed to assist countries in Asia in the development of capacity and guidelines to support implementation of the Code of Conduct with respect to shrimp aquaculture. The emphasis of the project is on working at a practical level to translate the global Code of Conduct for Responsible Fisheries to national and local levels.

SEAFDEC has also recently approached NACA for cooperation in providing assistance to SEAFDEC Member Countries in the implementation of a global code of conduct in aquaculture.

Development of "best practices" in shrimp aquaculture

In addition, NACA is participating in a number of regional and international research initiatives aimed at identifying "Best Management Practices for Sustainable Shrimp Culture" which is partly supported by the World Bank. As part of this global collaborative effort, FAO is also planning to organize a global expert meeting on best management practices in shrimp culture in late 2000 or early 2001, to provide the opportunity for the various international and national initiatives to present and discuss their findings in an open forum of experts and stakeholders interested in sustainable shrimp culture development.

Research to support sustainable shrimp aquaculture

ACIAR and NACA also collaborated in an analysis of researchable issues for shrimp aquaculture in the Asian region. The key areas identified in this review (which is in press) are as follows:

- to develop high health, low risk pond management methods;
- to develop practical methods of immuno-prophylaxis for shrimp;
- to investigate interactions between nutrition and shrimp health;
- to assess causes of water quality deterioration and the effects on shrimp health;
- to develop effluent management and waste treatment technologies;
- to investigate endocrinology of broodstock maturation;
- to develop domesticated stocks;
- to develop high health health hatchery production methods;
- to better understand pond dynamics and ecology;
- to understand the role of biological agents and microbial ecology in improving the pond environment; and
- to develop more effective strategies for collaboration with farmers and transfer of research results to the farm.

These and other research and development initiatives should provide a significant support to countries of the region in the development and implementation of improved management practices for shrimp aquaculture.

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Developments In Marine And Brackishwater Fish Culture In Southeast Asia

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ABSTRACT

Freshwater, brackishwater, and marine ecosystems are recognized as distinct from each other and aquaculture is often conventionally categorized accordingly. However, the brackishwater aquaculture category is by no means universally recognized. China, India and Japan recognize only two categories: inland and marine aquaculture. Thailand and Vietnam, on the other hand, report production from brackishwater and marine aquaculture together under one category: coastal aquaculture.

An examination of the species involved would show that there is such a wide overlap between so-called "brackishwater species" and "marine species" so that the two groups are virtually congruent with each other. Brackishwater species are euryhaline and can survive just as well in varying salinity levels and may also be raised and grown in full-strength seawater. So-called marine species, on the other hand, can tolerate slight dilutions in salinity and can be grown just as well in what are technically brackish waters. Furthermore, most, if not all, of the so-called brackishwater species invariably require marine waters for propagation. Thus, it would appear that the distinction between brackishwater and marine aquaculture is meaningless in categorizing aquaculture species.

Saltwater culture of finfish in Southeast Asia may be characterized by low species diversity; sluggish industry growth, continued use and even dependence for some species on wild-caught seedstock, and heavy dependence either on fresh fish biomass or on fish meal for formulated feeds. There are only a few of finfish species or species groups that are now commercially raised in saltwater: milkfish, tilapia, grouper, and sea bass. Mangrove snapper and rabbitfish are to a certain extent already being cultured, but have not yet reached a significant proportion. Relative to other aquaculture commodities, particularly penaeid shrimps and seaweeds, the growth of saltwater fish culture in Southeast Asia has not been particularly spectacular. This is not for lack of market since there is a good international and local market for groupers.

While milkfish and sea bass fry can now be commercially produced in hatcheries, commercial production of grouper fingerlings seedstock remains elusive, despite a long R & D history. There is an urgent need to develop cost-effective feeds with a greatly reduced requirement for fish protein for saltwater aquaculture.

A Global Retrospective

More than three thousand years ago when fish was first cultured in China during the Shang Dynasty (1401-1154 B.C.), the species known to have been cultured was the common carp (Li, 1992). All through the millennia, as dynasties came and went in China, and as civilizations rose and fell elsewhere on the globe, it appears that farmed fish was mainly produced inland, largely carps, and that China was the major producer. Today, as we enter the third millennium, the situation has not really changed all that much. Most of the world's farmed fish are still produced inland, most of it still consists of the common carp and other cyprinids, and most of it is still produced in China.

Current FAO Statistics shows that in 1997, of some 18.84 million mt of fish produced from aquaculture, 16.73 million mt or 88.8% were produced inland of which 13.27 million mt or 70.4% were cyprinids and 67% were produced in China (Figs. 1, 2 and 3). Thus, as the second millennium ends, even as man has set foot on the lunar surface and unmanned probes are being sent to explore distant planets, mankind remains largely land-bound in aquaculture as it has been more than three millennia ago.

The sea beckons. With world population having reached six billion even before the new millennium is ushered in, demand for fish will continue to grow while sea-catch dwindles and user-conflict over land and freshwater resources becomes more intense. To produce more fish in the near future, there may be no other recourse but to increasingly turn to aquaculture and increasingly turn to the sea. After all, the sea covers more than three-fourth of the planet's surface.

Towards such direction, Southeast Asia has had a long head start. Many of the Southeast Asian countries have been farming the fringes of the sea for more than just one century. The region's coastal ponds produce 54% of the world's farmed shrimps and its seafarms, more than 85% of the world's carageenophytes. However, while more than half of the world's fish from brackish and marine aquaculture comes from Asia as a whole, neither China nor Southeast Asia has a clear lead over the other regions as shown in Fig. 4.

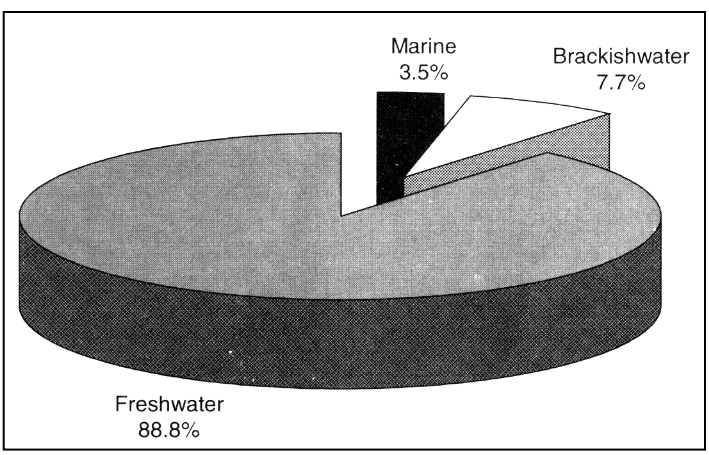

Figure 1. **Percent contribution of different aquatic ecosystems to world aquaculture fish production in 1997 (FAO, 1999)**

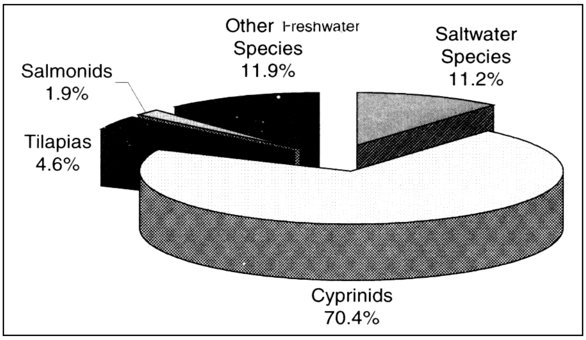

Figure 2. **Percent contribution of different species-groups to world aquaculture fish production in 1997 (FAO, 1999)**

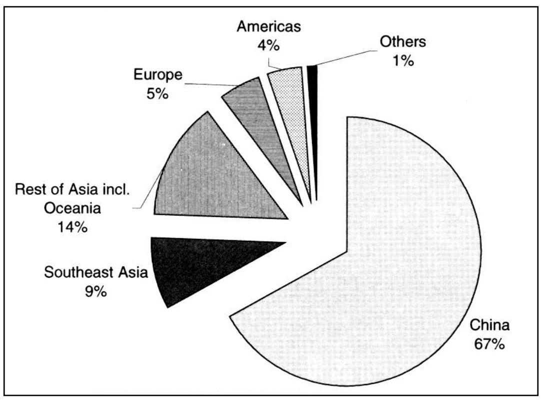

Figure 3. **Percent contribution of China and different economic regions to world aquaculture fish production in 1997 (FAO, 1999)**

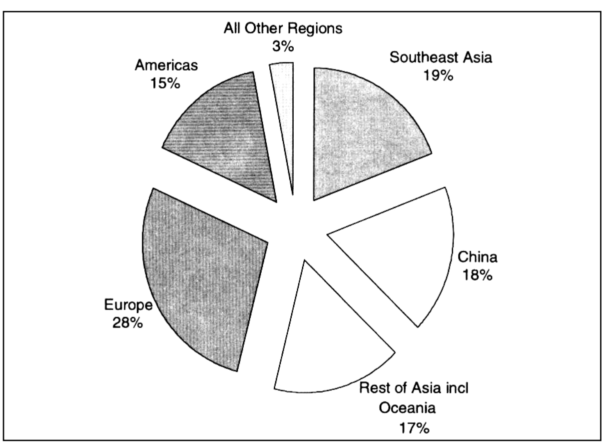

Figure 4. **Percent production of China and different economic regions to world production of fish from brackishwater and marine aquaculture in 1997 (FAO, 1999)**

A Question of Salinity

Categorization of aquaculture

When culturing fish or even when merely discussing aquaculture, one of the first parameter that comes to mind is the type of aquaculture in terms of the environment. Even before the use of the word 'aquaculture' was widely used, fish culture had always been categorized neatly into three sub-sectors based on the environment: freshwater, brackishwater, and marine. This is true in the Philippines in particular and Southeast Asia in general. This is also the system used by the Food and Agriculture Organization (FAO) in monitoring and reporting aquaculture activities and production. For a long time, this has remained unchallenged. After all it seems so logical and has a sound technical basis since it is based on the environment - or so most everybody must have thought.

Regional situation

A quick scan of the regional data reveals that the culture of a particular species is by no means uniformly categorized within the region. Singapore considers grouper culture as part of marine water culture but Malaysia, Brunei and Thailand classify it under brackishwater aquaculture. The Philippines reports the culture of grouper as part of brackishwater aquaculture if raised in ponds and as part of mariculture if raised in cages. Rabbitfish culture is similarly classified as the grouper in the Philippines but is considered part of marine water culture in Singapore. In fact, Singapore only has two categories: freshwater and marine water aquaculture.

Monitoring dilemma

The whole issue of brackishwater aquaculture as a category came up during the SEAFDEC-FAO Ad-hoc Expert Consultation on Variables and Terminology for Aquaculture Monitoring in Asia held in Bangkok, Thailand on September 13-16, 1999. Census and statistics experts anticipate difficulty in categorizing the ecosystem of a particular aquaculture activity properly due to the issue of when to consider a particular culture system as either brackishwater or marine in nature. Several "clear-cut" definitions of brackishwater were proposed for consideration by the body: 0.5 ppt to full strength seawater; less than 30 ppt but greater than 3 ppt; 0.50 to 17 ppt (Immink and Rana, 1999). These definitions clearly recognized salinity as a common factor. The census and statistics experts did not think it practical or feasible to require enumerators, who may not necessarily be aquaculturists or biologists, to bring along a salinometer just to classify an aquaculture area properly. Also as Yamamoto (1999) pointed out "salinity may differ from area to area even within the same day".

It turns out that China and Japan do not recognize brackishwater aquaculture as a category and only considers two categories: inland and marine culture (Liu and Deng, 1999; Saito and Ogawa, 1999). For the purpose of reporting to FAO, China disaggregates marine culture into marine and brackishwater culture based on the species cultured.

Thailand in their national fisheries statistics considers only two categories: freshwater and coastal aquaculture and disaggregates coastal into marine and brackishwater for FAO reporting purposes depending upon the species (Sirirattrakul, 1999). For China and Thailand, shrimps are reported to FAO under brackishwater aquaculture regardless of actual salinity. In national statistics however, Thailand which is now raising giant tiger shrimps inland, reports such production under coastal aquaculture. The Philippines on the other hand classifies fishponds as either freshwater or brackishwater while cages and pens are classified as either freshwater or marine (Recide, 1999). Thus aquaculture in coastal ponds is considered part of brackishwater aquaculture while aquaculture activities in cages or pens set in bays and coves are considered part of mariculture regardless of the actual salinity of the culture area.

India used to classify aquaculture into freshwater, brackishwater and marine but has recently changed the brackishwater aquaculture category into coastal aquaculture. This came about as a result of the Indian Supreme Court hearings on the legality of intensive shrimp farming during which the biologists and aquaculture experts failed to convince the justices that there is a clear-cut difference between brackish and marine waters. There being no legal basis to declare a water body as either brackish or marine, it was decided to classify shrimp farms as coastal rather than brackishwater ponds (Y.S. Yadava, Ministry of Agriculture, India, personal communication).

The consensus

There were strong arguments for following the Japanese model of having only two categories: inland and marine. Such a simple categorization is less subject to inconsistencies between countries and even within country from year to year. It will also make aquaculture reporting compatible with FAO capture fisheries reporting. However apprehensions were raised that the data will lose some details which may be useful for planning and management purposes.

In the end the general consensus of the countries represented in the consultation was to categorize aquaculture according to the geographic location: inland, coastal and marine. This will no longer require salinity consideration and may be more clear-cut for census taking and administrative purposes. Countries, which classify aquaculture into only two categories, may continue to do so and use the term inland and coastal or inland and marine as the case may be. Guidelines should however be made on dis-aggregating coastal or marine to coastal and marine. There is also a need to have a uniform operational definition of the coastal zone since coastal may be interpreted differently from one country to another. This classification is by no means final and may be considered only recommendatory.

Implications

One can understand the Indian Supreme Court's bewilderment over the difference between brackish and marine waters. While the brackish and marine categorization seems clear cut, it is not practical and leads to inconsistencies in reporting. It also leads to some gray areas. Some shrimp and milkfish farms for instance have been successfully operated using purely marine waters but are still considered brackishwater culture. Then there is the case of Iran. Along the Persian Gulf where the salinity normally ranges from 38 to 40 ppt, Iran is developing shrimp farms where river water is mixed with the Gulf water to bring down the salinity to 34 ppt. Does that make the water brackish?

Any reclassification of aquaculture activities is not likely to have a major impact on research and development activities since such classification is more for the purpose of planning, development and management purposes. However, it highlights the fact that while the freshwater species are distinct it is not possible to categorize the non-freshwater species as either marine or brackish in nature. Different species of fish may have their respective optimum salinity levels, but most, if not all, of the species now being farmed in coastal ponds and waters are euryhaline and as such can survive and grow almost equally well in brackish and marine waters. In fact, some ostensibly marine fish can grow as well in freshwater. The milkfish and seabass are prime examples. Regardless of their optimum salinity for growth, when it comes to propagation, all the euryhaline species cultured in Southeast Asia require full strength seawater for maturation, breeding and larval rearing. The brackish (and tidal) nature of the water supply comes into play and has to be considered in pond management but appears to have no functional value in categorizing fish species either for research or for statistical purpose.

Production Status

By country

Fish production from saline waters in Southeast Asia merely reflects world aquaculture; it takes a backseat to freshwater fish production. Of a total farmed fish production of 1.63 million mt in 1997, only 0.41 million mt comes from saline waters. Of the ten Southeast Asian countries, only one, Laos, is landlocked and is therefore limited to freshwater aquaculture. But three countries with coastlines, Cambodia, Myanmar and Vietnam do not have any report on fish production from saline waters. Myanmar and Vietnam do have coastal ponds but these are used exclusively for shrimps. Of

Table 1. **Farmed fish production by environment and by country in Southeast Asia in 1997 (FAO, 1999)**

	Production (mt)		
Country	**Freshwater**	**Saline Water**	**Total**
Brunei	30	69	99
Cambodia	11,534	-	11,534
Indonesia	356,890	237,622	594,512
Laos	14,000	-	14,000
Malaysia	26,901	6,193	33,094
Myanmar	87,306	-	87,306
Philippines	105,425	154,133	259,558
Singapore	115	818	933
Thailand	256,769	6,399	263,168
Vietnam	369,000	-	369,000

the six remaining countries, Indonesia, Malaysia and Thailand produce more fish from freshwater than from saline waters. Only Brunei Darussalam, the Philippines and Singapore produce more from saline waters. Indonesia is the region's top producer of farmed fish from saline waters with 237,622 mt followed by the Philippines with 154,133 mt as shown in Table 1. Thailand and Malaysia comes a very far third and fourth with 6,399 mt and 6,193 mt respectively.

By species

It is not possible to categorically use the term saline water species in denoting fish now raised in both brackish and marine waters. This is because some of the species now raised in such environments are clearly freshwater in origin such as for instance the Nile tilapia. In Indonesia, the Java barb (*Puntius javanicus*) is also reported as part of brackishwater aquaculture production.

Considering the diversity of marine fish, the number of species now being raised in saline waters in Southeast Asia is quite low. As many as 67 species representing some 22 families worldwide has been listed by Garibaldi (1996) as being raised in brackish and/or marine waters. This listing includes the cichlids represented by seven tilapia species. Within Southeast Asia, 17 species are listed in the statistics as being farmed in brackish and/or marine waters. However, this includes two tilapia species and one cyprinid and no production was reported for three of the species in 1997. Only eleven marine species

Table 2. **Fish production from aquaculture in saline waters in Southeast Asia in 1997. Species with no production reported for 1997 are still included to provide a complete listing of all species that have been reported farmed within the region (FAO, 1999)**

Common Name	Scientific Name	Quantity (mt)	Percent
All species		405,234	100.00
Milkfish	*Chanos chanos*	315,521	77.86
Mozambique tilapia	*Oreochromis mossambicus*	32,102	7.92
Sea bass (=Barramundi)	*Lates calcarifer*	13,419	3.31
Mullets	Family Mugilidae	11,563	2.85
Unspecified tilapia	*Oreochromis spp*	4,773	1.18
River eels	*Anguilla spp*	1,900	0.47
Groupers nei	*Epinephelus spp.*	1,492	0.37
Mangrove red snapper	*Lutjanus argentimaculatus*	1,392	0.34
Nile tilapia	*Oreochromis niloticus*	1,188	0.29
Greasy grouper	*Epinephelus tauvina*	799	0.20
Four-finger threadfin	*Eleutheronema tetradactylum*	409	0.10
Snappers nei	*Lutjanus spp*	71	0.02
Rabbitfish (=Spinefoot)	*Siganus spp*	43	0.01
Grunt	Family Theraponidae*	12	0.00
Spotted coral grouper	*Plectropomus maculatus*	-	0.00
Jacks	*Caranx spp*	<0.5	0.00
Scats	*Scatophagus spp*	-	0.00
Java barb	*Puntius javanicus*	-	0.00
Unspecified	Osteichthyes	20,550	5.07

* Percoidei in FAO Statistics since the species is reported under "Perches, breams, snappers, eels, etc." using the ISSCAAP system of grouping species but is identified as a theraponid in Philippine fisheries statistics.

Table 3. **Aquaculture production (mt) from saline water by species groups and by country in Southeast Asia in 1997 (FAO, 1999)**

	All Countries	Brunei	Indonesia	Malaysia	Philippines	Singapore	Thailand
All species	405,234	69	235,722	6,193	154,133	818	6,399
Milkfish	315,521	-	167,900	-	147,251	370	-
Tilapias	38,063	-	31,522	-	5,939	-	602
Sea bass	13,419	69	5,400	3,487	-	243	4,220
Mullets	11,563	-	11,200	-	-	-	363
Groupers	2,291	-	-	799	605	82	805
River eels	1,900		1,900				
Snappers	1,463	-	-	1,392	34	37	-
Others	21,014	-	21,600	515	304	86	409

belonging to six families are constantly reported as being produced as shown in Table 2.

One species dominates — milkfish. A total of 315,500 mt was reported produced in 1997. All the other species combined reach only 90,000 mt. After milkfish, there are only five species groups in Southeast Asia with total aquaculture production exceeding 1,000 mt namely, tilapia, mullets, sea bass, groupers, and snappers. In Southeast Asia, milkfish is to saline water aquaculture as the carps are to freshwater. Indonesia is the highest producer of milkfish, tilapia, mullets and sea bass in saline waters.

Malaysia reports the highest snapper production and Thailand, groupers, (Table 3). Production of other species such as jacks (*Caranx sp.*) are reported from Brunei, and rabbitfish (*Siganus* spp.) and grunts (Family Theraponidae) from the Philippines, but only on an intermittent basis and at very low levels to be really significant. FAO aquaculture statistics has had an entry for threadfin shad (*Eleutheronema tetradactylum*) production from Thailand since 1992, but at a very low level of 16 mt. Since 1996, however, threadfin shad production in Thailand has jumped to 409 mt.

With the threat of disease hanging over the shrimp industry, many Philippine shrimp growers are on the look out for a viable alternative to shrimps. While many have shifted into intensive milkfish production for lack of other viable species, some have shifted to groupers. In northern Mindanao, many brackishwater fishponds are now stocking tilapia after repeated failures with shrimps. An all-male saline tilapia hybrid is now being commercially produced and promoted both as a crop in itself and as a means to reduce the risk of vibrio infection in semi-intensive shrimp culture.

Culture systems

Four different enclosure systems are employed in the farming of fish in saline waters in Southeast Asia: ponds, pens, shallow water cages, and deep-water cages. FAO statistics do not contain any information on the culture systems. However, the relative importance of each culture system in the different SEA countries may be inferred based on the general knowledge of the common practices in the culture of the different species in each country and some statistics from at least two countries, Thailand and the Philippines (Table 4).

The use of earthen ponds for raising fish is popular only in Indonesia and the Philippines with their *tambaks* and *punongs.* Vietnam and Myanmar do have coastal ponds but these are used mainly for shrimps and any fish produced are purely incidental. Malaysia has some limited production of fish in earthen ponds but high value species such as groupers, sea bass and snappers are exclusively raised in cages. Thailand and the Philippines produce sea bass and/or groupers in both earthen ponds and cages. Indonesia is known to be producing a considerable amount of groupers in cages, particularly in the Riau island group off Sumatra but somehow the production figures do not appear in both national and international statistical time series. The Riau island group is less than one hour by fast craft to Singapore. The groupers produced are apparently shipped live to Singapore without being reflected in the national fisheries statistics.

In Vietnam and Cambodia, all fish cages are considered part of freshwater culture since these are set in rivers, particularly the Mekong River. Although parts of the Mekong is also influenced by tide and are at times technically brackish, the species involved are clearly freshwater species since these are propagated in freshwater, such as for instance the Mekong catfish, *Pangasius* sp.

The Philippines has the most diverse assortment of culture systems. In addition to the tidal ponds, Filipino fish growers also use fish pens and fish cages set in shallow coves and estuaries and lately the deepwater cages that is popular in Norway and Scotland for salmon farming. Singapore

Table 4. **Relative importance of different culture systems in the culture of fish in saline waters in Southeast Asia, based on estimated production (mt) share of each culture system in each country in 1997 (FAO, 1999)**

	All Countries[a]	Brunei	Indonesia	Malaysia	Philippines	Singapore	Thailand
All systems	405,234	69	237,622	6,193	154,133	818	6,399
Fishponds	388,651		232,222	515	153,700	86	2,128
Fishpens	140				140		
Shallow-water cages	16,073	69	5,400	5,678	293	362	4,271
Sea cages	370				1800[b]	370[c]	

[a]Except for the Philippines and Thailand where data by culture systems were obtained, the data for the other countries were disaggregated by culture systems based on the species and known practices. Sea bass and groupers were inferred to have come from cages while tilapia, mullets and unspecified species normally designated "Osteichthyes nei" in FAO literature, from earthen ponds. In the case of Thailand, figures from their 1996 statistics were used as a basis to proportionally disaggregate grouper and sea bass production by culture system since the statistical frame has remained the same. A new species in Thailand's aquaculture, the four-finger threadfin, *Eleutheronema tetradactylum,* was assumed to be produced in cages.

[b]Author's own estimate based on reported number and minimum production of each cage for one growing cycle. The Norwegian-type sea cages have not yet been included in the statistical frame of the Philippine Bureau of Agricultural Statistics and therefore remains unreported. This figure is not included in the total figures, which are still based on the original figures as reported.

[c]Total milkfish reported assumed to come from cages based on reports from the industry that Singapore has started to produce milkfish using Norwegian cages since Singapore, before 1997, has no report on milkfish production and is not likely to have any area for pond development.

recently started to produce milkfish using large rectangular cages. These cages, which are set in the same areas where groupers are cultured, enabled Singapore to report milkfish production for the first time in 1997.

Industry growth

Fish culture in saline waters as an industry in Southeast Asia as of 1997 is worth US$870.6 million based on the value of the fish produced. To provide a basis for comparison, the value of shrimps produced in Southeast Asia during the same year reached US$3,479.0 million. The disparity is due not only to the fact that shrimps are more expensive than fish but also to the fact that the region now produces more shrimps than fish in saline waters. This was not always so. Indeed, up until 1991, the region was producing more fish than shrimps as shown in Fig. 5.

Somehow while shrimp culture took off, fish culture lagged behind not only shrimps but also seaweeds and even crabs and lobsters. As shown in Table 5, fish culture in saline waters grew at an average of 5.9% per year between 1984 and 1990 but only 0.9% per year between 1991 and 1997. In contrast, the shrimp industry grew at an average annual rate of 25.7% from 1984 to 1990, and 9.4% from 1991 to 1997 and seaweed 11.9% and 13%, respectively. An average growth of less than 1% means the production of farmed fish in saline waters is not even keeping up with regional population growth, which ranges from 1.06% to 2.84%. Only Singapore, Thailand and Indonesia have a population growth rate of less than 2.0% (CIA, 1999).

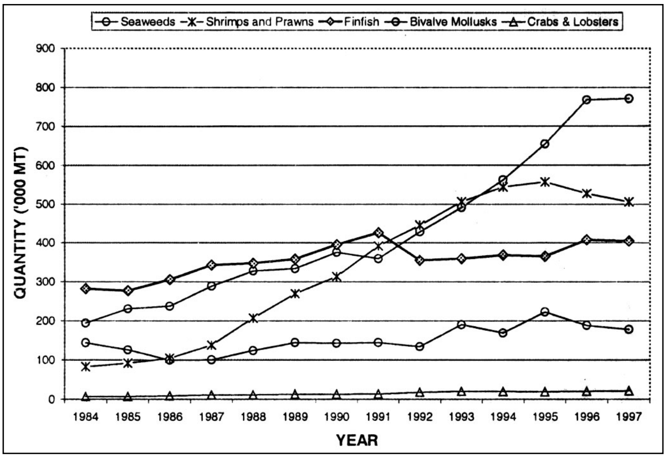

Figure 5. **World production of different commodity groups in brackishwater and marine aquaculture from 1984 to 1997 (FAO, 1999)**

Table 5. **Average annual growth (in percent) of saline water aquaculture industry by commodity group in Southeast Asia, 1984-1990 and 1991-1997**

Commodity	1984-90	1991-97
Seaweeds	11.9	13.0
Shrimps and prawns	25.7	9.4
Finfish	5.9	0.9
Bivalve molluscs	1.0	6.8
Crabs & lobsters	12.1	9.0

With the exception of Indonesia and the Philippines, saline water fish culture in all the other Southeast Asian countries is focused on the production of high value fish such as sea bass and groupers in sea cages, rather than food fish such as milkfish in earthen ponds. Earthen tidal ponds are used mainly for the culture of shrimps while food fish are produced mainly in inland freshwater areas. Most likely this situation is as much due to tradition (freshwater ponds being presumably older on the Asian continent) as it is to best economic use of tidal ponds.

Technology Status

Seed production

Aquaculture in saline waters in Southeast Asia is still heavily dependent on wild-caught fry. Of the species or species groups now being cultured in saline waters in Southeast Asia, the production of fry and fingerlings from commercial hatcheries is limited to sea bass and milkfish (Parazo *et al.,* 1990; Gapasin and Marte, 1990). The technology to propagate the striped or grey mullet, *Mugil cephalus,* in hatcheries, has been available since the mid - 1970s (Nash *et al.*, 1974; Kuo *et al.*, 1974), but there are no reports that any hatchery in Southeast Asia is producing mullet fry or fingerlings. Rabbitfish or siganids can likewise be mass-propagated (Duray, 1990) as can the mangrove snappers, *Lutjanus argentimaculatus,* but the lack of a strong demand for the fingerlings of either species appears to have hindered their full commercialization.

The mass propagation of grouper remains the equivalent of the “holy grail” to the Southeast Asian aquaculture R & D sector. The growing demand for live groupers, and the high price that affluent consumers are willing to pay for it, has driven up the prices of the dwindling supply of wild-caught fingerlings. Grouper fingerlings in the Philippines are actually priced by the “inch” and is currently at Philippine Pesos 10.00 (PhP10 or US$ 0.25) per inch. Grouper fingerlings with a total length of 15.2 cm can cost as much as PhP60 (US$ 1.50). Meanwhile, greater awareness on the dangers of cyanide fishing and more vigorous enforcement of existing laws against the practice cannot but push a shift in the production mode from fishing to aquaculture. The main constraint is a reliable supply of fingerlings.

Ever since Chen *et al.* (1977) reported on the first successful artificial spawning and larval rearing of the greasy grouper, *E. tauvina,* including the first successful hormonal induction of masculinity among mature females, most commercial grouper production are still based on the use of wild seed. Timing, size and nutritional quality of feed for early larval stages, sensitivity to disturbance and physical damage in the later larval stages and cannibalism during metamorphosis and nursing, all remain serious problems. (Datu-Cajegas *et al.,* 1998).

Commercial hatchery production of grouper fingerlings is restricted to Taiwan. It is not clear whether Taiwan has developed a better technology to enable their hatcheries to go into commercial production or that their technicians are better skilled. It is entirely possible that Taiwanese hatchery operators are just more willing and much better prepared financially, than their Filipino or Indonesian counterparts to face the risks involved in grouper fry production where survival rates may be no higher than 5% and may at times be 0%. Considering the current prices and demand for grouper fingerlings, such risks may indeed be worth taking.

There are reports that the Gondol research station for coastal fisheries in Bali, Indonesia is already extending grouper larval rearing technology to backyard hatcheries using eggs produced by the center in the same manner that milkfish hatchery technology was disseminated before. However, this is reportedly still done at a very limited scale, primarily to selected hatcheries. There has been no reported upsurge in Indonesian grouper production. In fact, Indonesian grouper production did not even appear in the FAO aquaculture statistics for 1997.

Feed technology

Feed continues to be a serious area of concern for all the species involved. Formulated diet in pellet form is now commercially produced for both milkfish and tilapia. Pelletized feed is now also available for grouper but acceptance by the fish is a problem and the fish reportedly do not grow as well as with fresh fish biomass.

The fact that feeds for some fish species are already mass-produced and marketed by no means indicate that feed technology for certain widely farmed species is already fully developed. Most if not all, of the feed now available commercially still use a considerable amount of fishmeal. Even feeds for such species as the milkfish, which can subsist and grow on a purely natural food diet consisting largely of algae, still contain some fishmeal. Carnivorous species such as sea bass, groupers and snappers on the other hand are totally dependent on fish biomass. Since it requires at least five kilograms of fish to produce one kilogram of a carnivore species, such species are in fact “protein reducers" rather than protein producers as Tacon (1994) puts it. While financially profitable due to the high market value of such carnivore species, this is hardly ecologically sustainable nor is it morally defensible in light of dwindling fish resources and still widespread problem of malnutrition. More research and development work need to be done to develop cost-effective diet, which requires little or preferably no fish protein. For intensive fish farming to be sustainable in the long term, more sustainable protein sources will need to be found and developed to replace fish meal in compounded diets. Similarly, compounded diets should be developed for carnivore species such as groupers in order to reduce if not completely eliminate the need for fish biomass.

Research need to be done not only on the diet composition but also on the form of feed most acceptable to a particular species. Groupers, for instance, do not readily take to dry pellet. Would a dough-like moist form similar to formulated eel diet (which is moistened only before feeding) be more acceptable? Feeding dynamics and optimal feeding rate, feeding time and frequency also need to be established for each species being cultured. For instance, maximum feed intake for milkfish have been observed to occur between 11 am and 3 pm and again at 5 p.m. to 6 p.m. and that actual diet intake was only 0.82 % of fish biomass (Luckstaedt et al., 1998), thus indicating a large amount of wastage using a daily feeding rate of 2 to 3% biomass as is often recommended.

Natural food optimization

There is a considerable amount of work that has been done on pond fertilization based on pond nutrient dynamics particularly under the Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP). It has been shown in experimental ponds that annual yields of as high as 11,000 kg/ha or greater can be attained for Nile tilapia using only fertilization (Knud-Hansen and Lin, 1996). This is comparable to the yields in semi-intensive milkfish ponds using pelletized feed. It has also been found that the most efficient system for Nile tilapia is to grow the fish using fertilizer alone initially, with feeding commencing only when the fish have reached 100-150 g (Diana *et al,* 1996). There is no comparable work being done in tidal ponds using saltwater fish species.

Milkfish is traditionally grown in shallow water ponds using only natural food, which could either be the filamentous green algae or the blue green algal complex known as *lablab* in the Philippines and *klekap* in Indonesia. The use of plankton as food in deep water ponds has been demonstrated to result in higher yields but has not found local acceptance in the Philippines probably due to the additional expense required to raise the dikes to the required level. The conversion of many of the milkfish ponds into shrimp culture ponds both in the Philippines and in Indonesia has resulted in the availability of deeper ponds which might be suitable for an intensified fertilizer-based culture.

The usual fertilization method that has been extended to fish farmers is based on fixed-rates without any regard to the variations among ponds or during the season. Simplified methods of determining primary and secondary limiting nutrients using algal bioassay without requiring any instrumentation or advanced training have already been developed for freshwater systems (Knudsen, 1998). Yet, these have never been verified and adapted for use in tidal ponds.

There is a clear need to encourage the use of natural food in tidal ponds by developing more effective pond fertilization techniques that is based on pond dynamics rather than on fixed rates. It should be noted that such techniques need not be limited to tilapia and milkfish since this can be applicable as well to other species with similar food habits such as mullets. Even the culture of grouper and other carnivore species may also be similarly benefited since an effective fertilization technique can also result in the higher production of prey species, the use of which is being promoted as one way of reducing feeding cost (Baliao *et al,* 1998).

Fish health management

Unlike in shrimp farming, disease thus far is not a problem of serious concern in brackishwater and marine fish culture in ponds. Milkfish, which is the dominant culture species in the region, is mostly cultured in extensive, fertilized ponds and have very low risk of infection. Even the semi-intensive and intensive milkfish farms in the Philippines are not known to have problems with infectious diseases. Although parasitic protozoa, monogenean and digenean trematodes, bacteria and viruses are known to occur in groupers (reviewed by Baliao *et al.,* 1998), no case of mass mortality that can be attributed exclusively to such causes has been reported in brackishwater ponds. This is most likely due to the relatively lower level of industry development as compared with shrimps.

In contrast, reports of mass mortality are common for fish cage and fish pens set in shallow bays and estuaries regardless of species cultured. Subasinghe and Sharif (1996) have noted that environmental pollution-related problems are becoming increasingly important in marine cage culture. The pollution may come from external sources such as sewage discharge, industrial and agricultural effluents. Often times however, this may be self-induced being the result of over-stocking and satiation feeding with high protein diets - typically fish biomass. Such practices increase the organic loading and nutrient content in culture waters resulting in high bacterial loads. With the deterioration of water quality, dissolved oxygen and pH may become critical and result in mass mortalities.

In the Philippines, health problems are recognized by fish farmers as a constraint to grouper culture in cages. Clinical signs such as ulceration, exopthalmia, fin rot, tail rot, scale loss and white spots due to unknown causes have been observed to result in high mortality especially during the fry stage. This has been attributed to the proliferation of pens and cages, unstable climatic conditions and run-offs following heavy rains, leading to the deterioration of water quality (Somga *et al.,* 1999).

Since environmental deterioration appears to be the major problem confronting the cage and pen culture industry, the obvious solution is to have measures instituted to regulate spacing of cages and loading rate. While regulation is the domain of government agencies, research is needed to come up with the necessary data to formulate workable and effective regulations.

Various control and preventive measures for fish diseases are already practiced widely in Asia. Several common chemicals, drugs and antibiotics are already used in controlling fish diseases. However, immunization or vaccinations as a preventive measure is not used in Asian aquaculture. Instead, the use of natural products such as herbal medicines are often used in China and India (Subasinghe and Sharif, 1996). In the Philippines small-scale fish cage farmers reportedly use guava leaves and jackfruit peelings to treat white spots and tail and fin rots in groupers (J.R. Somga, personal communication). The use of such indigenous materials has not yet been scientifically validated. Furthermore, there is no report of any present or future research to screen indigenous plants for their potentials as disinfectant or therapeutant for fish.

Enhancing or manipulating growth and sexuality

Marine fish aquaculture in Southeast Asia is still at the stage of improving larval survival in the hatchery. Therefore, any talk of improving the stock either through selective breeding or development of transgenic strains as is now being done with salmonids can be considered premature. Meanwhile, all of the species now being cultured in saline waters are harvested long before they reach sexual maturity, so the question of manipulating sexuality at the fry stage to achieve a more uniform growth rate as is done with tilapia may be considered moot and academic.

Mention however has to be made on the success in inducing early masculinity of the orange-spotted grouper, *Epinephelus coiodes,* using male hormones instead of having to wait for 5 to 6 years (Tan-Fermin, 1992; Tan-Fermin *et al.,* 1994). This technique, which was developed more than 20 years ago (Chen *et al.,* 1977), has been recently refined by using silastic implants. Thyroid hormones have also been successfully used to improve survival of pre-metamorphic grouper larvae (De Jesus *et al.,* 1998).

One of the most exciting developments in marine fish culture is the molecular cloning of the growth hormone (GH) complementary DNA (cDNA) in the rabbitfish (*Siganus guttatus*) using *Eschirichia coli* as biological amplifiers (Ayson *et al.,* 1998). Similar work on milkfish (*Chanos chanos*) is reportedly also in progress. This development, it is hoped, will lead to the mass production of species-specific growth hormones, which might be used to accelerate fish growth once a suitable delivery or application method can be developed.

Engineering

Pond engineering in terms of dike design in relation to the soil characteristics of an area and size of supply and drainage canals and gates in relation to the culture system is already a mature technology since it is merely the application of civil engineering principles to aquaculture. However, the new concern over the effects of aquaculture, more specifically intensive aquaculture, on the coastal environment has meant putting pond-engineering back to the drawing board in a figurative and literal way of speaking.

In terms of degradation of the coastal environment, the focus now is on shrimp farming rather than fish farming. This is mainly because most of the intensive coastal aquaculture operations in the region are engaged in the production of shrimps rather than fish. It is probably only in the Philippines that intensive fish farming in coastal ponds is being pursued using erstwhile shrimp farms. But, whether raising shrimp or fish, once intensification is practiced, a much higher organic load in the wastewater can be expected. Thus, the problem can be considered common to both aquatic commodities.

One possible approach to greatly minimize if not completely eliminate the polluting effect of intensive aquaculture is to employ low or even zero water discharge systems. Such a system requires the treatment of wastewater using mechanical and biological means and re-using the treated water instead of drawing in new water. This clearly is a problem in aquaculture engineering. Since it can be assumed that very few new areas, if any remains for new aquaculture development, the focus shall be on retrofitting existing pond systems. While actual designs will be farm-specific, it is necessary to establish basic parameters such as the optimum ratio of treatment ponds to culture ponds, residence time of water in the treatment ponds relative to species, stocking density, feed type and feeding rates.

Beyond the coastal ponds, engineering is also required in designing affordable sea cages and mooring systems durable enough to be set in relatively open and deep waters. Most of the present fish cages are set in shallow waters using light materials such as bamboo. Such location is not ideal for two reasons. One is that such structures occupy near-shore communal fishing grounds which often are the only fishing grounds accessible to small fishers whose only means of propulsion may be a wooden oar. The second is that shallow waters are easily silted and degraded since circulation is more limited and is further reduced by the fish cages or pen structures. Available deep-water cages are priced far beyond the means of most fishers.

Issues and Constraints

Species diversification

As discussed earlier, the number of fish species cultured in brackish and marine waters in Southeast Asia is very limited. There is a need to screen fish species for their aquaculture potential or to at least develop the propagation protocols for more species. Of particular interest are species, which already have a good market, such as the jacks or carangids and those, which may be low in the food chain, spadefish or scats. Some of the species found to be fast growing may not be immediately marketable, but this is another matter and will be discussed in a subsequent section.

There are at least three good reasons for increasing the number of fish species in aquaculture. One, it will give both growers and consumers more choices. Two, it may improve market prospects since fish farmers need not flood the market with the same product and some may even have the option to cater to niche markets. Three, stock enhancement using hatchery-reared fry may be the only way to re-populate depleted fishing grounds.

Food versus cash

There is one of school of thought espousing that aquaculture development should be guided towards the production of food fish, i.e., low trophic level species which can be produced at a low cost and can be mass marketed as a cheap source of animal protein. Some research institutions and international donor agencies as well as individuals have this kind of orientation. While such view is valid, it is not flawless. To produce fish at a low cost, the only alternative is to use fertilizers rather than feeds. This means the use of ponds rather than cages. Pond-based aquaculture requires access to land and considerable capital to construct the ponds. This puts fish culture in coastal waters out of reach to the poor.

The only way for the poor to engage in fish culture is to use cages. And the only option to earn enough to support one's family using a few square meters of net cages is to culture high-value species. Cages do not require land. The coastal waters, at least, is still common property and cages do not require large capitalization. With the sale of a few kilograms of groupers, one can already buy rice and other basic staples including not only lower value food fish but also meat. One can find such operations throughout the region.

Environmental considerations

Whether ponds or cages are used, the impact of fish culture or other aquaculture activities, on the environment is already well known. To construct tidal ponds, mangrove forests were traditionally clear-cut. With so little original mangrove left and with greater environmental awareness on the part of most countries and governments, such practice is already discouraged if not completely halted in most of Southeast Asia. At any rate when intensification became practiced, and mere tidal exchange became insufficient, it became clear that the mangrove was not the best area after all and there was a shift to the use of low-lying coastal agricultural lands with its attendant conflict with agriculture.

The impact does not end with the clearing of mangroves and the possible salinization of agricultural lands. Aquaculture, it turns out, also pollutes especially if conducted on an intensive basis. In present-day Southeast Asia, this is of course happening only in shrimp culture. This is so because, as was explained earlier, with the exception of Indonesia and the Philippines, most of the coastal ponds in the region are used primarily for shrimps and most of the brackishwater fish culture in the two countries is done extensively or at most semi-intensively.

This situation may not be for long, however. Depending on the bio-technical as well as the demand and supply situation, it will be quite easy for the present day extensive fishponds to intensify or for intensive shrimp farms to shift to intensive fish culture. This is already happening to a certain extent in the Philippines where because of the recurring disease problem affecting shrimps and the high local demand for milkfish, pond operators shifted back to milkfish but this time on an intensive level. Thus far, pollution from such practice is not evident yet. Perhaps because as practiced now, intensive milkfish farming is not as widespread as shrimp farming was in its heyday. If intensive fish culture becomes the norm, auto-pollution could very well also happen in fish culture as it did in shrimp culture.

The potential of intensive milkfish farming in polluting the environment has been amply demonstrated in fish pens and fish cages set in shallow waters in the province of Pangasinan, Philippines. With the fish cages and pens set so close to each other, circulation of water was hampered and the normal tidal exchange apparently was not able to adequately freshen the coastal waters. Fish kills became a recurring problem. Set close to the shores, the pens and cages not only hamper the access of small fishers to their traditional fishing grounds but also reduce the available fishing ground.

Sea cages which are designed for installation in deeper waters (30 to 50 m) have not yet been in use for long within Southeast Asia. So far, the 60 units or so that have been installed within Sual Bay, Pangasinan, Philippines do not appear to have the same problems as the shallow water pens and cages have. For one, the units are positioned farther from each other while the deeper water allows better circulation. This does not mean they are completely without any negative impact to the environment.

The effect of salmon cages in northern Europe particularly Norway and Scotland is well documented. Gowen and Bradbury (1987) as cited by Barg (1992) estimated that a salmonid farm producing 50 mt of fish requires 100 mt of food of which only 80% is consumed. Of the portion consumed, 10,560 kg carbon and 616 kg nitrogen are released to the marine environment as fecal waste while 3,203 kg ammonium-nitrogen and 801 kg of urea-nitrogen are released as excretory waste. The 20% that are uneaten contain 8,800 kg carbon and 1,540 kg of nitrogen. There is still no similar study made on milkfish cages in the Philippines but it is well to note that each 19-m diameter cage has been found to be capable of producing at least 30 mt of milkfish in 4 to 5 months.

Marketing and economics

Aquaculture operation does not end with successfully breeding and growing a particular species. Unless the product is marketable at a price that will allow the producer to recover capital cost, production costs plus a profit margin that is significantly higher than bank placement rates, then the operation cannot be considered successful. High survival rates and fast growth rates are meaningless if these can be achieved only at a cost that far exceeds the prevailing market value of the fish produced. The converse is also true. Lower survival rates and lower growth rates do not matter if it is the only way to make the operations profitable.

Fish price like that of most other commodities is governed by the supply and demand situation. Due to such characteristic, the production of milkfish in the Philippines typically goes through a boom and bust cycle. When milkfish supply is low, prices go up thus encouraging growers to intensify and produce more. When the growers start unloading their produce in the market, prices go down thus discouraging many from stocking too much the next time. Once supply is low, prices go up and growers are encouraged to stock intensively again. This is exacerbated by the fact that the market for fish is not rigidly species-specific. Thus an abundant sea-catch can pull down the prices of milkfish as occurred in the Philippines in 1997-98 during the height of the El Niño phenomenon.

On the other hand, while consumers may exercise some flexibility as to species depending upon the price, there is also strong regional preference for or against certain species. This issue has to be considered if brackish and marine water aquaculture is to have a broader species based. Within Southeast Asia, milkfish is eaten only in the Philippines and Indonesia and, even within these two countries, there are localities where the species is more highly desired than in others. Sea bass meanwhile is highly sought in Thailand, Malaysia and Indonesia but has a highly localized market in the Philippines where it is popular only in the Western Visayas area.

Due to consumer biases and preferences, the aquaculture industry typically falls into a rut wherein all growers are producing the same fish species year after year thus further bringing down prices due to over supply. Yet, it need not remain so. Fish can also be marketed and promoted just like the proverbial soap or toothpaste. The experience of the channel catfish in southern United States is a classic example. Catfish used to have a highly regional market limited to the American south. Elsewhere in the US, consumer acceptance used to be a big problem. Even its very name “catfish” does not sound too appetizing. In 1986 in an effort to expand the market and save the industry, catfish producers in the state of Mississippi agreed to a voluntary $6 per ton assessment on feed to fund market development. The effort paid off. A net producer return of $0.48 to $7.46 per media dollar expended suggest that the industry’s advertising effort was a profitable activity for the catfish producers. Despite its small budget the catfish advertising program has been successful both in terms of increasing consumer demand for catfish and improving the net returns of catfish producers (Kinnucan and Venkateswaran, 1991).

Social equity

The common perception is that coastal aquaculture is always a big-time operation and is exclusive to rich individuals or large corporations. This may be partly true in the Philippines but is by no means universally true throughout Southeast Asia. In the Philippines, a 1977 survey of brackishwater ponds, whether privately owned or public land under a fishpond lease agreement (FLA) showed that 79.3% by area but only 35.1% by number are more than 10 ha (Table 6; Librero *et al.,* 1977).

The picture has not changed much more than 20 years later. As shown in Table 7, based on a total count using actual licensing records, 77.8% by area but only 34.7% by number of the fishponds under FLA in 1998 are more than 10 ha in size. In contrast, the backbone of Thailand’s immensely

Table 6. **Size-frequency distribution of a random sample (n=l,175) of brackishwater fishponds in the Philippines, whether under Fishpond Lease Agreement (FLA) or privately-owned, by number and by area (Librero *et al.,* 1977)**

Size-class	Number	Percent number	Area (ha)	Average area (ha)	Percent area
1 ha and below	178	15.2	110.01	0.62	0.9
1.01 to 5.00 ha	392	33.4	1,109.39	2.83	8.6
5.01 to 10.00 ha	192	16.3	1,457.85	7.59	11.2
10.01 to 20.00 ha	201	17.1	2,926.86	14.56	22.6
20.01 to 50.00 ha	153	13.0	4,768.12	31.16	15.3
More than 50 ha	59	5.0	5,367.07	90.97	41.4
All sizes	1,175	100.0	15,739.30	13.40	100.0

successful shrimp culture industry are the small farmers who make up 80% of the 12,500 intensive shrimp farms, each consisting of 1 to 2 ponds, ranging in size from 0.16 to 1.6 ha (Kongkeo, 1995).

With all the coastal tidal lands already occupied, there's little hope for the smallholders to acquire coastal fishponds in the Philippines unless fishponds once again is subject to agrarian reform as they were briefly in 1987 under the Comprehensive Agrarian Reform Law. This is not likely to happen in the near foreseeable future. Thus it appears that for the coastal poor in the Philippines the only avenue for them to engage in aquaculture as a livelihood is to use cages instead of ponds. As shown in Table 8, fish cages do not require large investments and give adequate financial returns.

Table 7. **Size-frequency distribution of brackishwater fishponds in the Philippine under Fishpond Lease Agreement (FLA) by number and by area (based on BFAR FLA Records as of November 1998)**

Size-class	Number	Per cent Number	Area (ha)	Average area (ha)	Percent area
1 ha and below	111	2.4	72.041	0.649	0.1
1.01 to 5.00 ha	2,418	51.5	9,458.368	3.912	15.1
5.01 to 10.00 ha	537	11.4	3,925.285	7.310	6.3
10.01 to 20.00 ha	678	14.4	9,742.785	14.370	15.5
20.01 to 50.00 ha	852	18.2	26,471.038	31.069	42.3
More than 50 ha	98	2.1	12,956.310	132.207	20.7
All sizes	4,694	100.0	62,625.827	13.34168	100.0

Table 8. **Comparative economics of pen/cage farming by species (in Philippine Pesos), Lingayen Gulf, Philippines, 1997. Figures are average values (adapted from various tables in Morales and Padilla, 1998)**

	Milkfish	Grouper	Siganid	Polyculture
Number of farms in sample	80	6	5	4
Farm size (m^2)	1,385	170	160	207
Investment cost	66,962	13,517	10,768	12,350
Fixed cost per cropping	7,629	1,424	1,473	1,944
Variable cost per cropping	88,415	36,112	31,285	15,317
Production per cropping (kg)	8,875	169	355	Milkfish 148 Siganid 176
Farm-gate price	61	332	118	
Gross revenue	195,339	55,886	41,914	24,364
Net profit	99,037	18,013	8,567	6,514
Culture period (mo)	4.0	6.7	3.9	3.75
Margin for profit and risk	4,815	2,841	1,667	694
Imputed family labor	590		2,839	2,839

Gross profit = Revenues - Variable costs
Net profit = Gross profit - Fixed costs

Prospects for the New Millenium

Southeast Asia has considerable potentials for the farming of saline water fish in coastal ponds and waters. It has the resources for saline water fish culture in the form of coastal ponds, it has a strong tradition for aquaculture, and it has the technical manpower. The region's ponds are now mostly being used for raising shrimps primarily because of the continued strength of the global shrimp market. But these can always be shifted to fish production if and when the market for a particular fish species gains strength and its production prove to be equally or more profitable than shrimp farming.

Such shift is already happening in a limited scale in the Philippines where at least one farm has shifted totally from growing black tiger shrimps to groupers without requiring any physical modification. While many other erstwhile shrimp growers are looking on with interest in view of the continued onslaught of luminescent vibriosis in shrimps, two factors are proving to be major deterrents: the lack of a reliable supply of grouper fingerlings and the need to use fish biomass as feed. What is true for grouper is applicable as well to other high-value marine species. These two constraints, it is hoped, can be addressed during the early part of the new millenium as hatchery technologies for grouper and other fish species become commercially viable and acceptable feeds are formulated.

The successful use of marine cages set in relatively deep waters for milkfish in the Philippines points out to their potential in helping address the issue of food fish security as the catch from capture fisheries continues to dwindle. One 19 m diameter cage can produce a minimum of 30 mt milkfish in 4 to 5 months. Taking the Philippines as an example, the country's projected shortfall of some 300,000 mt by year 2005 can be filled by using only 5,000 units of such cages. All in all the 5,000 units will occupy no more than 180.5 ha. In fact, the entire Philippine milkfish production from brackishwater ponds which in 1998 reached only 141,073 mt could have been produced only in 2,351 such cages. This means all these erstwhile mangrove forests could be replanted without jeopardizing the supply of milkfish in the Philippines by the simple act of shifting to cage culture.

But there's a catch. Although mangrove-friendly fish cages may not be coral reef friendly. As discussed earlier, a fish cage also produces a large amount of organic waste, which invariably settles on the seabed. If installed over or close to a reef area, the waste can smother a coral reef. And here's another catch. These cages as presently designed and installed are terribly expensive. As currently installed, these cages can not possibly be promoted as an alternative livelihood to fishing for the small fishers. Thus, two things should be addressed at the start of the new millenium. Areas where such cages can do the least harm should be identified and smaller and more affordable cages should be designed for individual ownership by small fishers. Towards both ends, the concept of designating a mariculture park should be seriously studied. Such a mariculture park will not merely designate an area for cage installation but will actually provide mooring facilities just like a marina. And like in a marina, fish cage operators can pay a mooring fee. Mooring in deep waters can easily cost as much or even more than the cage itself. With such infrastructure provided and with smaller cage units, marine cage culture technology can be made affordable to the coastal poor.

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Developments In Freshwater Fish Culture In Southeast Asia

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Abstract

Aquaculture has been practiced for more than a century in a few countries of Southeast Asia (Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Papua New Guinea, Philippines, and Singapore). Currently, the industry is carried out in various ecosystems such as ponds, paddy fields, raceways, fish pen and cages in freshwater, brackishwater, and marine environments. Developments in freshwater finfish culture in Southeast Asia are becoming prominent. Currently, the industry is carried out in various ecosystems such as ponds, paddy fields, raceways, fish pen and cages in fresh water, brackishwater, and marine environments. With respect to finfish culture in freshwater, Southeast Asia is showing prominent development. Freshwater fish culture production in the region accounted for 4.4% of the total world freshwater fish and shellfish culture production. In 1997, world freshwater fish culture production amounted to 16,212,730 mt. An indicator of development is the increasing number of the cultured species. In 1988, the number of freshwater fish species cultured in the region was not more than 34 species, but a decade later the list has become longer, attaining more than 36 species. The major ones are common carp and Nile tilapia. These two species are widely cultured in the region. Eight of 10 Southeast Asian countries culture common carp and Nile tilapia. Further diversification of cultured species is still widely open since there are more than a dozen freshwater fish species available in rivers and lakes in the region that are potential candidates for aquaculture. The success in mass production of fry in the hatchery in some Southeast Asian countries has contributed much to these developments in freshwater fish aquaculture in the region, owing to the application of advances in science and technology. Supports from ancillary industries such as feed mill plants, cold and ice storage, etc. and the development of networking that rapidly disseminates information and aquaculture technologies within and outside the region have also contributed to the development of freshwater fish culture in Southeast Asia. Nonetheless, there are constraints to further development and these are discussed in this paper.

Introduction

In some Asian countries, freshwater fish culture has been practiced for centuries, resulting in the bulk of world aquaculture production being derived from this region. Presently, mainland China together with India and Japan leads the world in fish aquaculture production. Mainland China alone produced 11.94 million mt of fresh water fish in 1997 (FAO, 1999). With Hongkong and Taiwan, altogether China produced more than 12 million mt of freshwater fish.

Freshwater aquaculture in Asia contributed significantly to world aquaculture production. In 1997, Asia produced 16.21 million mt of freshwater fish, which is equal to 45% of the total world aquaculture production or 56% of the total world fish and shellfish culture production. The said statistics indicate the importance of freshwater fish culture as an economic activity, providing protein food for the world's population.

This paper attempts to identify the development of freshwater finfish culture in Southeast Asia during the last decade (1988-1997). The approach utilized was analysis of data from available sources on some development indicators such as production growth, number of species cultured, application of science and technology, transfer of aquaculture information and technology, and support from ancillary industries, specifically fry and feed industries.

Data and information presented in this paper were derived from references rarely available in the countries under study. In countries where freshwater finfish culture has developed, such as Indonesia and Thailand, the references are plentiful, whereas in countries where the industry is developing like in Vietnam and the Philippines references on freshwater fish culture are rather scarce. In other countries of Southeast Asia where freshwater fish culture has just started, references are hardly found.

Southeast Asian Countries

Countries in Southeast Asia include Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. This sub region of Asia lies mainly in the basins of the Irrawady and the Mekong river systems with peninsular or archipelagic countries influenced by high ambient temperature and high rainfall. These countries possess rich freshwater resources provided by their river systems and associated floodplains.

At present, Southeast Asia is populated by almost half billion people and around 40% live in Indonesia, the largest country in the region. The GDP of the Asean nations (minus Myanmar) amounted to US$838 billion and total exports of US$338 billion in 1996 (Severino, 1998).

The per capita supply of fish in this region averaged about 23 kg per year and contributed about 51% of the total animal protein supply (Shang ,1992 in Shang ,1994). The consumption rate most likely has been influenced lately by an increase in disposable incomes of the people in the region. For example, Duangsawasdi (1998) reported that the average annual per capita consumption of fish in Thailand is approximately 30 kg. Guerrero (1998) stated that average products from fisheries account for 70% of the total animal protein intake among Filipinos. In Indonesia, the average supply of fish in 1997 was 28 kg per capita per year.

Global and Regional Trends of Aquaculture Production

Aquaculture expanded continuously during the last decade (1988 - 1997) as indicated by FAO (1997). During the said period, aquaculture production increased at the rate of 13.20% per year from 15.54 million mt in 1988 to 36.05 million mt in 1997. Production was valued at US$50.37 billion.

As mentioned earlier, the bulk of aquaculture production came from developing countries in Asia. In 1997 the region produced 32.77 million mt, which is equal to around 91% of the total world aquaculture production. China (including Hongkong) and India as the leading countries produced 24.04 million mt and 1.78 million mt, respectively. Along with these two countries, there were 12 other countries, which were classified as principal producers of world aquaculture. Eight of them were Asian countries: Japan, Indonesia, Thailand, Bangladesh, Vietnam, Republic of Korea, Philippines, and Taiwan. The other four were USA, Norway, France and Chile. In 1997, these countries individually produced over 250 thousand metric tons. During the last decade, mainland China, India and Japan have maintained their first, second and third positions among the 14 principal producers, respectively. Indonesia, whose position in 1988 was fifth, ranked fourth in 1997. Thailand progressed significantly, from being tenth rank in 1988 to fifth in 1997. Likewise, Vietnam also progressed from twelfth in 1988 to seventh rank in 1997. However, the Philippines dropped from seventh in 1988 to twelfth in 1997 (Table 1).

Table 1. **Rankings of principal producers in fish aquaculture (FAO, 1999)**

Country	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Mainland China	1	1	1	1	1	1	1	1	1	1
India	2	2	2	2	2	2	2	2	2	2
Japan	3	3	3	3	3	3	3	3	3	3
Indonesia	5	4	4	4	4	4	4	4	4	4
Thailand	10	8	9	7	8	5	5	5	5	5
Bangladesh	11	11	11	11	9	9	9	8	6	6
Vietnam	12	12	12	12	12	12	13	7	7	7
USA	6	6	8	6	5	6	6	6	8	8
Korea, Republic of	4	5	6	8	7	7	8	9	9	9
Norway	13	13	13	13	13	13	12	13	10	10
Philippines	7	7	5	5	6	8	7	10	11	11
France	9	10	10	10	11	9	11	11	12	12
Chile	14	14	14	14	14	14	14	14	14	13
China Taiwan	8	9	7	9	10	10	10	13	13	1

Aquaculture production of Southeast Asian countries in 1997 amounted to 3.2 million mt, which is equivalent to only around 13% of China's production (Table 2).

Table 2. **Aquaculture production (mt) by country in Southeast Asia (FAO, 1999)**

Country	Freshwater Fish			Total aquaculture		
	1988	1997	Annual increase (%)	1988	1997	Annual increase (%)
Brunei Darussalam	1	30	290	2	156	770
Cambodia	4600	11534	15	4600	11800	16
Indonesia	209266	407990	9	499597	911610	8
Laos	7000	14000	10	7000	14000	10
Malaysia	7761	20303	16	46957	103360	12
Myanmar	5668	87306	144	5673	87320	144
Philippines	81232	97189	2	430374	957548	12
Singapore	0	115	-	1969	4088	11
Thailand	91542	257371	18	220416	575901	16
Vietnam	111157	369000	23	154317	492000	22
Total	518,27	1,264,838		1,370,905	3,159,780	

Aquaculture in Southeast Asia may be in freshwater, brackishwater, and marine environments. Historically, the former has been practiced since centuries ago. In the past, freshwater fish culture was meant to fulfill daily fish demand of rural households. In such a case, the freshwater ponds generally were located at the backyard. As the demand for fish increased, fish culture became a commercial activity and special ponds were constructed in suitable areas. Other culture systems and facilities were utilized such as paddy fields, cages, pens, etc. Production increased yearly at 14.4% since 1988, amounting to 1,264,838 mt freshwater fish produced in Southeast Asia (Table 1).

Cultured Freshwater Finfish Species

More than 43 species of freshwater fish are cultured in Asia at present. Thirty six species are cultured in Southeast Asia alone, 13 species in mainland China, 9 species in South Asia (mainly India), 9 species in East Asia (in Japan and Republic of Korea), and only 6 species in West Asia (mainly Iran, Table 2). Most of the cultured species are indigenous to Asia. The only species exotic to the region are fishes of the genus *Oreochromis* and carps.

Out of the 43 cultured finfish species, the common carp is cultured in many countries in Asia and Europe. This species is exotic to Southeast Asia, however. Their tolerance of wide differences in pond temperature and chemistry, their ease of management, and their high growth rates have made them a favorite of fishery development programs worldwide. The wide acceptance of the species by people of various social status in many countries may likely be due to the taste of its meat, few bones, and the ease of propagating and culturing the common carp. Eighty percent of Southeast Asian countries have cultured common carp. The other dominant exotic species that are being cultured in 5 to 6 Southeast Asian countries are grass carp, silver carp and tilapias, especially *Oreochromis niloticus.*

Of 36 fish species cultured in Southeast Asia, 25 species are indigenous. Among them are java carp, nilem carp, catfish, and one diadromous species, namely sea bass. These species are cultured in 5 to 6 countries in the sub region. Although these species have been cultured for quite some time, data on their biology is still scarce. Only a few of these species have been fully domesticated.

Compared to 1988, six additional species were cultured in 1997. Attempts to culture more species have been conducted in several countries, especially those considered indigenous such as two spot-glass catfish (*Ompok maculatus*), red-tail mystus (*Mystus wyckiodes*), giant catfish (*Pangasius gigas*), red cheek barb (*Puntius orphoides*), brook carp (*Tor soro*), *Catlocarpio siamensis*, which can attain a size of 2.5 m, *Cyclocheilichthys enoplos*, *Probarbus jullieni*, and some hybrids of tilapias, catfishes, etc. To some extent, some countries have also grown some exotic species for aquaculture, such as *Colossoma sp.* in Indonesia. In Malaysia, the breeding and culture of this species is done small-scale.

Culture Systems

Aquatic resource systems for aquaculture in Southeast Asia are ponds, rice paddy fields, disused mining pools, lakes, reservoirs, streams and rivers, and land-based tanks. The types of culture facilities in these resource systems are embankments and excavated structures (pond and paddy field), irrigated or rain-fed, floating net cages, bamboo cages, fish pens, raceways, and concrete or fiberglass tanks. Utilization of the latter is limited to mass production of fish fry and grow out of high-value fish products such as eel.

Southeast Asia has considerable potentials for further developments of freshwater fish culture. Around 1.4 million ha of inland water area are suitable for aquaculture development in Vietnam (Son, 1998). Thailand also has high potential for aquaculture (Duangsawasdi, 1998). Although Malaysia does not have natural lakes, it has man-made reservoirs with a total area of 160,000 ha (Yussof *et al.,* 1994). Indonesia has around 2.1 million hectares of lakes and man-made reservoirs and more than one million hectares of irrigated paddy fields. In the Philippines, more than 356,000 ha area of inland open waters are present (Guerrero, 1998).

Fish culture in ponds is the most popular activity of freshwater aquaculture in the region, being practiced in all countries in Southeast Asia. The fish selected for culture depends on the pond system, whether these are irrigated or rain-fed ponds, or disused mining pools. In irrigated ponds, the water flows through continuously, making the pond suitable for the culture of fish species, such as common carp, java carp, silver carp, and the like, which require waters with high dissolved oxygen content. Such ponds may produce 1.6 mt to 3.9 mt per ha per year (Huat and Tan, 1980). On the contrary, species cultured in rain-fed pond are fishes, such as the air-breathing gouramy, the clariid catfishes, snakehead, etc., which can tolerate low dissolved oxygen. In Malaysia and to certain extent also in Indonesia, disused mining pools have been converted for fish farming. These ponds from dredged excavation, gravel extraction, and hydraulic mining range in size from 0.2 to 35 ha and in depth from 3 to 15 m, producing from 0.3 mt to 3.9 mt fish per ha per year (Huat and Tan, 1980).

Pond productivity may be improved through a polyculture system and supplemental feeding. This culture technique is adopted in ponds, disused mining pools, cages, and rice paddy fields. Constraints to further development of fish culture in pond are competition for land use with other sectors, environmental degradation, and pollution.

Fish culture in paddy fields began in China 2000 years ago (Chapman, 1996) and, more recently, practiced in Indonesia, Laos, Philippines, Thailand, and Vietnam. This culture system has very high potential in Southeast Asia, due to vast areas of irrigated rice field in the region. At present, the area of rice cum fish culture in Indonesia amounts to 140,000 ha. In Vietnam, out of 400,000 ha of irrigated paddy fields suitable for rice cum fish culture, only 35,000 ha have been utilised (Nhan, 1997). With the addition of potential areas of paddy fields in Malaysia, Philippines, Thailand, and other countries in Southeast Asia, the area for rice cum fish culture in the region is estimated to be around one million hectares. Assuming fish production of paddy field is 250 kg per ha per crop or 500 kg per ha per year, the existing paddy fields in Southeast Asia potentially may produce around one million metric ton fish per year. Fish cum rice culture not only produce fish, but also increase paddy production by up to 14% (Sabri *et al.* in Oka *et al,* 1992).

The type of fish culture systems in paddy fields has not changed since 50 years ago, wherein fish are concurrently cultured with the growing rice, and follows a rotation system where the fish is reared as a single annual crop of rice (Huat and Tan, 1980).

The fish species cultured in paddy fields differs from one country to another. Huat and Tan (1980) listed 19 fish species harvested in rice fields in Asia. However, in many countries, *Cyprinus carpio* is most common. In Indonesia, aside from the common carp, fish species cultured in paddy fields are Nile tilapia and giant gouramy. In the past, polyculture of kissing gouramy, Java carp or "tawes", *Osteichthyes hasseltii,* common carp and Mossambique tilapia (Ardiwinata, 1957) was common. At present, fish culture in rice field in Indonesia is focused more on fingerling production, rather than fish for consumption. In Vietnam, the farmers also stock rice paddy fields with silver barb (*P. gonionotus*) and Nile tilapia (Nhan, 1997). In the Philippines, common carp, Mossambique and Nile tilapia are cultured. In Thailand, farmers grow the following species: snakeskin gouramy, java carp, and common carp. In Laos, the species grown in paddy fields are common carp, tilapia, *Puntius spp*., *Trichogaster spp,* and various local species (Singh, 1994).

Fish culture in rice field has some advantages and disadvantages. Fish cum rice culture is a means to increase fish production and to improve the paddy field's ecology. The system has been proven to be advantageous in fingerling production in floating net cages. Fish cum rice culture may also be suitable as a subsistence-type activity, which provide fish for family consumption (Bocek, 1992).

Floating net cages and fish pens can be found in lakes or man-made reservoirs in Indonesia, Philippines, Malaysia, and Vietnam. Floating or submerged bamboo cages are also common in rivers or streams in Indonesia. The most common species cultured in floating net cages in Southeast Asia is *C. carpio*, and milkfish in fish pens. Other species are Nile tilapia, red tilapia, pangasiid catfishes, and milkfish. Common carp and carnivorous fish such as *Channa spp.* are grown in bamboo cages.

Recently, a double-cage culture technique has been developed in Indonesia and already adopted by fish farmers. In this technique, the inner cage is stocked with common carp, while the outer one with Nile tilapia, which feed on the leftover food of common carp, thus contributing to efficiency in food conversion. Such practice also reduces the amount of uneaten feed released to the surrounding environment.

Tanks, concrete or fibreglass, are used in hatchery and in indoor culture of *Anguilla* sp. This technology is capital intensive.

Contribution of Science and Technology to Aquaculture

Aquaculture technology can contribute significantly to fish supply to meet the increasing demand for fish protein. The increase of freshwater aquaculture production in China during the last decade was perhaps the result of the application of research on breeding and biotechnology, and the diversification of cultured organisms (Yingren, 1998). Although research in various institutions in Southeast Asia is active, innovative research remains lacking. In order to cope with the rapid pace of expansion, aquaculture must be backed up by scientific principles and relevant technologies. Since aquaculture is a commercial activity, it requires economic and sociological inputs. Thus, innovative research to back up aquaculture should be extended also to relevant economic and social aspects.

There are three major interrelated aspects concerning aquaculture technology, i.e. the cultured organism, the culture environment, and feed. Application of science and technology to aquaculture should be focused on these aspects. With respect to the cultured organism, knowledge of its biology should be well recognized. Unfortunately, data and information concerning the biology of individual cultured species is still very scarce. Information is scarce on many aspects of taxonomy, anatomy and morphology of organs, reproduction and life cycles, genetics, growth, food and feeding habits, nutrition and metabolism of both non-traditional and indigenous species. Except for the transfer of diseases and parasites, there are several advantages of using native species such as preserving the genetic integrity of wild native stocks. Likewise, local markets are more familiar with native species, precluding the need to develop a market for new products, thus reducing total operational cost (Heggberget, 1994).

Regarding the culture environment, science and technology application could explain the dynamics of aquatic ecosystems to help improve the environment of the cultured organisms, thus reducing pollution. Likewise, science and technology should also be directed towards the conservation of water resources. Boyd *et al.* (1998) stated that freshwater aquaculture ponds should be operated without water exchange, and that they be drained every few years for pond repairs and inventory adjustment. In this regard, precise definition of water quality requirements of traditional and non-traditional species should be established.

Aquaculture requires various inputs such as feed, both natural and artificial. The type of natural food varies depending on the feeding habit of the fish species. Natural food for herbivorous/omnivorous may be grown by water or bottom soil fertilization. Unfortunately, the existing knowledge on natural food fertilization does not provide specific procedures to stimulate the growth of the desired plankton, so that applying the same fertilization protocol may stimulate the growth of different types of phytoplankton and zooplankton.

Natural food is of utmost importance in the operation of a hatchery. In certain cases, facilities required to grow plankton are several times larger than those required for larval rearing. The growth of certain plankton species may be a problem during certain seasons. However, this problem may be solved by cryopreservation of natural food.

The artificial feed used in herbivorous or omnivorous freshwater fish culture may involve a single raw material such as rice bran, colocacia leaves, etc., simple mixtures of ingredients, or complex formulated compound feed. For carnivorous fish like *Channa spp.*, the feed may consist of a single ingredient such as trash fish or a compound feed, i.e. pellet or moist feeds. At present, no formulated feed has ever been produced for freshwater carnivorous fish, probably because of a lack of data on the nutrient requirements, feeding habits, and other nutrition aspects of this species.

As aquaculture production systems become more intensive, their dependency on the external provision of manufactured compound aquafeeds becomes great. In fresh water fish culture, intensive feeding is practiced in cages, pens, running water ponds, and raceways. Such practice will sooner or later accelerate eutrophication, especially in closed water bodies where cage and pen structures are installed. Moreover, there have been serious mortalities in heavily stocked cages in Cirata and Saguling reservoirs in West Java, Indonesia as reported by Zerner (1992). The problem actually may be avoided by limiting the number of cages so that it will not exceed the carrying capacity of the water bodies. Unfortunately, no data are available on the carrying capacity of any water bodies in the region. Periodic monitoring of water quality has also been neglected even as culture intensity in cages has been increasing by the introduction of double net cage technology.

FAO (1995) estimated that aquaculture used 15% of the global fishmeal supply in 1995. It is imperative, therefore, that research to find substitutes (partly or completely) for fish meal in the diet of some species be pursued. For aquaculture to be sustainable in the long term, it is also imperative that donors, development agencies, and government promote the culture of species with herbivorous and omnivorous feeding habits, or species which are not dependent on the use of high quality protein-rich feed inputs, and which are able to make maximum benefits from naturally available food organisms and farm-made supplementary inputs (Tacon (1994) in FAO, 1995).

Development of Related Ancillary Industry

Freshwater finfish culture is important in providing food and in providing employment opportunities, especially for rural people in the region. Development of the industry, therefore, warrants proper attention from all parties concerned. To develop fish culture requires a sufficient supply of quality fry and fingerling, which can be fulfilled by the establishment of a sufficient number of hatcheries. A significant development in freshwater fish culture during the last decade has been the availability of hatchery-produced fry and the establishment of feed plants. The hatcheries are mostly owned by private entrepreneurs.

Aquaculture Information and Technology Transfer

The level of fish culture technology applied throughout the region differs from one country to another. The most progressive countries are Indonesia and Thailand, followed by Malaysia, Philippines, and Vietnam. In Indonesia, the dissemination of aquaculture technologies is done by extension services in collaboration with scientists from the newly established Institute for Agricultural Technology. The laboratories of the Institute are available in every province in Indonesia (Cholik *et. al.,* 1997). The promotion of fish culture in Thailand includes the transfer of improved seed and production technique directly to private hatcheries, quality testing and endorsement of fish seed at hatcheries, and technology dissemination through hatcheries and traders (Ingthamjitr *et al.,* 1997).

The development of freshwater fish culture in Southeast Asia maybe accelerated through the establishment of research networking. Through this, the exchange of information among scientists concerned will be facilitated. Research collaboration among network members can be accommodated to benefit all. An example of a research network is INGA of ICLARM.

Constraints to Freshwater Fish Culture Development

Several constraints associated with further development of freshwater fish culture in Southeast Asia include resource-use conflicts, habitat destruction, water quality deterioration, and unequitable distribution of benefits (Chua, 1994). Another common constraint is low market price and high costs of production. Ja Cho (1997) reported seven issues and constraints to aquaculture development that have been identified from her survey in Asia, which included five Southeast Asian countries (Indonesia, Malaysia, Philippines, Thailand, and Vietnam). The most common constraints to those countries are related to weak institutional and organizational linkages and coordination among related agencies and program. Other common issues are ineffective transfer of technologies, including lack of technology packages, pollution and environmental degradation. Heggberget (1994) summarized limiting factors to aquaculture development which may also be applicable to Southeast Asia as follows: 1) coordination and marketing, 2) aquaculture economy (cost reduction), 3) technological standards, 4) water resources, 5) information and information flow, 6) biological knowledge of cultivated species, 7) diseases and parasites, and 8) environmental effects. Absence of legal aspects and poor law enforcement are other constraints to aquaculture development in the region.

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Developments In Integrated Aquaculture In Southeast Asia

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Abstract

Integrated aquaculture is inclusive of interactive utilization of resources and ecosystems in the artificial rearing of aquatic animals and plants. By the nature, purpose and scale of the operation, integrated fish culture can be categorized into five major modes. One is the traditional small-scale subsistence farming where fish are produced by recycling on-farm wastes in ponds or rice field, two is recycling of human excreta, three is the "industrialized" commercial operation by integrating medium and large-scale poultry or livestock farms with ponds for fish production, four is integration of aquaculture with natural ecosystems, e.g., shrimp culture with mangroves, cage and pen culture in lakes, cove culture in reservoirs. The fifth is environmental-oriented integration, where waste effluents from intensive aquaculture ponds are recycled to improve water quality and to grow filter feeder/ herbivores or macrophytes as secondary crops. This paper presents concepts and practical examples for some of these systems.

Introduction

Integrated aquaculture systems have been widely practiced throughout Southeast Asia for centuries. The purpose of these systems is to maximize the use of finite resources for food production through recycling energy and nutrients. The traditional practices involving small-scale farms with crop/fish/livestock have received major promotion by many national and international agencies for rural development in Southeast Asia. A wealth of information has been documented by many institutes and organizations throughout the region. A large number of feature articles based on field observations and practices on integrated aquaculture has been published frequently in AARM Newsletter (AIT), Aquaculture Asia (Network of Aquaculture Centers in Asia, NACA), Asian Aquaculture (Southeast Asian Fisheries Development Center, SEAFDEC), Naga (International Center for Living Aquatic Resources Management, ICLARM), Aquaculture News (Food and Agriculture Organization, FAO), etc. However, relatively few quantitative description based on systematic experiments exist. To further improve and promote integrated crop/fish/livestock in the region requires multidisciplinary systems approach (Edwards, 1998). Dalsgaard and Oficial (1998) recently developed the ECOPATH model to illustrate the intricate interactions and quantitative expressions of energy flow and nutrient cycles of integrated aquaculture in context of various farming systems. Depending on the source of waste materials, fish production units are most commonly integrated with a variety of livestock, vegetable crops, rice paddies, household wastes, etc (Little and Muir, 1987). In general, fish productivity derived from on-farm low-input systems is relatively low and often considered as a subsistent practice. The rising trend in integrated aquaculture systems is to generate cash crop with either greater fish production or higher-valued species as economic incentive. For instance, in Thailand the integration of chicken, duck or pig with fish in medium or large-scale operations is an economically attractive business. This industrialized fish/livestock integration (Little and Edwards, 1999) has contributed a large quantity of relatively inexpensive freshwater fish raised in ponds. In Vietnam, integration of marine shrimp with rice (Binh and Lin, 1995) and with mangrove (Fitzgerald, 1997; Johnston *et al,* 1999) has become popular in the Mekong Delta. To mitigate environmental impact of intensive shrimp farm effluents, an integrated recycle system was initiated in Thailand using mollusks as filter feeder (Lin *et al,* 1993). Integration with herbivorous fish and seaweed are potential inclusions to utilize pond effluents.

In an attempt to increase economic incentive of integrated aquaculture and to mitigate environmental impact of intensive aquaculture, researchers at the AIT have developed integration of small-scale cage culture in ponds (Lin and Diana, 1995; Yi *et al,* 1996), and catfish (Lan, 1999) or freshwater prawn (Giap, 1999) culture in rice fields.

Recycling Waste Effluents and Pond Mud from Intensive Aquacultures

With increasing demand of seafood product from aquaculture, intensive culture systems with high stocking density and protein-rich feed are becoming increasingly popular in Southeast Asia. The species commonly raised intensively in ponds are catfishes (*Clarias spp.* and *Pangasius spp.*), snakehead (*Channa spp.*), milkfish (*Chanos chanos*), tilapia (*Oreochromis spp.*), freshwater prawn (*Macrobrachium rosenbergii*) and penaeid shrimp (*Penaeus monodon*). As those species are typically raised with either formulated diets, trash fish or slaughterhouse wastes, water quality in culture ponds deteriorates rapidly and frequent water exchange is therefore required to prevent detrimental consequences from accumulated wastes. The effluent discharged from those ponds to surrounding waterways has become a major environmental concern as it accelerates eutrophication of natural waters (Beveridge, 1984; Ackefors, 1986; Lin, 1990).

Since the waste effluent from intensive culture ponds contain rich nutrients and abundant planktonic organisms material (Pillay, 1990; Edwards, 1991), it can be reused for raising herbivorous or omnivorous fish in ponds in an integrated fashion. In addition, the effluent can also be used for land crop irrigation (Seim *et al.*, 1997).

To illustrate the integration of intensive fish culture with various fish and land crop production systems a series of experiments were conducted recently at the AIT in Thailand.

Fish-fish Integration through Caged Feeding in Ponds

A good example of fish-fish integration is the polyculture of several species with different feeding habits to maximize utilization of natural food as a result of recycling of wastes derived from artificial feed to certain high-valued species. However, in a mixed polyculture pond, the low-valued species may consume costly high protein diets, reducing economic return from fish production. The alternative approach is a cage-cum-pond integrated culture system whereby the high-valued species are raised intensively with artificial feed in cages within a pond stocked with species that depend on natural diets in open pond (Fig. 1). This system was developed using catfish-tilapia (Lin *et al.*, 1989; Lin, 1990; Ye, 1991; Lin and Diana, 1995) and in tilapia-tilapia integrated culture (Jiang, 1993; Yi *et al.*, 1996; Yi, 1997).

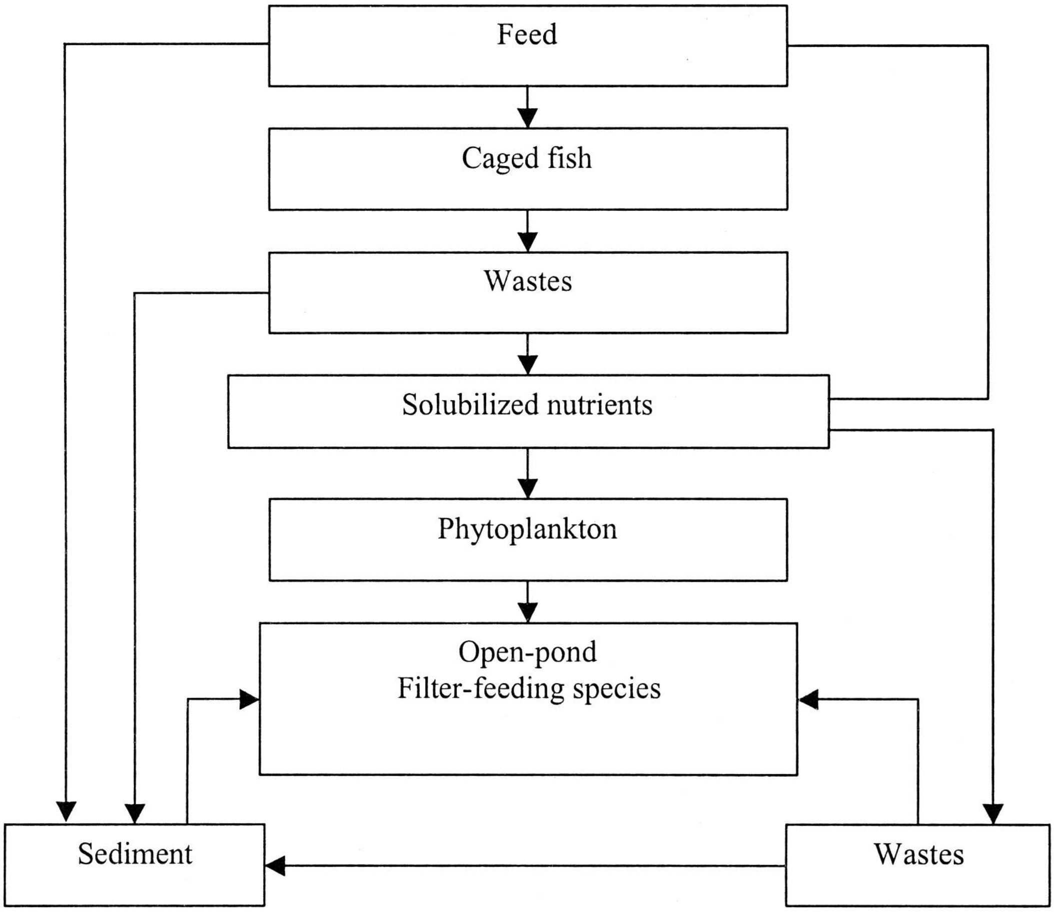

Figure 1. **Schematic diagram for integration of intensive cage culture in semi-intensive pond culture system**

Catfish-tilapia integrated cage-cum-pond culture

Hybrid catfish (*Clarias macrocephalus* x *C. gariepinus*) and Nile tilapia (*Oreochromis niloticus*) are commonly cultured freshwater fishes in Thailand with an annual production of 41,700 and 91,000 mt, respectively (DOF, 1997). While the major production system for tilapia is semi-intensive with inorganic or organic fertilizer inputs, hybrid catfish are intensively monocultured at extremely high density (30-100 fish per m^2) with production of 12.5-100 mt in earthen ponds. The most common diets for hybrid catfish are chicken offal, trash fish or pelleted feed. Wastes as uneaten feed and metabolic products in the hybrid catfish ponds often result in excessive phyto- and zooplankton blooms. Although the hybrid catfish can tolerate low dissolved oxygen due to their air-breathing nature, water quality may affect their growth and survival (Diana *et al.*, 1988). To maintain favorable water quality, the pond water with rich nutrients and organic matter is periodically exchanged with new source water, causing pollution in natural waters (Lin and Diana, 1995). The nutrient load from intensive fish culture may have contributed to uncontrollable weed growth in most canals in central Thailand. In Northeast Thailand, the catfish pond effluents laden with overwhelming nutrients have

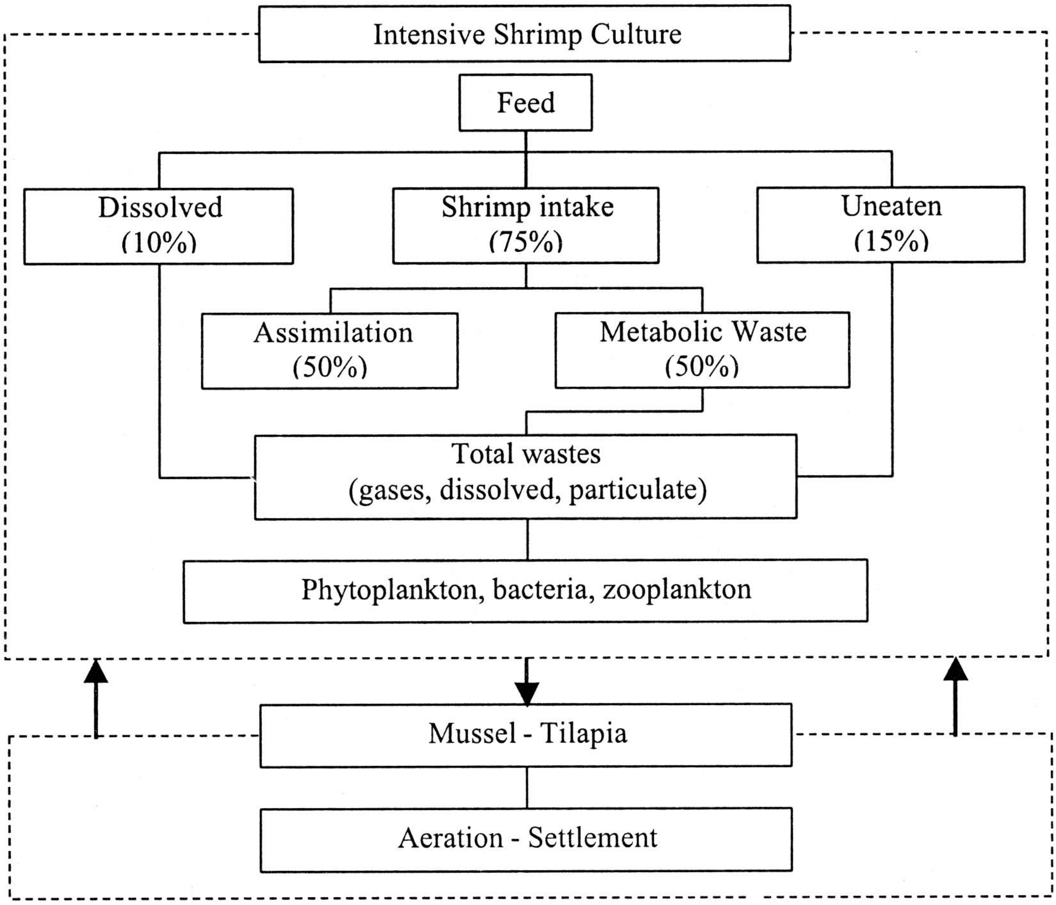

Figure 2. **Schematic diagram for integration of intensive aquaculture waste effluent with filter feeders**

damaged rice paddies, which eventually became wasteful artificial wetlands (C.K. Lin, personal observations).

To develop an integrated catfish and tilapia culture, a preliminary experiment was conducted in two 250-m^2 earthen ponds each with two 3.2-m^3 cages suspended 20 cm off the pond bottom near center of each pond (Lin *et al.,* 1989; Lin, 1990). Catfish fingerlings were stocked in cages and tilapia were stocked in open ponds. The final production of hybrid catfish ranged from 33.7 to 83.0 kg per cage in 146 days, and the open-pond tilapia production was 62.8-80.3 kg per pond with a mean weight of 367-408 g. The nutrient budget showed that 15% N and 21% P was recovered in the tilapia biomass from the wastes produced by caged catfish. Since the amount of nutrients generated from caged catfish depend on the stocking density, Lin and Diana (1995) conducted further experiments under similar culture conditions to determine the productivity and practical stocking ratio between catfish and tilapia of 2:1 and 4:1. Catfish fingerlings were stocked at a density of 275 fish per m^3, with a total of 880 and 1760 fish per pond in low and high density treatments, respectively; and tilapia were stocked at 2 fish per m^3. The two catfish:tilapia stocking ratios did not significantly affect catfish growth with a mean weight gain of 2.16 g per fish per day, but did on tilapia growth with a

Table 1. **Summary of growth performance of caged catfish and open-pond tilapia in a catfish-tilapia integrated cage culture in ponds for 122 days (Lin and Diana, 1995)**

	Treatment A		**Treatment B**	
Performance measures	**Caged catfish**	**Open-pond tilapia**	**Caged catfish**	**Open-pond tilapia**
Water volume (m^3)	3.2	220	3.2	220
Cage number/pond	1		2	
Stocking				
Density (fish/m^3)	275	2	275	2
Total no. (fish)	880	440	1760	440
Total wt. (kg)	12.6	3.1	26.4	3.0
Mean wt. (g/fish)	14.3	7.0	15.0	6.7
Harvest				
Survival (%)	95.8	90.5	87.5	69.8
Mean wt (g/fish)	273.8	179.2	270.2	297.2
Net yield (t/ha/year)	26.1	8.1	46.9	10.3
Gross yield (t/ha/year)	27.6	8.5	50.0	10.6
FCR	1.94		2.24	
Waste loading rates (kg/ha/d)	3.71 N and 1.01 P		8.06 N and 2.20 P	
Nutrient recovery rates (%)	12.75%N and 14.27%P			
7.42%N and 8.27%P				

Table 2. **Summary of nutrient budget in a catfish-tilapia integrated cage culture in ponds for 90 days (Ye, 1991)**

	Nitrogen (%)		**Phosphorus (%)**	
Nutrients	**2.5 catfish to 1 tilapia**	**5 catfish to 1 tilapia**	**2.5 catfish to 1 tilapia**	**5 catfish to 1 tilapia**
Feed	100.00	100.00	100.00	100.00
Nutrient gain				
Catfish	35.44	29.92	43.85	36.89
Tilapia	13.41	4.05	17.28	4.94
Total	48.85	33.97	61.13	41.83
Nutrient lost				
Sediment	23.38	34.87	31.04	51.09
Water	11.94	6.86	4.92	4.09
Other	15.84	24.30	2.90	2.99
Total	51.16	66.03	38.86	58.17
Nutrient recovery rates by tilapia	20.77	5.78	30.77	7.83

mean weight gain of 1.41 and 2.38 g fish per day in the low and high density treatment, respectively (Table 1). Based on pond surface area, the extrapolated catfish production ranged from 30 to 50 mt per ha per year, an amount comparable to that in traditional intensive open pond culture systems, and tilapia production ranged from 8 to 11 mt per ha per year, which surpasses that in ponds fertilized with conventional chicken manure (Green, 1992) or chemical fertilizers (Diana *et al.*, 1991).

The nutrient budget in integrated catfish and tilapia culture system, as shown in Table 2, was estimated by Ye (1991) based on catfish:tilapia stocking ratios of 2.5:1 and 5:1. After the 3-month experiment, production of 1 kg catfish generated 48.0-60.0 g N and 10.0-12.5 g P as metabolic wastes; approximately 30-35% N and 37-44% P input from the feed were incorporated into catfish; 4-13% N and 5-17% P were incorporated into tilapia; 7-12% N and 4-5% P were remained in pond water; 23-35% N and 31-51% P were accumulated in pond sediment; 16-24% N and 3% P were unaccounted for. Among the nutrients in the wastes, tilapia recovered 6-21% N and 8-31% P.

Tilapia-tilapia integrated cage-cum-pond culture

Nile tilapia are commonly grown in semi-intensive ponds based on fertilizers or on integrated systems with livestock (Boyd, 1976; Edwards, 1986, 1991; Diana *et al.*, 1991). However, fish harvested from those ponds are usually relatively small with an average of 200-300 g in five months (Diana et al., 1991), and it may take as long as five more months to rear the fish to 500 g under semi-intensive culture (Diana et al., 1994). In some countries such as Thailand, the market price of Nile tilapia increases with its size, resulting in a trend to culture the fish intensively in cages in rivers and lakes. Moreover, it has been shown that the most economically effective way to produce large size tilapia in pond culture is to start supplemental feeding at 100-150 g size (Diana *et al.*, 1996). The cage-cum-pond integrated culture system is based on a waste recycle concept to produce large size tilapia intensively in cages in ponds and meanwhile to nurse small fish in open ponds semi-intensively.

A series of experiments were conducted in fifteen 330-m^3 earthen ponds with 4-m^3 cages suspended 20 cm off the pond bottom to develop a tilapia-tilapia cage-cum-pond integrated rotation system, in which large size tilapia can be fattened in cages and small size tilapia can be nursed by utilizing cage wastes and then can be removed every three months to restock the cages (Yi et al., 1996; Yi, 1997). In the first experiment, the optimal stocking density of caged tilapia was determined as 50 fish per m^3 with a total of 200 caged fish per pond. Results of the second experiment indicated that the appropriate number of cages per pond was 2 cages per pond. To make this system rotate every three months, the third experiment was conducted to determine the optimal density of open-pond tilapia. The results showed that the optimal stocking density of open-pond tilapia was 1.4 fish per m^3, and also indicated that the carrying capacity and growth performance of caged tilapia could be enhanced by lowering the stocking density of open-pond tilapia. The fourth experiment was conducted to compare the growth performance of both caged and open-pond tilapia between the integrated cage culture and the traditional mixing-size pond culture. Results revealed that the growth performance of both caged and open-pond tilapia was significantly better in the integrated cage culture than in the traditional mixing-size pond culture.

In the optimized integrated cage-cum-pond rotation culture, large size tilapia (124 g) were stocked at 50 fish per m^3 in two 4-m^3 cages suspended in 330-m^3 earthen ponds with the surface area of 313-393 m^2 and water depth of 1-1.2 m, and small size tilapia (16 g) were stocked at 1.4 fish per m^3. Final production of caged tilapia was 91.9 kg•$cage^{-1}$ with an individual weight of 465 g and daily weight gain of 4.06 g•$fish^{-1}$ in the 86-day experimental period (Table 3). The final mean weight of open-pond tilapia production was 124 g with mean daily weight gain of 1.35 g per fish per day. The extrapolated tilapia production was approximately 6.7 mt per ha per year. The nutrients incorporated in caged

Table 3. **Summary of growth performance and nutrient efficiency of both caged catfish and open-pond tilapia in a tilapia-tilapia integrated cage culture in ponds for 86 days (Yi, 1997)**

Performance measures	Caged tilapia	Open-pond tilapia
Water volume (m^3)	4	330
Stocking		
Density (fish/m^3)	50	1.4
Total no. (fish/pond)	400	462
Total wt. (kg/pond)	49.4	7.2
Mean wt. (g/fish)	124	16
Harvest		
Survival (%)	98.8	92.0
Mean wt (g/fish)	456	124
Net yield (t/ha/year)	18.2	6.2
Gross yield (t/ha/year)	24.9	7.1
FCR	1.22	
Waste loading rates (kg/ha/d)	1.75 N and 0.37 P	
Nutrient recovery rates (%)	20.52% N and 27.98% P	

tilapia accounted for 36.41% N and 45.47% P of the total nutrient inputs. The nutrients in the wastes fertilized the ponds at a rate of 1.75 kg N and 0.37 kg P ha per day, giving a N:P ration of 4.73. Open-pond tilapia recovered 20.52% N and 27.98% P contained in the wastes produced by caged tilapia.

Fish-fish integration through water recycling

Recycling nutrient-rich water from intensive fish culture ponds to semi-intensive units can be done through recirculation. Water recirculation can also facilitate mixing in intensive ponds, minimizing ammonium accumulation and undesirable anaerobic zones in the pond (Avnimelech *et al,* 1992). An experiment was conducted to recirculate nutrient-rich water from intensive catfish tanks to tilapia tanks once every 3 or 7 days (Sethteethunyahan, 1998). Water recirculation significantly increased daily weight gain of individual catfish, but did not result in significant differences in survival and yields. The extrapolated tilapia production in the 7-day recirculation treatment was 6.5 t per ha per year, which recovered 3.1% N and 4.5% P of the nutrients from the catfish wastewater.

System-system integration through circulating pond water to rice fields

Wastewater from fish culture can also be reused for fertilizing agricultural crops, but such integration between aquaculture and agriculture farming systems have seldom been practiced. This system may lead to community sustainability and environmental enhancement (Huat and Tan, 1980; Edwards, 1993). An experiment was conducted in Vietnam using wastewater from intensive hybrid catfish culture ponds to irrigate and fertilize rice fields in comparison to regular chemical fertilizers (Lan, 1999). No significant differences were observed in grain yields between those two treatments. But, the grain yields from the wastewater treatment was improved with inorganic fertilizer supplement. This experiment indicated that it is feasible to use the wastewater from the intensive fish culture effluent for rice crops, but the N:P ratio needs to be adjusted using phosphorus fertilizer to achieve better rice performance.

System-system integration through extracting mud nutrients by rooted crops

The nutrient distribution in bottom mud of fish ponds accounted for about 70% of total N and 35-40% of total P in intensively manured tilapia ponds (Green and Boyd, 1995), 23-35% N and 31-51% P in a catfish-tilapia integrated cage-cum-tank culture (Ye, 1991), 20-29% N and 27-45% P in a tilapia-tilapia cage-cum-pond culture (Yi, 1997). Pond mud is a major sink for phosphorus and the adsorption capacity is related to mineral composition and clay content of pond mud (Shrestha and Lin, 1996). In rice-fish integrated culture, most nutrients end up in sumps and trenches with limited benefit to rice fields (Giap, 1999).

As sediments function as phosphorus sink in ponds, regeneration of adsorbed P from mud to water is minimal. Thus, the sedimentary nutrient loss and its reuse has become a major concern. The traditional techniques to recycle those trapped nutrients are to apply the pond mud for land crop cultivation (Muller, 1978; Delmendo, 1980; Brown, 1983; Hu and Yang, 1984; Zweig, 1984; Little and Muir, 1987; Christensen, 1989). In a preliminary experiment, cowpea (*Vigna unguiculata*) and taro (*Colocasia esculenta*) were cultivated with mud or mixture of mud and sand taken from AIT's fish ponds. Cowpea recovered 6.4% N and 1.0% P from pond mud and 7.8% N and 1.6% P from mud-sand mixture, and taro recovered 13.9% N and 3.3% P from pond mud and 13.4% N and 3.6% P from mud-sand mixture (Shrestha, 1994). However, removing pond mud is labor intensive and its practicability is questionable (Edwards *et al.,* 1986).

The alternative method to recover those nutrients is to grow rooted aquatic plants in ponds, since aquatic macrophytes can mobilize and extract them effectively (Denny, 1972; Boyd, 1982; Smart and Barko, 1985). The aquatic macrophytes selected for planting in pond together with fish especially between two fish crops should have comparable economic values with fish culture. For example, lotus (*Nelumbo nucifera*) with high-value edible rhizomes is a suitable candidate, being an emergent macrophyte commonly planted in fields or ponds with nutrient-rich mud and having a growing season of 100-150 days.

Marine shrimp culture

In recent years, effluents discharged from intensive marine shrimp farming have caused serious deterioration of water quality in coastal environments (Phillips *et al,* 1993). In Thailand, shrimp pond effluents annually contribute an estimated 187,500 t of organic matter, 13,050 t of nitrogen and 4,200 t of phosphorus to the environment (Lin *et al*., 1993). To reduce or alleviate the pollution load from those wastes, a closed or integrated recirculation system has been developed (Chien and Liao, 1995; Lin, 1995). An idealized model for integrated recirculation shrimp farming is presented in Fig. 2. A number of filter feeding fish, (e.g., species of tilapia, milkfish, mullet), bivalves such as the green mussel (*Perna viridis*) in combination with seaweed are potential candidates to be integrated. In a pilot scale demonstration farm, green mussel was grown in wastewater canal in a recirculation unit for 113 days, during which mean weight of mussel increased from 12 to 42 g. However, the major problem of integrating multiple species in the same culture complex is their compatibility of environmental requirements.

Conclusions

Integrated aquaculture has been extended from traditional on-farm closed systems to reuse of wastes from intensive aquaculture based on off-farm resources.

The development of recycling of wastewater from intensive aquaculture to semi- intensive culture or other agriculture crops is still in the artisanal stage.

A systems approach is needed for further development of integrated aquaculture, which requires proper engineering design, quantitative information on physical conditions, nutrient budgets and biological comparability among cultured species and systems.

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Socioeconomics Of Responsible Aquaculture In Asia

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Abstract

Aquaculture provided 20% of global fisheries production and 29% of food fish in 1996. Much of the production was from low income food-deficit countries (LIFDCs). Between 1990 and 1996, the average expansion rate of aquaculture in LIFDCs was nearly six times than in non-LIFDCs. The expansion in production is not free of problems, however. Environmental, biological diversity, socioeconomic, and consumer safety issues have been linked to intensive aquaculture. These problems are seen in the context of a need for good governance of aquaculture development. The socioeconomics of responsible aquaculture and approaches of good governance of aquaculture is examined in this paper.

Introduction

"Socioeconomics" is a very broad word and so is the word "responsible." For the benefit of all of us, I will clarify what is meant by these two words in the context of this discussion paper. Both these words are important in the social sciences. The social sciences are scientific in the sense that we seek true knowledge about society and its functions. It is the task of social scientist to examine the issues that affect humanity and society and take responsibilities as social engineers for inducing necessary changes in the political process so that better outcomes are realized for the society as a whole. Socioeconomics is made up of two words, "socio" and "economics." In using the word "socio" the focus is on society, organizations and social well-being. While in using the word "economics," the attention is on welfare, efficiency and equity. The word "responsible" refers to accountability, knowledge and understanding of one's actions and a value system that emphasizes the use of the knowledge and understanding of one's actions for improving the social well-being of society. Responsible also means the participation of governments, stakeholders, users and consumers and their understanding of the ecological support system on which aquaculture production depends on and takes place. Responsible aquaculture is therefore aquaculture activity which is accountable to society and involves the participation of all stakeholders in the decision-making process.

Aquaculture's contribution to world food supplies has been increasing rapidly in recent years and has maintained its position as one of the fastest growing food production activities in the world. Aquaculture provided 20% of global fisheries production and 29% of food fish in 1996 (FAO, 1998). Another important feature of aquaculture is that the low-income food-deficit countries (LIFDCs) feature among the top producers. In 1996, 82 percent or around 27.9 million tons of world total finfish, shellfish and aquatic plant production originated in LIFDCs. The contribution of this group of countries to world production has increased sharply since 1990. The average expansion of aquaculture production in the LIFDCs is nearly six times that in non-LIFDCs. Between 1990 and

1996, the average expansion rate of aquaculture in the LIFDCs was 16.7% compared to 2.9% in the non-LIFDCs (FAO, 1998). Most of the production comes from six countries namely China, accounting for 83%, India 6%, Indonesia 4%, the Philippines 3%, Democratic Peoples Republic of Korea 2%, and Bangladesh 1%.

The booming aquaculture production and trade coupled with its increased socioeconomic benefits such as employment and foreign exchange earnings are however not free from problems. Deteriorating environments, destruction of mangroves, displacement of local people, inequality in income and rent distribution are examples of some of the problems that have raised questions on the sustainability of aquaculture, especially of intensive aquaculture.

This paper will address some of the socioeconomic problems arising from aquaculture development and explore how these problems can be handled within an improved governance framework. It is the premise of this paper that most of the problems that arise from aquaculture development are the result of weak regulatory frameworks and inadequate governance of the industry. The greater participation of the various stakeholders involved within a coastal environment in coastal resource management can lead to reduced negative socioeconomic impacts and ensure sustainability of aquaculture.

Relationship between Social and Economic System and the Aquaculture Production System

Aquaculture production involves the use of natural resources such a land, materials, water, fry and feed and fertilizers. How these resources are acquired will depend on the property rights arrangement in the society. If property rights are well organized, there is less chance for the development of serious social problems. Social problems arise often when property rights to the resource used in aquaculture are not well defined. This can lead to displacement or taking away of rights to resources enjoyed by local communities as a result of an aquaculture development in a coastal area. In addition, the activity of converting these resources into aquaculture outputs creates wastes and how these wastes are managed creates opportunities for negative impacts on others.

The social and economic systems in a society determine the property rights arrangements and opportunity sets available for individuals in a society to use resources in the society. The development of effective property rights systems to manage coastal resources has been a very difficult task in most societies. The need to develop more efficient property rights regimes in coastal areas so that negative externalities can be reduced or prevented is one of the goals of responsible aquaculture.

Problems of Intensive Aquaculture Development

Shrimp aquaculture, once hailed as a promising export earner, has produced some social and environmental problems in many Third World countries, mainly in Asia. Hundreds of farming and fishing communities throughout the region have protested against the intrusion into their lands and the despoliation of their land and water resources by aquaculture farms (Patil and Krishnan, 1998). These farms have been set up by commercial companies, mainly in the past five to 10 years, along coastal areas, as part of national government policies and often aided technically or financially by international agencies. Since the 1970s, global production of cultured shrimp has increased rapidly, mostly in Asia, which in 1990 produced 556,500 metric tons or 80% of the world output. In the same year, it was also estimated that 820,000 hectares was being used for coastal shrimp aquaculture in Asia. (Khor, 1999).

Another problem associated with aquaculture according to Goldburg and Triplett (1997), is the so-called “fishmeal dilemma” wherein huge amounts of small pelagic fishes, such as anchovy, jack mackerel, herring, and sardine, etc. are harvested to make fishmeal and fish oil used in animal feeds. It is estimated that 27% (31,000,000 mt) of the world’s total wild fisheries production is now being converted to animal feeds. Of this, only 15% of this total is being used in fish feeds; however, many aquaculture feeds are 20 to 70% fishmeal, while most feeds for poultry and hogs are only a few percent fishmeal. The most obvious problem with feeding wild fish to farm fish is that it is inefficient. Feeding fish to fish leads to a net loss of protein in a protein-short world. Lesser obvious problems of the “fishmeal dilemma” are the ecological effects of massive harvest of small pelagic fishes. Removal by fishing vessels of huge quantities of small fish from the marine food webs means that less food may be available for commercially valuable predatory fish and other marine predators, such as sea birds and seals. The impacts of these activities will have to be studied carefully to examine the nature of negative externalities created by the “fishmeal dilemma.”

As a result of these problems, there are requests on governments to review their aquaculture and rural policies, and for the international and regional agencies financing and encouraging aquaculture to seriously reflect on some of the ill-effects of their funds and advice (Khor, 1999).

It should also be recognized, however, that aquaculture is capable of contributing to environmental improvement and conservation in many ways, such as through small-scale integrated farming systems, conservation of species, and water-quality improvement in coastal waters. It is also increasingly needed to meet the growing demand for aquatic food, which cannot be met by static or declining capture fisheries yields. It must be recognized that many of the environmental problems caused by aquaculture can be dealt with through improved management at various levels. From the farm level through to watershed or shared coastal area, and at local, national and regional levels, the challenge is to fully integrate an improved understanding of environmental interactions of aquaculture systems.

It is now increasingly acknowledged that environmental interactions of aquaculture should be viewed and resolved within a wider environmental and political context, with due account of the social and economic circumstances in which aquaculture is taking place (Barg and Phillips, 1997).

The Food and Agricultural Organization (FAO) of the United Nations, in its effort to make capture fisheries and aquaculture more sustainable, is lobbying for the need to promote and implement a Code of Conduct for Responsible Fisheries (FAO, 1999). The Code’s Article 9 on Aquaculture Development contains provisions relating to “aquaculture production, including culture-based fisheries, and their responsible development in areas of national jurisdiction and within trans-boundary aquatic ecosystems, to conservation of genetic diversity and ecosystem, and to responsible practices at the production level” (Barg and Phillips, 1997). The code is envisioned to create an “enabling environment” essential in striking a balance between the need for development and growth and the need for ecosystem conservation. Such an environment will consist of economic, legal, social and physical components and should guarantee fair access to resources, mechanisms for conflict resolution and access to information, credit and markets (FAO, 1998).

Socioeconomics of Responsible Aquaculture

An issue which has been contentiously debated in the realm of socioeconomics is who are the primary beneficiaries from aquaculture and to what extent the local communities benefit from such developments (Bailey, 1988).

On the downside of aquaculture development (Table 1), there have been reports of lands taken from farmers and coastal villagers to make way for intensive aquaculture (Sierra Club, 1996a,b). According to Bailey (1988), coastal villagers and farmers tend to have traditional rather than legally recognized rights. Until recently, government has allowed these people to exercise their traditional rights to the sustainable use of mangrove resources for the staples of life. Generations of women and children have collected wild fruits and vegetables, gathered plants for medicines and found construction materials for their homes. Farmers have harvested rice, millet and other crops from small plots while fisherfolks have repaired their boats and relied on small catches of fish and crustaceans spawned in

Table 1. **Socioeconomic problems in aquaculture**

Nature of Problem	Country	Aquaculture type	Reference(s)
Forest lands converted to aquaculture farms	Thailand, Bangladesh, Philippines	Shrimp aquaculture	Sierra Club 1996a; FAO, 1995; Tisdell 1995
Loss of mangroves, salination	Bangladesh; Andhra Pradesh and Tamil Nadu, India	Shrimp and culture ponds	Barraclough *et al* 1995; Sierra Club, 1996a; Tisdell 1995; Khor, 1999;
Increasing unemployment	India	Shrimp aquaculture	Shiva 1995; Patil and Krishnan, 1988
Social exclusion	India, Bangladesh	Shrimp aquaculture	Sierra Club, 1996ab
Social unrest and conflicts	India, Bangladesh, Thailand, Philippines, Taiwan, Vietnam, China	Shrimp Aquaculture	Sierra Club, 1996b
Disease outbreaks and abandonment of exhausted ponds	India, Bangladesh, Thailand, Malaysia, Philippines, Taiwan, Vietnam, China	Shrimp aquaculture; intensive monoculture aquaculture	Kutty, 1997
Income inequality	South Asia	Shrimp aquaculture; high end intensive aquaculture	Kent, 1995
Aquaculture versus tourist development and coastal ship traffic	Hong Kong, Singapore, Thailand	Offshore intensive aquaculture and offshore cages.	Beveridge *et al,* 1997
Sedimentation	Bangladesh, South and Southeast Asia	Shrimp aquaculture	Barraclough *et al,* 1995; Sierra Club, 1996a
Lands taken/land conversion	Andhra Pradesh, India	Shrimp aquaculture	Tisdell, 1995; Sierra Club, 1996a,b
Food security	Andhra Pradesh and Tamil Nadu, India	Shrimp aquaculture	Shiva, 1994
Dislocation of people	Andhra Pradesh	Shrimp aquaculture	Thamina, 1995; Sierra Club, 1996b

mangrove nurseries. The way of life of these people was changed abruptly with the introduction and expansion of large scale, intensive aquaculture (shrimp farming, etc.). What was traditionally been a multiple user system was turned into a privately owned, single-purpose resource.

In some cases, Kent (1995), insinuated that intensive aquaculture operations sometimes even make the poor worse off. An example is the case of fingerlings, which previously had been consumed by the poor, are fattened in aquaculture operations to cater to upscale markets. Coastal shrimp mariculture has displaced many traditional coastal fishermen in Asia, and has damaged or destroyed mangrove ecosystems, which have served as breeding grounds for local fisheries for local markets. Export-driven aquaculture operations often channels resources away from production for local consumption. In general, any land, water, labor, or capital that is devoted to aquaculture for upscale markets has an associated opportunity cost in that those resources could have been used to help feed the local people.

Moreover, the destruction of mangrove forests that usually accompanies intensive aquaculture development has a direct effect on the coastal communities' sources of income and employment. For generations, coastal populations have been enjoying unrestricted access to mangrove products, earning their livelihood by felling and gathering poles, making charcoal, gathering firewood, collecting materials for making wrappers, roofs and the like. However, with the expropriation of mangrove forest for intensive shrimp mariculture, what was originally a common property and multi-user coastal resource is now transformed into a privately owned single-purpose resource (Jahaya, 1994). The fact that coastal communities do not have legal property rights over mangrove resources makes it much easier for outsiders to expropriate this resource. The net result is the deprivation of the use of a resource by the coastal population dependent on such resource for their livelihood.

Declining municipal fisheries yield can also be traced to the decline and loss of mangrove covers among other factors. The conversion and salination of rice and other agricultural land also leads to marginalization of coastal rural communities. Farmers who are stripped of their land are then forced to seek work elsewhere, migrating to cities and swelling the ranks of urban unemployed (Primavera, 1997).

Moreover, governments at times offer to lease or sell coastal lands to the farmers at greatly inflated unaffordable prices. Many have had their land "acquired" and confiscated without any compensation at all. With no alternatives, thousands have been forced to work for wages on their own land, or to migrate to the cities for low-wage work (Sierra Club, 1996a,b).

If left unchecked, many of the environmental and socioeconomic problems that have accompanied the development of modern aquaculture could be repeated. It is up to the present generation to learn from the mistakes of the past and remedy its errors for there is still considerable opportunity to guide its future course.

According to Kutty (1998), aquaculture sustainability itself has been questioned in several international, regional and national studies and discussions. However, definitions of sustainable and "responsible" aquaculture still remain vague and ranged from "strong" to "weak", and from being ecocentric to technocentric. Many who have thought about it prefer to see it as a broad goal and a concept and not to be defined at all. The concept has been variously defined, from a general goal of inter-generational equity to concerns for biophysical, economic, and/or social stability in a specific production system (Batie, 1989).

Biological definition of sustainable aquaculture is more often defined as a method of culturing aquatic plants and animals at reasonable stocking densities, which allows efficient production without undue dependence on chemicals and artificial feeds and without any negative impacts on the environment.

According to Tisdell (1995), "the sustainability of an aquaculture industry depends on its continuing economic viability and its relative profitability," which in turn depends on how well the productivity of aquaculture is sustained utilizing natural factors, reflected in prices paid for inputs used in aquaculture and the price(s) obtained for its product(s). The impacts of a sustainable aquaculture industry cannot be determined in isolation from the rest of the economy or its broad impact on natural resources and environmental systems. For example, although the productivity and economic profitability of an aquaculture industry may be sustainable, this may only be at the expense of the economics of operating another industry or industries (e.g., because of pollution from aquaculture). The overall value of production may therefore be reduced and the potential income available to future generations might be lower due to natural resource depletion or deterioration. In this respect, most economists define sustainable development (aquaculture) as development that ensures that the income of future generations is no lower than that of present generations, as required by the inter-generational equity principle".

In the past, economics have ignored the dependence of economic activity on the maintenance of life-support systems, or often their maintenance has been taken for granted. Economics concentrated mainly on the social sphere with the inter-dependence of economic and natural systems being given little or no attention. It is now known that economic activity cannot be assessed in isolation from its impacts on the natural systems. Most economic activities, including aquaculture, use natural resources and returns wastes to these, thus forever changing the resource base of these systems and do so substantially when the economic activity occurs on a large scale (Tisdell, 1995).

In considering the sustainability of any aquaculture production systematically, it is important to 1) define concepts of sustainability and of sustainable development, 2) identify factors internal to aquaculture that contribute to its sustainability or otherwise, 3) isolate impacts from outside of aquaculture that affect the sustainability of aquaculture and identify consequences of aquaculture for the sustainability of economic activities and economic welfare external to aquaculture, and 4) discuss policies that should improve the ability of aquaculture to contribute to the fulfillment of sustainability objectives (Tisdell, 1995).

To make aquaculture more sustainable and responsible than it often already is will include attention to the activity not standing by itself, but being nested in a complex environmental, economic, and social matrix.

Aquaculture Developments in Asia

It is well recognized that the current debate on aquaculture is primarily focused on the environmental sustainability of salmonid and shrimp culture, which apparently is leading to attempts to control such types of coastal aquaculture. Much less attention has been given to the need to support and develop sustainable inland culture systems producing food affordable to poor consumers (Bailey and Skladany, 1991).

It has been suggested by Barg and Phillips (1997) "that semi-intensive systems are more environmentally friendly and more socially acceptable, due to their significant potential to use less exogenous supplementary inputs, while providing many opportunities of efficiently converting locally available nutrient resources into production of fish affordable to a wider range of consumers in rural communities and urban centers". In addition, as suggested by Bailey (1997), "such systems often are within the reach of a wider range Of resource-poor producers, being significantly less dependent on capital investment, and are therefore more likely to contribute to local economies and to enhance the ability of local communities to maintain social and economic viability."

In general, aquaculture can be a significant contributor to local food security providing food directly to the producer or to the immediate community, especially in many areas of Asia. This contribution can also be direct, as an economic activity, which is regular and reliable, especially in comparison with traditional capture fisheries, and as an option for diversification into new opportunities. In those locations where food security can be a significant issue, the key producers often operate at a small scale, directly involving families and communities. In terms of policy direction and options for specific development aims, this offers possibilities for involving disadvantaged groups, in targeting activities for the benefit of women, or in helping landless groups where there are under-utilized bodies of water.

Future Directions for the Governance of Aquaculture

In most of Asia, food production will always remain an overriding priority and thus intensification of aquaculture will continue. This will promote investment in research, which eventually leads to improved production efficiency. Sustainable development of aquaculture, be it intensive or extensive, would be the overriding strategic issue and challenge to all economic sectors. Issues of sustainability can be expected to change our perceptions of desirable forms of aquaculture development and management, and new ways of farming that will have to find a balance between food security, environmental and socioeconomic concerns.

According to FAO (1999) "over the last few years, there has been a growing interest in many countries to develop a comprehensive regulatory framework for aquaculture that will protect the industry, the environment, other resource users and consumers. This interest is being fueled by a host of factors which includes greater political attention as the economic importance and potential of aquaculture becomes more evident, greater awareness that inappropriate laws and institutional arrangements can significantly constrain the development of the sector, evidence of environmental damage and social disruption as a result of rapid and largely unregulated expansion of some high valued species in certain coastal areas, and a growing emphasis on assuring the quality and safety of aquaculture products in international trade". These issues have pushed FAO to advocate the Code of Conduct for Responsible Fisheries as an answer to problems associated with aquaculture and fisheries in general.

The Code is beginning to have a worldwide influence on the development of an "enabling environment" for a more sustainable and responsible aquaculture; however, much remains to be done. Greater progress can be expected as new guidelines are developed on how to strike a balance among economic, social and environmental concerns, how sustainability choices apply in practice and how to analyze the economic and social cost of resulting actions (FAO, 1999). The focus in the future will be the issue of governance of aquaculture.

The governance of aquaculture can be improved if aquaculture is seen as a part of an integrated coastal resources management program. The concept of an integrated coastal zone management can succeed in dealing with the negative socioeconomic impacts of aquaculture since the approach from the very beginning attempts to identify the links between different activities and resource requirements and tries to reduce the negative impacts of one activity on the other. The optimum use of resources thus becomes the overall objective (Lohmeyer, 1999). The regulatory framework will then focus on 1) the creation of a legal basis for environmental provisions to regulate harmful side effects (externalities) from industry in accordance with the polluter-pays principle so that one sector's development efforts do not hamper another's, and 2) clarification of the rights of use so that investors are accountable and exploit natural resources on a sustainable basis. The effective governance of aquaculture must therefore come from the prevention of externalities through integrated coastal zone programs and the management of externalities through regulation using the polluters-pays principle, as is the case in all other industries. In addition, clearer definition of rights to coastal areas would be a basis for effective reduction in negative social impacts of development. Legitimacy for any form of governance, however, has to come from the broader participation of both resource users and the local population. This is important to ensure that the de facto laws and de jure laws are close to each other. This means effective governance requires co-management with all the stakeholders and user groups.

Conclusion

Aquaculture will continue to expand especially in Asia but its development will be seen in much broader terms than the narrower technical aspects of production. Political, economic, social, environmental and legal aspects will be given greater emphasis as aquaculture emerges as an industry competing for resources from other sections of the economy. The need for well-informed policy measures and regulatory frameworks would push governments to consider frameworks for more responsible governance of the aquaculture industry. One such governance approach would be to include aquaculture as part of an integrated coastal zone management program. Such an approach will be concerned with the reconciliation of competing demands for the same coastal resources and trade-offs between competing uses. More responsible governance also means that the governing authorities should establish mechanism to work with all stakeholders in the coastal zones. Greater participatory management of coastal zones will be an important cornerstone of good governance to enable responsible aquaculture.

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Developments In Seaweed Farming In Southeast Asia

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Abstract

During the last thirty years, seaweed farming has progressed in the region comprising the Association of Southeast Asian Nations (ASEAN). Farm production reached a high of 146,500 mt of dried seaweeds in 1997 from an initial harvest of 500 mt in 1973. In 1997, the ASEAN region produced about 90% of the world's production of carrageenophyte seaweed, providing raw materials for the US$350 million world carrageenan market. Two species of carrageenophytes, *Kappaphycus alvarezii* (=*Eucheuma cottonii*) and *Eucheuma denticulatum* (=*Eucheuma spinosum*), constitute the base of the seaweed industry in the region. *K. alvarezii* is predominantly farmed in the Philippines and Malaysia while *E. denticulatum* is dominant in Indonesia. Vegetative propagation is still applied in all farmed species of carrageenophytes, while the monoline method remains the most popular method of farming. Non-traditional farming areas have been established in central and northern Philippines and in Sabah, Malaysia. The culture technology has been developed for *Gracilaria* sp.; however, no up-to-date reports on production are available. Seaweed farming has become one of the most important sources of livelihood for at least 100,000 coastal families in Southeast Asia, contributing apparently to the reduction of blast and cyanide fishing and to the relative improvement of peace and order in seaweed farming areas.

Introduction

The seaweed industry in Southeast Asia was first recognized in the Philippines in the mid-1960s when there was an unprecedented commercial harvest of the red algae *Eucheuma.* Initially, no attempts were made to farm seaweed. From a harvest of 415 mt in 1969 from wild natural growth, seaweed production increased to 1,240 mt in 1996. In the early 1970s, the Philippines first commercial seaweed farming was introduced in Sulu Sea in southern Philippines, but later on, it was adopted in many areas of the southern and central Philippines, particularly in the Sulu archipelago.

The expansion of farming carrageenophyte algae led to the introduction of *Eucheuma* farming in Indonesia. *Eucheuma spinosum* (=*E. denticulatum*) was introduced in Bali, Indonesia in 1978 and, in 1985, seedlings of *E. cottonii* (=*Kappaphycus alvarezii*) were brought to Bali from the Philippines. During the last thirty years, the seaweed industry has progressed in the ASEAN region. The ASEAN region produced about 90% of the world's production of carrageenophyte seaweeds providing raw materials for the US$350 million world carrageenan market. The regular cropping system now provides a reliable and sustainable environment-friendly alternative livelihood to coastal communities in the Philippines, Indonesia, and Malaysia. Farm production reached a high of 146,500 mt of dried seaweeds in 1997 from an initial harvest of 500 mt in 1973. Two species of carrageenophytes – *K. alvarezii* and

E. denticulatum constitute the base of the seaweed industry in the region. *K. alvarezii* is predominantly farmed in the Philippines and Malaysia while *E. denticulatum* is dominant in Indonesia. Vegetative propagation is still applied in all farmed species of carrageenophytes while the monoline method remains the most popular method of fanning. Non-traditional farming areas are developed in central and northern Philippines and in Sabah, Malaysia. The culture technology has been developed for *Gracilaria* sp.; however, no up-to-date reports on production are available.

Commercial Cultivation and Production of Seaweeds

Carrageenophytes

Two species of carrageenophytes, *K. alvarezii* and *E. denticulatum* are produced commercially through farming, thus constituting the base of the multi-million seaweed industry in Southeast Asia. In spite of the negative effects of the El Nino weather phenomenon that hit the *Eucheuma* farms in Southeast Asia and tsunamis that devastated the western Sitangkai in the Sulu archipelago in 1998, which is considered one of the biggest seaweed farming areas in the Philippines, the region has produced about 90% of the world's production of carrageenophytes, equivalent to a total of 144,225 mt. In the same year, Philippine seaweed production reached a total of 109,225 mt followed by Indonesia with 29,000 mt and Malaysia with 6,000 mt. The majority of production from the Philippines and Malaysia is *K. alvarezii* while the production from Indonesia is more of *E. denticulatum.* Presently, there are over ten strains of carrageenophytes farmed. The giant "tambalang" strain of *K. alvarezii* is farmed in southern Philippines. The search for a disease-tolerant strain led to the introduction of the "sacol" variety in the central and recently in the northern Philippines.

Agarophytes and Caulerpa

Among the agarophytes for the processing of agar are several species of *Gracilaria* and *Gelidiella.* A large portion of the raw material are cultured in ponds while the rest are still harvested from wild stocks. Pond and open-lagoon culture is followed in *Caulerpa lentillefera* farming. In spite of their huge economic potential and the availability of culture technology, no up-to-date information is available on the culture and production of these seaweed species.

Economic Importance

Beneficiaries

Due to the increased demand for *Eucheuma* raw material and the opportunities to earn higher income, seaweed farming has become the most important means of livelihood among coastal and island communities. Non-traditional farming areas are utilized for the mariculture of the two commercially important carrageenophytes. More than 100,000 coastal and island families in the Philippines, Indonesia, and Malaysia are presently engaged in seaweed cultivation An area of more than ten thousand hectares has been estimated for the mariculture of these carrageenophytes.

Average annual income per family

A family normally cultivates an area of a quarter to one half of a hectare. This area can accommodate 500 monolines of 10 m length and a distance of half meter between lines. Two hundred and fifty lines can be harvested monthly, with a 60-day growth cycle producing a net harvest of 12,500 kg fresh seaweeds. At a farm gate price of P20 per kg (US$0.50), a family earns an average gross annual income of P320,000 (US$8,000). An initial investment of P40,000 (US$1,000) is required.

Farming Methods

Vegetative propagation is still widely applied in all farmed species of carrageenophytes. From the original net method introduced by Dr. Maxwel Doty, the farmers have introduced innovations of farming to suit the condition of the farming site. The most popular is the monoline method of farming. Floating monoline method is utilized in deeper areas, while bottom monoline farming is generally used in shallow reef flats and coastal waters. Other farming methods include stake and net, bamboo raft, suspended rope and line with float, and broadcast. These methods are utilized for both *K. alvarezii* and *E. denticulatum.*

Polyculture potential

A polyculture system to integrate seaweed farming with other marine fauna like abalone, giant clams, sea cucumber and fish is also fast developing in the region. However, this polyculture potential remains to be developed and utilized. To maximize the production of resources per unit area, a research and development program should be initiated to focus on these aspects of seaweed polyculture.

Ecological Importance

The experience during the last thirty years of seaweed farming has shown a substantial regeneration and rehabilitation of the marine environment where the seaweed farms are located. In most ASEAN countries, particularly the Philippines, coral reef areas have been reported to be degraded, over-exploited, destroyed and virtually turned into ocean deserts. Destructive fishing activities such as dynamite and cyanide fishing are prevalent. With the introduction of seaweed farming in some areas, the seas became more alive and productive. For example, the establishment of MCPI Corporation's Ocean Farming Research Center in the Danajon Reef in central Philippines appeared to have restored the ecological balance in the area, resulting in a significant increase in the daily catch of abalones, sea cucumbers, sea urchins, mollusks, and fishes by local fishermen. Farmed seaweed beds in the area likewise attract various marine food organisms and could provide shelter to fish, mollusks, and other marine life. Hence, seaweed beds have become a new sanctuary and breeding ground for many marine organisms, consequently regenerating the reef and increasing the farmers' harvest from the reef.

Several concerns for potential disturbance and pollution of the reef ecosystem have been raised however. One of these is increased pollution in the farm area. But, the fact is seaweeds should not be farmed in polluted water since they require a clean environment and relatively strong water current to assure the flow of nutrients that nourish the plants. Likewise, farmers regularly clean the farm beds of foreign materials and guard them to ward off trespassers, dynamite fishers, cyanide sprayers and shell collectors. These practices may contribute to ecological stability and sustained productivity of the reef.

Recommendation

Seaweed farming is an important economic activity that provides not only an alternative livelihood for coastal communities but also promotes ecological regeneration. Both government and private sectors in ASEAN countries should therefore cooperate and encourage the development and advancement of farming, post harvest activity/processing and product applications of seaweeds.

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Developments in Mollusc Farming in Southeast Asia

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Abstract

Southeast Asia has a relatively long tradition in mollusc culture. The mollusc species of commercial significance in this region are the blood cockles (*Anadara granosa),* the green mussels (*Perna viridis),* the oysters (*Crassostrea* spp.) and the horse mussels (*Modiolus* sp.) Mollusc production has been observed to fluctuate dramatically in recent years due mainly to the inconsistent seed supply from the wild, which varies geographically and annually. These variations are often associated with pollution and also the uncontrolled harvesting of adults irrespective of their sizes, which reduces chances of spawning among adults. Production of the above-mentioned species in Southeast Asia in 1997 amounted to 73 820, 62 073, 36 779 and 5 300 mt., respectively. The culture of these bivalves is still dependent on traditional methods of obtaining seeds from the wild and transplanting them to culture sites for grow-out. Culture techniques for these bivalves are basically the same all over Southeast Asia, except for minor variations in the use of structures and materials to suit the local conditions. Whilst efforts are geared towards developing new technologies to promote mollusc culture in the region, it is important to facilitate and stimulate environmentally acceptable developments and sustainable management practices. Although hatchery propagation techniques have been developed for these cultured and other non-cultured species, the technologies have yet to be taken up commercially. Some of the common problems confronted by the region, which varies greatly by species and location, are inconsistent seed supply, lack of suitable areas for expanding culture activities, poor post harvest handling techniques, demand levels being below production capacity, environmental pollution, vagaries of nature, low price and lack of access to export markets.

Introduction

Amongst the four main groups of aquaculture products of the world, molluscs form the major component, followed by finfish, crustaceans and seaweeds. Molluscs are estimated to contribute about two thirds of the total global aquaculture production, while Asia accounts for two thirds of the world's molluscs produced. In Southeast Asia, countries which are actively involved in marine mollusc farming (based on their annual production) are Thailand, Malaysia and the Philippines (FAO, 1999) and the significant commercial species landed are the blood cockles (*Anadara granosa*), green mussels (*Perna viridis*), the oysters (*Crassostrea* spp. and *Saccostrea* sp.) and the horse/brown mussels (*Modiolus* sp.). However, several species, although widely harvested from the coastal waters, like the carpet clam (*Paphia undulata*), razor clam (*Solen* spp.), abalone (*Haliotis* spp.), hard clams (*Meretrix* spp., *Callista* sp), the giant clams (*Tridacna* spp.), pen shells (*Pinna* spp.) are not cultured.

Mollusc landings in Southeast Asia fluctuate yearly, and in recent years, annual production has in fact decreased in the region. The production of molluscs in Thailand, Malaysia, Philippines and Singapore for 1995-1997 is shown in Table 1 (FAO, 1999). Production data from other countries (Indonesia, Vietnam, Laos, Cambodia) are not available probably because of the lack personnel to gather the statistical information. In 1995, mollusc landings from countries with production data amounted to 222,980 mt compared to 188,393 mt and 178,022 mt in 1996 and 1997, respectively. This apparent decrease has been associated with several factors, namely the inconsistent and lack of seed supply, heavy exploitation of culture sites, resulting in lack of suitable areas for further expansion, poor post-harvest handling techniques, demand levels being below production capacity for certain species like the mussels, environmental pollution, vagaries of nature (monsoons and other calamities), low price for certain mollusks, and lack of access to export markets.

Table 1: **Annual mollusc landings (mt) by species for countries in Southeast Asia from 1995 to 1997 (FAO, 1999)**

Country/Species	1995	1996	1997
Thailand			
Perna viridis	51,182	35,489	45,800
Crassostrea sp.	23,037	23,420	22,800
Anadara granosa	14,403	15,836	15,420
Modiolus sp.	4,211	5,483	5,350
Total	92,833	80,228	89,370
Malaysia			
Anadara granosa	100,276	71,795	58,400
Perna viridis	778	1,164	1,779
Crassostrea spp. and *Saccostrea* sp.	26	42	126
Total	101,080	73,001	60,305
Philippines			
Crassostrea iredalei	11,874	11,776	13,853
Perna viridis	14,688	21,027	11,658
Total	26,562	32,803	25,511
Singapore			
Perna viridis	2,505	2,361	2,836
Total	2,505	2,361	2,836

Most countries in Southeast Asia share rich endowments of similar mollusc species and possess suitable environmental conditions for their culture. However, the status of development and the economic importance of the shellfish industry may differ in the respective countries. Although the farming technology of most molluscs in the region depends on conventional methods of collecting spat from the wild to be transplanted to the grow-out sites, the culture practices have been gradually and systematically improved over time by coastal fisherfolks with the aim of increasing production through sustainable management practices. This paper attempts to discuss some of the methods employed by coastal communities in Southeast Asia in the farming (spat collection and grow-out methods) of the various mollusc species.

Blood Cockles (*Anadara granosa*)

Major producers of cockles are Malaysia and Thailand and the most common species cultured is *Anadara granosa,* although *A. nodifera* and *Arca* sp. have also been reported to be cultured in Thailand (Sahavacharin, 1991) and in the Philippines (Davy and Graham, 1982), respectively. Extensive culture of *A. granosa* has also been reported in Vietnam but published information is limited. The culture methods in these countries are similar (Tookwinas, 1987) and to date, the system of cockle culture has been most developed (Davy and Graham, 1982). Both the spat and adult cockles inhabit the coastal mud flats, which are often classified as sandy-loam, and their distribution is intertidal or marginally sub-tidal (Broom, 1985) where water depth does not exceed 3 m, beyond which the pole dredge cannot be used to harvest cockles (Kamal, 1996). They require high salinity regimes and thus are found at highest densities in mudflats away from the estuaries.

Spatfall collection

In Malaysia, cockle spats are usually available throughout the year but two main peaks could be distinguished. The first peak is from January to March while the second is from May/June to September (Kamal, 1986). Consistency of spatfalls in an area is greatly dependent on the spawning success of both naturally occurring and cultured cockles, including water current, which disperses cockle larvae during their planktonic phase. As a result, Spatfall areas and the quantity of spat are not predictable and is expected to shift from place to place and varies yearly. Availability of spat in an area during a particular season does not confirm Spatfall in the subsequent years. Cockle spats are also found in coastal mudflats and usually these areas are protected by classifying them as Spatfall areas (in Malaysia), so that no culture work is carried out here. Utilising a Spatfall area for culture work can damage spats during culling activities in the culture plot for grow-out.

Spats are usually collected with a hand core (hand-made wire scoops with very fine mesh size of 2x2 mm) during low tide by sieving the mud flats and rinsing them in seawater prior to emptying the spat into plastic sacks, which weigh about 60 kg (when full) or in tins (18 l when filled). No mechanized collection is allowed. In Malaysia, spat collection is allowed from 6 am to 6 pm as specified in the Fisheries Act (1985) and only if a license is obtained from the Department of Fisheries after notification of Spatfall by the relevant authorities. The preferred spat size ranges from 6 to 10 mm in length and the best quality spat are those caught in the first few weeks of collection. In Malaysia, the legal size considered as spat for collection are those with an average size greater than 6.4 mm, which should be landed at sites specified by the Fisheries Authorities to facilitate monitoring. The size specified is in view of reducing mortality of spat while being collected and also during transportation to culture sites. The spat can be transported under semi-dry conditions (mixed with mud) over 48 h with very low mortality rate (about *5%).* The quality of spat depends on the content of impurities comprised of detritus and other clams.

Suitability of grow-out area

Areas considered suitable for cockle culture are tidal flats of soft flocculent mud, protected from strong wave action, and situated outside the mouth of estuaries. Some features in choosing a site for cockle culture are:

- Well sheltered from strong wind and current to prevent the spat from being buried under the mud;
- Mudflats with sandy-loam soil texture (mud content 40-50%);
- Salinity range of 28-30 ppt;
- Stable culture bottom with gradual or no slope; and
- Areas without pests or pollution.

Culture areas are usually further away, and in most cases, very far off from natural grounds. In Malaysia, most of the cockle culture operations are well organised by the Fisheries Development Authority (FDA) or through the Fishermen's Cooperatives, but some are operated by private organisations. The culturists would have to apply for a temporary occupation license (TOL), which is charged on a yearly basis by the land office to operate the culture beds. Currently some 4,500 hectares of mudflats are in use for the culture of cockles in Malaysia.

Preparation of culture plots

Most of the culture plots are bounded by natural landmarks, but where these are lacking, the boundaries are marked by other means such as mangrove poles and 'watch huts'. Prior to sowing of spat, the culture plots would be cleared of empty shells and predators if the area is small. But in some cases, the culturists reckon that clearing of extensive culture plots, which may easily exceed 100 ha, is extremely tedious and expensive. They also feel that, given time, the empty shells would sink into the mud. Thus, as soon as a batch of cockle is harvested from the plot, new spat are sown immediately into the area.

Due to lack of culture sites in the intertidal areas in Malaysia, efforts have been geared to utilise deeper areas (exceeding 3 m and about 500 m from the shoreline) for cockle culture. Due to the depth of water, harvesting of cockles have to be carried out by using a boat-towed dredge, similar to that used for collecting carpet clams (*Paphia undulata*). Preliminary results showing that survival rate was higher (90%) compared to the usual rate obtained (70-80%; Kamal, 1996) have been encouraging. The usual problems of barnacle encrustation and predators were minimal.

Stocking density

Stocking density of spat per acre depends on the size of spat. For spats of about 5000 pieces per kg, 150 to 200 tins of spat per acre appear to be the best stocking density. Expected yield per acre from 200 tins of 5000 pieces per kg spat is about 1,200-1,400 gunny sacks (each sack is about 80 kg of adult cockles). Some of the cockle densities recommended by the culturists from the various culture sites are as follows:

Number of spat (per kg)	Size of spat (mm)	Culture density (spat per m^2)
6,700 - 8,000	5 - 6	3,000 - 4,000
3,300 - 5,000	7 - 8	1,600 - 2,000
1,600 - 2,500	9 - 10	1,600 - 2,000
1,000 - 1,200	11 - 12	650 - 900
250 - 400	> 13	320 - 640

The most sought after spat are those of about 8,000 pieces per kg, but the most commonly available spats range from 5,000 to 6,000 pieces per kg. Some culturists buy spat in bulk and stock them in an area where they are culled from time to time using a bigger core (various mesh sizes for varying spat size) with a handle into grow-out areas. The stocking rate can thus range from 220 to 320 tins per ha. Spats brought to the culture area are sown during high tide, to enable the boats to go round distributing the spat on the seabed. Spats are poured off the sacks from the rear of the boat so that the propeller can help to distribute the spat in the water column. Or, spats are spread with a plate or scoop as the boat is moving. Spats are sown at a high density in a corner of the culture plot before being culled or spread into the grow-out area over the culture period.

Management

As usually practiced, the first thinning or culling is done after two months then every 3 weeks or so. In cases of deeper water of more than 3-4 m, no thinning is required because of the difficulty in collecting and distributing the cockles. The culture period is usually more than a year.

Harvesting

The culture period for cockles usually exceeds a year but this depends on the initial size of the spat used. Cockles are harvested from a boat during high tide by means of a core (coarser mesh size) with a handle. The average cockle size allowed to be harvested is no less than 31.8 mm for conservation purposes (Malaysian Fisheries Act, 1985). About 10-15 gunny sacks (weighing 80 kg per sack) of adult cockles can be harvested by 2 persons working 5-6 hrs a day. Harvesting of marketable cockles depends on demand, which is usually practiced on a contract basis. Some are sold in dried or canned form (Mohd. Noor, 1988).

Mussels

Green mussels (*Perna viridis*)

This bivalve, noted as an inexpensive protein source, is common in the Southeast Asia and is an important commercial species cultured in Thailand and the Philippines. Small-scale cultures are carried out in Singapore, Malaysia, Vietnam, and Cambodia. In most of these countries, mussel production was developed by artisanal fishermen who harvested them from the wild from bamboo fishing stakes during low tide. Green mussels are found clustered in the intertidal and sub-littoral zones. Owing to their ability to secrete byssal threads, they are found attached onto hard substratum. As in the case of cockle culture, mussel culture operation also involves four stages namely, spat collection, grow-out, management, and harvest.

Spatfall and Collection

Forecasting of Spatfall is very important to ensure the timely collection of spat on the cultch materials. Like cockle spats, mussel spatfalls occur almost throughout the year with peaks around February-May and October-November in Singapore and Malaysia (Cheong and Beng, 1984). However, their seasons and densities vary yearly and geographically.

Depending on the type of grow-out operations, countries have adopted various methods to collect mussel spat. Spats are collected from the culture sites or obtained from distant areas for transplantation. In Thailand, the pole method is popular wherein collected spats are left to grow to harvestable size in bamboo poles driven into the mud bottom (Sahavacharin, 1991). In the Philippines, bamboo poles, abaca ropes, coco wood and *cabo negro* (black natural fibre) are used as cultch for spat collection (Samonte *et al.,* 1992). In Malaysia, old fishing nets (trammel nets) are twisted to form a rope of 2 m length to collect mussel spat from the water column (Mohd. Noor and Choo, 1985) and the spats are allowed to grow to an average size of 20-30 mm before they are transplanted for the next phase of culture. During transplantation to the culture site, they are further wrapped with medical gauzes to prevent the spat from dropping off the cultch.

Suitability of grow-out area

The presence of mussel stocks in area is an important criterion in establishing spat collection/ culture site as this would ensure a reliable source of spat. Most of the spat collection farm sites are situated in sheltered estuarine areas. Some of the considerations for a good culture site are:

- presence of good mussel stock around the proposed culture site;
- well-sheltered from very strong winds and current;
- salinity range of 27-32 ppt;
- chlorophyll a content ranging from 15 to 40 mg per 1 seawater; and
- depth of water and substrate bottom depending on culture system.

Culture methods

Collected spats are transplanted to the culture sites using boats or lorries in the case of distant sites. The culture period usually takes about 7-8 mos depending on the size of the spat. Several methods are employed for the grow-out of mussel spat. In Thailand, the major culture areas are located near estuaries of large rivers where spat are collected on bamboo poles driven into the mud bottom and are grown to harvest size in the same area (Sahavacharin, 1991). A number of culture systems are employed in the Philippines (Samonte *et al*., 1992) namely:

- *On bottom culture:* This method is used in relatively shallow waters where spat collected on bamboo poles are relayed on the semi-muddy bottom of the farm which is located in estuarine areas.
- *Stake culture:* Since spats are collected using bamboo poles, the manner of staking appears to vary with the strength of water current and the depth, which differ in the various provinces. The sizes of stakes used and the distance they are placed apart also tend to differ. The advantage of this system is that it is cost-efficient and allows easy harvest.
- *Raft culture:* Rafts measuring 9x12 m composed of 40-50 posts are allowed to float within the confines of the bamboo posts in the first 2-3 mos. When the mussels become too heavy, the rafts are tied to the posts at a fixed position in the water column. The material for raft making varies from country to country depending on the culturists' capacity.
- *Rope-web method* (Rosell, 1982b): This method employs webbed synthetic ropes and bamboo poles. Two 6 m long synthetic ropes positioned 2 m apart are tied to bamboo poles positioned 5 m apart in the mud bottom. Another 40 m polypropylene rope is webbed between the two 5 m parallel baseline ropes in zigzag fashion at 40 cm intervals. Pegs are inserted at contact points with baseline ropes to prevent the sliding of zigzag lines when the top is heavy with mussels.

In addition to these methods, the rack culture is also used for mussel culture in Malaysia. The dimensions of racks are similar to those of the rafts (6.7x6.7 m), but they are stationary and are supported by 'nibong' (local palm highly resistant to seawater and marine borers) poles driven into the bottom. Racks can be relatively cheaper if made of mangrove poles.

Management

The very common management practices in mussel farming are:

- Thinning ensures better growth rates so that competition for space and food is reduced;
- Cleaning of bio-foulers such as barnacles, tube-worms, sponges and sometimes other mollusks require regular cleaning to ensure the appearance of the harvested mussel.
- Control of predators such as crabs, starfish, and puffer fishes are required since they prey on small mussels (20-30 mm long), which are most vulnerable.
- Maintenance of breeding stocks in the farm is a common practice. Mussel stocks are not harvested completely in order to enhance the population stock in the area.

Harvesting and Product Form

Mussels are harvested when they attain an average length of 7-8 cm. Handling of the harvest (declustering) is done either at the culture site or at the landing sites depending on the culture operation. In the Philippines, mussels are selectively harvested by cutting off their byssal threads with a sharp blade or stripped off the bamboo poles with spade or any hard object (Rosell, 1982b). But the former is noted to be a better method because it prevents damage to the byssal gland and prolongs the life of the harvested mussels. Usually the bigger ones are taken first, leaving the under-sized stock behind for the next cropping. Freshly harvested mussels can retain their freshness for about 1-2 days if they are kept moist in gunny sacks (Cheong and Beng, 1984). They are sold in various forms such as shell-on (fresh), boiled/steamed but shell-on, shucked but fresh and shucked but preserved (smoked, sun dried, pickled, canned, bottling, freeze dried etc.).

Horse/brown mussels (*Modiolus metcalfei*)

Horse mussel is another bivalve commonly distributed and cultured throughout the coastlines of Thailand and in some parts of the Philippines. The requirements of this species are different from the cockles and the mussels. Its culture requires a hard substrate with a mixture of silt, sand and mud and they are usually found to inhabit the intertidal shallow waters having depths of usually less than 3 m. Probably due to its low market demand (Sahavacharin, 1991), the culture of this species is not widely developed in Thailand except in Chonburi Province (Yan, 1990). The culture method is simple. Farmers collect spats when they average 5-10 mm in size and transfer them to suitable mud flats that usually ranges from 9 to 10 rais (6.25 rais = 1 ha). The culture period extends from 8 to 12 months and the mussels are harvested by dredging when they attain an average size of 20-30 mm. The production per rai ranges between 12 and 35 mt.

Oyster

Several species of oysters have been reported to be cultured in the region namely, *Crassostrea belcheri, C. lugubris, C. iredalei, C. malabonensis, Saccostrea* spp. and *Ostrea folium.* However, oysters of the genus *Crassostrea* and *Saccostrea* are most commonly and widely cultivated and these will be considered for the purpose of discussion here. Oysters in general require a hard substrate for attachment such as wood, plastic drums, roots of mangrove trees, stones or rocks. Both the spat and the adult inhabit estuarine areas and the culture systems employed depend on the type of substratum in the area.

Spatfall collection

Oyster culture in the region is still dependent on the spat supply from the wild. These spats are either raised in the vicinity of collection or can be transplanted to other suitable areas for culture. Spatfall is seasonal as in the case of cockles and mussels and varies with locality. In the Philippines, spatfalls peak within the months of May to September (Rosell, 1982a) while in Malaysia it coincides with rainfall when salinities drop, i.e. April to June and October to December (Wong *et al*., 1991; Ahmad *et al.,* 1992; Hasbullah, 1992).

Knowing the appropriate time to suspend collectors/clutches can be easily determined by using gonad maturity studies, plankton hauls, test panels, and observation of spat on substrates. The choice of cultches depends on the type of culture system employed. Some of the kinds of collectors used are:

- *Stake method* is very common. Often, bamboo poles or wooden stakes are driven into the mud and spats collected are grown until size at harvest is attained.

- *Hanging method* is considered effective and practical. The common cultches used are oyster/ coconut shells threaded by synthetic ropes or wires, netlon pieces dipped in a cement-sand mixture and these cultches are hung from long lines, rafts or racks.
- *Broadcast method* employs empty oyster or other mollusc shells, which are scattered on the bottom of an area where Spatfall is likely to occur, usually on a hard substratum.
- *Used tyres* are either used as a single piece or tied together to form a reef and placed in locations where Spatfall usually occur.
- *Rock method* is also very common in Thailand where rocks are used as substrate for spat collection. Rocks are piled in groups of 50-80 cm apart. Some farmers in Chonburi and Chantaburi Provinces, Thailand use concrete poles instead of rocks.

Suitability of grow-out area

Paramount criteria for site selection are the setting intensity and the duration of Spatfall for a profitable operation. However, if the spat is transplanted from elsewhere, then some considerations for the culture are:

- salinity range of 25-30 ppt. depending on the species;
- protection from strong winds if raft culture/long lines are to be employed;
- culture systems do not interfere with fishing activities or navigation;
- moderate depth, to reduce anchoring of culture systems;
- proximity to the farmer's village to reduce maintenance and operation costs and to simplify watch-and-ward.

Culture Systems

Most culture methods employed are semi-traditional and are more or less similar to the systems used for mussel culture. Some of the most common culture systems used are:

- *Rack method* is usually used in shallow areas, e.g. lagoons in Malaysia. They are stationary and their heights are adjusted according to water depth in the area during high and low tides.
- *Concrete pole tubes* have a dimension of about 15 cm diameter and 40 cm height (Sahavacharin, 1991). Oyster spat are cemented onto these concrete tubes and they are fitted onto bamboo stakes driven into the mud bottom of the culture area. The pole or tubes are placed in rows and the oyster spats are left there until they attain harvest size. This technique is widely practiced in Surat Thani Province, Thailand.
- *Raft method* employs structures made of good quality wood/bamboo/mangrove poles and acts to support and hang materials like trays (tyres, plastic trays/baskets, netlon holders) to hold the oysters for grow-out.
- *Longlines* that stretch about 50 m have been found economical in Malaysia. The simple structure consists of parallel polyethylene ropes lashed to 40 l plastic drums which serve as floats. The longline is anchored at either end, with allowance for the depth difference between low and high tides. Longlines are well suited for slightly exposed areas, allowing for better water circulation around the oysters to promote fast growth (Nair *et al*., 1993).

Management

An advantage of oyster culture as an income generating activity for the culturists and fisherfolks is its relatively low operating cost. However, labour is required to maintain stocks in optimum condition and to maximize production. The basic maintenance operations are similar to mussel culture:

- *Controlling siltation and bio-fouling organisms* such as sponges, ascidians, barnacles and blister worms is important. Heavy siltation can foul culture trays, which can be overcome by using a water jet, vigorous shaking of the cultch or trays or removing fouling organisms manually.

- *Culling* oyster spats (if single spat are used) monthly reduces density and separates fast-growers from others to enhance growth rates. In other cultches, spats are left to grow until the large ones are harvested.
- *Controlling predators* such as crabs can be made by covering culture trays or baskets.

Harvesting

Harvesting methods depend on the culture system. Those hanging method employs declustering oysters from their cultch. Oysters cultured on hard substratum are knocked off and often their meat is shucked, especially if shell shape is not presentable. In the broadcast method, oysters are either handpicked (for small areas) or dredged (for larger areas) and selective harvesting is practiced whereby smaller oysters are thrown back to sea for the next cropping. Oysters separated during the spat stage to be cultured as single spat in baskets or in trays will be sold shell-on. Oyster meat is either sold fresh for stews, omelets or processed like frozen, salted, sauce and canned.

Pearl oysters (*Pinctada spp.*) and Mabe oyster (*Pteria penguin*)

Most countries in Southeast Asia (Indonesia, Malaysia, Philippines, Thailand, and Myanmar) have private farms for pearl oysters. Pearls are objects of high value while pearl shells are used for decorative objects (Gervis & Sims, 1992). Some of the pearl oyster species cultured are *Pinctada maxima, P. margaritifera,* and *P. fucata* for the production of spherical pearls while *Pteria penguin* is cultured for the half-pearl industry. Hatchery propagation of pearl oysters has been developed for *P. maxima* (Philippines, Indonesia, Malaysia, Myanmar, and Thailand) and *P. margaritifera* (mainly Philippines), but production is still limited due to heavy fouling in the grow-out areas.

Pearl culture operations typically involve three phases: collection, on-growing and pearl culture. Farming methods typically employed for pearl oysters are the raft and longline methods. Basket nets of various shapes and sizes are used for intermediate culture; choice oysters are hung in unit net panels with pockets or in galvanised wire baskets in waters 6-10 m deep.

Adult *P. maxima,* which is used for nuclei insertion, is about 25 cm, while *Pteria penguin* can range from 15 to 20 cm in length (Sahavacharin, 1991). Round pearls are harvested in 1-2 years, while half pearls in about a year. The major constraints facing the expansion of this industry are lack of trained personnel for nuclei insertion, limited seed supply, and the availability of nuclei.

Window-pane oyster (*Placuna placenta*)

Although this species is distributed throughout the region, it is a major export commodity in the Philippines. The industry is based on the shells and not for the meat. The thin translucent shells are used in the handicraft industry for window glazing, shellcraft, and other decorative items.

A sedentary benthic bivalve, it remains unattached in the bottom of bays, coves and estuaries with sandy-muddy or bluish muddy substratum in the interdtidal area at depths of 10 m (Rosell, 1991). A suitable salinity range of 18-35 ppt is required for this species; however, they can also be encountered in salinities of 2-40 ppt.

At present, no commercial culture has been reported, but successful trials have been conducted in the Philippines by some farmers who collect them from wherever and whenever they may be found and then transplanted to the culture site.

Other Molluscs

Abalone (*Haliotis spp.*)

There are about 100 species of abalones but only some are of commercial importance. The larger ones are common in temperate areas, the smaller ones in tropical waters. The common and most suitable species for culture in the tropics is *H. asinina* because of its comparatively large size (large fleshy foot), although other small abalones such as *H. varia*, *H. ovina*, and *H. diversicolor* have also been considered for culture. These species have been harvested from the wild to be sold live or in processed forms. The increasing demand and the lucrative prices offered for these gastropods have aroused the interest of research institutions in the region to develop hatchery propagation techniques and culture methods.

Although extensive research in the hatchery propagation of abalone and culture methods in tanks and ponds and net cages have been developed in Thailand, Philippines, and Vietnam, no commercial farm is in operation so far. This could be due to farmers' reluctance to gather wild or grow cultured seaweeds (another valuable fishery commodity) just to be fed to abalones. Moreover, abalones have slow growth rates (Anon; 1997).

Giant clam (*Tridacna spp.*)

Giant clams are the only known phototrophic animals which command high price for their adductor muscles. Populations of the tridacniids in Southeast Asia are in a state of decline due to reef degradation and overharvesting to meet commercial and subsistence needs (Deliani *et al*., 1998; Tan & Zulfigar, 1998). Thus, mariculture of this bivalve has become a serious consideration to enhance the population in the wild (Govan, 1995), which requires large-scale production of these clams in the hatchery. Many countries in the region are actively indulged in seed production of tridacniids.

Most of the species like *T. maxima, T. squamosa* and *T. crocea* (mainly for aquarium) have been successfully induced bred and raised in land-based nursery or in ocean-based nurseries and grow-out systems. Several culture facilities are available in countries like Indonesia, the Philippines, Malaysia, and Thailand, which employ all or some of the above nursery and grow-out systems (Govan, 1995).

Constraints Facing the Mollusc Industry

Most problems faced by the industry in the region are similar and inter-related. Some of the more common but serious constraints are:

- **Inconsistent and inadequate seed supply.** Mollusc culture operations are dependent on the seed supply from the wild, which is highly seasonal. The wild seed supply being irregular and most often inadequate to fulfill the needs of the culturists, the industry has been unable to maintain or increase its production levels.
- **Poor post-harvest handling techniques.** Reports of diseases (hepatitis) have been one of the major factors that have affected the consumption and the marketing of shellfishes. Most shellfish produced are handled at landing complexes, which make use of nearby river water, that could be contaminated, to rinse the harvest. The shellfish are then packed into gunny sacks (common packing method) and the waiting period to be loaded onto lorries can sometimes be a few hours before finally arriving at the marketing outlets. This condition leads to a further deterioration of the quality of the shellfish. In some cases, the concentration of enteric or feacal bacteria far exceeds the World Health Organization's (WHO) standards or the Food Acts Regulation of certain countries in importing food products.
- **Harmful algal blooms.** Threats of red tide (often in the Philippines, Sabah, Malaysia, and

Indonesia) caused by dinoflagellates (*Pyrodinium bahamense var compressa*) often render shellfish cultured in the affected area unsafe for consumption.

- **Lack of regulatory measures in harvesting shellfish.** Most countries in this region do not have regulatory measures pertaining to the harvest of shellfish, especially for those with slow growth (abalones and *Tridacna*). This often results in the indiscriminate harvest and collection of shellfish irrespective of their sizes, obviously contributing to the depletion of wild stock that takes a long period to replenish.
- **Low market price/market demand for certain species.** Certain molluscs like mussels fetch very low prices locally or even abroad so that the price offered is not even able to offset operational costs. This deflects the farmers' interest to indulge in other more profitable culture operations like shrimp or fish farming.
- **Inadequate processing and packing systems.** The 'half shell' for oysters and 'live' market for other species have been identified as a most potential or lucrative outlet. Very few processed forms exist to extend their shelf life in the market. The most commonly processed shellfish are in the form of canned product, dried, smoked, pickled or salted and are not innovative enough to win new markets.

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Health Management for Sustainable Aquaculture

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Abstract

Aquaculture is a dynamic activity. To be successful and sustainable in this business, new techniques have to be continually developed, and adopted by farmers. Over the last decade, "sustainability" has become a key word for many different activities, including aquaculture. Many factors are involved in aquaculture sustainability, and health management has an important role among these. In order for aquatic animal health management at the farm level to aid the achievement of optimum yields, the following issues should be considered: suitable site selection, quality of broodstock and seed, reasonable stocking density, feed and feeding programme, water management, prophylactic and therapeutic treatment, and information dissemination. The sustainability of aquaculture at the national and regional levels requires different considerations among which are national policy, assistance priorities for farmers, legislation needs, technology development, and information needs.

Introduction

Since 1950, global aquaculture production has increased rapidly as a result of the successful development of many new technologies in a variety of fields. Spawning and breeding techniques have enabled the mass production of seeds, and production and survival levels have increased due to improved feed quality and new methods for disease prevention and control. As a result, global aquaculture production has increased at an average of 10% per year. Aquaculture systems have changed from extensive to semi-intensive, intensive and super intensive because most farmers want to achieve the highest yield from each cycle. Along with this rapid development and the over-utilization of natural resources, there have been various damaging effects on the environment, resulting sometimes in dramatic declines in aquaculture production. Therefore, the concept of sustainable aquaculture was conceived and has been implemented over the past 10 years. Now, most farmers realize that if they want to maintain their business they have to develop aquaculture in a way that causes minimal environmental impacts.

Sustainable Aquaculture

The word "sustainability" became popular in aquaculture development plans and project documents after it was accepted that the potential for aquaculture development was threatened by increasing environmental problems, including serious disease outbreaks, which have exacted heavy economic losses in various aquaculture systems. Sustainable aquaculture was defined as "the wise and productive methods of culturing aquatic animals and plants, using natural resources in a manner that is environmentally non-degrading, technically appropriate, economically viable and socially acceptable; ensuring the attainment and continued satisfaction of critical human needs for the present and future generations" (ADB/NACA, 1998).

How can health management support sustainable aquaculture? It is important to understand the relationship between disease control and health management. Diseases in aquaculture often depend on the quality of the environment of the ponds. Therefore, maintaining optimal environmental conditions and providing good health management in the culture unit is important to reduce losses and sustain production levels. To achieve good health management at the farm level and maintain optimum yields, the following issues should be considered:

Suitable site selection

The site used for aquaculture is important in terms of initial start-up and the eventual success of the venture. The criteria for site selection should include: assessment of soil quality, water quality and quantity, land use, infrastructure and economic viability. Guidelines for site selection for different types of aquaculture are available in many countries. Such information should be modified and made suitable for local conditions.

Quality of broodstock and seed

Stocking with natural or wild seed is a health risk factor in the farm. Development of domesticated brood stocks will ensure the regular supply of certified seed. Use of specific disease resistant seed is another option for farmers to avoid production loss due to a particular disease. Therefore, sustainable aquaculture requires a supply of seed of sufficient quality and quantity.

Reasonable stocking density

It is very difficult to change the common practice of farmers to over-stock ponds. Information about pond capacity should be strongly promoted to educate farmers that over-stocking does not mean that the pond is being optimally utilized. During the early stages of culture, the animal may be able to grow and survive but later on, problems of competition for space and feed may cause slow growth or death of the animals. Therefore, the use of optimum or reasonable stocking rates should be practiced for successful aquaculture. A suitable stocking density for specific pond depends on many factors such as water quality and quantity, number of farms in the area, available equipment, quality of seed, seasonal variation, and experience of the farmer.

Feeds and feeding programme

Proper selection and preparation of feed need to be considered before stocking to ensure that there is appropriate food available to the animal. Feed quality and quantity need to be considered. Starvation, malnutrition or nutritional deficiency can easily cause slow growth, increased susceptibility to diseases, and death in aquatic animals. However, over-feeding can increase production costs and also pollute the pond water, thereby predisposing the animals to disease or poor health. Therefore, an appropriate feeding programme is required for each species cultured.

The use of animal manure for inducing plankton blooms may introduce eggs of digenean parasites to the pond, which can cause metacercarian disease in fish. Using moldy feed that contain aflatoxins can cause liver disease in fish.

Water management

It is very difficult to set up the standard programme of water management for aquaculture as a whole. Optimal water quality parameters vary for each species of aquatic animal cultured. Management should ensure water quality is maintained at a level suitable for optimum growth. Cleaning incoming water and use of flow-through water is usually the ideal option for aquaculture, which is applicable for some species of high market value like trout, salmon or some ornamental fish. However, changing water can sometimes introduce disease to the pond.

Prophylactic and therapeutic treatment

Health problems and disease outbreaks are recognized as significant constraints to aquaculture production. Diseases in aquatic animals always involve an environmental component. Some infectious diseases can be prevented by pond management such as increasing water flow, reducing the stocking biomass of fish, eliminating sources of skin or gill irritants, and filtration of the inlet water to reduce the number of incoming pathogens. Maintaining good water quality, improving the environment, and good management practices are of great value for the success of aquaculture.

There are however a number of virulent pathogens, which are capable of causing high mortality, even under excellent culture conditions. Prevention measures are the most effective way to control these virulent diseases. Rapid detection of the disease at the very early stages helps the prevention process. Rapid diagnostic procedure for serious diseases of fishes of high economic value should be further developed and made more widely available. Reliable and rapid diagnosis helps in the screening of diseases and can prevent the introduction of important diseases of aquatic animals to new areas.

Chemotherapy is effective in hatcheries and ornamental fish farms, but in grow-out ponds chemical treatment is normally difficult and uneconomical to undertake. Antibiotics are widely used in aquaculture and residues can be detected in the animals. The improper use of antibiotics can result in the development of resistant strains of bacteria.

Diseases of cultured aquatic animals can be reduced by maintaining a healthy environment or through proper management practices.

Information dissemination

Information dissemination systems should be developed to ensure that farmers have access to research information. The sharing and exchange of information between and among fanners, and from researchers to extension officers and farmers, is of particular importance. Government should disseminate information on health management to farmers. Promoting contacts between research institutions, extension officers and farmer groups can enhance the dissemination of research finding to farmers. Small group seminars or workshops organized by farmer associations, feed companies or government are other effective means of dissemination.

National or regional Policy

Clear policies on the direction of aquaculture development for each country or region should be formulated and implemented. The rapid expansion of aquaculture and the transport of aquatic animals between countries are recognized as potential risks to aquaculture sustainability. Therefore, appropriate regional guidelines on aquatic animal health and quarantine should be formulated, and used for the development of national legislation.

Legislation

The rapid expansion of aquaculture emphasizes the need for a legal foundation for the industry in many Asian countries. Governments of each country should review existing legislations affecting aquaculture and define which activities are to be covered by legislation. The enforcement capacity and capability should be considered to ensure compliance with existing legislation.

Development of aquaculture zones may promote sustainable aquaculture. Codes of practice should be established as interim measures before new legislations are issued. Governments should undertake regular monitoring and evaluation of aquaculture activities and implementation of any necessary corrective measure.

Research

Research is essential to identify and assist the removal of constraints to health management in aquaculture. Therefore, donor agencies should support more research projects that focus on farm management and sustainability. As the aquatic animal health constraints in many countries are similar, collaborative research should also be focused at problems of socioeconomic significance to each country.

Research institutions should be strengthened in aquatic disease diagnosis and prevention. Research on economical and practical ways of maintaining water quality and managing farm effluents using recycling systems should be considered. Applied and adaptive research at the farm level should be more focused. Appropriate biotechnology research related to health management for aquaculture sustainability should be enhanced.

Governments should attempt to provide necessary incentives in order to maintain sufficient number of trained personnel in research institutes. National lead centers in aquatic animal health should be strengthened.

Regional information

Knowledge about health management among the countries in the region is variable such that some countries have more knowledge and capability than other countries. Therefore, networks or linkages for the sharing of aquatic animal health information in the region should be stimulated to function actively. Information on sustainable aquaculture technology should be further promoted and shared among countries.

Governments and the private sector should consider the establishment of a central facility with a database of information on aquatic animal health management to provide the necessary information to end-user farmers. Research information should flow to the farmers through government extension officers or NGO workers.

Conclusion

Aquaculture is a very dynamic activity, and management techniques are continually being modified as exemplified by shrimp culture in Thailand. As in other shrimp culturing countries, shrimp farming systems in Thailand have developed over the last 10 years from extensive systems spread along coastal areas to semi-intensive, intensive and super intensive units. Farmers have over-utilized natural resources, causing severe damage to the environment. Infectious diseases involving parasites, bacteria and viruses have caused severe losses to the shrimp industry. Farmers and researchers need to work together to find solutions to the problems. Culture systems have been greatly modified. For example, open systems, which require massive exchange of water, have resulted in good production at the early stages of shrimp farming development in Thailand, but later on, when viral diseases became a major problem, semi-closed and closed systems were adopted, and high-cost chemicals were used in the farms. Still, diseases spread and caused losses to the industry. From that point, low salinity systems became more popular and farms have expanded into rice-production areas. This movement, and the resulting environmental impacts, caused great conflicts between rice farmers and shrimp farmers. Following this, integrated closed systems of low salinity shrimp culture were developed and practiced, requiring farmers to move back to less intensive systems to sustain the operation of shrimp farms. Farmers have utilized ponds at optimum stocking levels to avoid risk of diseases. Shrimp farming is a rapidly changing industry and techniques are continually being developed and modified.

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Markets and Marketing Trends for Aquaculture Products in Southeast Asia

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Abstract

Despite the fact that Southeast Asian countries are among the main producers and exporters of fish and fishery products in the world, the region has also increasingly become an important market. According to the Food and Agriculture Organization (FAO), imports of fish and fishery products into countries comprising the Association of Southeast Asian Nations (ASEAN) increased from only US$471 million in 1984 to more than US$2 billion in 1997. High per capita fish consumption, huge market size (population), increasingly strong purchasing power, coupled with relatively liberal trade policies are among the factors behind this trend.

Even though the economic crisis in the region has scaled down the degree of market expansion for the last two years, it has, on the other hand, provided trade opportunities among the regional countries for fishery products, including those from aquaculture. Tens species are being cultured commercially in the region, but only a few are important in the intra-regional trade.

Shrimp, particularly black tiger shrimp (*Penaeus Monodon*), is the most important species being cultured and traded in the region, both in terms of volume and value. The other major species are carps, tilapia, and milkfish, but these are mostly consumed locally and only a limited quantity is traded between countries in the region. Meanwhile, cultured Asian sea bass, grouper, snappers and mud crab are relatively small in production, but these are important species in the intra-regional trade.

This paper reviews the current trends in Southeast/Far East Asian markets for major aquaculture products, including marketing issues on demand and product trends, safety and quality issues as well as marketing access in major Asian markets.

Introduction

Southeast Asian countries are important markets for fish and fishery products due to the following factors 1) seafood consumption in the region is comparatively high, above the world's average; 2) market size is huge in terms of the population; more than 550 million consumers live in ten ASEAN (Association of Southeast Asian Nations) Member Countries; 3) consumer purchasing power is strong in some countries like Singapore, Malaysia and Brunei and improving in others like Thailand, the Philippines and Indonesia; and 4) the region, in general, is an open market where there are very minimum trade barriers.

Table 1. **ASEAN per capita fish supply in 1995 (kg/year; FAO, 1998)**

Country	Population ('000)	Per capita fish supply (kg) in live weight
Brunei	313	27.4
Cambodia	10,024	9
Indonesia	206,000	17.4
Laos	4,882	9.2
Malaysia	21,400	55
Myanmar	45,107	15.6
Philippines	72,200	33.4
Singapore	3,500	31.9
Thailand	59,600	32.5
Vietnam	76,700	12.9
Total	553,726	**ASEAN (average) 24.4** **World (average) 15.3**

Average per capita fish consumption in 10 ASEAN Member Countries is around 24.4 kg (live weight), far above the world's average of 15.3 kg. Even though per capita fish consumption in some countries is relatively low, such as in Cambodia (9 kg), Laos (9.2 kg) and Vietnam (12.9 kg), in other Member Countries the rate is relatively higher (Table 1).

It is obvious however that the growth in the regional seafood market has been hindered by the prevailing economic and financial turmoil, which began two years ago. The crisis has badly hit the trade of high-value seafood species, as consumers have switched to lower-priced species and reduced their expenses on dining-out and family celebrations (Pawiro, 1999b). This paper reviews the current market and marketing trends of aquaculture products in the region.

Market Briefs on Selected Asian Countries

In the intra-regional trade of fish and fishery products within the ASEAN countries, Malaysia, Singapore and also Thailand play an important role as the main importing countries while others are mainly suppliers (exporting countries). Besides those three ASEAN countries, Hong Kong, China and Taiwan import a large quantity of seafood through intra-regional trade (Table 2). The following brief reviews will focus on these markets.

Malaysia

Consumption of seafood has been growing in Malaysia for the last 7-8 years. Per capita fish consumption is currently 45 kg and is projected to be 56 kg by 2010. To cater to the growing demand, annual imports also grew over the years, totalling 253,659 mt in 1997 and increasing further to 293,000 mt in 1998 (Anon., 1999c). The main suppliers of imported seafood products are Thailand, Indonesia, Taiwan, India, Bangladesh, and New Zealand. The most popular species sold in the market

Table 2. **Total imports of fishery products into selected asian countries from 1993 to 1998**

		1993	**1994**	**1995**	**1996**	**1997**	**1998**
Hong Kong	Q (mt)	324,336	339,730	332,030	328,157	317,831	271,227
	V (HK$ million)	10,643	12,700	14,142	14,879	16,627	16,845
Malaysia	Q (mt)	261,631	275,880	260,568	257,084	253,659	293,005
	V (RM million)	691	808	824	835	916	1,237
China	Q (mt)	936,362	1,253,766	1,343,737	1,388,847	1,513,261	1,140,000
	V(US$ million)	576	856	962	1,206	1,216	1,020
Singapore	Q (mt)	167,077	178,537	181,090	156,077	150,257	114,390
	V(S$ million)	902	921	929	901	901	500*
Taiwan	Q (mt)	592,569	581,720	553,920	508,044	515,337	282,738
	V (NT$ million)	15,741	16,722	17,504	18,881	22,028	16,782
Thailand	Q (mt)	760,919	893,585	872,824	797,386	710,115	728,960
	V (Baht million)	21,629	21,329	21,925	22,425	27,439	36,497

* Excluding ornamental fish and fry.

are: mackerel, scad, squid/cuttlefish, sardinella, threadfin bream, shrimp, and pomfret.

The devaluation of the Malaysian currency since mid-1997 has however affected the import trade of fishery products. The effect has been more prominent with regard to high-valued items and those imported from distant nations. As fish is one of the main sources of cheap protein and the government still maintains its open trade policy, demand has shifted to medium and lower value species. Imports from the ASEAN sources (Thailand, Indonesia and Myanmar) have increased as payment can now be made in regional currencies.

Singapore

With a population of about 3.6 million, fish is the major source of protein for Singaporeans. Its annual per capita fish consumption of 35 kg is among the highest in Asia. With its excellent infrastructure and services, Singapore has become an important seafood import and re-export trade and processing center in the region. Its wholesale market complex at Jurong plays an important role as the landing point for foreign vessels and trucks bringing in fish from neighboring countries like Indonesia, Malaysia, and Thailand.

Domestic fish production in 1997 was only about 9,247 mt, thus around 90% of total seafood supply comes from imports. In that year, imports of fishery products totalled 150,257 mt, valued at S$901.2 million (US$608.9 million). A large volume of products is imported in live, fresh/chilled, and dried/salted forms.

Singapore is primarily a market for fresh products and there are very active wholesale markets serviced daily by fishing vessels and airfreight consignments from all over the region. Even though neighboring countries like Malaysia, Indonesia, and Thailand are the main suppliers, there has also been an increase in imports from other countries such as India, Taiwan, Japan, Australia, New Zealand, and Norway.

Thailand

Thailand has become the main player in the world seafood industry. Within the last decade, there has been a great deal of expansion in the frozen shrimp, cephalopods, and canned tuna processing industries. The Thai Frozen Food Association (personal communication) estimates that domestic landings can supply only 60% of the raw materials needed by the processing industry, while the rest (40%) has to come from imports. A large portion of the imports comprises tuna/skipjack for canneries, while other important items include shrimp, cephalopods, and frozen fish. The total import of fish products in 1998 was 728,960 mt. Of the finished products, the bulk is re-exported with a very small percentage used for the domestic market.

Hong Kong

Effective July 1997, Hong Kong has become a part of China with the status of "Special Administrative Region (SAR)," allowing the territory to retain its position as a free trade zone. Being a large market for seafood, Hong Kong imports a substantial volume annually for domestic consumption. In addition, it has always been a major trading channel for goods, including fishery products, to the Chinese market.

On average, over 300,000 mt of seafood are consumed in Hong Kong annually and most of it is imported. About 88% of these products are consumed in live, fresh/chilled, and frozen forms. It is estimated that about 27,735 mt of live finfish and shellfish were consumed in 1997, besides some 255,000 mt of fresh/chilled and frozen products. In 1998, for the first time in many years, Hong Kong's economic growth rate was negative, which had a similar effect on consumption of seafood, particularly the high value items (Pawiro, 1998).

Mainland China

With its population of more than 1.2 billion, China has become one of the world's major markets for fish and fishery products, causing supplying countries and individual exporters to watch closely any developments in the country. Even though China is the top producer of fish and fishery products in the world, supplies of preferred species are insufficient to meet the high domestic demand. Thus imports of fishery products into the country have increased steadily over the past five years. From a negligible volume in the early 1980s, China now imports more than 1.1 million mt of fish and fishery products annually.

In 1997, imports reached 1,513,261 mt valued at US$1.2 million of which fish for human consumption was around 524,000 mt and the rest was fishmeal. Until mid-1998, imports into China continued to rise, but of late, government intervention to curb illegal imports and misuse of duty-free import quotas has created great uncertainty in the market. Consequently, imports in 1998 dropped by 24% in terms of volume to 1.14 million mt valued at US$1,020 million.

Taiwan

Taiwan's current per capita fish consumption is around 45-50 kg compared to 35-40 kg ten years ago. Despite the high volume of domestic production, which reached 1.3 million mt in 1997, Taiwan also imports a considerable amount of fishery products to cater to increasing local demand. Imported fishery products in 1997 totalled 515,337 mt valued at US$705 million, showing an increase compared to the previous years. However, in 1998, imports dropped by 45% in volume to 282,738 mt compared to 1997 due to the current regional economic crisis. Imports of edible seafood dropped by 30% from 152,019 mt in 1997 to 106,358 mt in 1998, while imports of non-edible products such as fishmeal dropped by 51% during the same period. Although import duties on fishery products in Taiwan are high compared to other countries in Asia, the high disposable income of the population in this affluent country offers great potential for market expansion.

Table 3. **ASEAN: Aquaculture Production (mt) from 1990 to 1997 (FAO, 1999)***

Country	1990	1991	1992	1993	1994	1995	1996	1997
Brunei	6	1	17	36	72	103	119	156
Cambodia	6,400	6,700	8,550	7,900	8,200	9,511	9,600	11,800
Indonesia	499,824	517,507	550,368	600,404	597,522	635,288	733,088	754,610
Malaysia	52 306	64,845	79,700	105,241	114,112	132,745	109,505	103,360
Myanmar	7,087	26,033	51,876	65,079	73,648	74,255	68,135	87,320
Singapore	1,857	2,000	2,350	2,350	2,360	3,625	3,567	4,088
Philippines	379,940	408,618	386,876	392,072	387,588	361,540	349,442	330,443
Thailand	291,719	353,367	370,974	457,314	509,800	559,504	551,431	575,901
Vietnam	160,076	165,104	167,899	183,061	217,056	394,316	402,500	480,000
Laos	10,000	12,000	12,000	12,000	12,800	14,400	14,400	14,000
Sub-total	1,409,215	1,556,175	1,630,610	1,825,457	1,923,158	2,185,287	2,241,787	2,361,678
World total	13,084,142	13,731 381	15,477 350	17,888 258	20,790 848	24,484 132	26,764 875	28,808,414
Percentage of world total	10.8	11.3	10.5	10.2	9.3	8.9	8.4	8.2

* Fish and shellfish.

Markets and Marketing Trends for Major Cultured Species

Aquaculture production of fish and shellfish in all ASEAN member countries reached 2.36 million MT in 1997 where Indonesia, Thailand, Vietnam, Philippines, and Malaysia were the main producers (Table 3). Ten species are being cultured commercially in the region, but there are only a few species which are important in the intra-regional trade. Shrimp, particularly black tiger shrimp, is the most important species in the region in terms of quantity and value, both produced and traded in Southeast Asia. Meanwhile, carp, tilapia and milkfish are the most important finfish being cultured in Southeast Asia but only a limited quantity is being traded between countries in the region.

There are also some farmed species, which are relatively small in production but are important in intra-regional trade, namely: Asian sea bass (*Lates calcarifer*), grouper, snapper, and mud crab. Of the molluscs, blood cockle (*Anadara granosa*) is another important species being cultured and traded, but it is almost exclusively limited to Malaysia and Thailand (Table 4).

The following are brief reviews on markets and marketing aspects of the above-mentioned major species groups.

Table 4. **Aquaculture production (mt) of ten ASEAN Member Countries by major species group from 1990 to 1997 (FAO, 1999)**

Species Groups	1990	1991	1992	1993	1994	1995	1996	1997
Common carp	94,533	90,318	101,613	138,898	143,197	161,444	187,487	213,607
Tilapia (all species)	154,22	161,563	199,531	219,045	222,881	238,875	259,088	288,781
Milkfish	343,314	375,147	318,148	313,413	314,099	302,114	312,278	329,696
Asian sea bass	6,315	10,156	7,734	9,507	9,259	8,264	11,191	13,419
Grouper	3,107	7,471	1,835	2,680	4,271	2,324	2,299	2,340
Snapper	482	189	380	1,059	1,609	2,071	2,087	1,463
Shrimp (black tiger & banana shrimp)	280,824	361,147	419,936	469,941	509,210	525,303	493,570	471,248
Mud crab	2,492	2,062	5,764	7,831	7,111	5,698	4,600	4,964
Blood cockles	48,232	73,067	74,391	98,332	93,659	114,679	87,631	73,820
Total	933,421	1,081,120	1,129,332	1,260,706	1,305,296	1,360,772	1,360,231	1399,338

Table 5. **Fresh/frozen shrimp imports (mt) from 1990 to 1998**

Countries	1990	1991	1992	1993	1994	1995	1996	1997	1998
Taiwan	10,000	12,000	13,355	19,217	25,104	23,461	22,880	23,239	16,754
Singapore	34,236	22,001	21,848	22,815	23,553	18,303	17,445	16,716	15,119
Hong Kong	58,800	49,294	37,595	28,417	33,191	28,817	29,687	23,019	22,044
Malaysia	22,497	28,794	25,799	24,053	25,000 (e)	27,513	24,735	21,548	20,000*
Korea, Republic of	2,564	1,184	1,345	1,036	4,824 (e)	NA	NA	9,407	2,740
Indonesia	-	-	-	-	-	386	531	1,453	1,000*
Thailand	1,088	2,179	3,472	4,765	7,367 (e)	9,954	9,344	12,199	14,492
Total for Southeast Asia	129,185	115,452	103,414	100,303	119,039	108,434	104,622	107,581	92,030
Japan	283,448	284,433	272,761	300,489	302,975	292,909	288,762	267,247	239,151

* Projected figures.

Shrimp

Besides being the main producer for cultured shrimp, Asia has also become a major market. The main markets in the region are Hong Kong, Taiwan, Singapore, Malaysia, and Thailand as well as the Republic of Korea. It was estimated that imports of fresh and frozen shrimp in these countries in 1998 were about 93,000 mt but in reality the figure would be much higher due to the large volume of unrecorded traditional trade among ASEAN countries such as between Indonesia and Singapore (Table 5).

Hong Kong and Singapore are established as the non-producing shrimp exporting countries in the region. Hong Kong imported more than 22,000 mt of fresh/frozen shrimp in 1998. Imports of shrimp into Hong Kong have been declining for the last five years, due to the falling trends in processing and re-exporting activities. Thus, most of the shrimp imported is now consumed locally. A similar trend is noticed for the importation of shrimp into Singapore. In 1990, Singapore imported 34,236 mt of fresh/frozen shrimp but in 1998, the volume was less than half at around 15,200 mt. The main reason is that neighboring countries such as Indonesia, Malaysia, and Thailand have developed their own shrimp processing industries and exports are increasingly sent direct to the country of destination rather than going through Singapore.

Imports of shrimp into Taiwan have expanded since the devastating crop failures in the 1980s crippled the domestic cultured production. Around 17,000 mt of fresh/frozen shrimp are imported into Taiwan with the main suppliers being Thailand, Singapore, Australia, and Indonesia. Meanwhile, Malaysia and Thailand are important markets for raw materials where imported shrimp are mostly being re-processed into value-added products and re-exported to other developed markets. Imports of fresh/frozen shrimp into Thailand have been growing steadily from only 1,088 mt in 1990 to 14,492 mt in 1998. Current imports of shrimp into Malaysia are around 20,000 mt. Indonesia and Vietnam also import shrimp as raw materials to feed their processing industries; in 1997, Indonesia imported 1,453 mt of frozen shrimp.

Carp and milkfish

The worldwide production of common carp is more than 1.4 million mt and in the ASEAN region alone, it is more than 200,000 mt (FAO, 1999). However, we can hardly see this species being traded in international markets or in intra-regional trade. Thus, although carp are an important freshwater fish species in the region, they are almost exclusively cultured and consumed locally. In the ASEAN region, common carp is the most extensively cultured and utilized, particularly in Indonesia. It is particularly popular in many parts of the Java Island of Indonesia and the northern part of Sumatra. There is a significant quantity of other carps, mainly bighead carp and grass carp, which are involved in cross-border trade between Malaysia and Singapore and mainland China and Hong Kong. In 1997, Singapore imported 510 mt of live carps from Malaysia, mostly from areas near the border such as from Johor. Meanwhile, Hong Kong imported 22,085 mt of live carps from China in 1998; most (85%) were grass carp and bighead carp.

A similar pattern is also seen for milkfish, which is extensively cultured and consumed in Indonesia and the Philippines. Milkfish is very popular along the north coast of central and east Java Island of Indonesia as well as in the southern part of Sulawesi Island. It is also among the most important foodfish in the Philippines. Like carps, however, milkfish also contributes an insignificant amount in international trade. There were some reports of shipments of milkfish products to the USA and Canada, targeted to Filipino communities living abroad and from Indonesia to the Netherlands and Saudi Arabia, targeted to Indonesian communities living in these countries. Exports are also reported for tuna bait but the quantity is unknown. Taiwan exports around 10,000 mt of frozen milkfish annually with the main markets being the USA, Canada, and Saudi Arabia. In 1998, Taiwan exported a small quantity of frozen milkfish to the region namely to Hong Kong (21 mt), the Philippines (53 mt), Singapore (20 mt), and Malaysia (25 mt).

Tilapia

This “aquatic chicken” is increasingly popular both in the local market and in international markets. The Philippines, Indonesia, Thailand, and Malaysia are the main producers of Nile tilapia and Mozambique tilapia. However, Indonesia and Thailand are the main suppliers of frozen tilapia fillets to the international market mainly to the US.

The intra-regional trade in tilapia is dominated by live fish, which are exported from Thailand to

Malaysia or from Malaysia to Singapore. Processed tilapia such as in fillet form are expected to gain popularity in the near future. Processors/exporters in the region are still focusing on the US market where tilapia is the fastest growing cultured product. Imports of fresh and frozen tilapia into the US in 1998 were 27,820 mt, of which Thailand and Indonesia supplied 173 mt and 885 mt, respectively, in frozen fillet form. Taiwan is the main supplier of frozen tilapia from this region and, in 1998 it exported 35,119 mt of frozen tilapia with the main markets being the USA, Saudi Arabia, Canada, and the UK. Within the region, Taiwan exported tilapia to Hong Kong (87 mt) and to the Philippines (10 mt) during 1998. Live and fresh forms, which are mostly sold through traditional outlets, dominate the regional market for tilapia; thus the markets are very sensitive to the supply situation, resulting in price fluctuations.

Marine finfish

Marine finfish culture is a relatively young industry compared to shrimp or to freshwater aquaculture. As it is still in the initial stages in many parts of the region, production levels are also relatively low. The most popular species for marine culture in the region are Asian sea bass, grouper, and snapper. Even though the production from aquaculture is relatively small, the above species are widely traded within the region, mainly in live and also fresh/chilled forms.

The main producers of sea bass in the region are Thailand, Malaysia, and Indonesia, while the main markets are Singapore, Malaysia, Thailand, and Hong Kong. Sea bass is sold live to seafood restaurants and in fresh/chilled form to retail outlets, including wet markets and supermarkets. Demand in Thailand and Malaysia are satisfied by local production, while Singapore and Hong Kong import significant amounts of sea bass annually.

Singapore is considered the main market for low-value live marine finfish such as sea bass. It is estimated that more than half of the live marine finfish imported into Singapore is sea bass, with Malaysia being the main supplier. Hong Kong also imports a considerable amount of sea bass from China and also Taiwan, but the exact quantity is unknown. Considered as low-value fish, sea bass is mostly consumed by households.

Hong Kong and the southern part of China are considered the markets for high-value marine finfish such as live grouper and also snapper. The Hong Kong Agriculture and Fisheries Department (AFD) estimated that in 1997 the apparent consumption of live marine finfish was 27,735 mt. From various sources, we can predict that live grouper consumption in Hong Kong is around 5,000 - 6,000 MT per year (Pawiro, 1999a).

The main suppliers of live grouper into Hong Kong are Indonesia, the Philippines, and Thailand. As a result of the economic crisis, demand has declined and prices have weakened for most live seafood especially high-value species, including grouper. Less consumers dining out as well as budget cuts for business entertainment are the main factors behind the negative trends. Even though imports of grouper into Hong Kong increased in 1998, most of the fish were re-exported to meet growing demand in southern part of China. Imports of live marine finfish and live grouper into various markets are presented in Tables 6 and 7.

Mud crab

The most commercially important species of crab that is widely cultured in the region is mud crab (*Scylla serrata*). The production of the species in all ASEAN countries was nearly 5,000 MT in 1997 (FAO, 1999). Traded in its live form, Hong Kong, Singapore, and Malaysia are the principal markets and the restaurants are the main outlets. The average c&f price for live mud crab in Singapore is around US$ 5/kg. Singapore imports around 3,000 mt annually of live and chilled crab with the live crab originating from India, Sri Lanka, Bangladesh, and the Philippines.

Table 6. **Imports of live marine finfish, excluding fry and ornamental fish, into major markets in the Asian region from 1994 to 1998**

Country		1994	1995	1996	1997	1998
Hong Kong	Q (mt)	NA	28,213	NA	20,001	19,366
	(HK$1000)	-	-	-	1,027,898	907,488
Taiwan	Q (mt)	-	111	81	135	71
	V (NT$1000)		17,605	13,553	28,838	19,722
Singapore	Q (mt)	1,841	1,549	1,466	1,244	541
	V (S$1000)	9,724	11,582	9,829	7,943	1,137
Malaysia	Q (mt)*	-	-	-	14,218	6,341
	V (RM1000)	-	-	-	49,220	63,794

* All live fish.

Table 7. **Import of live grouper, excluding fry, into selected Asian countries from 1994 to 1998**

Country		1994	1995	1996	1997	1998
Hong Kong	Q (mt)	-	-	-	5,715	6,555
	V (HK$1000)	-	-	-	352,565	404,383
Taiwan	Q (mt)	-	20	9.3	17.5	28.6
	V (NT$1000)	-	3,567	1,832	3,500	6,436
Singapore	Q (mt)	270	232	220	187	81
	V(S$1000)	NA	NA	NA	NA	NA

Figures are based on industry sources that around 15% of imported live fish consist of grouper.

Future Prospects and Marketing Issues

Demand trends

Recent studies by FAO (1999) estimated that global demand for fish and fishery products (including aquaculture products) in 2010 is likely to be 105-110 million mt (live weight). This is less than the predicted estimate in 1995 due to the following reasons:

- The current economic downturn in East Asian countries;
- Slower global population growth;
- Competition from cheaper poultry and pork products from Europe; and
- Fall in per capita demand by 8% in Asia, 4% in North America and 6% in Europe.

It was predicted that the fall in demand, if it proves correct, will be felt more in Asia than in other parts of the world due to its position as a major producer of cultured products (Nambiar, 1999). The fall in demand especially for high-value species has been noticed for the last two years since the beginning of the economic problems in the region. It was reported for example, that per capita fish consumption in the Philippines has dropped from 31 kg in 1995 to 27 kg in 1997 due to lower supply and price increase of fishery products (PCAMRD, 1999).

For high-value species such as shrimp and grouper, future demand in Southeast Asian countries will largely depend on the economic situation and disposable income of the consumers as most of those products are utilized in hotels and restaurants. Therefore, based on the current economic situation, demand for high-value species will remain weak for the next two to three years and will increase only when the economic growth in the region gets back on track.

For medium to low-value species such as sea bass, tilapia, milkfish, etc., future demand will be determined by availability of supplies and prices of the products. A production-driven approach will be needed to boost demand through increasing output and reducing costs, thus lowering the sale prices of the cultured products.

The development of the salmon industry can be taken as a lesson for the aquaculture industry in the region. Atlantic salmon used to be a very expensive product at the beginning of the 80's, but nowadays it has become a commodity, which is available worldwide including in the region. This industry has successfully increased production and reduced production cost, thus the end product can be sold at cheaper prices. It has been reported that the Norwegian farmed salmon industry has successfully cut its production cost by half within the last decade, allowing the industry to stay profitable even though prices have dropped a lot during the period. Moreover, salmon producers have also succeeded in entering new markets especially in Southeast and Far East Asia. The question is, can our local cultured species such sea bass or tilapia do the same?

Product trends

Traditional presentations are no longer adequate for today's market places whether they are in the developed countries such as Japan, the USA and the European Union or in the developing countries of Southeast Asia and the Far East. While the processing of value-added seafoods for traditional developed markets requires much preparation and changes in raw materials, for the emerging Asian markets, improved harvesting technology, handling, packaging and transportation could be the means to add value to fishery products.

Future product development in the region will be based on the consumer preference for live and fresh fish. Therefore, fresh/chilled products in various forms such as fillets, and in various presentations and packaging will dominate the markets. Fish fillets or breaded fillets in convenience packs suitable for the catering and retail sales as well as international products such as breaded or tempura shrimp will become more popular in the future where more people will buy fish products from supermarkets and hypermarkets.

Safety and quality issues

The fisheries industries in Southeast Asian countries are very good in responding to any new requirements from developed importing countries regarding seafood safety and quality. For example, most ASEAN countries have implemented Hazard Analysis Critical Control Points (HACCP) programs as requested by the main importing countries in the European Union (EU) and North America. This program is currently being expanded to the aquaculture sector. There are HACCP plans for cultured catfish and crayfish in the USA, and some countries in the region such as Thailand and Indonesia will follow suit. FAO and WHO are now also revising a Code of Hygienic Practice for the Products of Aquaculture (FAO, 1999).

There is an increasing interest in the region for safety and quality of products to be given more attention especially for products, which are sold locally and traded within the region. Eco-abelling is another issue in the aquaculture sector where its implementation seems to be a matter of time.

Marketing access

In general, countries in the region apply a liberal policy in trade of fish and fishery products where there are relatively minimum trade barriers or, as in the cases of Hong Kong and Singapore, a free market for imported products. Even though Hong Kong has joined China, its status as a free port remains unchanged where there are no import tariffs, quotas or value-added taxes for any goods, including fishery products. Clearance procedures for imported consignments are very straightforward following international practices.

Similarly, Singapore is also a free port and most products, including fish and fishery products, enter duty free with no qualitative restrictions. However, a 3% Goods and Services Tax (GST) is levied on most products including seafood. Import controls on fish and fishery products in Singapore are enforced under the Fisheries Act (Import, Export and Marketing) to ensure that only safe and wholesome products are imported. Except for high-risk fish products, import control requirements for other products follow international standards. The imports of high-risk products (oysters, crabmeat, blood cockle meat, and cooked shrimp) must be accompanied by a Health & Competent Authority certificate from the country of origin and samples are collected from every consignment for microbiological testing.

In Thailand, generally, import duties for fishery products are applied at different rates ranging from 10% up to 60%. The current normal import duty rates for fishery products are as follows:

HS Code	Import Duty
– 0301-0307 (live/fresh/frozen/salted/dried/smoked)	60%
– 15.04 (fat/oil)	10-30%
– 16.04-16.05 (prepared/preserved/canned products)	30%
– 23.01 (fish meal)	10%

The above rates will be reduced by up to 50% by 1999 according to a WTO agreement, while under the ASEAN Free Trade Area (AFTA) agreement, the import duties for all product categories will be reduced to 5% in 2003. However, there are also import duty exemptions for most products intended for further processing (such as raw materials) and fish caught in international waters by Thai fishing vessels under joint agreements. Quota restrictions do not apply in the importation of fishery products into Thailand.

No quantitative restrictions are applied for the import of fish and fishery products into Malaysia. Import duties of between 10 and 20%, and a 5% sales tax are applicable only to processed and value-added products, while for live, fresh and frozen fish and crustaceans there are no import duties or sales taxes. The Malaysian Fisheries Development Authority (LKIM) is responsible for checking fresh and frozen products at the point of entry at minimal charges (RM0.05/kg).

Conclusion

Despite the current economic downturn faced by countries in the region, fish trade has increasingly played an important role especially for exporting nations. At a time when many businesses have closed, the fisheries business is in relatively stable condition. In fact, it has become the main export hard currency earner for certain nations.

Even though the economic crisis has scaled down the degree of market expansion for the time being, it has on the other hand promoted trade among the regional countries. While imports of high-value species have declined to some extent in the regional markets, lower value species are in greater demand as these markets strive to keep fish supply stable. The introduction of Bilateral Payment Arrangements (BPAs) among the ASEAN members is another factor allowing more fishery trade within the region as payment can be made using local/regional currencies.

Value addition will be the key word for success in the future in order to limit pressure on fishery resources and promote better utilization of raw materials by giving more attention to responsible fanning, proper handling, and quality control from harvesting to processing. Asian markets will certainly demand quality fish in the future.

The most important factor for possible market expansion in the region is the fact that fish is not a luxury item for Southeast Asian consumers but is a necessity. Therefore, once economic recovery is complete, the demand for fishery products, including high value species, will improve.

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Community-based Coral farming for Reef Rehabilitation, Biodiversity Conservation, and as a Livelihood Option for Fisherfolk

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Abstract

The present condition of marine resources in the Philippines is critical and a majority of coastal communities live below the poverty line. If it continues, the progressive degradation of coral reefs and overexploitation poses a dangerous trend. Coastal resource management strategies are facing a new challenge: the integration of social, economic and natural sciences in future concepts to reverse the current status of ecosystem destruction and improvement of the people's living conditions. Hence, the primary objective of the coral farm is to provide alternative livelihood to fisher families from their resources on a sustained basis. The second objective is the rehabilitation of degraded reefs. Currently coral colonies of 64 species are taken through fragmentation from the wild. After 6-12 weeks (depending on the species) of grow-out in the farm, the fragments were deployed at the rehabilitation site at an average of 2 fragments per square meter (=12.5% cover). The survival rate of fragments is high at 84%, despite the fact that some coral colonies were placed in unsuitable substrates by the fisherfolk. More trainings have to be conducted to improve their knowledge of coral biology and community structure. The net cost of rehabilitating a one-hectare reef is U$2,100 for 12.5% cover. Additional profit from coral marketing is used for community projects identified by the fisherfolk. In this case, coral farming may be an option for livelihood and a cost-effective tool for reef rehabilitation.

Introduction

The persistent large-scale destruction of coral reefs worldwide as a consequence of pollution, overexploitation, natural calamities, and destructive fishing practices, among other perturbations, is well known (Wilkinson, 1993; Hodgson, 1999). Globally, it has been estimated that 10% of the world's coral reefs have already been seriously destroyed (ICRI, 1995). According to REEF CHECK data, there is no more pristine coral reef in the world (Hodgson, 1999). In the Philippines, host to one of the most diverse reefs on earth, surveys on the status of coral reefs at 14 sites revealed that only 2-4% could be considered in excellent conditions having 75-100% live coral cover while three-fourths were in the fair to poor category having 0-49% coral cover (Gomez *et al.*, 1994). Given the importance of coral reef ecosystems as a major source of dietary fish for coastal communities, as basis of tourism economy, as host to high level biological diversity, and as an effective coastal protection system against strong wave actions (White and Cruz-Trinidad, 1998), there is a sense of urgency to stop or even reverse the present situation and rehabilitate damaged reefs back to their normal productive condition. Two recognized problems that hinder large-scale reef rehabilitation are the cost and the source of coral colonies.

While in the past there have been efforts to rehabilitate degraded coral reefs, these were not cost-effective in terms of the methods employed and working time of scientists (Harriott and Fisk, 1988; Clark and Edwards, 1995; Kaly; 1995: van Treek and Schuhmacher 1997, Lindahl, 1998). To overcome these constraints, low-cost community-based coral farming was introduced. In 1998, the farm was established as a coral nursery until the fragments have attached to limestone substrates and ready to be transferred to any rehabilitation site. The coral farm maintains diverse coral species and serves as a source of income for the local community.

The most important factor in driving a change among coastal communities is the development of small-scale enterprises (Moffat *et al.*, 1998). In coral farming, the combination of reef improvement and the income potential for fisherfolk could be one way of raising responsibility of stakeholders through livelihood options. We believe that the success of any resource management effort is largely dependent on the level of community involvement. The coral farm is operated and managed with strong participation of the fisherfolk.

Materials and Methods

The coral farm site

The coral farm is located at the northeastern tip of Olango Island with an area of 20,000 m^2 (Fig. 1). The site is exposed to open water with occasional strong wave impacts during the rainy season and wave protection during the dry season. Tidal currents could reach up to 1 m per second. The seafloor at 5 to 10m depth is sandy with sparse seagrass beds and isolated coral heads. Water visibility ranges from ≤ 12m to 50m. The lowest water temperature recorded was 26°C and the highest 31.4°C; salinity is relatively stable at 1 m depth, ranging from 32.8 to 33.5ppt.

Collection and transport of coral fragments

Coral fragments were collected bi-weekly from four donor sites: Cordova reef, Gilutongan reef, Talima reef, and Tungasan reef in central Visayas, Philippines from January 1998 up to the present time (Fig. 1). Fragments of 64 scleractinian and 2 non-scleractinian coral species were taken using scuba. For most branching and delicate species, fragments were cut off manually using pliers, while massive, sub-massive, foliose, columnar and some encrusting species were cut with a hammer and chisel (Fig. 6a,b). To ensure continued growth of the donor colonies and maintain the good condition of the reef, only about 10-20% (from large colonies) of each donor colony were taken and in no case more than 50% (from small colonies). Since the start of the study, some donor corals were monitored for continued growth (Fig. 6c,d). The cut fragments were collected in 30-liter plastic baskets and transferred to styrofoam boxes or 80-liter barrels filled with seawater on board. During transport from the donor sites to the coral farm, which usually took less than an hour, all containers were covered to protect from direct and intense sunlight. Seawater was changed at 30 min intervals due to mucous secreted by the corals. The entire operation of fragmentation, transport, fixation to the substrate, and final placement into the Coral Nursery Units (CNU) at the farm site was a maximum of 4 h. At that time, the corals remained submerged in seawater, except during the fixation process, which took less than 5 min.

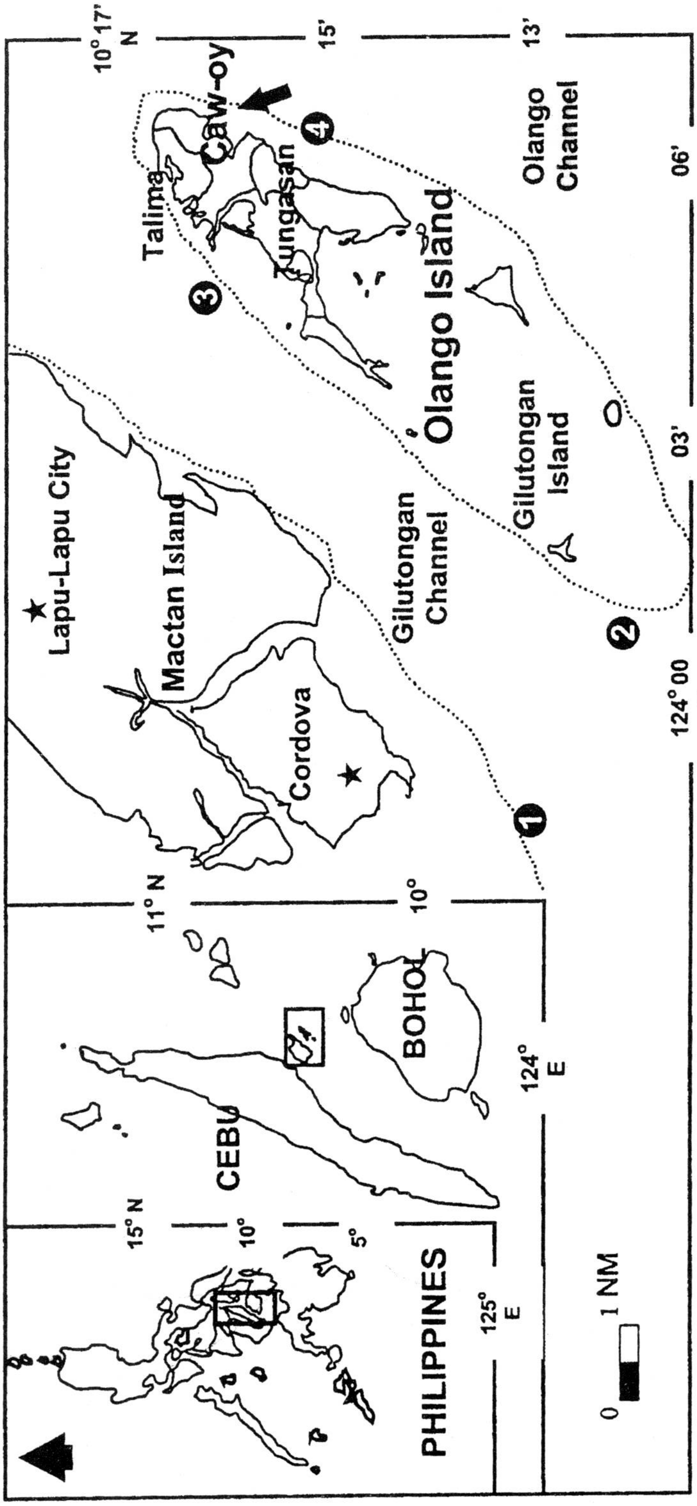

Figure 1. **Location of the coral farm site in Caw-oy (arrow), Olango Island, Cebu. Numbers indicate coral donor sites: Cordova reef (1), Gilutongan reef (2), Talima reef (3) and Tungasan reef (4)**

Substrate and fixation

After testing several substrates in a previous study (Heeger *et al.*, 1999), the results showed that customized-cut fossil limestone (20x5x1.3cm) was the most suitable. The individual limestone slabs were further subdivided to adjust to fragment size. Before the fragments were fixed, all substrates were washed with seawater and dried. At the farm site, the fragments were attached to the substrate using galvanized wire (1/16 and 1/18), tightened with pliers, and excess wire cut off (Fig. 6e). As much as possible, the fragments were always vertically positioned. Large polyps such as that of *Lobophyllia hemprichii* were fixed laterally to the substrate slabs.

Nursery technique

After attaching the fragments to the substrates, these were transferred to the CNU at depths of 6 to 9m using scuba (Fig. 6f). The CNUs are concrete frames of 1.2 x 10cm wide and 10cm high made by the fisherfolk (Fig. 6f, Fig. 7f). One bag of cement and a waterproofing substrate were used to produce one CNU. The seafloor inside the CNU was covered with plastic canvass to prevent the fragments from falling down and being buried in soft sediment after the intensive scavenging activity of infauna and fishes (Fig. 6f, Fig. 7d).

Reef rehabilitation

A 2,000 square-meter degraded reef located off Mactan Island is the site of the rehabilitation efforts. Before transferring the coral colonies, a survey of the site was conducted using scuba to assess the general condition of the reef and the coral community structure (e.g., dominant species and lifeforms) and to identify the most suitable spots in the reef to place the fragments. A series of line-intercept transects was made to obtain baseline data on coral cover (Fig. 8).

The coral fragments were collected from the CNUs with the help of fishermen using surface air-supplied compressor systems and then transferred to plastic barrels or styrofoam boxes filled with seawater on board. Only firmly attached and healthy colonies were chosen for rehabilitation. During transport, all containers were covered with canvass to protect the corals from direct sunlight. The transport of farm grown coral fragments to the rehabilitation site took less than an hour and, upon reaching the site, they were immediately deployed on the seafloor. On the average, 2 fragments per square meter were deployed, which is equivalent to a coral cover of 12.5% (Kaly, 1995).

Results

Community profile

The site of the Coral Farm Project (CFP) is Barangay Caw-oy located northeast of Olango Island, Lapu-Lapu City, Cebu, Philippines. Generally flat with limestone bedrock, it is the smallest of the eleven barangays in Olango Island with a total land area of 0.36 km^2 (Fig. 1). It has 200 households with an average family size of 5 persons. The population of Caw-oy is 1,002 with a population density of 2,783 persons/km^2. Caw-oy has a young population with more than 70% under 40 years old and only very few have finished high school and college education (Figs. 2 and 3). Although 95% own their house, only 68% own the lot where they are residing. Houses are predominantly made of light materials. A majority (71%) of the households have no toilets and the people use un-cultivated areas or the sea for human waste disposal. About 70% of the households are connected to the power line, which provides electricity from 12:00 noon to 11:30 pm.

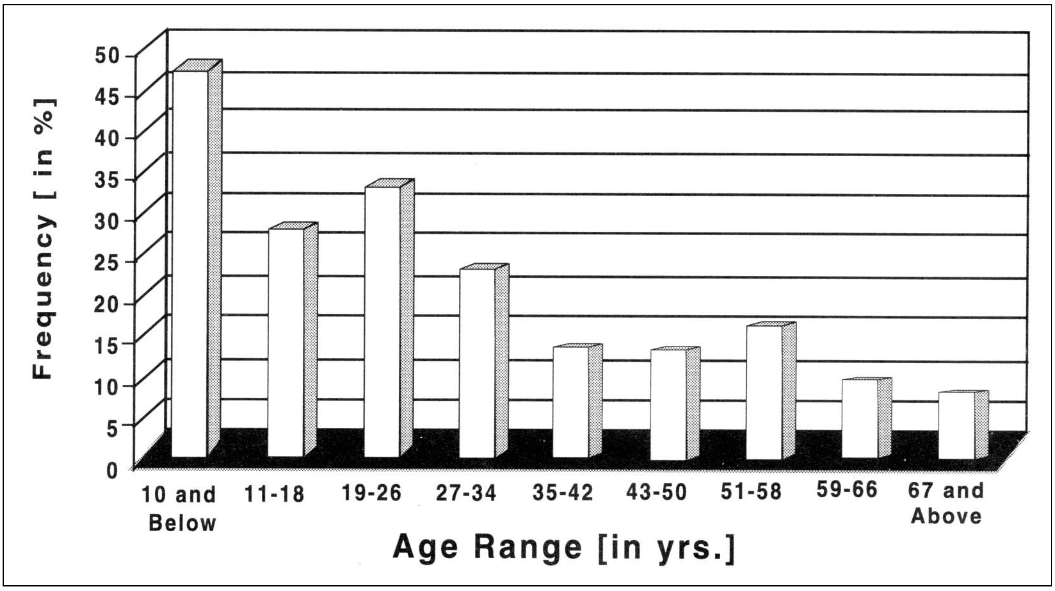

Figure 2. **Age profile of household members in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

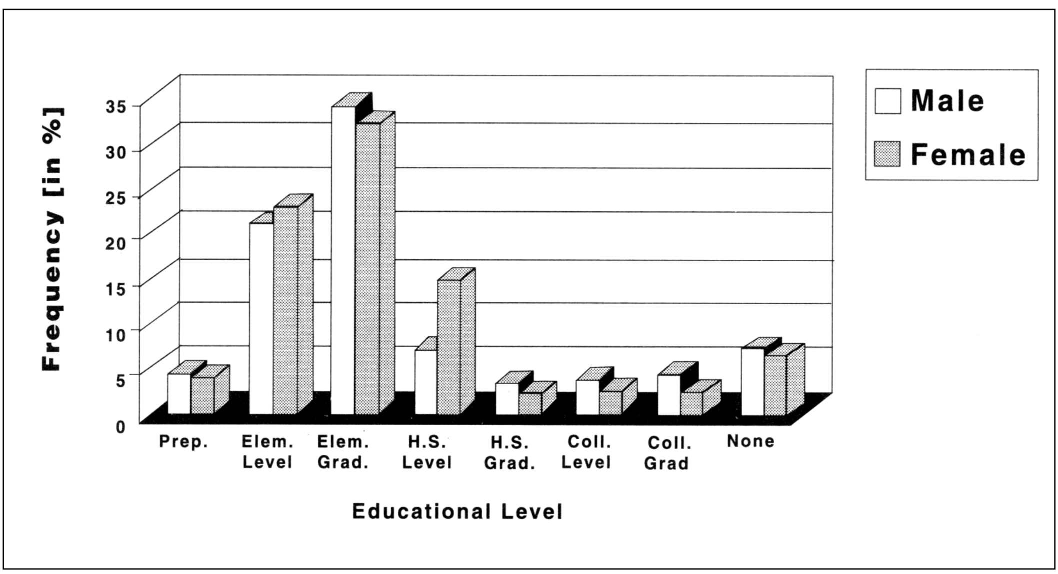

Figure 3. **Educational attainment of household members in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

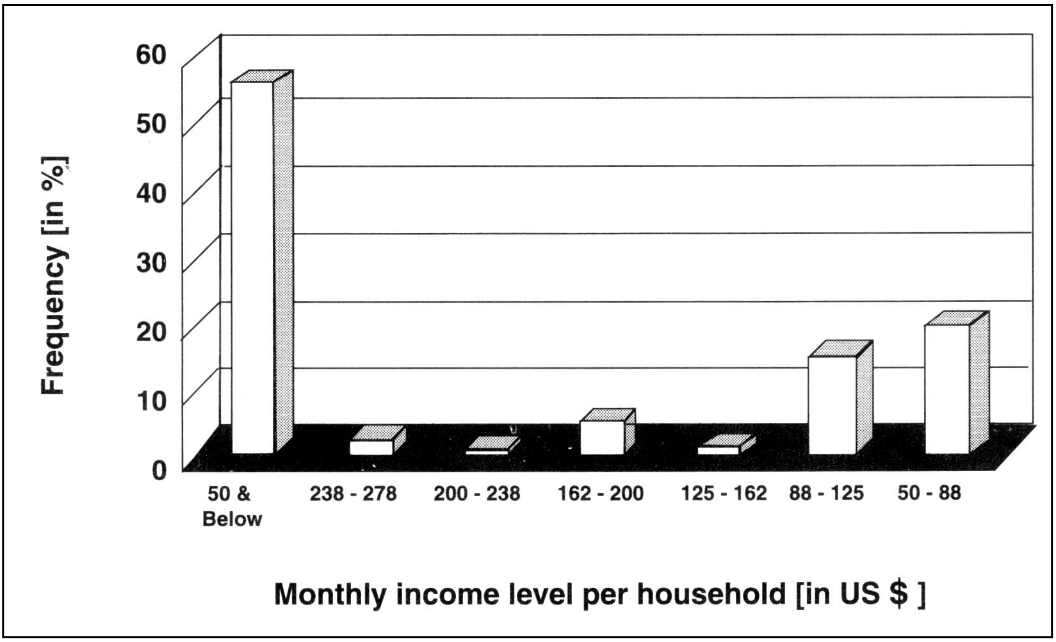

Figure 4. **Monthly income level (in US $) of families in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

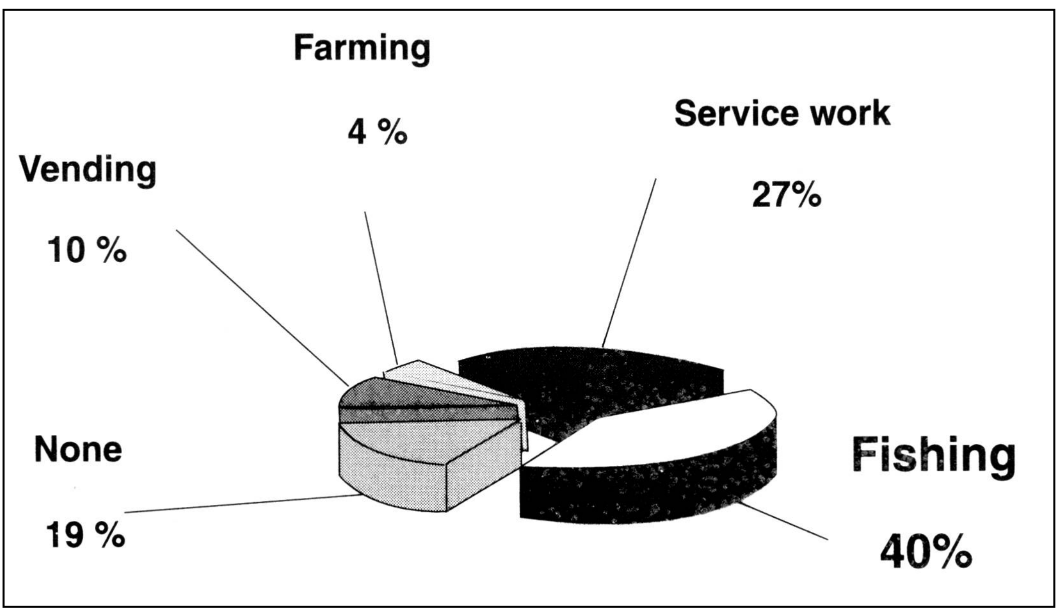

Figure 5. **Occupation of household members in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

Figure 6. **A) A diver cuts off hard fragments of *Acropora valenciennesi* with pliers. B) Fragments of strong-built branching or other coral life forms are chipped off with hammer and chisel. C) One week after cutting off fragment, the margin of a *Porites* colony has already started to overgrow the scar (arrow). D) Five weeks after fragmentation, the area has been completely overgrown (arrow). E) The fisherfolks are trained in fixing the coral fragments to the hard substrate. F) All fragments are placed inside a concrete square (1 m^2 inner area), which defines the Coral Nursery Unit (CNU), at a density of 60 to 80 fragments. The CNU wards off predators and the plastic canvass prevents the fragments from falling down due to the intensive activities of infauna and fish.**

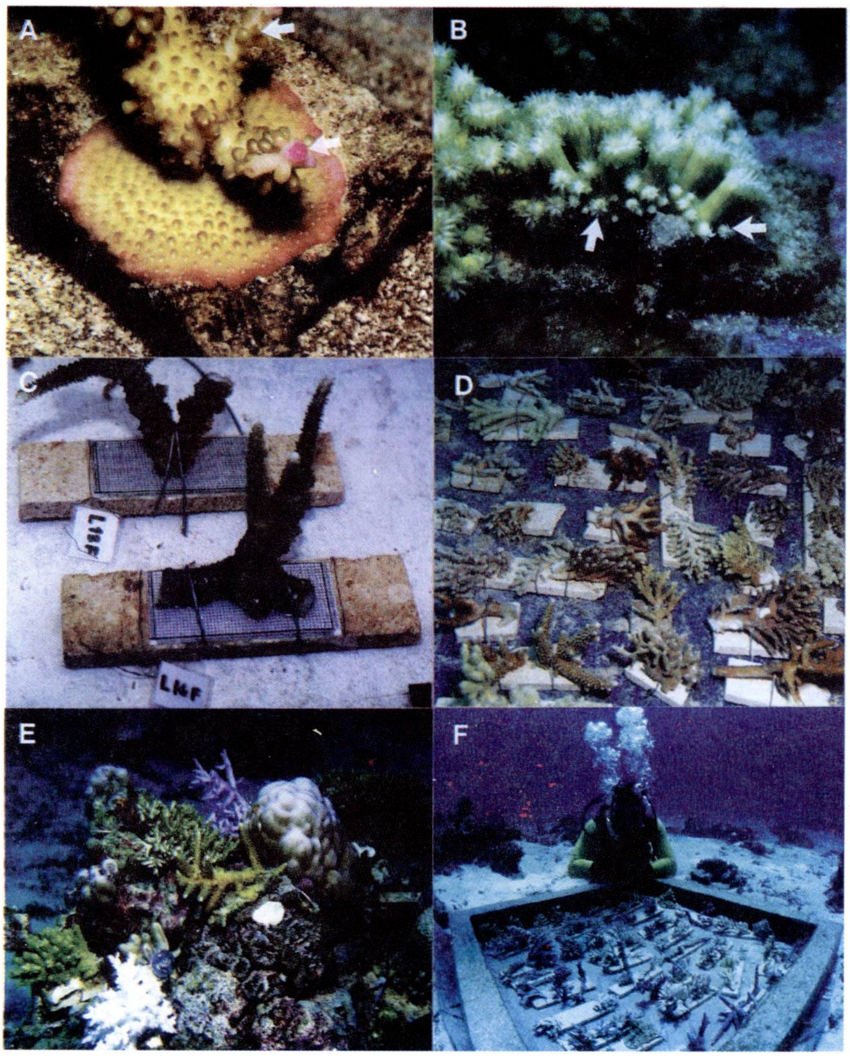

Figure 7. **A) A fragment of *Acropora divaricata* 12 weeks after fragmentation. The secondary basal disc stabilizes the fragments on the substrate. Newly formed branches (arrows) follow the natural symmetry of the coral colony. B) Numerous buds on the side of *Galaxea fascicualris* fragments document fast regrowth at the fragmented site. This species is quite aggressive and needs to be distanced from other species as extend it can extend its sweeper tentacles up to 15 cm at night and therefore harm other adjacent coral colonies. C) An experimental set up of *Acropora grandis* fragments fixed horizontally and vertically (background) on the substrate with laminated grids to document the area and time interval of secondary basal disc formation according to vertical or horizontal orientation of the fragment. D) A view inside a CNU showing some of the 60-80 fragments. The number of fragments, which can be placed together, is species- and initial fragment size-dependent. E) An area of a nearby reef, which have been rehabilitated with tagged fragments of 22 different hard and soft coral species. This experiment was conducted to acquire basic data on "reef scaping". F) A SCUBA diver checks the growth of fragments. At present the farm has 233 CNUs having a total of more than 18,000 fragments ready for marketing.**

The poverty threshold was pegged at U$110 per month in 1997 (NEDA). The survey of 42 households shows that 56% earn (Fig. 4) less than U$50, and another 25% of the households earn between U$87.50 and U$275 per month, showing that 75% of the households live below the poverty line with a monthly income of U$110. Among 42 respondents, 40% indicated fishing as their most significant livelihood (Fig. 5). Other livelihoods are service work (27%), vending (10%) and land-based farming (4%). About 19% of the respondents claimed to have no source of livelihood at all. Since the use of destructive fishing methods in Caw-oy has been totally banned in 1998, fishing is now dominated by fish trap, long line, hook and line, set net and compressor diving (hookah-hookah). Few fishers work on long distance trawlers or shell collectors, which usually last for up to four months at sea.

Reef rehabilitation efforts

A 15m outrigger boat and a team of at least 4 divers are capable of transplanting 1,000 coral colonies in a 500 m^2 of reef in a day. On the average, twelve 60-100 liter containers were required to transport 1,000 fragments submerged in seawater. The placement of the coral colonies on suitable areas was dependent on the type of substrate present. Hard substrate such as coralline rocks, dead table corals, sandy patches with underlying hard limestones and an open space versus resident corals are preferred, as these offered stability. Suitable spots for coral fragment placement in the rehabilitation site were patchy in distribution. The actual number of fragments deployed ranged from 0 to 8 colonies per m^2. Some fragments have grown to a size that caused instability when positioned vertically on hard substrate. In this case, the fragments were positioned so that the side having the largest surface area was in contact with the natural substrate. Whenever possible, the fragment's fixed substrate was firmly secured in the crevices of the reef. Aside from special requirements or adaptations of coral species, which were considered during deployment, the resulting community pattern through reef rehabilitation was at random.

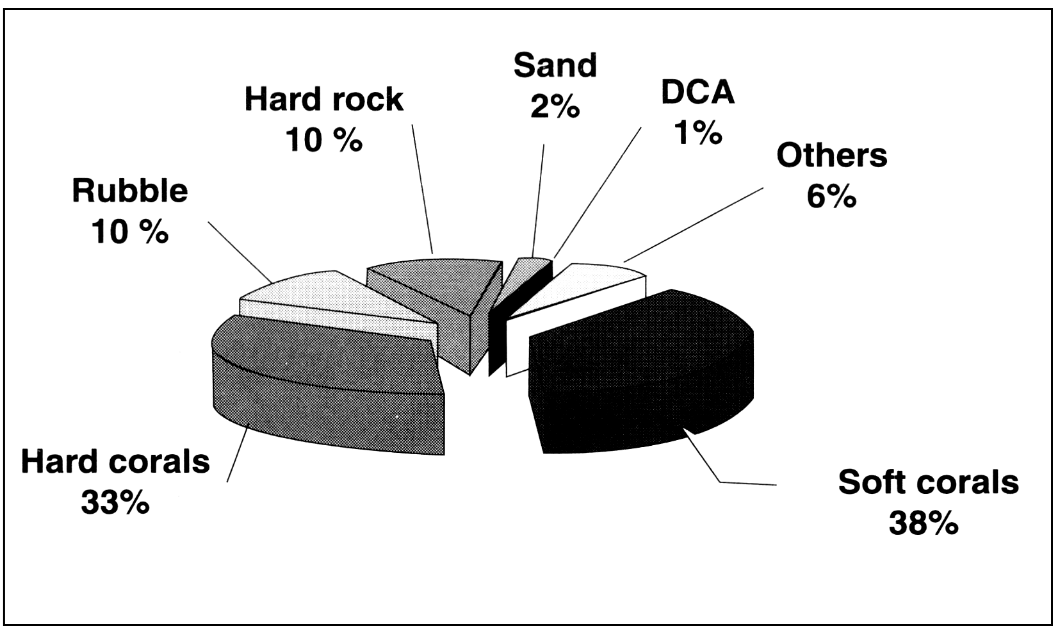

Figure 8. **The benthic community profile at the rehabilitation site**

Fast growing branching species like *Acropora muricata*, *A. nobilis*, and *Goniopora djiboutinensis* were placed on sandy substrate while slow growing plate-forming, encrusting or foliaceous colonies like *Montipora undata, Oxypora labra* and *Mycedium elephantotus* were placed on elevated hard substrate. *Galaxea fascicularis* was properly spaced with other scleractinians because it is known to extend its polyp tentacles during the night thus stinging other species with their nematocysts. Some species (*Acrhelia horrescens, Acropora echinata, A. grandis A. millepora, A. sarmentosa, A. valenciennesi, Echinopora lamellosa, Stylopora pistillata, Turbinaria peltata* and *Heliopora coerulea),* which were not recorded during the surveys, were introduced from the farm. At depths of 8-10m in the rehabilitation site, the soft coral, *Xenia* sp. was dominant at 38% coral cover compared with the other hard corals at 33% (Fig. 8). *Xenia* sp. colonies were luxuriant because of high inflow of particulate organic matter from public beaches near the rehabilitation site. Colonies of *Xenia* sp growing on hard substrate were removed and replaced with farm-grown corals. The average survival rate of coral colonies transferred to the rehabilitation site was 84%.

Table 1. **Cost of reef rehabilitation with 100 coral transplants (US$1 = Php 40)**

Item	Cost (US $)
Gathering	1
Fixing (including tie wire and limestone slab)	2.75
Tending	2
Transportation	2.5
Deployment	1
Overhead	1.25
Total	10.5

Overall cost of reef rehabilitation

The breakdown of expenditures of the entire rehabilitation process from gathering of fragments to monitoring of growth and survival rate of the deployed coral colonies appears in Table 1. The coral fragments were marketed at U$25 per 100 fragments, inclusive of rehabilitation efforts and monitoring of survival rate for 3 months. After deducting the expenses of U$10.5, a profit of U$14.5 was realized. This profit is used for the maintenance of the farm, the dive gears, boat etc. and for community projects, which the fisherfolk themselves proposed.

Income of fisher families through coral farming

Women did the fixing of coral fragments on the substrates and they are paid U$1.5 per 100 fragments. The daily income of women fixing fragments for less than 2 hours range from U$2 to U$4 while the fishermen were paid U$5 for 4 hours of coral farming per day. On the average, a couple earns U$7 to U$9 daily for a total 6 man-hours work, which could amount to U$180 monthly income. About 75% of a typical 5-member household in Caw-oy has an average monthly income of less than U$87.5 with more than 8 working hours.

Discussion

Reef degradation caused by natural events such as coral bleaching following a rise in seawater temperature (El Niño phenomenon), crown-of-thorns outbreaks or coral diseases may have detrimental effects on local coral reefs. Globally, this may be negligible compared to human impacts such as overexploitation and the use of destructive fishing techniques. Reef scientists agree that coastal communities generally lack the consciousness and the responsibility to stop the over-harvesting of their marine resources. But actually, fisherfolk have no option for environment-friendly, sustainable use of their resources. About 75% of Caw-oy residents in Olango Island, a few minutes by boat from tourist resorts in Mactan Island, involved in CFP live below the poverty monthly income of U$110.

The successful co-existence of coastal communities with the sea providing unlimited food resource has changed dramatically over the past decades. Too many fishers have been competing for dwindling resources (Pauly and Chua, 1988). Although strict law enforcement and regulations have tried to limit overexploitation, this strategy has generally not been successful. The vicious cycle of increasing population growth and dwindling resources has led to irreversible destruction of the reef ecosystem, and eventually the collapse of commercially targeted species. This trend of marine ecosystem degradation has to be reversed and requires a new strategy in managing coastal resources by integrating livelihood options and limiting the number of future resource users.

Alternative livelihoods should have a strong entrepreneurial component to trigger a change in the attitudes of coastal communities towards sustainable utilization of their resources (Moffat *et al.*, 1998). To date, implementable livelihood options are very limited. Small projects such as mat-weaving, poultry and livestock raising, variety store etc. are not viable in the long-term, probably because these ventures are not related to fishery or these are simply unprofitable. Future programs of coastal resource management should devise low-cost and income-generating sea ranching activities in consonance with their fishing tradition. Hence, the coral farming concept highlights the livelihood options for fisherfolk and at the same time contributes to the rehabilitation of degraded reefs. The economic benefits derived from farming corals increases the responsibility of stakeholders to manage their resources wisely.

The constraint identified so far is the limited experience of successful reef rehabilitation. Most efforts in reef rehabilitation have been confined only to “minor repair” after impacts of ship groundings (Precht *et al.*, manuscript submitted) or reef damage following construction activities. In such cases, the entire live coral colonies from adjacent reefs were transplanted to the damaged sites, resulting in loss of coral biomass *per se* since survival is less than 100%. Although methods of coral fragmentation and “nursery” maintenance need improvement, the time has come to undertake mass coral cultivation to provide enough coral colonies for large-scale rehabilitation. According to Salvat, (1995), urgently needed solutions will not be found through additional experimentation but through application of that which we already know.

The parameters set in “reef scaping” are based on coral biology, reef community structure, and cost-effectiveness. First, the rehabilitation site has to be checked for suitable conditions that support coral growth. If basic conditions are not present because of the use of destructive fishing techniques, pollution, sedimentation, high organic influx, etc., the impact of rehabilitation efforts would be nil. Second, a reef selected for rehabilitation should have a coral cover of at least 20% to provide sufficient protection for the newly transferred fragments against predators. An observed effect after rehabilitation was an increase in the number of microhabitats within the individual coral symmetry, lower mortality rate of coral recruits, and higher abundance and diversity of invertebrates. Fish population is expected to increase over time. The CFP supports the idea of rehabilitation to approximate natural species diversity similar to the coral community before the destruction. Priority in the selection of fragments is not focused on the fast growing species, but on those species tolerant to fragmentation. For instance, almost all branching corals are easy to fragment and grow fast (*Acropora*, *Porites, Pocillopora* etc.) while some massive species (*Lobophyllia*, *Diploastrea, Favia*, *Goniopora* etc.) need utmost care and experience if fragmented. On the alteration of the coral community structure due to rehabilitation, only coral species occurring abundantly in adjacent reefs of up 15 nautical miles from the site were selected. Thus, deployment of species not recorded during the pre-check of the rehabilitation site are not considered as introduced species, since these species may have been present in the site prior to rehabilitation.

Third, the actual placement on the reef for transplanting coral recruits by local fisherfolk must be closely supervised. In many instances, despite briefing before deployment, almost 30% of the fragments were placed in unsuitable or sub-optimal substrates. For example, slow-growing species have been placed on sand, while fast-growing species on elevated positions. Some fragments also were placed on top of resident colonies or too close to it. More “hands-on” training for local fisherfolk need to be conducted before deployment.

And, fourthly, *Xenia* sp., grows luxuriantly in the rehabilitation site, out-competing resident and transplanted scleractinians. The high inflow of organic particles near the rehabilitation site that favors the growth of this soft coral should therefore be mitigated to ensure the success of the rehabilitation effort.

Acknowledgements

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Biological Hazard Possibly Produced by Aquaculture and Its Control

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Abstract

Blooms of *Heterocapsa circularisquama,* a novel dinoflagellate, have been causing mass mortality of both wild and cultured shellfish in embayments at the western part of Japan since 1988. Physiological and epidemiological studies suggest that the alga has been partly dispersed with the movement of shellfish in aquaculture activities.

A recent outbreak of an epizootic iridovirus in red sea bream (*Pagrus major*) has caused extensive damage to marine fish culture in Japan. A research group at the National Research Institute of Aquaculture (NRIA), collaborating with prefectural fisheries research laboratories and an R&D company, clarified the etiology and developed a diagnostic method and a commercial vaccine.

Penaeid acute viremia (PAV), a synonym of white spot syndrome, caused catastrophic loses in kuruma shrimp (*Penaeus japonicus*) culture in Japan. An epidemiological study of the research group at NRIA and the prefectural fisheries research laboratories strongly suggests that the causative virus was newly introduced to Japan from imported shrimp seeds for aquaculture. The group clarified the etiology and established diagnostic methods. Based on their studies, NRIA proposed a protocol to check the virus during larval culture and before seedlings are shipped.

Introduction

Aquaculture in Japan has encountered various severe biological and environmental damages such as red tide, diseases, and environmental pollution over the last decade. In the present article, three events in fisheries (red tide from a novel algae and new diseases), which were possibly produced or enhanced by aquaculture activities, were examined to estimate the biological impacts of aquaculture. The paper also presents how and what measures were developed to control them.

Red Tide of *Heterocapsa circularisquama*

Three types of harmful and toxic algae, which are important to fisheries in Japan, are known. The first type is especially harmful to fish. *Gymnodinium mikimotoi, Heterosigma akashiwo*, and *Chattonella antiqua* belong to this type. Red tides caused by these algae often result in mass mortality among cultured fish stocks and has been a major concern from the point of fisheries. The second type of algae does not kill shellfish species but are generally toxic to other aquatic species. The potent toxins produced are accumulated in shellfishes, which find their way through the food chain, ending in humans to cause a variety of food poisoning symptoms such as paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP), and neurotoxic shellfish poisoning etc. In Japan, *Allexandrium* *tamarense* and *A. catenella* cause PSP and *Dinophysis fortii* causes DSP. Recently, a novel dinoflagellate, *Heterocapsa circularisquama,* which was first found in 1995 in Japan (Horiguchi, 1995), has been causing mass mortality in bivalves and has been demonstrated to be harmful also to gastropods. However, its harmful effects in fish and crustaceans, and in human public health has never been reported (Matsuyama, 1999).

A red tide bloom of *H. circularisquama* first occurred in Shikoku Island in 1988 and since then the occurrence of the red tide has expanded to all over the western part of Japan for the last decade (Fig. 1). The blooms have caused destructive mass mortality of both wild and cultured bivalves such as short-necked clam, Pacific oysters, and pearl oysters. In those places where the red tide of *H. circularisquama* once occurred, a series of blooms of the same alga often followed thereafter, suggesting that the alga had settled down in these areas. These places are semi-closed bays or rather calm areas, and the places are generally utilized for some kind of aquaculture including pearl oyster culture.

Honjo et al. (1998) examined the potential for accidental transfer of *H. circularisquama* via consignment of pearl oyster for aquaculture purpose. They experimentally exposed pearl oysters to *H. circularisquama* and then placed each oyster in a dry beaker and checked the state of algae thereafter. They found that the motile algae decreased with time but that some cells remained motile both inside and on the surface of the shell even 24 hr after the transfer to the dry beaker (Fig. 2). Moreover, they found that the most immotile cells became motile again in several days of culture in fresh culture medium. From these results, the authors suggested the possibility of transport of the algae with pearl oyster from an alga abundant area to new places by aquaculture activities.

Red Sea Bream Iridovirus (RSIV)

A new epizootic, which caused high mortalities of 20 to about 60% among cultured red sea

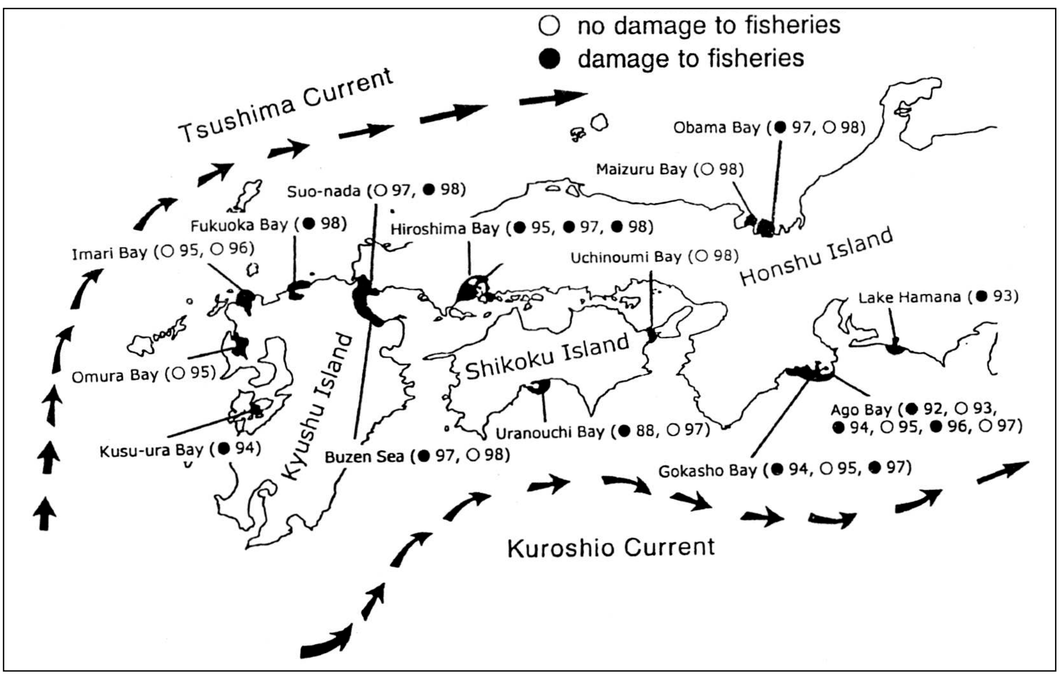

Figure 1. **Occurrence of red tide from *Heterocapsa circularisquama* blooms in Japan (Matsuyama, 1999)**

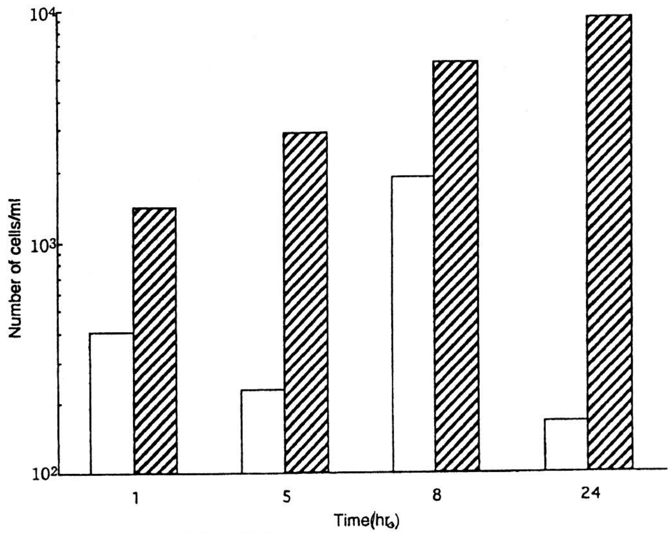

Figure 2. **Changes in the number of motile and immotile *H. circularisquama* in drip water from pearl oyster after the transfer of oysters, which were experimentally exposed to the algae, to individual dry beaker. Open bars denote motile cell number and hatched bars immotile cell number (Honjo *et al.,* 1998)**

bream *Pagrus major* in Shikoku Island, Japan in 1990, has been reported. The diseased fish became sluggish and showed severe anemia and petechiae of the gill. Histology revealed typically enlarged cells with basophillic stainability in the spleen, heart, kidney, liver, and gills. From localization and morphology of the cells, these enlarged basophilic cells were considered leucocytes (Inouye *et al.*, 1992). Electron micrograph showed a number of hexagonal virions in the cytoplasm of these enlarged cells. The virion measured 200~240nm in diameter and with a dense core and electron translucent zone. A cytopathic effect was produced on various fish cell lines by inoculation of the filtrate (450nm) of spleen homogenate of the diseased fish. Intraperitoneal inoculation of the filtrate (450nm) of both the spleen of the infected fish and the replicated virus on cell culture induced pathological changes similar to those of spontaneously diseased fish. These results indicate that the virus caused the disease. The morphology and physico-chemical properties of the virus as well as pathogenesis to various fish species indicate that the virus is new a one belonging to iridoviridae (Inouye *et al.*, 1992; Nakajima and Sorimachi, 1994).

Table 1. **Occurrence of red sea bream iridovirus disease in various prefectures and number of infected fish species in Japan (Matsuoka *et al.*, 1996)**

Year	Number of prefectures	Number of infected fish species
1990	1	1
1991	12	7
1992	15	8
1993	10	7
1994	14	15
1995	17	17
Total	17	20

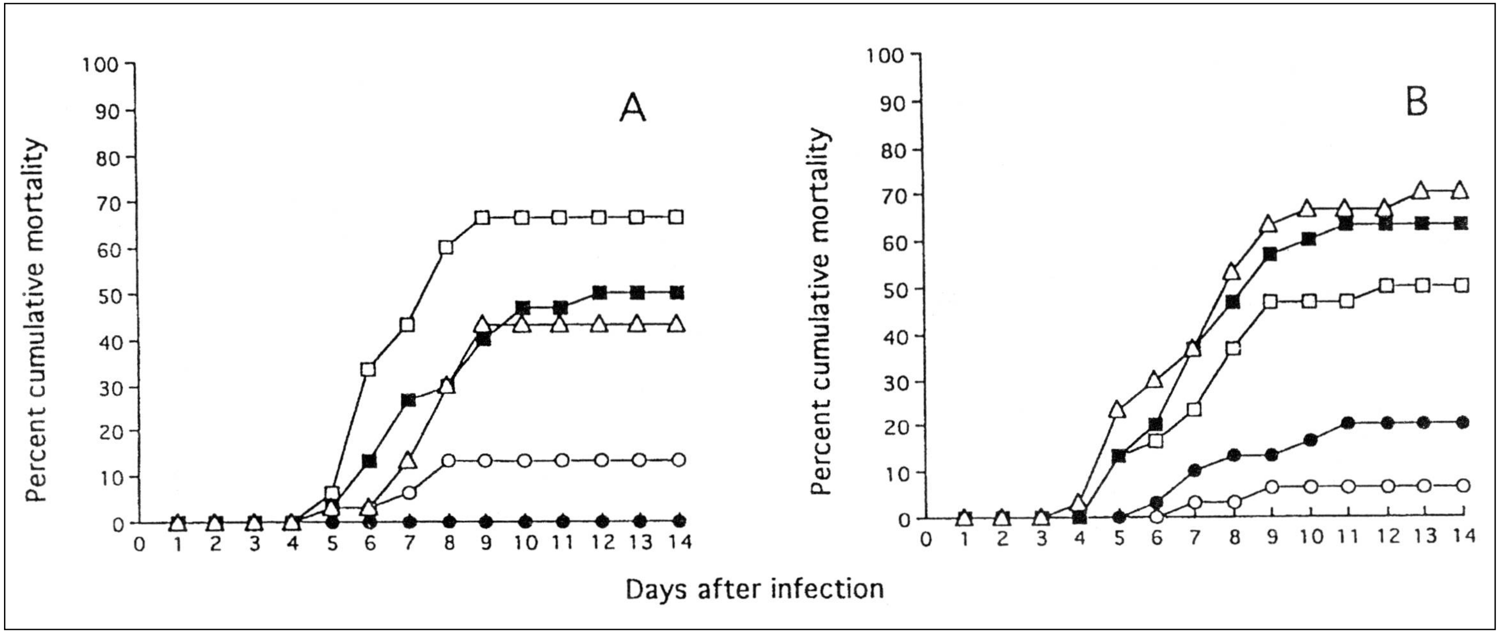

Figure 3. **Mortality of vaccinated juvenile red sea bream challenged with different doses of RSIV. Experimental fish were vaccinated by intraperitoneal injection of either formalin inactivated RSIV-infected GF cells (•›), formalin inactivated cell culture supernatant of RSIV-infected GF cells (•œ), formalin inactivated non-infected GF cells (•) or formalin inactivated cell culture supernatant of non-infected GF cell (•¡). One group of fish (•¢) received no injection. Ten days after vaccination all the fish were challenged with RSIV at doses of $10^{3.5}$ TCID $_{50}$/0.1ml (A) or $10^{4.5}$ TCID $_{50}$/0.1ml (B) (Nakajima *et al.*, 1997)**

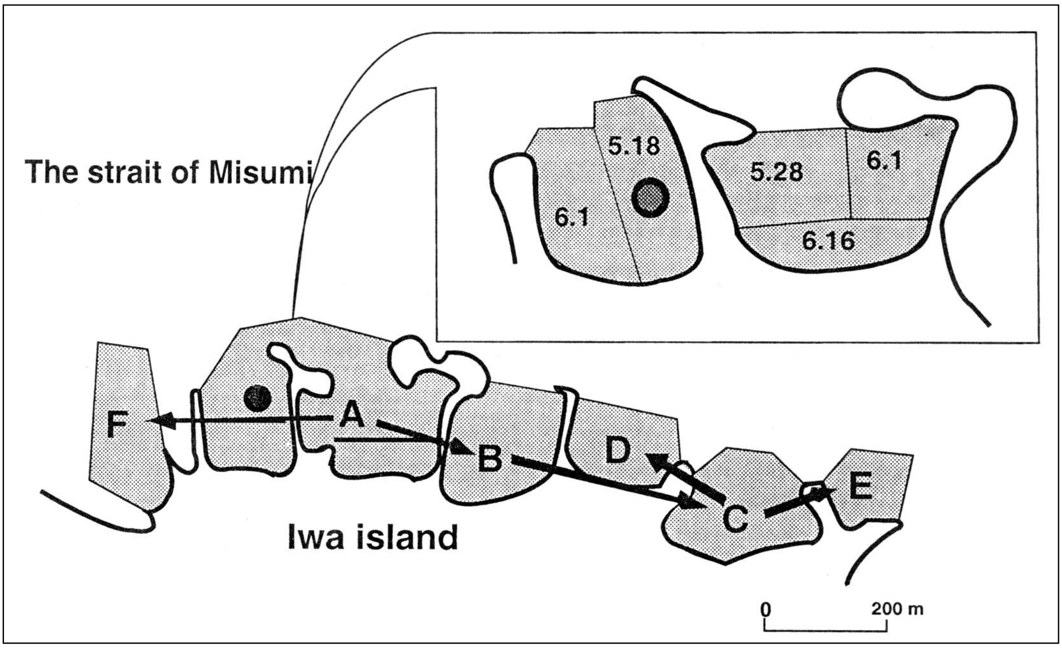

Figure 4. **Spread of mass mortality of kuruma shrimp due to PAV at Iwa Island in Kumamoto prefecture. The pond marked by the circle contained seedling shrimps from China introduced one month before the occurrence of the mass mortality. The arrows indicate the possible transmission route of the disease (Nakano *et al.*, 1994)**

The disease spread rapidly over farmed areas and among cultured fish species (Table 1). Disease occurrence during the early period was associated with red sea bream fingerlings produced by a specific hatchery, suggesting that the aquaculture activity may have spread the disease. The transfer of the disease from red sea bream to other species was also possibly a result of horizontal transmission in the aquaculture area. NRIA therefore organized a research group and collaborated with prefectural fisheries research laboratories. First, the group developed a presumptive diagnostic method using Giemsa staining on an imprint of the spleen (Inouye *et al.*, 1992). Then, they developed a monoclonal antibody against this virus (Nakajima and Sorimachi, 1995), and utilized this antibody to develop a rapid and confirmative diagnostic method using an immuno-fluorescence test (Nakajima *et al.*, 1995). The diagnostic method was then transferred to prefectural fisheries research laboratories through training programs. The research group of NRIA also developed a vaccine against the disease (Nakajima *et al.*, 1997). They found that vaccination of both formalin-inactivated RSIV infected GF cells and formalin-inactivated cell culture supernatant of RSIV-infected GF cells effectively increased the survival rate of the artificially infected fish (Fig. 3). In collaboration with an research and development company, the vaccine utilizing inactivated cell culture medium became commercially available since 1999.

Penaeid Acute Viremia

In 1993, a new epizootic disease causing high mortalities of more than 80% occurred among cultured kuruma shrimp in several prefectures in Japan. White spot on the surface skeleton and abnormal red coloration and discoloration were characteristic signs of the disease (Nakano *et al.*, 1994). Again, NRIA organized a research group that collaborated with prefectural fisheries research laboratories. Histology showed degenerated cells characterized by hypertrophied nuclei, which were

Table 2. **Occurrence of mass mortalities of cultured kuruma shrimp in Japan in 1993**

Prefecture	Total number of farms	Introduction of foreign kuruma shrimp			Mass morality				Dead shrimp	
		Number of farms	Exporting country	Month	Occurrence	Number of farms	Mortality (%)	Month	Number (10^6)	Body weight (gm)
Hiroshima	1	1	China	April	Yes	1	100	April	4.2	0.02-13.0
Yamaguchi	11	2	China	March-April	Yes	4	100	April-September	16.1	0.3-8.0
Ohita	5	1	China	April	Yes	1	86.8-100	April-July	1.8	5.5-11.0
Kumamoto	68	10	China	April-May	Yes	50	50-100	March-October	38.7	0.01-22.5
Kagoshima	15	1	China	March	Yes	1	90-100	May-June	3.4	0.8-4.0
Okinawa	19	1	China	April	Yes	1	100	April-June	10.2	2.0-20.0
Others[1]	31	0	-	-	No	-	-	-	-	-

[1] Niigata, Ishikawa, Kyoto, Wakayama, Hyogo, Ehime, Kagawa, Tokushima, Saga, Nagasaki, and Miyazaki prefectures (Nakano *et al.*, 1994).

homogeneously stained with hematoxilin, in various tissues such as cuticular epidermis, connective tissue, lymphoid organ, antennal gland, hematopoietic tissue and nervous tissue (Momoyama *et al.*, 1994). Electron microscopy revealed a number of rod-shaped, enveloped, non-occluded viruses in nuclei in these cells. The nucleocapsid of the virus measured 84±6x226±29nm (Inouye *et al.*, 1994; 1996). The research group succeeded in inducing experimental infection similar to those of spontaneous infection by inoculating the filtrate (450nm) of the homogenate of the diseased shrimp (Nakano *et al.*, 1994). From morphology, some physico-chemical properties, and host range of the virus, it was judged to be a new virus named penaeid rod shaped DNA virus and the disease penaeid acute viremia (PAV) since the virus was always found in the hemolymph of the infected shrimp (Inouye *et al.*, 1996).

Fig. 4 typically shows how the disease spreads in an area. The first occurrence of mass mortality from the disease in Iwa Island was May 18 in a pond A area. Then, the disease spread all over A area in one month. In the next month, the disease then spread all over the shrimp pond of Iwa Island. The pond where the disease first occurred contained shrimp seedlings introduced from China about a month before the disease was detected. An epidemiological survey showed that all the places where seedlings were introduced from China in spring of 1993 had the disease during the spring to autumn in the same year. In contrast, the disease did not occur in other places where Chinese seedlings were not introduced in the same year (Table 2). In addition, the research group found typically degenerated cells with hypertrophied nuclei in several tissues of a shrimp seedling in a consignment from China, before the shrimp was transferred in Japanese waters (Momoyama *et al.*, 1994). These results strongly suggest that the disease was newly introduced to Japan from imported shrimp seedlings for aquaculture.

The research group developed three types of diagnostic method: a rapid method using dark-field microscopy (Momoyama *et al.*, 1995), a confirmative method using electron microscopy (Momoyama *et al.*, 1995), and a rapid and confirmative method using PCR (Kimura *et al.*, 1996). For the dark-field method and electron microscopy method, samples were taken either from the stomach or from the blood. For the dark field observation, samples were directly put on a slide and observed with a microscope. In the dark field, affected hypertrophied nuclei were seen as white fine particles. The dark-field method is simple and rapid. However, the method can not diagnose the early stage of the disease or virus carrier shrimp (Momoyama *et al.*, 1995). For electron microscopy, stomach tissue from small shrimps was used and hemolymph from large shrimps. Virions or capsids were observed

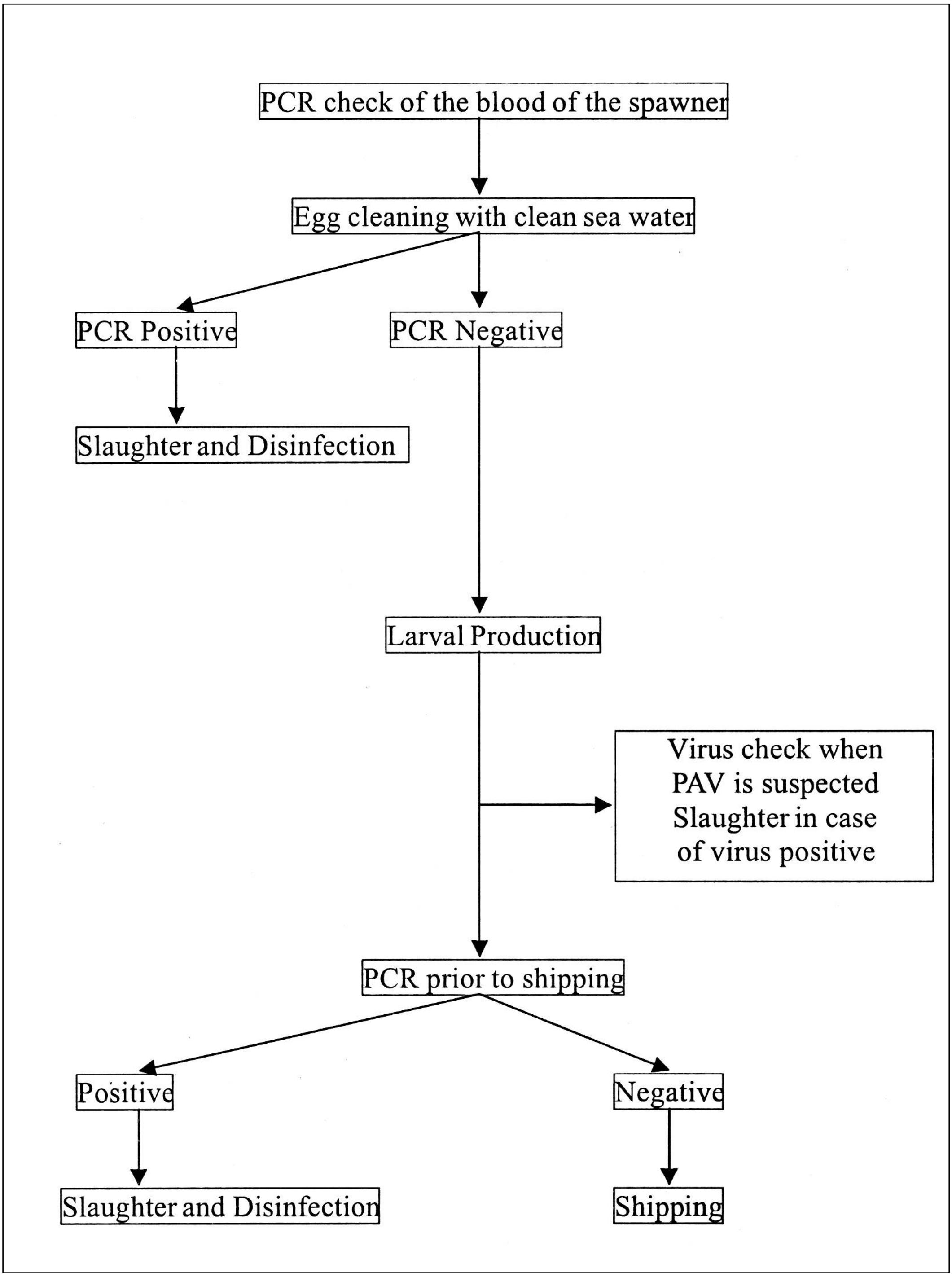

Figure 5. **Protocol for checking PAV during larval shrimp culture and before shipment of seedlings in the hatchery**

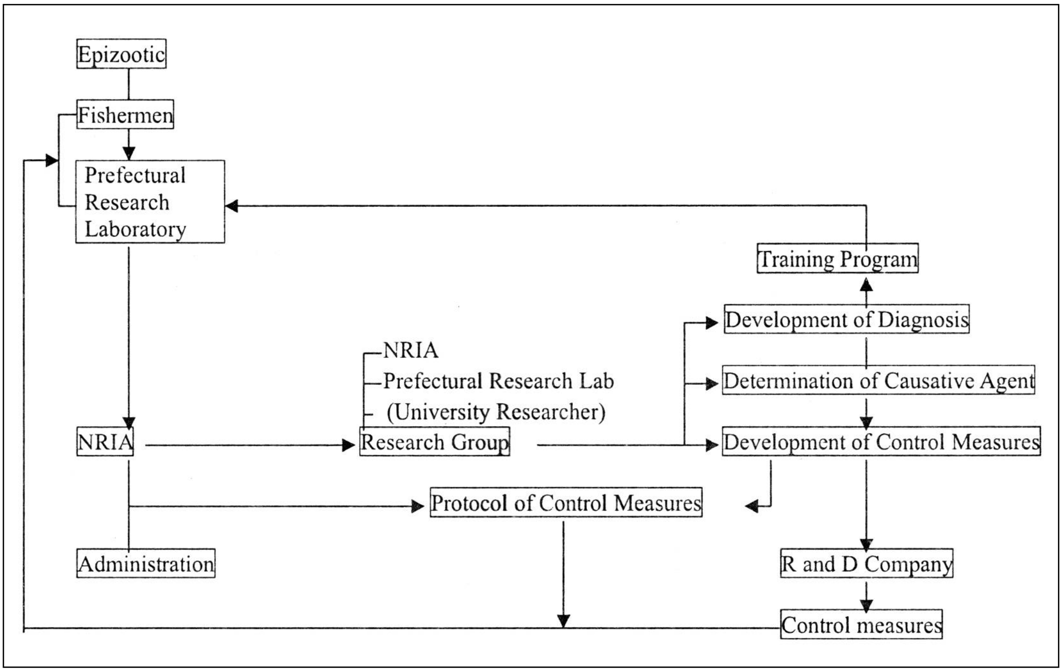

Figure 6. **NRIA's scheme for the development of control measures to a new epizootic**

on negatively stained preparations (Momoyama *et al.*, 1995). The research group purified the virus by gradient centrifugation, sequenced DNA fragment of the virus, and composed two pairs of PCR primers. Utilizing these primers, they established both one-step and nested PCR for the detection of the virus. The nested PCR can detect the virus during the early stage of the infection as well as from the excretion of experimentally infected kuruma shrimp (Kimura *et al.*, 1996). These diagnostic methods were transferred to prefectural fisheries research laboratories and public hatcheries through training programs. Based on the study and development of diagnostic method, NRIA proposed a protocol of checking PAV in the hatchery during larval culture and before the shipment of seedlings (Fig. 5). This hatchery protocol and some counter-measures in shrimp culture proposed by prefectural fisheries research laboratories (e.g., disinfection of the pond and reduction of the rearing density of farmed shrimp) appeared to have effectively reduced the occurrence of the disease.

NRIA's Scheme to Control a Novel Disease

Fig. 6 shows the scheme of NRIA to control new epizootics.

1. When a new disease occurs, the fisherman asks the diagnosis and control measures from prefectural fisheries research laboratory.
2. When the prefectural fisheries research laboratory finds the disease to be a new one or difficult to control, it informs NRIA.
3. NRIA usually makes some preliminary study and organizes a research group to collaborate with prefectural fisheries research laboratories and university researchers, if needed.
4. When diagnostic methods are developed, they are transferred to prefectural fisheries research laboratories through training programs.
5. If common control measures are needed, NRIA discusses with the administration office and

recommends control measures.

6. Research results are used to develop practical control measures in collaboration with a research and development company, if needed.

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Environmental Impacts of Marine Fish Farming and their Mitigation

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Abstract

The environmental impact of marine fish farming depends on species cultured, culture method, stocking density, feed type, hydrography of the site, and husbandry practices. In all cultured systems, however, a very large percentage of organic carbon and nutrient input into a marine fish culture system as feed may be lost into the environment through feed wastage, fish excretion, faeces production, and respiration. The high pollution loading have caused considerable environmental concern in many countries, especially in water with limited carrying capacity. Furthermore, the use of chemicals (therapeutants, vitamins, pigments, and anti-foulants) and the introduction of pathogens and new genetic strains have also raised environmental concerns.

Despite the high pollution loadings, results from various studies show that some 23% of C, 21% of N and 53% of P of feed input into the culture system is being accumulated in the bottom sediments and the significant impact is normally confined to within 1 to 1.5 km of the farm. The major impact is on the sea bottom, where high sediment oxygen demand, anoxic sediments, production of toxic gases, and a decrease in benthic diversity may result. Decreases in dissolved oxygen and increases in nutrient levels in the water are normally confined to localized areas, and it is unlikely that fish farming activities will cause eutrophication over large areas. There is also no good evidence to support the suggestion that fish farming would increase the incidences of harmful algal blooms, nor that the present use of therapeutants, vitamins and antibiotics, and the introduction of pathogens and new genetics strains would pose a significant threat to the environment.

Practical ways to mitigate environmental impact of fish farming include keeping stocking density (and hence, pollution loadings) well below the carrying capacity of the water body. Computer simulation and hydraulic models have been applied to estimate maximum stocking density in which water quality could be maintained in a sustainable manner. Pollution loading and environmental effects can also be significantly reduced by improved feed formulation and integrated culture (using macroalgae, filter-feeders and deposit-feeders).

Introduction

Globally, marine fish culture has grown dramatically in recent years, and further growth is expected in the coming decade (New and Csavas, 1995). The rapid growth of the industry has already led to growing concerns over environmental impacts and conflicts with other coastal usage in Europe, North America, Australia, and Asia (Hammond, 1987; Waldichuk, 1987a,b; Morton, 1989; Miki et al., 1992). Indeed, environmental concerns have led to a tighter control measures being introduced in many countries. For example, moratoriums on new developments and tighter control have been introduced in New Zealand, Denmark, Norway, Canada, and Hong Kong (Duff, 1987; Wu, 1988, Morton, 1989; BC Ministry of Environment, 1990). In Scotland and Hong Kong, there is a general tendency to force marine fish-farming offshore (Aldridge, 1988; Wu et al., 1994). This paper reviews our existing knowledge on environmental impact of marine fish farming, and discusses practical ways in which such impact might be mitigated.

Pollution Loading from Farming Activities

Marine fish farming generates high organic and nutrient loadings, mainly from feed wastage, fish excretion and faecal production (Fig. 1). Feed wastage (Ackefors and Enell, 1990; Seymour and Bergheim, 1991) may range from 1 to 38%, depending on the feed type, feed practices, culture method, and species (Fig. 2), and constitutes one of the most important pollution sources. It is noteworthy that feed wastage is much higher in open-sea cage culture systems where trash fish is used as feed. Deposition of organic waste was estimated at 3 kg per m^2 per yr in the vicinity of a farm and 10 kg per m^{-2} per yr or 1.8-31.3 kg C per m^2 per yr underneath (Gowen and Bradbury, 1987). Fluxes and mass balances of C, P and N determined for a salmonid cage farm (rainbow trout fed with dry feed) indicated that 80% of C, 76% of N, and 82% of P of feed input into the system were lost to the environment (Hall et al., 1990; Holby and Hall, 1991; Hall et al., 1992).

Leung *et al.* (1999) constructed a N-budget for groupers cultured in open-sea cages, and estimated

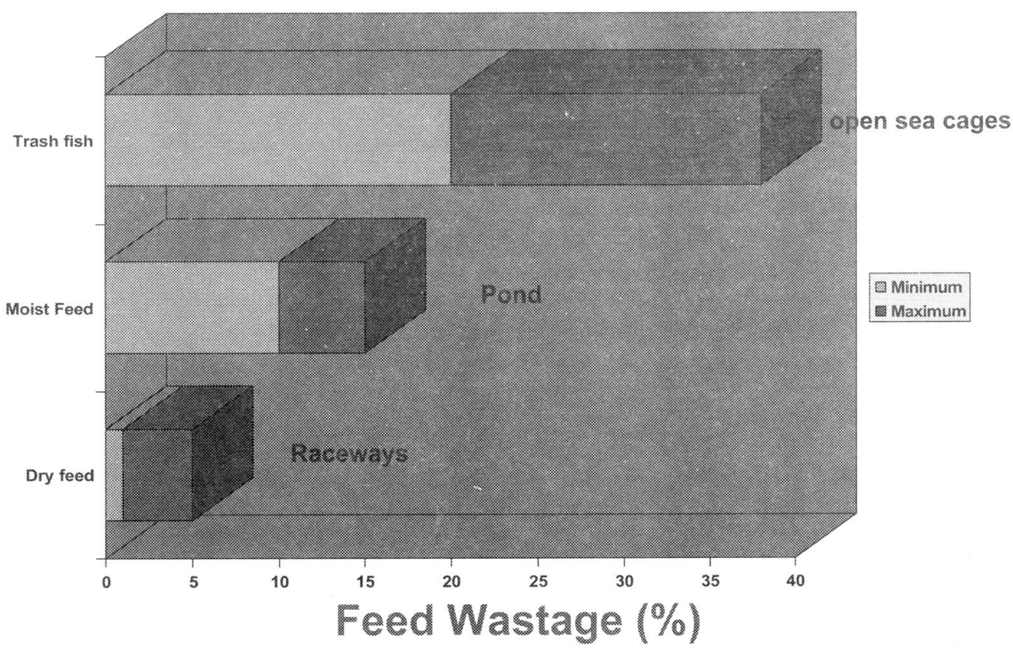

Figure 1. **Feed wastage arising from various culture methods (Warren-Smith, 1982 and Leung *et al.*, 1999)**

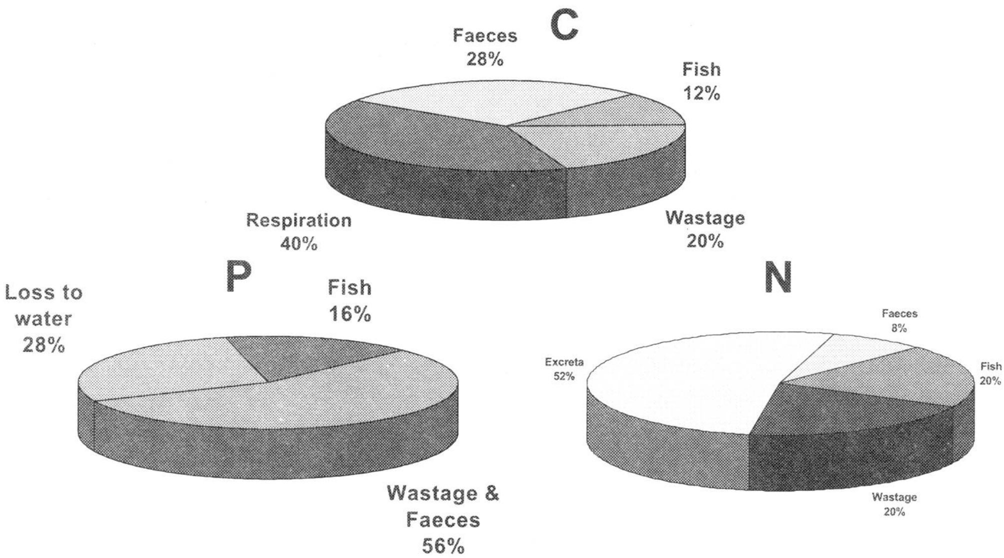

Figure 2. **Fate of C, N and P in land based fish farm (Gowen & Bradbury, 1987)**

that 87.7% of the total N input into the open-sea-cage grouper farm was lost to the environment (equivalent to 321 kg N per t of fish production). Ammonia excretion was the most important N loss (46%), followed by feed wastage (37.7%) and then faecal production (4%). In a European salmonid farm using artificial feed, it was estimated that eventually some 80-84% of C, 52-95% of N and 82% of P in the feed may be lost to the environment. (Fig. 2). The total environmental loss of N for salmonid sea farming was estimated at between 95 and 102 kg N per t production (Hall *et al.*, 1992), and deposits from fish farms covered some 3.8 times the area of the farm itself (Hall *et al.*, 1990).

It was estimated that only 10% of organic matter deposited onto the sediment underneath the salmonid farms is broken down annually (Aure and Stigebrandt, 1990). Sediment fluxes of C, N and P are very low, and 79% of C, 88% of N and 95% of P in farm deposits (equivalent to 23% of C, 21% of N and 53% of P of the feed input) will be accumulated in the sediment and become unavailable. Handy and Poxton (1993) estimated that 59-66% of P in the feed is accumulated in the sediment. Phosphorus can be recycled to water by desorption and biological processes but the release becomes insignificant when the deposit is > 7 cm thick (Hansen *et al.*, 1990). Since N mineralization mainly occurs in oxic surface sediments, the rate would be very slow in deposits underneath farms where the sediment is normally anaerobic and without bioturbation and epifaunal reworking (Rublee, 1982; Huettel, 1990). Indeed, Kaspar *et al.* (1988) failed to detect in-situ nitrification in sediment directly under a salmonid farm.

Vitamins (e.g., B_{12} and biotin), antibiotics (e.g., aureomycin, oxytetracycline, terramycin, furazolidone, and nitrofurazone) and pigments are often added to artificial feed in temperate fish culture. Additions of these chemicals, however, are uncommon in the tropics and sub-tropics where trash fish is predominantly used as a feed. Therapeutants (e.g., malachite green, formalin, copper sulphate, and dipterex) are commonly used to treat fish diseases. Toxic chemicals (metals and sometimes tributyl tin, TBT) are often used to treat cage netting to control fouling (Davies and McKie, 1987; Thrower and Short, 1991), although their use has been banned in many countries since 1990. Alabaster (1982) estimated that the use of therapeutants (aureomycins, oxytetracycline, terramycin, ivermectin, furazolidone, and nitrofurazone) was between 70 and 2000 mg per kg feed. In Norway, the use of therapeutants for fish-farming (nitrofurazolidone, oxytetracycline, oxolinic acid, sulphamerazine, and trimethoprim-sulphadiazine) has increased from 3.7 t in 1980 to 32.6 t in 1988 (Grave *et al.*, 1990); and it was estimated that some 430 g of antibiotics was used in producing 1 t of salmon (Rosenthal *et al.* 1988).

Statistics on the use of chemical therapeutants in other countries is not available, but the quantity used is expected to be large (Chua, 1993). The quantities of therapeutic chemicals released into the environment, however, remain virtually unknown.

The P and N loading generated from fish farming corresponds to a negligible fraction (0.6% and 0.2%, respectively) of overall loadings on coastal areas of Sweden, although local effects may be significant (Ackefors and Enell, 1990). Similarly, the impact of marine fish farming was considered low compared with other waste generating activities along the west coast of Canada (BC Ministry of Environment, 1990). In Hong Kong, where open-cage culture is practised and trash fish is used, BOD and N generated by the mariculture industry constituted about 3% of total loading discharged into Hong Kong waters (Ove Arup *et al.*, 1989). The total discharge of P from a farm with a production of 50 t per yr would correspond to treated discharge from 7000 people, assuming 90% of P is removed from the discharge (Holby and Hall, 1991). However, it should be noted that fish-farm waste is not directly comparable to domestic sewage, mainly because of different C:N:P ratios and significant differences in settleable and soluble wastes (Rosenthal *et al.*, 1988).

Fouling on net cages is often significant, and disposal of fouling biomass into the water after cage cleaning may occasionally add a high pollution loading to the environment. For example, the fouling biomass on fish cages in Hong Kong was estimated at 1.78 t (wet biomass) per t fish production per yr (equivalent to 31 kg BOD, 5 kg N and 70 g P) (Mak, 1982; Ove Arup *et al.*, 1989). Pollution loading could be substantial if these fouling biomass is disposed into the culture water.

Environmental Impact

The environmental impact of fish-farming depends largely on species, culture method, hydrography of culture site, feed type, and husbandry practices. In general, major impact of marine fish culture is on bottom sediment and, to a much lesser extent, on water quality.

Impact on bottom sediment

Organic matters and nutrients derived from fish-farm wastes deposited on the sea bottom may cause an increase in sediment oxygen demand, anoxic conditions, and production of toxic gases (e.g., methane and H_2S) in bottom sediments, thereby adversely affecting benthic organisms (Tucholski *et al.*, 1980; Enell, 1982; Hall and Holby, 1986).

Changes in benthic diversity and soft benthos near fish farms as a result of organic enrichment of sediment and anoxic bottom conditions have been well demonstrated in Norway, Scotland, Japan, and Hong Kong (Olsgard, 1984; Skogheim and Bremnes, 1984; Brown et al., 1987; Tsutsumi et al., 1991; Wu et al., 1994). An azoic zone was typically found underneath the cages and a decrease in benthic diversity occurred in the vicinity of the farm (Ritz et al., 1989; Tsutsumi et al., 1991; Wu et al., 1994). Benthic assemblages were normal between 25 and 150 m away from the cages in which salmonids were fed with artificial feed (Brown *et al.*, 1987; Weston, 1990) while the affected area may extend to 1 km where trash fish are used and flushing is poor (Wu *et al.*, 1994). A recent study by Lu and Wu (1998) showed that benthic recolonization on sediments enriched by fish farm deposit occurred within months, suggesting that fish farming is unlikely to have a long term impact on benthic communities once farming activities are reduced/ceased.

Organic matter settled on the sea bed may lead to the development of anoxic and reducing conditions in the sediment and the production of toxic gases (e.g. ammonia, methane, and hydrogen sulphide). Sediment oxygen demand (SOD) of bottom sediments enriched by fish-farming activities may increase by two to five times (Wu, 1990a; Wu *et al*., 1994), while total sediment metabolism may be ten times higher (Holmer and Kristensen, 1992). The dramatic increase in SOD may, in turn, cause hypoxia/anoxia in bottom waters.

In general terms, despite high organic and nutrient loadings generated from farming activities, marine fish culture only has a localized effect on bottom sediment, and did not appear to extend beyond a distance of 1-1.5 km from the fish rafts. (Gowen and Bradbury, 1987; Wu *et al*., 1994). The localized impact may partly be due to the low dispersal of wasted food and faecal materials (Frid and Mercer, 1989; Lumb *et al*., 1989), and the lock-up of organic matters and nutrients in the sediment.

Impact on water

An increase in the levels of suspended solids, BOD and nutrients (P, organic and inorganic N, total C) and a decrease in oxygen in the water column were generally found around fish farms (Muller and Varadi, 1980; Bergheim *et al*., 1982; Beveridge and Muir, 1982: Enell, 1982: Penczak *et al*., 1982; Enell and Lof, 1983; Wienbeck, 1983; Beveridge, 1985; Bohl, 1985; Phillips and Beveridge, 1986; Molver et al., 1988). Eloranta and Palomaeki (1986) demonstrated that phytoplankton biomass, chlorophyll *a* and primary production increase in response to nutrient loading from fish farms. Changes in suspended solids, light extinction coefficient, chlorophyll *a* and phaeopigment were either insignificant or localized (Beveridge *et al*., 1994; Wu *et al*., 1994).

In Hong Kong, levels of ammonia, inorganic phosphate, nitrite and nitrate as well as phytoplankton numbers in water column are generally higher, while levels of dissolved oxygen are lower in many fish culture zones (Wu, 1988). The study of Wu *et al.* (1994) at four fish culture zones demonstrated a clear gradient of DO, BOD and nutrients when moving away from the fish farms, and these water quality parameters resembled those of background values 1 km away from the farms.

Nitrogen is considered to be the limiting nutrient for primary production in coastal areas (Gundersen, 1981). Ammonia and urea excreted by fish can be readily taken up by phytoplankton and hence may stimulate their growth. It is noteworthy that fish excreta and waste food have a N:P ration close to 7:1 w/w (the Redfield ratio) (Aure and Stigebrandt, 1990), and hence provide well-balanced nutrients for phytoplankton requirement. Leung *et al.* (1999) estimated that some 53% of nitrogen input into grouper culture system (in open sea culture cages) is lost into the environment as ammonia, and the loading was estimated at 169.8 g ammonical-N per kg production. Un-ionized ammonia is acutely toxic to marine life and toxicity is dependent upon salinity, temperature and pH, and may also promote algal blooms. Phosphorus, on the other hand, is not important in promoting algal growth in the marine environment and, therefore, unlikely to have a significant effect (for a review, see Handy and Poxton, 1993).

Eutrophication caused by cage farming has been documented in several studies (e.g. Enell and Lof, 1983). However, it appears unlikely that marine fish-farming may cause eutrophication on a large scale, although the possibility of localized eutrophication occurring in areas of poor flushing cannot be excluded (Gowen and Bradbury, 1987; Aure and Stigebrandt, 1990; Wu *et al*., 1994). Although there is laboratory evidence suggesting a relationship between fish-farm discharge and red tides and algal blooms (Nishimura, 1982; Takahashi and Fukazawa, 1982; Molver *et al*., 1988), there is no conclusive evidence to support that fish farming will promote the occurrence of red tides.

The environmental effects of pigments and vitamins are poorly known. Biotin has been shown to stimulate growth of certain phytoplankton species and is implicated in the toxicity of the dinoflagellate *Gymnodinium aureoles* (Gowen and Bradbury, 1987). Vitamin B_{12} has been shown to be one of the growth-promoting factors of the alga *Chrysochromulina polylepis* (which caused massive kill of caged culture salmon in Scandinavian waters) and the dinoflagellate *Heterosigma akashiwo* (Graneli *et al*., 1993; Honjo, 1993). Fish meat and faeces have been shown to stimulate the growth of the red tide species *Gymnodinium* type 65 and *Chatonella antigua* in laboratory culture (Nishimura, 1982). Despite these laboratory results, there is no good scientific evidence to relate the field occurrence of red tides to fish farm wastes.

The use of antibiotics in fish farms may lead to the development of resistance in bacterial pathogens of fish, and the possibility of transfer of resistance to human pathogens has also raised concern (Aoki, 1989; Dixon, 1991). The development of a resistant bacterial population in the sediment has been documented (e.g. Austin, 1985; Homer, 1992). For example, up to 100% of oxytetracycline-resistant bacteria have been recorded from marine sediment near fish farms after medication; and resistance persisted for more than 13 months afterwards (Torsvik *et al*., 1988; Samuelsen *et al*., 1992). The area of sediment containing oxytetracycline residue however was found to be very localized (< 100m away from the farm). Only trace amount of residue was found in oysters collected near the farms, while levels of residue in crabs were well in excess of the US Food and Drug Administration limit for commercial seafood of 0.1 µg per g (Capone *et al*., 1996). On the other hand, furazolidone can be rapidly degraded by microbes and hence antibacterial activity was not detectable in sediments (Torsvik *et al*., 1988; Samuelsen *et al*., 1991). Inhibition of sulphate reduction in sediment underneath cages after antibiotic treatment has been reported (IOE, 1992). The effects of vitamins on the marine environment are still not well known. In oxic environments, however, the half-lives of most antibiotics and vitamins is short (e.g., <7 days in seawater and 32-64 days in fish-farm sediments for oxytetracycline and biotin) (Samuelsen, 1989; Capone et al., 1996), and the accumulation of vitamins and antibiotics in the environment is highly likely. Although oxytetracycline may be very persistent in anoxic fish-farm sediments (up to 419 days), it is not biologically available in such cases (Bjoerklund *et al*., 1990). Ivermectin is widely used to treat sea-lice infection in farmed salmonid fish, and high toxicity of this theuraputant has been demonstrated in a number of marine invertebrates, raising concern about its possible adverse impact on the marine biota (Grant and Bigg, 1998). The long half-life (>100 days) of ivermectin and its high toxicity to polychaetes poses a significant risk to marine benthos around fish cages (Davis *et al*., 1998).

TBT contamination has been identified from the tissues of cultured fish (Davies and McKie, 1987; Waldichuk, 1987b), and water (Balls, 1987; Thrower and Short, 1991) where TBT-treated net pens were used. However, no significant changes in mortalities and growth rates were observed in TBT-contaminated fish (Thrower and Short, 1991). Imposex has also been reported in dogwhelks from sea lochs in Scotland where TBT was used in treating fish cages (Davies *et al.* 1987).

Despite growing concern regarding the spread of disease from farmed fish to wild stock (Hill, 1991), there have been very few documented examples. In most cases, disease identified in one population cannot be positively traced as having spread from another population (Brackett, 1991).

Cultured species may be less adaptable to the natural environment, and escaped cultured fish may inter-breed with the wild stock, thereby altering the gene pool of the latter. However, there is insufficient evidence to ascertain the ecological impact of escaped stock. It is likely that the introduced gene in wild stock might be eliminated by natural selection very quickly.

Mitigating Environmental Impacts

Keep pollution loading under carrying capacity

Environmental impacts of marine fish farming are highly dependent on water circulation, stocking density, husbandry practices, and feed types (Wu *et al.*, 1994). Pollution effects were less significant at sites where water circulation was good and culture stock was low, suggesting that the environmental impact of fish farming can be greatly reduced by selecting sites with good water circulation and tidal flushing, and by keeping the stocking density under the carrying capacity of the culture water (Wu *et al.*, 1994).

The carrying capacity of the water depends on tidal flushing, current and assimilative capacity of the water body to pollutants. Oxygen consumption of culture species ranges from 83 to > 400 g 02 per t per h (Wu, 1990b; McLean *et al.*, 1993). Assuming that dissolved oxygen in seawater is 7 mg O_2 per l, at least 17-57 m^3 of fresh seawater would be required to compensate for the oxygen consumption alone of 1 t of culture fish, not to mention the additional oxygen demand exerted by wastes from the farming activities. In open-water cage culture systems, it has been suggested that an annual production of 200 t fish would require 1 m^3 per sec of current flow (Tervet, 1981).

Once the acceptable limits for water and sediment quality parameters to support fish growth and marine life have been defined, the maximum permissible stock that the defined water/sediment quality should not exceed can be estimated by water quality modeling techniques (Fig. 4). Water quality models have been developed for determining the carrying capacity of water in relation to culture stock and fish culture zones (Wu *et al.*, 1999). In this study, two deterministic models (viz., a hydrodynamic model and a water quality model) were used. The first model is a 2-D, 2-layer hydrodynamic model of tidal flow and salt transport, which calculated the water level, velocity, and salinity in each grid cell of 50 m^2 in each layer within the culture zone approximately 30 sec during a tidal cycle. Results from this flow model provide hydrodynamic data for input into a 3-D tidal water quality model, which was run to simulate water quality due to specific pollutant loadings from the marine fish culture operations (Fig. 5). The water quality model quantifies the relationships between major biotic components (i.e., bacteria, phytoplankton, zooplankton, macroalgae, benthos, and fish) and abiotic components (i.e., salinity, organic carbon, dissolved oxygen, nitrogen, phosphorous, and oxygen) at a fish culture site, and also describes the prevailing major biological and chemical processes (including oxidation of organic carbon, nutrient and phytoplankton dynamics, hydrolysis and oxidation of organic and inorganic N, growth, photosynthesis and respiration and decay of plant carbon, SOD, fish respiration, and BOD). Fish biomass and the resulting pollutants (organic waste and nutrients) generated from various activities (e.g., food wastage, fish faeces and excreta, etc.) were quantified and inputted into the model. Based on the input organic and nutrient loadings from a given stocking density, the model calculates the resulting levels of NH_3, NO_2 NO_3, total organic N, dissolved oxygen, and BOD in the receiving water.

The results of the simulation are in close agreement with those from a field study of the same site reported upon earlier (Wu *et al.*, 1994). By comparing the output of water quality data under different scenarios of stocking density, the model serves as an effective tool to help management decisions on the maximum fish stock permissible at a particular fish culture site so that acceptable water quality objectives can be met for the sustainable development of the industry.

In Scotland, a suite of simple box model has also been developed to provide a basis for assessing the impact of marine fish farming and regulating farming activities in sea loches (Gillibrand and Turrell 1995).

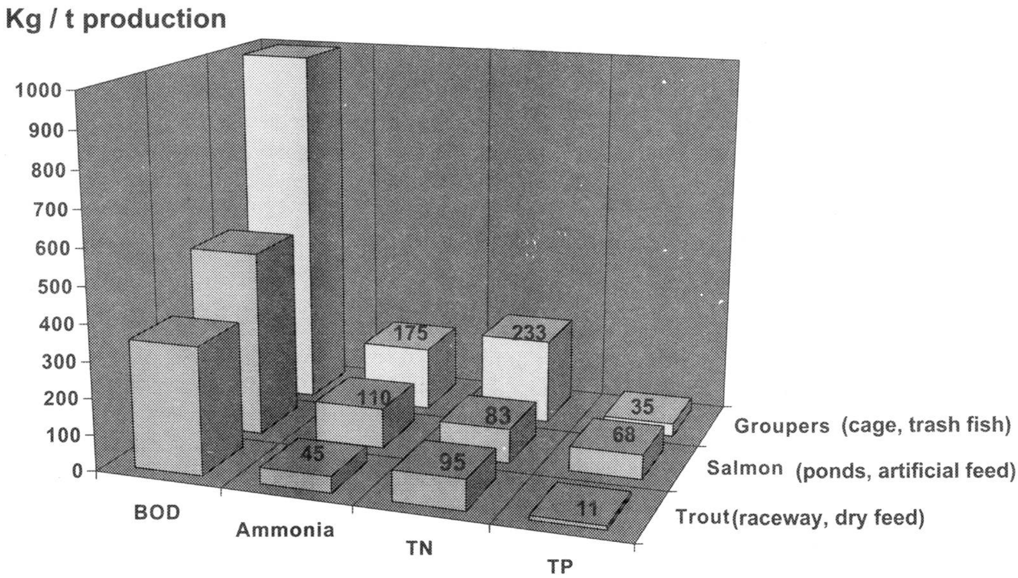

Figure 3. **Pollution loading from various types of marine fish culture**

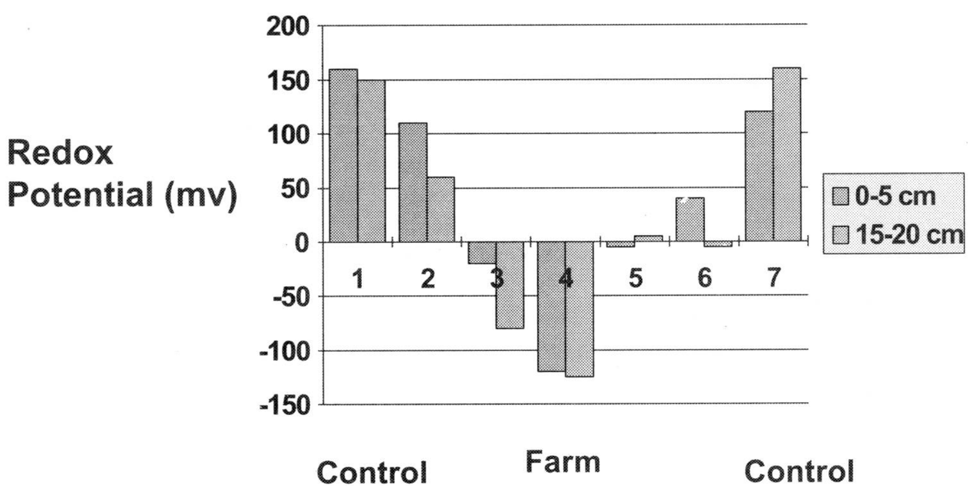

Figure 4. **Changes in redox potential in sediment along a transect across a fish culture Hong Kong (Wu et *al*., 1994)**

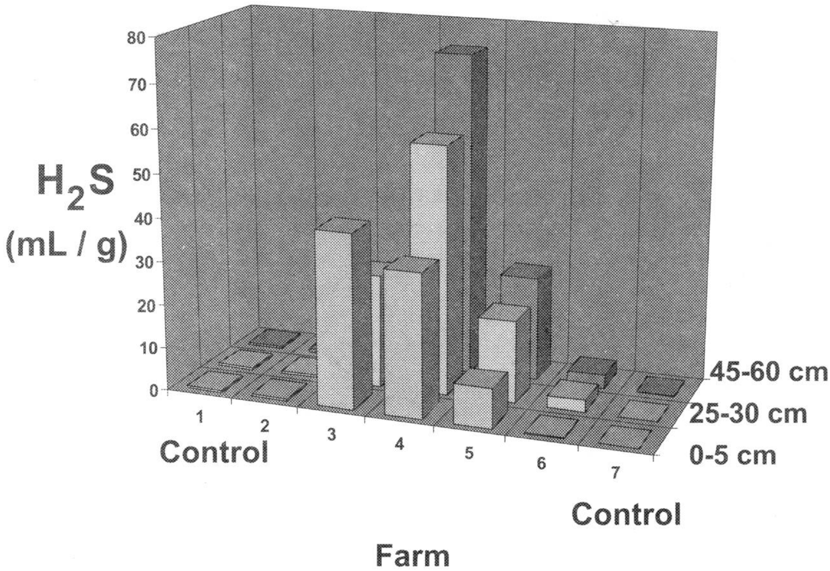

Figure 5. **Changes in hydrogen sulphide in sediment along a transect across a fish culture zone in Hong Kong (Wu *et al.*, 1994)**

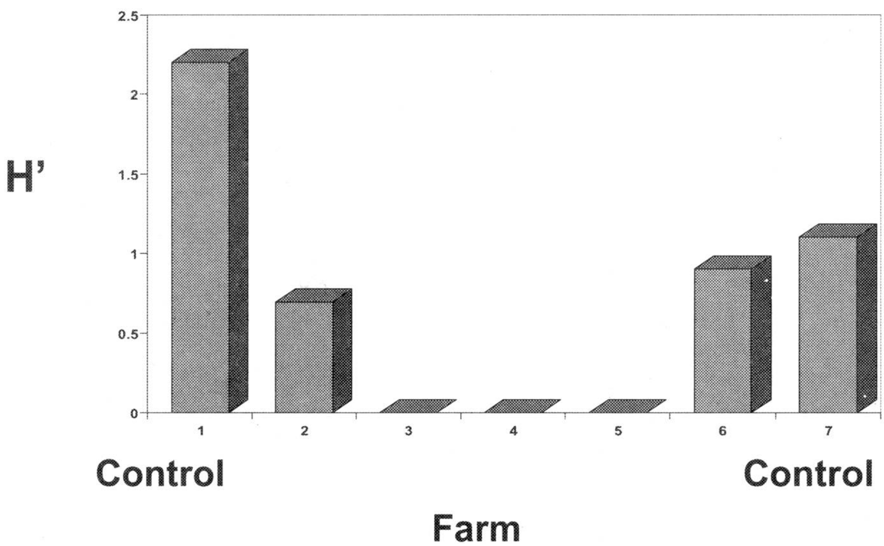

Figure 6. **Changes in diversity index (H^1) along a transect across a fish culture zone in Hong Kong (Data from Wu *et al.*, 1994).**

Reduce pollution loading by feed manipulation

About 80-84% of C, 52-95% of N, and 82% of P in feed input to the culture system may be lost through feed wastages, excretion and faecal production (Fig. 3), and such losses can be minimized by improved feed technology.

Feed wastage can be reduced by increasing the stability and reducing the sinking rate of feed, and providing the fish with an optimal size of feed at different stages of development. Ammonia excretion by fish is a function of protein intake and can be kept to a minimum; with a highly digestible feed an optimal protein/energy ratio can be provided for each species and its developmental stages. The energy requirements of fish can be satisfied by carbohydrates and fat, so that protein can be spared for body tissue construction. It has been shown that protein retention in *Sparus aurata* can be increased from 24.3 to 31.3% by increasing the dietary lipid by 37% (Kissil and Lupatsch, 1992). Obviously, reduction of N in the diet can only be achieved if artificial feed is used. There is little doubt that formulated artificial feed is superior to trash fish, in terms of its nutritional value, storage, supply, and pollution loading. The reason that trash fish is still widely used in Asia (e.g., Japan, Hong Kong, Singapore, and Thailand) is due to our poor understanding of the nutritional requirements of the various non-salmonid species cultured. This points to the urgent need for research into the nutritional requirements of these non-salmonid species.

Integrated culture

Marine macroalgae can take up N, whereas filter feeders (e.g. bivalves) can remove particulate and phytoplankton from water at remarkable rates. (Inui *et al*., 1991; Prins *et al*., 1994). Harvesting nutrients generated by marine fish farming by macroalgae and filter-feeders would be an attractive option since this would alleviate nutrient pollution on one hand and increase productivity on the other.

The use of mussel/oyster beds to control phytoplankton growth and eutrophication has been suggested by Cloern (1982) and Loo and Rosenberg (1989). Recently, integrated culture in closed or semi-closed culture system using macroalgae (*Ulva* sp. and *Gracilaria* sp.), shellfish and fish has been tried out successfully in Israel, Chile, Canada, France, and Norway (Kaas, 1998). It has been shown that 1 kg of *U. lactuca* can remove 90% of ammoniacal nitrogen in effluents produced by 75 kg of fish and give a maximum yield of 55 g per m^2 per day dry wt in a land-based fish farm (Cohen and Neori, 1991; Neori *et al*., 1991). Jimenez *et al.* (1996) also showed that 153 m^2 of *Ulva rigida* tank surface (at a stocking density of 2.5 g fresh weight per l) is required to recover 100% of DIN produced by 1 t of *Spaus aurata.* Similarly, culturing brown macroalgae (*Laminaria* and *Macrocystis*) near fish farms for nutrient removal was considered to be both economically and technically feasible by Petrell *et al.* (1993). An increase in fish yield (by 1.5%) and dissolved oxygen (by 9%) has been reported from a Japanese open-cage culture system consisting of red sea bream and sea lettuce (Anonymous, 1994).

In a land-based culture system, Shpigel *et al.* (1993) demonstrated that some 63% of N in the feed can be recovered by bivalves (*Crassostrea gigas* and *Tapes semidecussatus*) and seaweed (*Ulva lactuca*) cultured in the same system. Culturing shellfish to remove nutrients derived from farming activities appears to be a viable and practical option and should be adapted to open-cage culture systems. Furthermore, seaweed and shellfish of economic values may be used to improve culture profit.

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Research on Marine Fishes

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Abstract

Research on marine fishes at SEAFDEC/AQD from 1995 to date was mostly on milkfish *Chanos chanos.* Studies focused on the refinement of broodstock and seed production techniques to improve egg and larval production as well as to eliminate morphological deformities in hatchery-bred fry. A verification study with former shrimp hatchery operators demonstrated the technical and economic viability of the AQD-generated milkfish hatchery technology. Production and efficiency of semi-intensive grow-out in ponds were enhanced by the use of formulated feeds and appropriate feeding scheme. Milkfish farming in the Philippines was critically reviewed and recommendations to sustain milkfish culture production were made. Tobacco dust and metaldehyde formulation were proposed as alternatives to organotin-based pesticides in controlling the population of pond snail. The growth hormone of milkfish has been isolated and purified.

Addition of highly unsaturated fatty acid (HUFA)-rich oils in the diet did not improve the quality of spawned eggs of grouper *Epinephelus coioides.* A protocol for the intensive larval rearing of grouper was developed based on the results of several studies. A semi-intensive seed production method using copepod nauplii during the early feeding stages was also developed as an alternative to intensive method. Metamorphosis of larvae was significantly accelerated by exogenous thyroid hormones. Nutritional studies to reduce the amount of fish meal in grouper diets are in progress. Groupers grown in ponds or cages harbor a variety of parasites.

Biochemical criteria to assess the quality of spawned Asian sea bass *Lates calcarifer* eggs was characterized. *Diaphanosoma* or other copepods may be an alternative or supplemental live prey to *Artemia* during sea bass larviculture. A practical diet for sea bass culture was developed. Studies to determine the essential amino acid requirements of sea bass are about to be completed. The effects of immuno-stimulants in sea bass are presented.

Induced and natural spawning of mangrove red snapper *Lutjanus argentimaculatus* in concrete tanks or floating net cages has been documented. An improved larval rearing method has been developed using screened rotifers during the early feeding stage of the larvae. Exogenous thyroid hormones have advanced metamorphosis of larvae. A practical diet for snapper is under development.

Research on rabbitfish *Siganus guttatus* were geared to developing tools for growth enhancement. Pituitary growth hormone (GH) has been cloned, allowing

the production of recombinant rabbitfish GH. Rabbitfish prolactin, somatolactin have also been purified.

Studies on marine ornamental fish focused on two species of seahorses, *Hippocampus kuda* and *H. barbouri*, and on blue tang *Paracanthurus hepatus.* Progress on the biology, breeding, and seed production of seahorses are presented. Successive natural spawnings of blue tang in concrete circular tank have been recorded.

Introduction

Research on marine fishes at the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC/AQD) from 1995 to date followed the list of priority species and recommendations of the Seminar-workshop on Aquaculture Development in Southeast Asia (ADSEA) in 1994. On top of the priority list was milkfish *Chanos chanos,* followed by grouper *Epinephelus coioides,* mangrove red snapper *Lutjanus argentimaculatus,* Asian sea bass *Lates calcarifer,* rabbitfish *Siganus guttatus,* striped mullet *Mugil cephalus,* and marine ornamental fishes. Except for striped mullet, SEAFDEC/AQD has addressed most of the recommended research areas in the other species. This paper presents the highlights on marine fish research at SEAFDEC/AQD from 1995 to 1999.

Milkfish

Broodstock management

Studies were continued on broodstock nutrition to further improve the quality of spawned eggs. More spawns and higher egg viability were observed in broodstock fed diets supplemented with vitamin C alone or in combination with Vitamin E than those fish fed without vitamin supplementation. Cumulative survival rates from eggs to normal larvae appeared to be higher in spawns of broodstock fed vitamin C alone or in combination with vitamin E (Emata et al., 2000).

A protocol for the transport of milkfish broodstock was developed (Emata, 2000; Garcia, *et al.*, 2000). All milkfish broodstock survived after 10 h of overland transport in sealed oxygenated plastic bags with chilled (20-24 C) and diluted (28 ppt) seawater. Spawning of sexually mature milkfish subjected to such transport stress was not impaired.

Seed production

Hilomen-Garcia (1997) characterized the morphological abnormalities in hatchery-bred milkfish fry and juveniles. Abnormalities predominantly appeared as a cleft on the branchiostegal membrane and as a deformed operculum. The occurrence of these abnormalities in hatchery-bred juveniles reared in commercial ponds was highly variable (3-26%). Further observations suggest that such morphological abnormalities do not only affect the appearance of the fish but also impair growth and survival.

Several studies were conducted to reduce if not eliminate morphological abnormalities in hatchery-bred milkfish. Eggs transported at the "eyed stage" had higher viability compared to those transported at the cleavage, blastula or gastrula stage (Toledo *et al*., 1996a). Although no significant difference in survival was observed, the percentage of 45 day-old larvae with apparent morphological abnormalities was lower in groups transported at the "eyed" stage compared to other stages tested. The shock sensitivity of milkfish eggs was highest during cleavage until the early segmentation stage, rapidly declined as segmentation proceeded until the head and tail started to separate from the yolk, but returned to high levels when the embryo began twitching and the heart beating until hatching (Hilomen-Garcia, 1998). These results suggest that the sensitivity of milkfish eggs to mechanical shock varies during development and C-shaped embryos may be manipulated or transported with minimum risk or injury.

The aerobic bacterial flora of milkfish eggs and larvae was examined (Fernandez *et al.*, 1996). *Pseudomonas* was the dominant bacteria in eggs and incubation water. Bacterial number in larvae and in rearing water increased during the culture period. *Pseudomonas* was detected as the dominant bacteria in the yolk-sac larvae. *Vibrio* predominated in the intestines as soon as the yolk-sac was absorbed among Day 3 larvae.

Duray (1995) examined the effect of tank color and rotifer density on rotifer ingestion, growth, and survival of milkfish larvae. The number of ingested rotifer, growth and survival of larvae were higher in black tanks than in tan tanks.

Enrichment of rotifer and *Artemia* with highly unsaturated fatty acid (HUFA) before feeding to milkfish larvae enhanced growth and resistance to salinity stress but not overall survival (Gapasin *et al.*, 1998). Forty-day-old milkfish previously fed HUFA+ vitamin C-enriched live food had significantly lower incidence of opercular deformities (8-15%) compared with those given HUFA-enriched (16-24%) or un-enriched (27-34%) food.

A nutritionally balanced and cost-effective diet for milkfish larvae was developed (Borlongan *et al.*, 2000). This diet could be fed to milkfish larvae in combination with rotifers starting 2 or 8 days post hatching, and could be fed alone starting from Day 15.

Semi-intensive seed production of milkfish was developed as an alternative to the intensive system (JD Toledo, unpublished data). Milkfish larvae were stocked in 10-ton tanks at 5 to 10 individuals/1 and provided *Acartia* and *Pseudodiaptomus* nauplii and rotifers as food. Supplementary artificial feed was given from Day 10 onwards. Survival at harvest (Day 18) ranged from 42 to 80%.

Four hatcheries formerly used in shrimp seed production were selected to verify SEAFDEC/ AQD's milkfish hatchery technology and to assess its economic viability (Garcia et al., 1999). Two hatcheries were classified as large scale and the rest as small scale. Survival rates at harvest ranged from 15 to 42%. Cost-return analysis showed high profits for both types of operation. Return on investments varied from 54 to 61% with a payback period of 1.5 years.

Grow-out culture

Bagarinao (1998) extensively discussed the alleged milkfish fry shortage in the Philippines and the supply from hatcheries and fisheries. SEAFDEC/AQD in collaboration with the Bureau of Fisheries and Aquatic Resources (BFAR) and the International Center for Living Resources Management (ICLARM) also conducted a milkfish fry assessment study in five selected sites in the country. Generally, the supply of milkfish fry from traditional fry grounds is decreasing. As perceived by the fry gatherers themselves, the decline in catch is likely attributed to environmental degradation, pollution, and illegal catching of milkfish spawners. With the increase in demand due to intensification of grow-out operations, hatchery production should therefore be intensified to supplement production from wild sources.

Artificial feeds for nursery rearing of milkfish larvae have been formulated (Alava and Kanazawa, 1996). Growth and survival of larvae were higher at lower salinity and dietary level but was not affected by lipid source (cod liver or coconut oil). Overall, diets with 9% lipid promoted better growth than those with 18% lipid content (Alava, 1998).

Sulfide toxicity can be a causative factor in fish kills of milkfish and tilapia in brackish and marine waters. Bagarinao (1998) showed that sulfide, hypoxia, and acidic conditions are each toxic to milkfish at particular levels and aggravate each other's toxicity. Recommendations to avoid fish kills were made such as the maintenance of fully oxygenated conditions to avoid build-up of sulfide, ammonia, carbon dioxide, and other toxic substances.

Sumagaysay and Borlongan (1995) determined the most economical combination of dietary protein and feeding levels for semi-intensive milkfish culture in brackishwater ponds. Partial budgeting analysis shows that bigger profits can be earned with a 24% diet with balanced amino acids at a feeding rate of 4% of body weight daily. However, supplemental feeding should not exceed 38 kg/ha/day to maintain good water quality (Sumagaysay, 1998).

In contrast, a feeding rate of 4% could be wasteful and may be reduced to 2% of body weight per day (SEAFDEC/AQD, 1998). About 60-70% of the particles in the gut of milkfish in semi-intensive ponds are detritus. Natural food such as *lablab* makes up 15-20% and formulated feeds make up the remainder. Because milkfish do not feed in the morning when the dissolved oxygen is low, feeds should be given only from mid-morning when oxygen level is adequate for feeding.

The pond snail *Cerithedea cingulata* are long considered as pests in brackishwater ponds. Research on the biology of pond snails shows that: 1) they are deposit feeders; 2) they are able to retract into their shell and survive anaerobic conditions for extended periods; 3) they are intolerant of fresh water, sun-drying, very high and low pH, and very high ammonia levels; 4) they grow fast and sexually mature in one year of age; 5) 60-90% of the snails have mature gonads and spawn between March and November; 6) they have high fecundity, high hatching rates, low dispersal, and high recruitment in the pond system (T. Bagarinao and I. Olaguer, personal communication). Recommendations for an integrated management of the pond environment to control snail population were made.

Organotin pesticides (Brestan or Aquatin) have been used to control the population of pond snails in milkfish ponds in the Philippines. Coloso and Borlongan (1999) demonstrated that tin and triphenyltin residues accumulate in the sediment of brackish water ponds and milkfish tissue samples. The ban on organotin usage in milkfish pond should be strictly implemented to reduce the threat of this pesticide to the environment, natural resources, and public health.

Viable alternative methods to the use of organotins in brackish water ponds were developed. Snail mortalities (86-87%) in experimental ponds did not vary significantly 7 days after application of 80 to 120 kg/ha of 10% metaldehyde formulation (Coloso *et al.*, 1998). In field trials, in a heavily infested pond (more than 2000 snails/m^2), a dose of 120 kg/ha was effective under both dry and wet conditions. In a moderately infested pond (less than 2000 snails/m^2), a dose of 80 kg/ha of 10% metaldehyde formulation was effective under dry conditions but a dose of 120 kg/ha was needed under wet conditions. As metaldehyde is rapidly degraded in the aquatic system, its efficacy in controlling pond snails depends on a high initial dosage.

Tobacco dust is toxic to pond snails at certain levels (Borlongan *et al.*, 1998). The 72-h LC(lethal concentration)$_{99}$ of tobacco dust with 2.8% nicotine content are 290,522 and 720 kg/ha for juvenile, sub-adult, and adult snails, respectively. LC_{99} increased as the life stages or the size of the snails increased. The nicotine content of the tobacco dust directly affects its effective application rate. Milkfish juveniles can tolerate nicotine concentrations lethal to the pond snails.

Bagarinao (1998) revealed a disturbing trend in the milkfish industry in the Philippines: decline in production, continued low average yields, high production costs, and unfavorable market forces. During the past decade, the annual milkfish production declined and fluctuated to about 150,000 mt from a peak of 240,000 mt in 1982, due to the shifting of farms to shrimp production, loss of ponds in Central Luzon to lahar, the non-renewal of Fishpond Lease Agreements, and low farm gate prices. The decline in milkfish production in fish pens in Laguna Lake was traced to domestic and agricultural pollution, and overcrowding of fish pens. Milkfish farming in marine pens and cages proliferated after it started in 1995 in Davao, Pangasinan, and Quezon. Harvests reached very high levels but fell drastically soon when the carrying capacity was exceeded in most sites and the cost of cages and feeds became prohibitive. Likewise, many pens and cages were ordered dismantled or were destroyed by storms.

The cDNAs encoding milkfish growth hormone (GH) and insulin-like growth factor-I (IGF-I) were cloned and sequenced (EGT de Jesus, personal communication). Milkfish GH and IGF-I cDNAs show higher sequence identity with carp and salmonid GH and IGF-1 cDNAs than GH and IGF-I cDNAs of other teleosts.

Grouper

Broodstock management and seed production

The use of 17-alpha methyltestosterone (MT) to induce sex reversal in *E. coioides* was continued following the pioneering study by Tan-Fermin (1992). MT in silastic capsules was implanted to adult females at a dose of 4 mg/kg BW. Functional males were observed after 7-10 weeks of hormone implantation. Spermiation was maintained by implanting MT capsules every 3 months (Marte *et al.*, 1995).

Sex inversion in grouper can also be enhanced by manipulating the social environment of the spawners. A large female reared separately with smaller males in tank or floating net cage may naturally change to a male after 1-2 months (Quinitio *et al.*, 1997).

High variability of egg quality in *E. coioides* is partly due to the inconsistent quality of fish by-catch fed to broodstock. Enrichment of fish by-catch with oils rich in HUFA did not improve egg production, spawning frequency, fertilization and hatching rates, and egg viability (Quinitio *et al.*, 1996). Likewise, naturally spawned grouper eggs should be collected after neurulation when the optic vesicles are already formed to increase egg viability and hatching as well as to reduce mortality and occurrence of embryos (Caberoy and Quinitio, 1998).

Incorporating the results of previous studies (Duray *et al.*, 1995; Duray et al., 1996b; Chavez *et al.*, 1995), a protocol for the intensive seed production of grouper was developed (Duray *et al.* 1997). Larvae are initially fed screened rotifers previously enriched with high HUFA boosters. Enriched *Artemia* nauplii or *Anemia* meta-nauplii are fed from Day 20 until metamorphosis when larvae are able to feed on minced fish.

Semi-intensive larval rearing was also developed (Toledo *et al.*, 1999). To propagate copepod nauplii in larval tanks, sub-adult and adult copepods, *Acartia tsuensis* and/or *Pseudodiaptomus annandalei,* collected from brackish water ponds are inoculated in the larval tanks 2-3 days before stocking of larvae (not more than 10 larvae/1). First-feeding grouper larvae preferred copepod nauplii than rotifer. Larvae fed copepod nauplii survived and grew better than larvae fed rotifers (Doi *et al.*, 1997; Toledo *et al.*, 1996b and 1997). *Acartia* contains high levels of HUFA particularly docosahexonoic acid (DHA), known as an essential fatty acid for marine fish larvae. Optimum densities of copepodids and adults of *Acartia* and *Pseudodiaptomus* to consequently produce nauplii for early feeding larvae were also determined (Toledo *et al.*, 1999). Studies to develop mass production techniques for *Acartia* and *Pseudodiaptomus* are ongoing.

Grouper larvae show an ontogenetic shift to changes in salinity and temperature (GF Quinitio and NB Caberoy, personal communication). Day 20 larvae preferred salinities of 8-32 ppt at 25 C but these were narrowed to 8-18 ppt at 30 C. At Day 40, survival were similar between 8 and 40 ppt at 25 and 30 C despite changes in gill Na^+,K^+-ATPase activity and chloride cell morphology. No major changes were observed in enzyme activity, chloride cell morphology as well as plasma osmolality in Day 60 juveniles.

The process of metamorphosis in grouper requires more than two weeks to be completed. Thyroid hormones, triiodothyronine (T_3) or thyroxine (T_4) accelerate metamorphosis in grouper larvae in a dose-dependent manner (de Jesus *et al,* 1998). Three-week old larvae immersed in 1 ppm T_3 or T_4 completed metamorphosis within 2 days. Larvae treated with 0.01 ppm of the hormones completed metamorphosis in 5-6 days whereas, untreated controls took 10-21 days to complete metamorphosis. Thyroid hormone treatment after collection and during transport did not improve the post-transport survival of wild-caught pre-metamorphic grouper larvae. Post-transport mortalities were associated with the sudden shift of diet from live prey to minced trash fish or formulated feeds and the sudden confinement of un-domesticated larvae to smaller space (MC Estudillo, personal communication).

Grow-out

Nursery and grow-out for hatchery-bred juveniles were developed in earthen-ponds (IB Tuburan *et al*., personal communication). Survival ranged from 50 to 67% and from 72 to 85% in nursery and grow-out, respectively. Economic analysis shows both culture systems as highly profitable with a payback period of 1.7 years. Morphological abnormalities in hatchery-bred grouper such as open operculum, depressed antero-dorsal fins, and deformed lower jaw were noted.

Nutritional studies to eliminate or decrease dependence on trash fish to feed groupers were undertaken. Best growth and survival of grouper fry were obtained in diets containing 42% protein, 10% lipid, and a supplementation of 1% HUFA. Poorest weight gain was observed in diets without HUFA supplement (OM Millamena, personal communication).

Research aimed at reducing the fish meal component of artificial diets for grouper is currently being undertaken. The apparent digestibility of locally available protein sources and its acceptability in a compounded diet for grouper juveniles is presently examined. Preliminary results indicate that white cowpea meal can be used as a partial replacement for fishmeal in grouper diets (PS Eusebio, personal communication). Other protein sources such as slaughterhouse by-products are being tested. Up to 60% of fish meal may be replaced by blood meal in artificial diet for grouper juveniles (OM Millamena, personal communication).

Disease among cultured grouper is an emerging problem. Higher diversity of parasites and intensity of infection were observed in groupers grown in floating net cages than in brackishwater ponds (E Cruz-Lacierda, personal communication). Cage- and pond-reared grouper harbor various species of protozoa, parasitic worms, and nematodes. Research on the life cycle of a predominant monogenean infecting grouper is now ongoing (GE Pagador, personal communication).

Mangrove Red Snapper

Broodstock and seed production

Wild-caught mangrove red snapper adults reared in floating net cages or in concrete tanks are sexually mature from April to October. Successful spawning of spermiating males and mature females with mean oocyte diameter of at least 0.42 mm injected 1,000 IU hCG/kg or 100 μg LHRHa/kg body weight occurred from June to October but not on April or May. Latency period was 32-40 hours after hormone injection. Egg and larval quality were highly variable (AC Emata, personal communication). Broodstock from wild-caught or hatchery-produced fry reared in floating net cages or concrete tanks were sexually mature after 5 years among males and 6 years among females. Natural spawning was observed in cages and tanks stocked at 1:1 or 3:4 (female:male) sex ratio. Spawning occurred up to 4 consecutive days with egg collection ranging from 250,000 to 1 million eggs per spawning. Egg larval quality was more superior than those produced from induced spawning (AC Emata, personal communication).

Duray *et al.* (1996a) describe an improved hatchery rearing of mangrove red snapper larvae in large tanks using small rotifer and *Artemia.* The feeding regime consisted of *Chlorella*, *Brachionus, Artemia,* and minced trash fish. Best survival was achieved when larvae were fed screened *Brachionus* (<90 μm) during the first 14 days. Larvae fed *Artemia* at 2 per ml had highest survival when ration was given four times a day. Studies on the effects of supplement feeding, stocking density, and continuous lighting on the growth and survival of snapper larvae is ongoing (MN Duray, personal communication). Tolerance of *L. argentimaculatus* larvae to abrupt change in salinity was related with age (CB Estudillo, personal communication). Tolerance to abrupt salinity change increased remarkably starting on Day 28. Average survival was significantly higher at 16 ppt (7.6%) than at 40 ppt (4.3%) during the first 21 days of rearing. However, no significant difference in survival was observed among the salinities tested at the end of the second phase of rearing.

Thyroid hormones accelerate metamorphosis in *L. argentimaculatus* larvae. Three week-old larvae immersed in 0.01 ppm T_3 or T_4 completed metamorphosis after 1 week while no larvae metamorphosed in the thiourea-treated or untreated control groups. Five-week old larvae showed a dose-dependent response to both hormones (EGT de Jesus, personal communication).

Grow-out

Six diets with three protein (35, 42.5, and 50 %) and two lipid (6 and 12 %) levels were tested to formulate a practical diet for red snapper (MR Catacutan, personal communication). After 100 days of culture with 100% survival in all treatment groups, fish attained a final average weight between 116 and 165 gm from an initial mean weight of 25 gm. The optimum protein level was found to be 42.5%. Because fish carcass of samples from fish fed 6% lipid still contained 27-34% crude fat, it is likely that lipid level in the diet could still be lowered. The preferred protein-energy ratio was estimated at 130 mg protein/kcal.

After 98 days of culture, substitution of soybean meal to 30% of a control diet was found adequate. Substitution of defatted soybean meal higher than 30% adversely affected liver histology (MR Catacutan, personal communication). The formulated practical diet will be tested in pond- and/or cage-culture to further determine its bio-technical and economic feasibility.

Sea Bass

Broodstock and seed production

To establish a criteria for egg quality assessment, biochemical characteristics of fertilized sea bass eggs was correlated with egg quality. Positive correlation was observed among the following: total saturated fatty acids, phosphoserine, and aspartic levels with fertilization rates; DHA/EPA (eicosapentanoic acid) level with hatching rate; and DHA and aspartic acid content with normal zygotes. Arginine levels in spawned were negatively correlated with hatching rate (Nocillado *et al.*, 2000).

Mature sea bass readily spawn after injection or implantation of hormones such as luteinizing hormone releasing hormone analog (LHRHa). The spawning response of mature fish was significantly reduced after injection of dissolved LHRHa stored for more than 90 days in a refrigerator (4-10 C) or for more than 30 days at room temperature (28-30C). In contrast, mature fish spawned successfully after injection of an LHRHa solution subjected to alternate freezing and thawing or implanted with LHRHa in pellet-form stored at room temperature (Garcia, 1996).

Research to reduce dependence on *Artemia* in sea bass seed production was continued. Nursery rearing may be done in illuminated floating net cages (Fermin *et al,* 1996; Fermin and Seronay, 1997). High zooplankton abundance at 300 lux consequently increased feeding incidence, gut content, specific growth rate, and survival of the larvae. Growth and survival were enhanced in larvae fed minced trash fish during the day. Partial replacement of *Artemia* by the brackishwater cladoceran, *Diaphanosoma celebensis,* in the larval rearing of sea bass was reported by dela Pena *et al*. (1998). Although *Diaphanosoma* contains higher crude protein and crude fat than *Artemia,* its percentage of n-3 HUFA particularly EPA and DHA was lower than *Artemia.*

Grow-out

Research to ascertain the essential amino acid requirements of sea bass juveniles is almost completed. The essential amino acid levels for arginine, lysine, methionine, threonine, tryphtophan, phenylalanine, and hestidine was already determined while experiments for isoleucine, leucine, and valine is ongoing (RM Coloso, personal communication).

Catacutan and Coloso (1997) formulated a practical diet for sea bass containing 20% carbohydrate, 10-12 % lipid (1:1 mixture of cod liver oil and soy bean oil), and 42 % dietary protein with an energy level of about 337-358 kcal/100 gm diet and a protein:energy ratio close to 128 mg of protein per kcal. White cowpea and green mungbean meals can be used to replace 18% of the protein sources in practical diets for sea bass without affecting their growth (Eusebio and Coloso, 2000).

Experiments on disease prevention and control focused on the use of immuno-stimulants on the non-specific immune response of sea bass. Based on plasma lysozyme levels, betaglucans and levamisole enhance the nonspecific immune response while handling/transfer stress and poor water quality negatively affect the immune response of sea bass (JME Almendras, personal communication).

Rabbitfish

Research activities on rabbitfish were geared towards developing tools for growth enhancement in fish. GH was isolated from pituitary glands of rabbitfish by gel filtration and high performance liquid chromatography (Ayson et al., 1999). The yield of pure GH was 1 mg/gm wet weight of pituitary glands. In the process of purifying GH, prolactin, and somatolactin, two pituitary hormones related to GH, were also purified. Antiserum against rabbitfish GH was produced in rabbits.

Rabbitfish GH cDNA was cloned for recombinant rabbitfish GH production (FG Ayson, personal communication). Excluding the poly-A tail, rabbitfish GH cDNA is 860 base pairs long. It contains a 588 base pair open reading frame encoding a signal peptide of 18 amino acids and a mature protein of 178 amino acid residues.

Marine Ornamental Fishes

Breeding and seed production of seahorses

Studies on the breeding and seed production of seahorses focused on two species, *Hippocampus kuda* and *H. barbouri.* After 90 days, parturition events (7-8/pair) and greater brood size (87-91 juveniles/gm female) were higher in *H. kuda* fed HUFA-enriched *Artemia* adults, mysids, and tilapia fry than those fed *Artemia* adults alone (2-3 parturition/pair and 18-26 juveniles/gm female). When groups of newly born *H. kuda* were fed *Brachionus* alone, copepods alone, or their combination, only seahorses on a combination diet survived at Day 10 (GH Garcia, unpublished data).

Results of experiments on the effect of illumination on daily feeding pattern of *H. kuda* indicate that seahorses may not eat for 12 h when food is not available but will compensate for the 12 h non-feeding period when food becomes available. Food consumption of *H. kuda* juveniles was significantly higher during daytime than during nighttime. Under natural photoperiod, a distinct diurnal feeding behavior was also observed in *H. barbouri* (GH Garcia, personal communication).

Simulated transport experiments on 33-day old hatchery-bred *H. kuda* showed that seahorses were grasping each other by the tail and had higher survival rates at higher loading densities (10 and 20 juveniles/500 ml) than those at lower densities (5 juveniles/500 ml). This result suggests the need of providing a holdfast during transport at low densities (GH Garcia, unpublished data).

Broodstock management of marine ornamental fish

Successive spawnings in the blue tang *Paracanthurus hepatus* have been documented. Spawning occurred for 5-12 consecutive days with egg collection ranging from 5,000 to 30,000 eggs per day. All larvae died 6 to 7 days post-hatching. Studies to determine the appropriate food and environmental conditions for the first-feeding larvae are going on.

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Research on Freshwater Fishes

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Abstract

Studies on tilapias focused on the refinement of strain comparison methods, refinement and pilot-testing of broodstock improvement procedure, selective breeding and evaluation of red tilapias, genetic variability determination in hatchery-bred tilapia and the development of criteria for tilapia fingerling quality assessment.

On carps, feeding of bighead carp (*Aristichthys nobilis*) to enhance reproductive performance was done and stunting was applied as a technique in broodstock development. Studies on the tolerance of bighead carp fry to low salinities were conducted. Free-living nematodes were tested as alternative larval food. The culture potential of grass carp in lake-based cages was also determined.

Research on the native catfish (*Clarias macrocephalus*) focused on endocrine studies during the final stages of maturation. Hatchery techniques were refined by identification of factors that increase fry production. Practical diets were developed for broodstock, hatchery, nursery and grow-out phases. A collaborative project on the ecological impact of African catfish (*C. gariepinus*) introduction in natural waters was undertaken.

The occurrence of EUS (epizootic ulcerative syndrome) among wild fishes in Laguna Lake decreases the marketability of both wild and cultured fishes from the lake. Hence, the bacteria and virus associated with EUS and their virulence, modes of disease transmission, developmental stages of dermal lesions and hematological changes in severely affected fish were studied.

Laguna Lake, where fish catch and aquaculture production contribute significantly to the country's total freshwater fish production, has been the focus of extensive ecological research in collaboration with other local and foreign research and academic institutions.

Introduction

The species of freshwater fish that are the subject of research at SEAFDEC Aquaculture Department are the tilapias *Oreochromis niloticus* and *Oreochromis* spp. (red tilapia), bighead carp *Aristichthys nobilis*, grass carp *Ctenopharyngodon idella*, and the Asian catfish *Clarias macrocephalus.* The extent of African catfish *Clarias gariepinus* farming in the Philippines was assessed as a special collaborative project between SEAFDEC/AQD and the Bureau of Fisheries and Aquatic Resources (BFAR).

The tilapias are a major group of freshwater fishes produced in the Philippines, Thailand, and

Malaysia (FAO, 1999). They are second only in production to the common carp *Cyprinus carpio* in Indonesia and are equally important with other freshwater fishes in Laos and Brunei. In the Philippines, the bighead carp has become an important food fish cultured mainly in pens and cages in Laguna Lake, the country's largest lake. More recently, some fish farmers have started culturing grass carp. The native catfish, *C. macrocephalus*, is one of the favorite freshwater food fishes in the Philippines but it is fast becoming scarce in many natural habitats. Lately, there is a renewed interest in the culture of *C. macrocephalus* due to advances in its artificial propagation.

As a continuation of the reports on studies on freshwater fishes conducted prior to 1994 (Carlos and Santiago, 1988; Fermin, 1988; Basiao, 1994; Emata, 1995), the present review focuses on research activities over the past five years (1995-1999) that address persistent problems in the culture of some freshwater fishes. It also includes a project on lake ecology and other related studies implemented during the period.

Nile Tilapia *Oreochromis niloticus* and the Red Tilapia

Strain comparison procedures

The efficiency of using an "internal reference" population in detecting strain differences under different environmental conditions has been demonstrated (Basiao and Doyle, 1990a,b; Romana-Eguia and Doyle, 1992, Romana-Eguia and Eguia, 1993). Recently, the growth and growth depensation of three strains of Nile tilapia fingerlings under crowded condition showed that inclusion of an "internal reference" strain increased the sensitivity of the statistical test to detect a 7% significant difference among strains (Basiao *et al*., 1996). The Israel and NIFI strains grew significantly faster than the CLSU strain under experimental conditions. The crowding effect was eliminated after 12 weeks of compensation. The reference strain improved the resolution of the strain-testing experiment as shown by an increase of r^2 from 0.06 to 0.91. Approximately 450 replicate families would have been needed to detect the significant strain differences if the reference strain had not been included in the experimental design. In aquaculture, the cost of making a Type II error, i.e. believing that no difference exists when there is a real difference, can lead to opportunity costs of forgone production.

Broodstock improvement procedure

In artisanal spawning, there is a high non-genetic size variation among fish that are nominally of the same age. Large size is therefore not an accurate indicator of breeding value. For this and perhaps other reasons the conventional mass selection on tilapia has not shown positive results. The collimation procedure or early size-grading and culling of large fry reduces the self-amplifying phenotypic variance in growth. Collimation increases the genetic to phenotypic variance or heritability at the time of selection. The usual mass selection procedure was modified by size-grading the fingerlings before a two-step directional mass selection procedure was applied on Nile tilapia stocked in net cages in Laguna Lake. One generation of collimated mass selection resulted in a significant positive response of 3% relative to the control (Basiao and Doyle, 1999). The realized heritability (h^2) of » 16% is comparable with other recent estimates of h^2 in aquaculture populations of tilapia.

Farm-based broodstock improvement

The collimated mass selection procedure developed at BFS was pilot-tested in a small hatchery farm in Laguna, Philippines. This collaborative, farmer participatory research aims to assist farmers develop their own tilapia broodstock. Results of the farm trial showed a 7 to 9% response to selection after three months of culture (ZU Basiao, unpublished data). An important implication of the collimated mass selection is that fish farmers would have more control over their choice of good quality spawners. Dependence on a "franchise-dealer" type of seed production will be minimized and socio-economically self-sustaining genetic conservation of breeds will be achieved.

Selective breeding and evaluation of red tilapia strains

The genetic improvement of a Philippine red tilapia strain through introgressive hybridization with Nile tilapia from Thailand and subsequent application of size-specific mass selection is in progress. Four distinct phenotypes e.g., bright red orange, orange with black blotches, pale pink and the grey color, were observed in the progenies of the mass-spawned introgressed red tilapia. One generation of introgression resulted in a significant positive response of 2.5% as measured by the percent differences in the lengths of introgressed red-orange offspring and the normal red tilapia (ZU Basiao, unpublished data).

A 2x2 factorial experiment to determine the reproductive efficiency of the introgressed red tilapia and the normal red (not introgressed with NIFI strain of Nile tilapia) fed a SEAFDEC-formulated diet and a commercial feed is another on-going study. Preliminary results showed that the number of spawning and seed (fry and egg) production were highest in the normal red breeders fed the commercial feed. The introgressed red and normal red tilapia fed the SEAFDEC-formulated feed showed comparable number of spawnings. However, fry production was higher in the normal red breeders, while egg production was higher in the introgressed red tilapia. The lowest spawning frequency and seed production were observed in the introgressed red breeders given the commercial feed (ZU Basiao, unpublished data).

The reproductive efficiency of three genetically diverse Philippine red tilapia strains (BFS, FAC and PF) and one Thai red tilapia strain (NIFI) in two seed production systems were compared with the objective of improving red tilapia fry production (Eguia, 1996). Results over a one-year period showed that seed (fry and egg) production in all strains was considerably higher in tanks than in cages. Mean daily seed production in tanks was highest for FAC (12.4 per spawner), followed by NIFI (11.2), BFS (9.5), and PF (5.6). Mean daily egg and fry harvests per female in fine-meshed net cages were 2.2 (BFS), 1.4 (NIFI), 1.2 (FAC), and 1.1 (PF).

In another study, the growth of three Philippine red tilapia strains and two imported Asian red tilapia strains (NIFI and HL) in freshwater, brackish water (17‰) and seawater (34‰) was evaluated (Romana-Eguia & Eguia, 1999). The five Asian strains grew best in brackish water. Likewise, the Taiwanese strain HL grew fastest in freshwater, and the Philippine strain PF in seawater, demonstrating that some Asian red tilapia strains can be developed for semi-intensive culture in brackish water ponds or marine cages.

Monitoring of genetic variation in hatchery-bred tilapia

The sustained growth of the aquaculture industry will depend largely on the development of a genetically promising seed with high level of genetic variation. Genetic drift, which can rob the hatchery population of genetic variance, is unavoidable in any selective breeding program. The genetic variation of hatchery-bred tilapia using protein and enzyme electrophoresis at BFS addresses this concern. Sixteen enzymes and 24 loci screened in three generations of hatchery-bred Nile tilapia using horizontal starch gel electrophoresis showed high levels of genetic variation in the enzymes SDH, GPI, PGM, CK, EST, and IDH. The six polymorphic loci detected in the parental population were also detected in the F_1 and F_2 generations (ZU Basiao, unpublished data), indicating that the level of genetic variation in the parental population was still present in the two succeeding generations.

Assessment of Tilapia Fingerling Quality

Research on tilapia fingerling quality evaluation is scarce. In fact, there is no standard method for assessing good quality tilapia fry and fingerlings. A quality assessment protocol is currently being developed and tested in several hatchery-bred tilapia fingerlings. A scoring index based on individual morphological, physiological and behavioral traits is used to rate tilapia fingerlings collected from ponds and lake-based farms around Laguna Lake. These fingerlings are also subjected to various stress and culture performance tests - i.e., handling and transport, salinity, growth and survival. From the results of the rating index and performance tests, a standard technique for fingerling evaluation will be established.

Bighead Carp *Aristichthys nobilis*

Broodstock development and management

The inconsistent number and viability of carp larvae from a female fish are among the major problems in bighead carp hatcheries. On the basis of previous results on supplemental feeding of bighead carp in cages in Laguna Lake (Santiago *et al*., 1991), a follow-up study was conducted to determine the effect of diets with or without vitamins A, E and C supplements on reproductive performance (Santiago and Gonzal, 1999). These vitamins were tested because of their known effects on reproduction in other fish species. The onset of gonad maturation was 2-3 months earlier in bighead carp given supplemental diet regardless of vitamin supplementation than in fish without supplemental diet. The test vitamins in the broodstock diets did not influence the number of gravid and milting fish monthly after sexual maturation has occurred. Results of induced spawning showed that fish fed the diet with supplemental vitamins A, E and C or vitamins A and C significantly increased the hatchability of eggs and the number of 3-day-old fry. The study further indicated that supplemental vitamin E was unnecessary, probably due to the high residual vitamin E in the diet ingredients.

High maintenance cost of bighead carp broodstock in cages, the relatively late sexual maturity (2-3 years), and unavailability of standard broodstock management techniques contribute to the problems encountered in carp hatchery operations. Stunting is being explored as a technique in carp broodstock development since stunted bighead carp demonstrates compensatory growth (AC Gonzal, unpublished data). An ongoing study compares the growth and reproductive performance of bighead carp stocked directly in cages in the lake from juvenile stage (control) and those of fish reared in tanks for multiples of 6 months prior to stocking in cages (AC Gonzal, personal communication). Preliminary results show that growth is faster in bighead carp reared in cages than in tanks, and some of the control fish have attained sexual maturity in 24 months.

Shortage of good quality broodstock hampers the commercial production of bighead carp. Population genetic studies using protein and enzyme electrophoresis have been initiated to document the genetic structure of bighead carp populations in Laguna Lake. This will be the basis for proper broodstock management and sound genetic improvement program. Initial result from one farm showed possible polymorphism only in a-GDH and IDH. The enzymes ADH, 6PGD, PGM, MDH, CK, GPI, HBDH and ME were all monomorphic (ZU Basiao, unpublished data).

Nursery

The culture of bighead carp in the Philippines is done mostly in Laguna Lake. Carp hatcheries in lakeshore communities support the nurseries and grow-out in cages, pens and ponds. However, the lake is subjected almost annually to saltwater inflow from Manila Bay through the Pasig River when the lake's water level drops below that sea tide levels. A study was therefore conducted to assess the tolerance of bighead carp fry to a range of low salinities and determine the effect of salinity on growth (Garcia *et al.*, 1999). Mean and median survival times of the fry (11, 18 and 35 days post-hatch) directly exposed to salinities ranging from 0 to l6‰ decreased as salinity of the rearing medium increased. Older fry were more tolerant to these salinities than younger fry. Survival in saline water also depends on the age of fry during initial exposure to low salinities. Median lethal salinity after 96 h revealed higher tolerance among 35-day old fry (7.6‰) than 18- (6.0‰) and 11-day old fry (2.3‰). The 18-day old fry reared in 0 and 2‰ for 3 and 4 weeks had higher growth than those reared in 4 and 6‰. The results demonstrate that bighead carp fry have some capability to osmoregulate that enables them to survive and grow in bodies of water subjected periodically to saltwater inflow.

Free-living nematodes constitute a portion of the diet of some fishes and crustaceans in natural environments. As part of a larger collaborative project funded by the European Union, a study on the suitability of free-living nematodes as alternative food for bighead carp larvae as well as those of several other fish species has been started. Preliminary results show that growth and survival of bighead carp larvae were lower than or comparable to those of larvae fed *Artemia* nauplii (CB Santiago, unpublished data). The ongoing study will test enriched nematodes as larval food for bighead carp and other fish species. The techniques for the mass production of free-living nematodes and a medium for their transport and storage in a semi-dry state will also be developed.

Grass Carp *Ctenopharyngodon idella*

Grow-out

Experiments were conducted to determine the culture potential of grass carp in Laguna Lake. Fingerlings with initial mean weight of 5 g were grown under different feeding regimes in net cages in the lake. After seven months, mean weight gain was highest (41 g) in the control fish fed rice bran (T Miharu and ZU Basiao, unpublished data). Fish fed the aquatic plant *Najas* sp. and the aquatic fern *Azolla* sp. had comparable weight gain (35.5 and 36.6 g).

Larger fingerlings with initial weight of 50 g were given two other aquatic weeds and rice bran as feeds. Preliminary results showed that the mean weight gain of fingerlings fed kangkong *Ipomoea aquatica* (21.4 g) and rice bran (20.8 g) did not differ significantly after six months. Fingerlings given water cabbage (*Pistia* sp.) had the lowest weight gain (15.4 g) (ZU Basiao and T Miharu, unpublished data).

Asian Catfish *Clarias macrocephalus*

Broodstock development

Endocrine studies during the final stages of maturation include the determination of optimum season for artificial propagation based on development of the gonads and serum steroid hormone profiles at different times of the reproductive cycle, and development of methods to minimize the sacrifice of male broodstock.

Captive *C. macrocephalus* contain mature oocytes (Tan-Fermin *et. al*., 1997a) and abundant spermatozoa (Tan-Fermin *et. al,* 1997b) year-round but do not spontaneously release the gametes. In spite of this, captive catfish show seasonality in gonad development during an annual cycle. Changes in reproductive parameters (gonadosomatic index or GSI, oocyte diameter, fecundity) and serum steroid hormone levels (testosterone or T and estradiol-17β or E_2) in female catfish suggest that the period January to April was not the best months to induce *C. macrocephalus* to spawn (Tan-Fermin *et. al.*, 1997a). Fluctuating mean values of GSI and serum steroid hormones (T and 11-ketotestosterone or 11-KT), lower levels of the maturation hormone (17α, 20β-dihydroxy-4-pregnen-3-one or DHP) and lower count of spermatozoa in January likewise indicated that, except in January, males can readily be a source of milt for artificial propagation any time of the year (Tan-Fermin *et. al.*, 1997b).

Another study showed that luteinizing hormone releasing-hormone analogue plus pimozide (LHRHa+PIM)-injected fish during the off- and peak seasons similarly underwent oocyte maturation at 12 h post-injection followed by ovulation 4 h thereafter. However, mean values of the serum steroid hormones T, E_2 and DHP were lower during the off-season than peak season (Tan-Fermin et. al., 1999a). Egg production (20 eggs/g BW), fertilization (36%), hatching (20%) and larval survival (47%) rates were also much lower when gravid females were induced to spawn during the off-season than during the peak season (88 eggs/g body weight, 97%, 73%, and 95%, respectively; Tan-Fermin *et al*., 1997c).

Attempts to induce male catfish to spermiate and release milt by hormones (DHP, human chorionic gonadotropin, oxytocin) (JD Tan-Fermin, unpublished data) and pheromones (11ß-etiocholanolone-glucuronide, prostaglandin F2á) (LMaB Garcia, unpublished data) were unsuccessful. Hence, alternative methods to minimize the sacrifice of male catfish were pursued. An artificial seminal plasma was developed to immobilize sperm to conserve their energy. Milt diluted with the catfish artificial seminal plasma at 1:100 was activated with 0.6% NaCl to fertilize 5-10 g of ovulated eggs (Tan-Fermin *et. al.*, 1999b). Activating the milt with 0.6% NaCl increased the number of motile sperm and duration of sperm motility. By this method, milt obtained from one male can be used to fertilize eggs from three to four females.

Catfish broodstock were usually given fish by-catch (trash fish) alone or in combination with an artificial feed for nourishment. Since fish-by-catch is scarce and supply is unreliable, nutritionally adequate diets were developed as alternative food and tested in feeding trials to determine their effect on reproductive performance (Santiago and Gonzal, 1997). Catfish fed some of the diets had high relative fecundity, hatching rate, and number of 3-day-old larvae demonstrating that artificial diet alone can enhance reproductive performance and that fish by-catch is dispensable in the daily ration of the catfish.

Hatchery

Hatchery techniques were refined by improving the hatching efficiency of the eggs, determining the appropriate food for first-feeding larvae, and conducting studies on zooplankton density, weaning, stocking density and feeding rates.

To improve the hatching efficiency of catfish eggs, the best rinsing solution following dry fertilization, optimum stocking density and water hardness during incubation were determined. Fertilization and hatching rates were high when the fertilized egg mass were rinsed with solutions containing salt or tannin, or upon stocking the eggs at 2000 - 4000/1. Total hardness of the incubation water (0-400 ppm) did not seem to be a critical factor for hatching catfish eggs in a flow-through water system (JD Tan-Fermin and P Subosa, unpublished data).

The best food for first-feeding catfish larvae was determined by comparing the efficiency of selected live organisms (*Artemia* sp., *Brachionus calyciflorus, Chironomus plumosus, Moina macrocopa, Tubifex* sp.) and an artificial diet (39% protein) given at 25% of fish biomass. In two feeding trials, best growth was consistently observed in *Tubifex*-fed larvae, indicating that *Tubifex* sp. can be a partial or complete substitute for the more expensive *Artemia* (Duller-Evangelista, 1996). However, the lack of techniques for sustained mass production of *Tubifex* sp. limits its use as live food for catfish larvae on a commercial scale.

Catfish larvae fed newly hatched *Artemia* nauplii at 10 and 20 individuals/ml had significantly higher size, specific growth rate (SGR), and survival than those fed at lower prey densities of 0.5-5 individual/ml (Fermin *et al.*, 1995). Catfish larvae reared exclusively on a dry diet had significantly smaller body size, and lower SGR and survival than those given *Artemia* during weaning or on *Artemia* alone (Fermin and Bolivar, 1991). Four-day-old catfish larvae stocked at 50-150 individuals/ l showed comparable growth and survival (Fermin *et. al.*, 1995).

A feeding rate of 20% of body weight given twice daily was optimal for growth of Day 10 - 15 catfish fry when an artificial diet containing 40% crude protein was used. The same diet can be fed once daily at 5-10% to older fry (AC Fermin, unpublished data).

Nursery

Production of catfish fingerlings in the nursery was done by rearing the fry in fiberglass tanks and in net cages installed in 3-ton concrete tanks and 3000 m^2 ponds at different stocking densities for one month.

Twenty- to 25- day old catfish fry maintained with or without shelters in fiberglass tanks at 1 individual/l and 2 individuals/l both reached 3.5 cm total length. However, those stocked with shelters at 1 individual/l had higher survival than those reared at 2 individuals/l (AC Fermin, unpublished data).

Catfish fingerlings maintained at 200 and 300 had final total lengths of 4 cm and 5-6 cm when reared in tanks and ponds, respectively (AC Fermin unpublished data). Mean total lengths of 3 cm and 4 cm, acceptable sizes for stocking in the grow-out, can likewise be attained when fish were reared at 400-800 fry/m^2 in tanks and at 800-1200 fry/m^2 in ponds (R Bombeo *et al.*, unpublished data). The faster growth of fingerlings in ponds than in tanks was probably due to the abundance of zooplankton, the preferred food of catfish fry during the early stage, in the rearing water. Furthermore, survival rates were high when fry were grown in net cages suspended in either tanks or ponds.

Grow-out

SEAFDEC-formulated diets containing 19% (Diet 1) or 34.2% (Diet 2) crude protein (CP), commercial fish pellets with 28.9% CP (Diet 3), and a combination of blanched chicken entrails and rice bran containing 31.8% CP (Diet 4) were tested as grow-out feeds for catfish (E Coniza *et al.*, unpublished data). After 120 days of culture, fish fed Diet 2 showed the highest mean body weight (108.9 g), total length (23.3 cm), specific growth rate (2.85%), weight gain/day (0.88 g), apparent lipid retention (131.7%), and production (18.15 kg/25m^2). Fish on Diet 2 also had lower feed conversion ratio (2.5). Fish fed Diet 4 had the highest protein efficiency ratio (2.35) and whole body crude fat content (34.5%). Fish given Diets 3 and 4 had higher growth and production than fish fed Diet 1. Survival rates (67.7-81.2%) and results of sensory evaluation of the odor, flavor, and appearance of the flesh showed that these were not significantly different among the treatment groups.

Cost-return analysis on a per hectare per crop basis showed that catfish fed Diet 2 gave the highest net profit after payment of tax (P473,037), a return of investment (ROI) of 75% and lowest payback period of 1.3 years. Culturing catfish with Diets 4 and 3 resulted in similar ROI of 43%, while growing juveniles using Diet 1 was a losing investment.

African Catfish *Clarias gariepinus*

Based from the assessment of BFAR and SEAFDEC, African catfish farming in the Philippines is popular in Luzon, including the Bicol region, and some parts of Panay. Feeding experiments in the laboratory indicated that *C. gariepinus* consume a wide variety of live food, with high preference for shrimp and small fishes. Monitoring of fish catch and collection of African catfish proved that escapees in Laguna Lake can grow up to 12 kg. Examination of stomach contents of wild-caught *C. gariepinus* suggested that this species is omnivorous and can feed on almost any available food, especially fish and plant materials. Data indicate that the presence of African catfish in the lake can adversely affect the indigenous fish species in the wild and may contribute to biodiversity loss (AE Santiago and AC Gonzal, unpublished data).

EUS in Some Freshwater Fishes

The first confirmed outbreak of epizootic ulcerative syndrome (EUS) in the Philippines occurred in 1985 (Llobrera and Gacutan, 1987). EUS affected only some wild fishes in Laguna Lake such as the snakehead *Ophicephalus striatus*, Thai catfish *Clarias batrachus,* gouramis *Trichogater pectoralis* and *T. trichopterus,* white goby *Glossogobius guirus,* and climbing perch *Anabas testudineus.* The market value of both the wild and cultured fishes in the lake decreases whenever EUS-infected wild fishes are present.

Total bacterial counts of skin and muscle lesions increased with the severity of lesions in EUS-affected snakehead and Thai catfish (Lio-Po *et al*., 1992). Moreover, bacterial isolates were predominantly *Aeromonas hydrophila,* which, through injection, induce dermo-muscular necrotic lesions in fish. *A. hydrophila* isolated from normal, apparently normal, and EUS-affected catfish were all virulent to the catfish juveniles when injected intramuscularly (Leaño *et al*., 1996). However, only seven out of 16 extracellular protein (ECP) preparations induced dermo-necrotic lesions in the catfish, indicating a lack of correlation between virulence of *A. hydrophila* and ECP production.

Co-habitation with EUS-positive fish was a faster way of transmitting EUS in the snakehead than exposure to EUS-enzootic environment (Cruz-Lacierda and Shariff, 1995). Different modes of entry (intra-muscular injection, gastric gavage, fish food, and immersion of injured fish in water inoculated with the test bacteria) for A. *hydrophila* were tested, but only intra-muscular injection of at least 10^6 cfu/ml induced dermo-muscular necrotic lesions in *C. batrachus* (Lio-Po *et al*., 1996). In another study, *A. hydrophila* isolated from snakehead in the Philippines and *Aquaspirillum* sp., *Pseudomonas* sp., and *Streptococcus* sp. isolated from snakehead in Thailand were injected intramuscularly into healthy snakehead and catfish. Differences in the susceptibility of the two fish species to the bacteria were evident, with *A. hydrophila* inducing the most severe lesions in both species (Lio-Po *et al*., 1998).

Based on gross and histopathologic features, the developmental stages of dermal lesions in snakehead were characterized (Cruz-Lacierda, 1995). Histopathologically, all stages exhibited chronic, necrotic, and mycotic granulomatous inflammatory response to infection. A highly invasive, broad, branching, aseptate fungal hyphae were associated with all stages. Ultrastructural examinations showed that the fungal hyphae contained mitochondria with tubular cristae, which are morphologically consistent with Class Oomycetes. The stomach, spleen and kidney of fish with advanced stages of EUS also exhibited the mycotic granulomatous response to the infection.

Hematological changes in snakehead severely affected by the EUS include a significant decrease in hematocrit values and in serum protein and hemoglobin concentrations compared to those of normal and apparently normal fish (Cruz-Lacierda and Shariff, 1994). In addition, granulocyte counts were significantly higher among severely affected fish than in normal and apparently normal fish.

Viruses have also been associated with EUS. A rhabdovirus (65x175 nm) from EUS-affected snakehead was isolated in snakehead spleen cells (SHS). The virus induced dermal lesions or caused high mortality in young snakehead (Lio-Po, 1998). Related studies on mixed infection, histopathology, and viral protein characterization were likewise conducted.

Lake Ecology and Related Studies

Water quality, nutrients, and plankton in Laguna Lake

As part of a bigger collaborative project funded by the European Union to develop a scientific base for a sustained and rational management of Laguna Lake especially for fisheries and aquaculture, the Lake was monitored from 1995 to 1997. Four institutions collaborated to monitor water quality as well as nutrients and plankton, fish biota, sediments, and watershed. Data gathered were used in calibrating water quality models developed for the lake by two other collaborating agencies.

Data gathered by the SEAFDEC/AQD team showed that temperature, dissolved oxygen, pH, alkalinity, and total hardness in Laguna Lake are favorable to lake aquatic biota and comparable with conditions for fish culture in ponds (AC Gonzal, unpublished data). Because of its shallow depth (average depth = 2.8 m) and vast surface area (90,000 ha), the lake is subject to wind-driven mixing of water, which disturbs the sediment thereby causing its generally turbid condition. Soil erosion from the watershed also contributes to lake turbidity. Field and laboratory data confirm earlier reports that turbidity in the lake can be controlled naturally by allowing saltwater inflow from Manila Bay through the Pasig River, usually during the peak of summer. The generally high turbidity of the lake limits primary production and, when water clears up following saltwater intrusion, the next limiting factor is nitrogen (N). Results of high frequency samplings after a typhoon, during algal bloom or during saltwater intrusion demonstrated rapid changes in water quality and nutrient levels, and the succession of diatoms and blue-green algae in the plankton community. Overall, primary production in Laguna Lake is low compared with other lakes having similar nutrient levels.

Effect of N/P ratios on phytoplankton from Laguna Lake

Changes in phytoplankton communities in lakes may be influenced by the quality and quantity of nutrient inputs, and by the ratio of N and phosphorus (P) in the water. When natural phytoplankton from Laguna Lake were batch cultured at three different N/P ratios (2N:1P; 6N:1P; 12N:1P) with each ratio containing two levels of phosphorus (0.5 and 0.25 mg P/l), all cultures were dominated by members of Chlorophyceae and Bacillariophyceae (M Cuvin-Aralar, unpublished data). The N/P ratios did not influence the number of species. However, the Shannon-Wiener diversity index (*H'*) and Index of Evenness (*J'*) were significantly low at the highest N/P ratio, demonstrating that this level of nutrient enrichment has led to the dominance of a few species. The proximate composition of the phytoplankton harvests did not differ significantly among the N/P ratios, but crude protein as percentage of organic matter was significantly higher in phytoplankton cultured in the two higher N/P ratios. Moreover, Nile tilapia fed with the phytoplankton grown at the highest N/P ratio had significantly better growth than fish fed harvests from the two lower N/P ratios (M Cuvin-Aralar, unpublished data).

Growth of dominant algal species from Laguna Lake

Because of the algae's importance to the development of a fish model, studies on growth of the dominant algal species in Laguna Lake were conducted. Three algal species each representing the blue-greens, greens, and diatoms (*Microcystis aeruginosa, Pediastrum duplex* and *Cyclotella meneghiniana*) were isolated from lake water, grown in appropriate media, and established in axenic condition. In a study to determine optimum light intensity, highest growth of *Microcystis* was observed at a light intensity of 1000 lx; *Cyclotella* at 3200 lx and *Pediastrum* at 6400 lx (S Baldia, unpublished data). Moreover, experiments on the kinetics of nitrogen and phosphorus utilization using starved *Microcystis* cultures were conducted. Similar experiments on *Pediastrum* and *Cyclotella* are in progress.

Toxins in Microcystis aeruginosa

The role of toxins from the blue-green alga *Microcystis aeruginosa* in fish kills that sometimes occur in Laguna Lake has not been demonstrated. However, preliminary analyses showed that *Microcystis* harvested from Laguna Lake in 1996, 1998, and 1999 blooms were positive for mycrocystin (Fastner, personal communication). An ongoing study further identified and quantified the toxins in *Microcystis* at different stages of algal growth and determined the environmental conditions favoring blooms and toxin production (S Baldia, personal communication). Feeding trials will also be conducted to determine their toxic effects on fish.

Feeding ecology of cultured and wild fishes

Commercial feeds are used more often in the culture of Nile tilapia, especially during periods of high turbidity and low phytoplankton production in Laguna Lake. To optimize the benefits derived from this food source, a study was conducted to determine the feeding periodicity and daily ration of Nile tilapia in cages. Weights of stomach contents (expressed as percentage of body mass) were determined in tilapia juveniles obtained at 3-h intervals over a 24-h period and analyzed by the computer model MAXIMS (Richter *et al.*, 1999). The model predicted that larger fish (mean weight = 31.5 g) on natural food alone fed continuously from dawn to dusk, ingesting an equivalent of 5.1% of fish body weight. Smaller fish (mean weight = 9.8 g) had two distinct feeding periods within daylight hours, ingesting 13.7 % body weight equivalent. Fish (mean weight = 81.7 g) given supplemental feed once in the morning when water was turbid fed intensely until the feed ran out before mid-day after which ingestion of natural food took place later in the day. The fish ingested supplemental feed equivalent to 5.8% of body weight and natural food equivalent to 5.1% of body weight. The feeding periodicity of milkfish *Chanos chanos* Forsskal in pens was likewise studied (H Richter, unpublished data).

Unlike cultured tilapia that feed mainly on phytoplankton when the lake is clear and on detritus when turbid (H Richter *et al.*, 1999), wild fishes in Laguna Lake consume large amounts of other natural food items. The silver perch *Terapon plumbeus* were observed to feed on zooplankton, benthic crustaceans, benthic algae, fishes, and insects (M Koch *et. al.*, in press). Fishes and benthic organisms were important food components in silver perch sampled close to a fish pen, while zooplankton and insects were more important for the fish in open water. In the case of the Manila catfish (*Arius manillensis*), zooplankton was the major food source at both stations (M Koch, unpublished data). In addition, molluscs were important in the diet of *A. manillensis* in the open water while crustaceans were more important in fish near the pen. Other food components (fish, insects, detritus and others) were equally important in fish at both stations. Small *A. manillensis* (<100 mm SL) fed mainly on zooplankton, while larger fish (>200 mm) fed nearly exclusively on fish. The above results demonstrate that aquaculture structures (the pens) enhance the food spectrum of wild fishes by forming a substrate for epiphytic algae that attract other potential food items. The pens also provide sanctuary to wild fishes and benthic organisms. Results also revealed that there is little competition for natural food sources between the wild and cultured fishes in Laguna Lake.

Fish feeds and their efficiency

About 50% of the cage operators and 30% of the pen operators in Laguna Lake use commercial artificial feeds in growing fish. It was estimated that fish farmers in the lake use about 1,339 tons of commercial artificial feeds/yr. Assuming the feeds contain 30% crude protein and about 40% of nitrogen intake is retained in fish, the amount of nitrogen released to the lake due to feeding is estimated at 38.6 tons nitrogen annually. This is much lower than the estimated annual load of total Kjeldahl nitrogen from the watershed inclusive of two typhoons and occurrence of saltwater intrusion. However, improved management of feeding can further reduce nitrogen load due to feeds.

Under controlled conditions, the efficiency and metabolism of two commercial feeds commonly used by fish farmers in Laguna Lake were determined in feeding trials using growth measurements, feed analyses, comparative carcass analyses, and respirometry to construct energy budgets. Growth of tilapia increased as feeding rate increased from 2.5% of fish body weight to 5%, but feed efficiency tended to decrease. Metabolizable energy was higher for the control diet than for the commercial feeds. Results of the bioenergetics approach of examining the response of the fish to the test feeds agree with the growth measurements. Tilapia given commercial feeds to satiation performed similarly, but fish given a standard laboratory diet had superior performance, indicating room for improvement for the commercial feeds (CB Santiago, unpublished data).

Future Activities

Continuing research studies on freshwater fishes will be completed and, if possible, commodities for research will be diversified to include other indigenous food fishes as well as aquarium fishes and prawns. The limnology of Laguna Lake will be further studied, with emphasis on toxic and hazardous substances in the water, sediment, and the food chain.

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Research on Crustaceans

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Abstract

Crustacean research at the SEAFDEC Aquaculture Department in 1994-1999 focused on two commercially important species: the tiger shrimp *Penaeus monodon*, and the mud crab *Scylla serrata.* Research on tiger shrimp dealt with broodstock development, refinement of shrimp culture systems, and health management. Broodstock development aimed to develop a technology for a sustainable supply of good quality captive broodstock through selective breeding. Initial efforts identified polymorphic stocks with low disease prevalence as base population and development of screening protocol to assess their health status using non-lethal procedures. Improvement of reproductive performance through studies on nutritional requirements and sperm quality was also conducted. To refine shrimp culture systems, emphasis was placed on the physiological requirements of tiger shrimp, including salinity adaptation and osmoregulatory capabilities, improvement of formulated diets, and development of culture systems that are compatible with the environment. In shrimp health management, disease problems in various culture systems with emphasis on luminescent vibriosis and some viruses were defined. The quality of hatchery-reared post-larvae compared with those caught in the wild was assessed.

Research on the mud crab *Scylla serrata* started late in 1996. Studies were conducted on all culture phases: broodstock, hatchery, nursery, and grow-out. Broodstock development emphasized the development of an appropriate maturation system and a suitable maturation diet. The influence of eyestalk ablation and dietary history on reproductive performance was assessed. The completion of the mud crab life cycle in captivity was attained in 1997 when spawns from pond-reared females were further reared to produce second-generation broodstock. In the hatchery, larval rearing based on previous trials on feeding schemes, salinity tolerance, and water conditioning hastened progress in larviculture and formed the basis for large-scale production of mud crab juveniles. Research has shown the feasibility of direct stocking of crab megalopae in hapa nets in nursery ponds. In grow-out culture, studies have been done on the effects of stocking density, monosex culture, and practical diet development for the mud crab. Practical diets, formulated using local materials as ingredients, with or without vitamin and mineral supplementation, were found to be economically feasible for mud crab culture in ponds. Grow-out culture in mangrove pens appears to be an environment-friendly alternative to the usual open pond culture system.

Introduction

Research on crustaceans at the SEAFDEC Aquaculture Department in 1994-1999 focused on two species of commercial importance: the tiger shrimp *Penaeus monodon*, and the mud crab *Scylla serrata*. Studies on the tiger shrimp were conducted on three major areas: broodstock development, refinement of culture systems, and health management. Studies on the mud crab were conducted on all phases of culture: broodstock, hatchery, nursery, and grow-out.

Studies on the Tiger Shrimp *Penaeus monodon*

Research on the tiger shrimp aimed to develop a sustainable supply of good quality broodstock, ecologically sound pond grow-out management techniques, and environmentally sound methods of health maintenance.

Broodstock development

Preliminary studies leading to the development of a selective breeding program for *P. monodon* was initiated. L de la Peña (personal communication) compared the genetic diversity between wild and captive shrimp populations in the Philippines using a randomly amplified polymorphic DNA technique. Wild shrimps came from different regions: Palawan, Panay, Negros, and Quezon while cultured shrimps came from Antique and Negros provinces. Wild shrimps were found to be more polymorphic (66-71%) than cultured shrimps (54%), with Palawan samples showing the most genetically diverse population and Negros the least diverse. Palawan is a pristine area with extensive mangroves and no major aquaculture activity while Negros has severe mangrove loss and highly intensive shrimp culture systems. It appears that biological diversity in tiger shrimp populations is related to the status of mangroves and intensity of culture systems.

Further, JH Primavera *et al.* (personal communication) compared the prevalence of infectious hypodermal hematopoetic necrosis virus (IHHNV) in various wild populations of *P. monodon* and related this with shrimp culture intensification and mangrove status. Lower viral incidence in wild shrimp was found in sites with primary mangroves and no major shrimp farms, whereas higher levels were found in areas with intensive farms and severely degraded mangroves. Wild populations had a lower overall IHHNV incidence of 51% compared with 100% among F_2 and F_3 generations *P. monodon.* In another study, Primavera and Quinitio (2000) observed some morphological abnormalities associated with the runt deformity syndrome (RDS) among an F_3 generation of *P. monodon* (>40 mm CL). RDS was characterized by a high carapace length-to-abdominal length ratio and a low carapace width-to-1st abdominal segment width ratio. Examination of external abnormalities and evaluation of morphometric ratios may complement existing protocols for disease and growth rates in shrimp breeding program.

Meanwhile, to improve their reproductive performance, studies on nutritional requirements and sperm quality of captive broodstock were conducted. Pangantihon-Kuhlmann *et al.* (1998) evaluated the effect of dietary supplementation with various levels (0, 50, 100, 150, 200 ppm) of astaxanthin, a major pigment in shrimps, on reproductive performance. A 50 ppm astaxanthin supplementation improved the fecundity; however, egg hatch rates and larval metamorphosis did not vary among levels tested.

Quinitio and Parado-Estepa (1995) found that sperm quality improved in captive males of at least 65g body weight and recommended this to be the minimum size requirement for broodstock. Regardless of size, tank-held males showed a decline in sperm quality after 35 days. Eyestalk ablation of males had a negative effect on sperm quality and produced more abnormal (deformed body, spikeless, bent spike or a combination of these characters) sperm, although the sperm counts did not differ.

Refinement of shrimp culture systems

Studies to refine existing shrimp culture systems were focused on salinity adaptation and osmoregulatory capability of juvenile tiger shrimp, improvement of shrimp grow-out diets, and development of ecologically sound pond management practices.

The ability of *P. monodon* to adapt to changes in salinity was studied by Parado-Estepa (1998). *P. monodon* postlarvae and juveniles were transferred from ambient salinity to salinities of 4-50 ppt at temperatures of 22 C, 28 C and 33 C. The ability to tolerate a wide range of salinities improved with age and survival, but was generally lower at 33°C. Another study showed that osmolality, sodium and chloride concentrations in the hemolymph were efficiently regulated at 8-32 ppt at all temperatures tested. However, loss of ability to osmoregulate was observed when *P. monodon* juveniles were exposed to extremes of salinity and temperature (i.e., 4 ppt and 22 C, 40 ppt or higher and 33 C).

Several studies were conducted to improve formulated shrimp diets for grow-out. Millamena *et al.* (1996, 1997a, 1998, 1999b) established the quantitative requirements of *P. monodon* for ten essential amino acids, which is crucial in optimizing growth and feed efficiency and in developing cost-effective shrimp diets. Peñaflorida (1999) determined the phosphorus requirement of *P. monodon* by dietary supplementation with various levels of phosphorus, P (0, 0.5, 1.0, 1.5, 2.0 ppm). Highest weight gain was obtained at 0.5 ppm P, which represents the optimum supplementation level. At this level, P pollution from shrimp culture effluents may be minimized.

Golez and Millamena (1998) studied the utilization of processed soybean meal (trade name: HP 300) as an alternative source of protein for shrimp feeds. Processed soybean meal can replace 6-9% of fishmeal, 5% of shrimp head meal, and 4-6% unprocessed soybean meal in the diet of *P. monodon* juveniles. Millamena and Triño (1997c) developed a low-cost diet using mostly locally available materials. Local fishmeal (*Thunnus sp*) and cowpea meal (*Vigna ungiculata*) were the main sources of dietary protein in a diet without vitamins or mineral supplements. The low-cost diet can effectively support pond production of *P. monodon* at 1.9-2.6 tons per ha at stocking densities of 5-10 per m^2 and alleviates the high cost of shrimp grow-out feeds.

Bautista-Teruel and Subosa (1999) evaluated the effects of processing conditions, heating time and temperature, on urease activity (UA) levels and on nutrient quality of soybean meal (SBM). Protein quality of SBM in terms of amino acid content was not significantly affected by processing condition. Heat treatment for SBM was adequate at 120 C for 20 min. Diets processed under this condition had the highest growth and survival among shrimps fed this diet. UA was minimal at 0.32 ppm compared with 20-25 ppm in diets with unprocessed SBM.

Shrimp health management

Studies on health management in culture systems focused on common disease problems in cultured shrimps: luminescent vibriosis and viruses. Lavilla-Pitogo *et al.* (1998a) reported the following observations on luminous bacterial (LB) disease: 1) the underlying cause of mortality are the vibrios, mainly *Vibrio harveyi*; *2)* the mode of infection is oral with the hepatopancreas, a major storage organ for nutrients, as the target organ; 3) vibrios are attracted to chitin, a component of crustacean exoskeleton; 4) vibrios exhibit a wide tolerance to environmental parameters compared with its host *P. monodon,* making control of vibrio infection by environmental manipulation difficult; and 5) exposure of post-larvae to luminous *Vibrio* levels equal to or greater than 10^3 colony forming units (cfu) per ml in the rearing water can cause mass mortalities. Quantification of the bacterial flora of affected shrimps showed a high luminous bacterial population of 9.0 x 10^4 cfu per hepatopancreas (hp) compared with 70 cfu per hp of healthy shrimps (Leaño *et al.*, 1998). They suggested some preventive measures against *Vibrio* infection as follows: 1) since the growth of vibrios is suppressed in a dry pond bottom, thorough pond drying should be adopted as part of pond management protocol; 2) the use of reservoirs to reduce luminous bacterial population in a water supply source by sedimentation followed by disinfection with chemicals such as hypochlorite.

Studies were conducted to understand microbial interactions in the shrimp hatchery (Lavilla-Pitogo *et al.*, 1998b). These studies showed that the natural microflora associated with diatoms, *Chaetoceros* and *Skeletonema,* are potential sources of bio-control agents. In another study, the bacteria, *Pseudomonas* spp, was shown to possess vibriolytic activity (Dalisay, 1999). To develop environmentally sound methods for disease control, Lavilla-Pitogo and Paner (1999) attempted to use probiotics or bioaugmentation implements that are available commercially. Probiotic treatment involves the addition of benign bacteria through the feed to alter shrimp gut microflora or as water and soil conditioner to create a healthy environment. Variable results were obtained with commercial probiotics due to factors like the lack of information regarding probiotics' biological components, mode of action, and conditions under which they may be effective, and loss of viability during transport and storage.

E Cruz-Lacierda (personal communication) examined viral diseases in *P. monodon* postlarvae and broodstock. Major viruses present in shrimp postlarvae were monodon baculovirus (MBV) and hepatoparvolike virus (HPV) with infection rates of 32% and 30%, respectively. These viruses were also detected among *P. monodon* broodstock, in addition to IHHNV and lymphoid organ baculovirus (LOW). Further studies to compare the infection rates of MBV and LB in hatchery-reared and in wild-caught shrimp postlarvae were conducted. Infection rates for both MBV (23%) and LB (79%) were significantly higher in cultured postlarvae (4% and 40%, respectively).

Another disease detected by Lavilla-Pitogo *et al.* (1999) in tiger shrimp postlarvae was the swollen hind gut syndrome manifested by enlargement and distention of the hind gut folds and its junction with the mid gut. Disease prevalence ranged from 8 to 12% of yearly batches examined. Postlarvae affected by the disease have high mortality rates and exhibited wide size variation within batches, making these postlarvae unsuitable for culture in grow-out ponds.

Studies on the Mud Crab *Scylla serrata*

Research studies on mud crab aimed at developing sound and reliable technologies on all phases of culture to promote consistent spawning and hatching of good quality larvae, increase survival and production of crablets, and improve pond yield.

Broodstock development

Good quality eggs and larvae are produced by broodstock that are housed in optimal living facilities and given a suitable diet. In mud crab broodstock development, emphasis was placed on developing an appropriate maturation system and a suitable maturation diet. The maturation system consisted of 10-m^3 circular concrete tanks provided with flow-through seawater supplied in an upwelling flow, sand substrate, and a shelter per female. Females were stocked at a low density of 1 per m^3. Multiple re-maturation and spawning, usually two to three times per female, are possible under this scheme. Using this maturation system, studies to develop a suitable maturation diet for *S. serrata* were conducted by Millamena and Quinitio (1999a). A combination diet of natural food (mussel meat and fish by-catch) and a SEAFDEC-formulated diet gave more consistent maturation and spawning of good quality eggs and larvae. The influence of eyestalk ablation on reproductive performance was further studied. Eyestalk ablation shortened the latency period but did not improve reproductive performance. The technique may be used when there is an immediate need for seeds in mud crab hatcheries. Studies to compare the reproductive performance of pond-reared females with those caught in the wild showed that rearing broodstock on a defined diet in ponds improved their reproductive performance (Millamena and Quinitio, 1997b). Completion of the mud crab life cycle in captivity was attained in 1997 when spawns from pond-reared females grew and were reared in ponds to produce the second-generation broodstock.

Larval rearing

The major bottleneck in crab culture is low and inconsistent survival of larvae. In the hatchery, larval rearing based on previous trials on feeding schemes, salinity tolerance, water conditioning schemes, and health management hastened progress in larvi-culture and formed the basis for large-scale production of mud crab juveniles.

The major food items and feeding density used in larval rearing of *S. serrata* are: *Brachionus plicatilis* at 10-15 individuals per ml and *Artemia sp* at 1-5 individual per ml. The suitability of alternative feeds was tested, which aimed at reducing feed costs. A micro-particulate larval diet developed by SEAFDEC can be used as partial substitute, thereby reducing dependence on natural food. Larval survival (9.3-10.5%) in this diet was improved compared with natural food alone (3.3%). Toledo *et al.* (1998) has shown that mixed zooplankton, *Acartia* and *Pseudodiaptomus* nauplii that are normally found in brackishwater ponds, can be used as supplement for rotifers.

Major morphological changes during larval development were characterized through light and electron microscopy. The major changes observed by G Loya-Javellana (personal communication) were setation, sclerotization, appearance and development of the gland filter, gastric mill and cardiac chamber. The implications on larval feeding ability and size-specific feeding regimes are: feeding may not be critical at the early zoea-1 stage and complicated feed types are suitable only at zoea-3. Parado-Estepa and Quinitio (1997) did studies to determine the optimum salinity levels for the zoeal stages and found that *Scylla sp.* larvae can tolerate a wide salinity range of 20-32 ppt. Gradual lowering of seawater salinity from ambient to 25 ppt starting at late zoeal stages, zoea-4 or zoea-5, until the megalopae stage improved larval survival. Further studies were conducted on water conditioning schemes. Aging, chlorination, and dechlorination with prophylaxis treatment were found to be suitable methods of water conditioning and were used as components of the larval rearing protocol.

Studies on health management in the hatchery conducted by Lavilla-Pitogo *et al.* (1998c) have shown that larval mortalities are mainly due to systemic bacterial infection. The major causative agent is the vibrios and all inputs to hatcheries such as spawned eggs, natural food, and untreated seawater supply are possible sources of infection.

Quinitio and Parado-Estepa (2000) conducted studies on simulated transport of mud crab zoeae and megalopae. They found that the optimal loading densities were: 10×10^3 individuals per liter for zoeae and 50 individual per liter for megalopae. These densities should be used during transport for subsequent stocking in nursery ponds.

Nursery rearing

Studies on nursery rearing, from megalopae to crablet, focused on nutrition and feeds, effects of stocking density, shelter and substrate requirements. Tank studies under controlled conditions and nursery pond studies in hapa nets were conducted.

E Quinitio *et al.* (personal communication) assessed the effect of various natural diets; *Acetes, Artemia,* mussel and snail, on survival and growth of crab instar-1. Specific growth rate of crablets fed *Acetes* was significantly higher compared with other diets. Survival after 30 days did not significantly differ among treatments. Large-scale production of crab megalopae using the best feeding and management schemes defined in small-scale experiments resulted in survival of 0.4 to 50% (zoea-1 to megalopae) and 19 to 47.3% (megalopae to instar-2). Subsequently, hatchery-produced megalopae have been cultured in ponds of private hatchery operators (Quinitio *et al*., 1997)

G Loya-Javellana (personal communication) examined the shelter and substrate preference of *S. serrata* juveniles. Larger juveniles, 10-14 g body weight, preferred net shelters. Gravel may replace mud as substrate for rearing smaller juveniles while sand may replace mud for rearing larger juveniles. Rodriguez *et al.* (1998) have shown the feasibility of direct stocking of crab megalopae in hapa nets in nursery ponds. Megalopae were stocked at 10, 20, and 30 individuals per m^3 in 20 m^2 hapa nets provided with dry coconut fronds as shelter and cultured for 30 days. Survival rates of 35.6-53.3% and mean final body weight of 2.9-3.4 g did not significantly differ among treatment groups. Growth rates in ponds were found to be 6-10 times higher than in tanks, demonstrating that direct stocking of megalopae in ponds can circumvent problems of inadequate nutrition and cannibalism.

Grow-out culture

Grow-out culture studies examined the effects of stocking density and monosex culture. The development of practical diets for the grow-out was also attempted. Triño *et al* (1999) evaluated the effects of stocking density and monosex (male or female) culture of *S. serrata* stocked at 0.5, 1.5 and 3.0 per m^2 in ponds. All-male culture gave significantly higher mean body weight (410-475 g) than all-female culture (325-332 g). Both male and female monosex cultures had high net revenue and return on investment of more than 100%. Stocking crabs at a density of 0.5-1.5 individuals per m^2 was economically viable, environmentally sound, and profitable.

Pond production of mud crab fed a formulated diet made of local materials as ingredients, with or without vitamin and mineral supplementation, was compared with trash fish diet as control. Growth of crabs fed diet with vitamin supplementation was similar to crabs fed trash fish but significantly better than those fed without vitamin supplements. The economics of feeding a formulated diet may outweigh the greater growth obtained with trash fish and can save on costs of storage equipment and electricity (Triño *et al*., 1998).

Mud crab farming in net pens or enclosures in mangroves was evaluated as an alternative to pond culture. Triño and Rodriguez (1998) showed that a stocking density of 0.5-1.5 individuals per m^2 gave survival of 30-52% and final body weight of 296-350 g. This culture system demonstrates the viability of an environment-friendly farming system.

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Research on Molluscs and Seaweeds

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Abstract

This paper reviews the progress of mollusc and seaweed research at SEAFDEC/AQD from 1995 to 1999. Because of the pressing need for seedstocks for stocking, research on the donkey's ear abalone, *Haliotis asinina* focused on the development of seed production and culture techniques. To improve the spawning performance and egg/larvae production of captive broodstock studies on reproductive biology, management of broodstock and development of diet were conducted. Studies to refine techniques for post-larval settlement and metamorphosis and development of nursery rearing techniques were carried out to increase production of abalone juveniles. An artificial diet has been developed to enhance growth rates of juveniles during nursery as well as grow-out. However, since long-term use of artificial feeds did not favor the growth and survival of abalone during grow-out culture in tanks due to difficulties in maintaining water quality, sequential feeding with artificial diets and then seaweed *Gracilariopsis bailinae* seemed more practical.

Broodstock development and seed production were the major research areas for the window-pane oyster *Placuna placenta.* Gonad development was enhanced by feeding a mixture of high densities of *Isochrysis galbana* and *Tetraselmis tetrahele* at a 3:1 ratio. *P. placenta* larvae reared with *Isochrysis* as feed showed the best growth and survival. Settling stage was reached after 14 days of rearing. A salinity of 34 ppt was optimal for larval survival. Poor growth and survival of larvae was observed at low (10 ppt) and high salinity (40 ppt) levels. Re-stocking of immature adults and juveniles was conducted in a depleted coastal bed to evaluate the potentials for recruitment of the window-pane oyster. After 91 days, a survival rate of 51% was observed among immature adults. No juveniles survived after re-stocking.

Studies on seaweeds focused on three economically important genera of red algae: (1) *Gracilaria,* (2) *Gracilariopsis,* and (3) *Kappaphycus.* These studies are in recognition of *Gracilaria* and *Gracilariopsis* as agarophytes and *Kappaphycus* as carrageenophyte having significant roles in the seaweed industry. Research studies therefore aimed to optimize culture techniques for and to develop environment-friendly aquaculture of these seaweeds. Optimization of biomass production was attempted by manipulating the nutrient environment, biomass density, the proportion of harvested biomass, and crop quality for conversion to agar and carrageenan. The use of *G. bailinae* as a bio-filter focused on the capacity of the seaweed and its agar to sequester heavy metals like cadmium copper, lead

and zinc after exposure to various concentrations of these metals. Likewise, excess levels of nitrogen and phosphorus in a finfish broodstock tank with re-circulating water were reduced, demonstrating the efficiency of the seaweed as a bio-filter in aquaculture. Eco-physiological studies of *Gracilaria changii*, *G. coronopifolia*, *G. firma*, and *G. bailinae* involved the mass production of spores *in vitro* as a possible source of seedlings for outplanting. A socioeconomic survey of *Kappaphycus* culture in the Philippines revealed that, although expensive, deep-sea farming of *K. alvarezii* using the multiple raft long-line technique was more productive and profitable than the traditional mono-line or the popularly practiced hanging long-line technique.

Introduction

Research on the donkey's ear abalone *Haliotis asinina,* window-pane oyster *Placuna placenta*, oyster *Crassostrea* spp., and green mussel *Perna viridis* was recommended during the Seminar-Workshop on Aquaculture Development in Southeast Asia (ADSEA) in 1994. However, during the last five years, mollusc research focused mostly on abalone. Abalone hatchery production is still limited by low post-larval settlement. Therefore, research studies centered on the refinement of hatchery and nursery techniques to increase the production of juveniles for grow-out culture. Since abalone are known to be slow-growers, probably due to the relatively low protein content (ca. 15-17 %) of the seaweed (*Gracilaria bailinae*) they eat, development of artificial diets aimed to improve growth rates and to replace seaweeds as a major food source. Refinement of hatchery techniques and rehabilitation of depleted beds by searanching or re-stocking are major concerns for the window-pane shell, *P. placenta* research.

Seaweed research focused on *Gracilaria* and *Gracilariopsis* spp., and *Kappaphycus alvarezii.* Studies optimized culture techniques for biomass production and developed environment-friendly culture protocols for these seaweeds. Eco-physiological studies of *Gracilaria* spp. involved the mass production of spores *in vitro* as a possible source of seedlings for out-planting. A socioeconomic survey compared the cost-effectiveness of the different culture techniques and determined the most applicable and most profitable culture method for seaweed farmers.

Molluscs

Donkey's Ear Abalone Haliotis asinina

Breeding

Histological observations of gonad sections from wild abalone adults showed that mature individuals were present only from January to April and from July to December (Capinpin et al., 1998). During the other months of the year (April, May, June), animals of both sexes have immature gonads or at a pre-proliferative stage. Maximum ripeness in both sexes was observed during October. The smallest wild-caught individual with mature gonad measured 41 mm in shell length (SL) while hatchery-bred adults attained first sexual maturity at 35 mm SL.

Abalones have an asynchronous spawning pattern based on their wide range of gonad bulk index (GBI), a measure of the degree of reproductive synchrony within a given population (Capinpin *et al*., 1998). Attempts to artificially induce spawning of captive *H. asinina* broodstock by desiccation, thermal shock treatment, ultraviolet-irradiation of seawater, and hydrogen peroxide immersion have not been successful (Capinpin and Hosoya, 1995). However, spontaneous group-spawning of tank-held broodstock occurred year-round (Fig. 1, Fermin et al., in press a). With the end-view of controlling

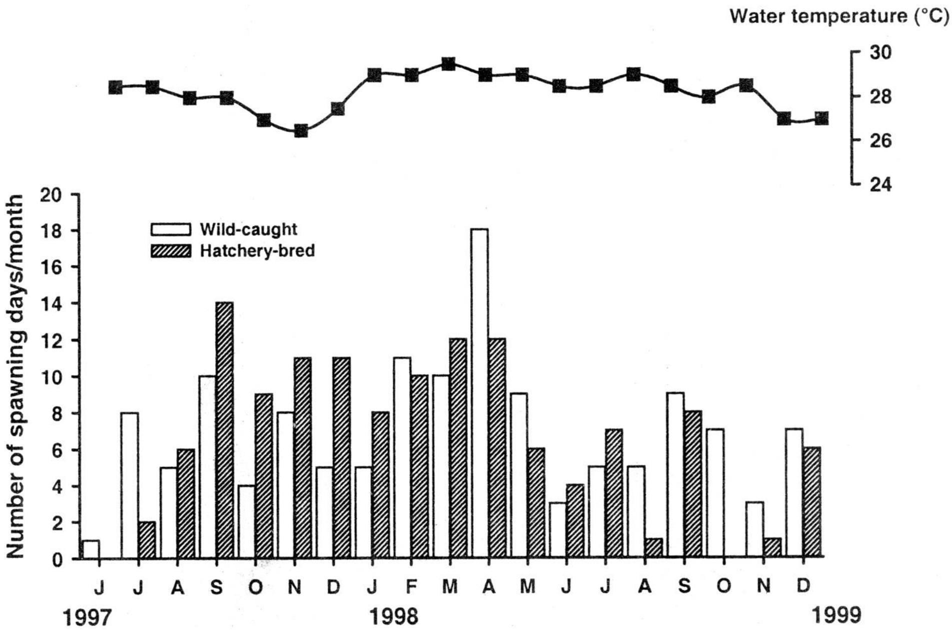

Fig. 1. Frequency of spontaneous spawning in *Haliotis asinina* held in tanks (Data from Fermin *et al.*, In press)

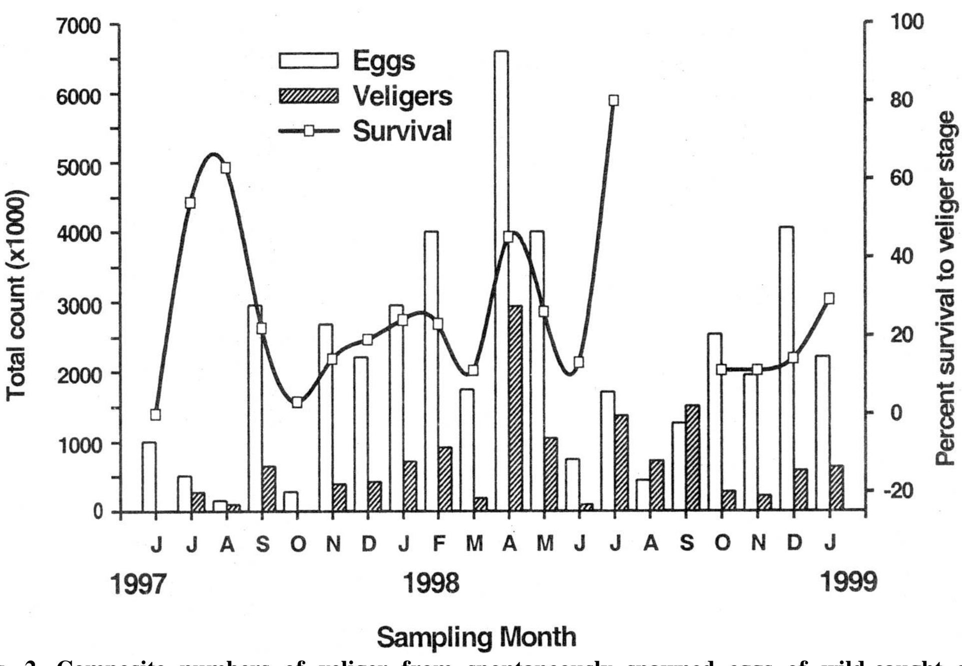

Fig. 2. Composite numbers of veliger from spontaneously spawned eggs of wild-caught and hatchery-bred abalone broodstock held in tanks. Asterisk (*) above bar means percent survival was not determined as veliger mixed with eggs during collection (Data from Fermin *et al.*, In press)

hatchery operations and maximizing larval production, optimal sperm concentration is important. For *H. asinina,* from $5x10^3$ to $1x10^5$ sperm per ml is required for maximal egg fertilization and normal trochophore development (Encena *et al*., 1999).

Potential fecundity or the total number of ripe oocytes of hatchery-bred females (size range: 56-71 mm SL) ranged from 6,000 to 12,000 oocytes per g body weight and it increased with body size (Fermin *et al*., in press a). In contrast, instantaneous fecundity or the total number of eggs spawned was higher (8,000 eggs per g body weight) in smaller females than in larger individuals (2,500 eggs per g body weight; Fig. 2). These results indicate the efficiency, in terms of lesser food consumption, of using younger (and smaller) females in the hatchery.

Hatchery-bred abalone have short spawning intervals that ranged between 15 and 30 days (Capinpin *et al*., 1998, Fermin *et al*., in press a). Younger female broodstock spawn more frequently than older females (Fermin et al., in press a). The short re-maturation period was attributed to sufficiency of food and optimal rearing conditions in captivity. Over a 20-month period, spontaneous mass spawning in tanks showed similar spawning frequency of 6 and 7 times per month for wild-caught and hatchery-bred broodstock, respectively (Fermin et al., in press a).

Evaluation of artificial feeds to replace partly or completely the seaweed *G. bailinae* as major food source for abalone was conducted with the end-view of improving the reproductive performance of captive broodstock. Spawning frequency of abalone fed artificial diets did not differ significantly with abalone fed seaweeds (Bautista-Teruel, in press). However, fertilization rate and spontaneous fecundity were higher in abalone fed a combination of artificial feeds and seaweeds than those singly fed either of the feeds.

Seed production

Studies to refine existing techniques of post-larval settlement and metamorphosis were conducted. Abalone settlement refers to the permanent attachment of larvae to a suitable substrate after shedding the velum to complete metamorphosis. Diatoms, preferably *Navicula* and *Nitzschia,* were cultured on settlement plates several days prior to stocking. "Hardiflex" boards (made of combined fiberglass and cement) as substrate materials for diatom attachment harbored the highest diatom (*Navicula* sp.) population (RSJ Gapasin, personal communication). Lowest counts were obtained from corrugated sheets, which is commonly used as a plate substrate for post-larval settlement. For *Nitzschia,* plexiglass boards had the highest cell counts while canvas the lowest. In terms of cell density (per cm^2), *Navicula* was higher than *Nitzschia*

A 24-h photoperiod significantly induced higher survival (12%) of metamorphosed larvae than did larvae at different light-and-dark periods (Fermin *et al*., in press b). Post-larvae held at 24-h darkness had the lowest or zero survival after 10 days of culture (Fig. 3). Oxygen depletion caused by diatom respiration and larval consumption may have caused heavy mortalities in larvae held in total darkness. Survival of metamorphosed larvae was inversely related to stocking density. A 12% survival rate was obtained at a stocking density of 100 larvae per l and was significantly higher than larvae stocked from 200 to 1000 larvae per l (Fermin *et al*., in press b).

The type of settlement substrate affected the survival of metamorphosed larvae. Corrugated polyvinyl chloride (pvc) plates filmed with a combination of epiphytic diatoms and mucus secreted by grazing abalone juveniles induced higher settlement and survival rates among metamorphosed larvae than ordinary diatom-filmed or clean pvc plates (Fermin *et al*., in press b).

After 60 days on pvc plates coated with epiphytic diatoms and mucus, early juveniles attained

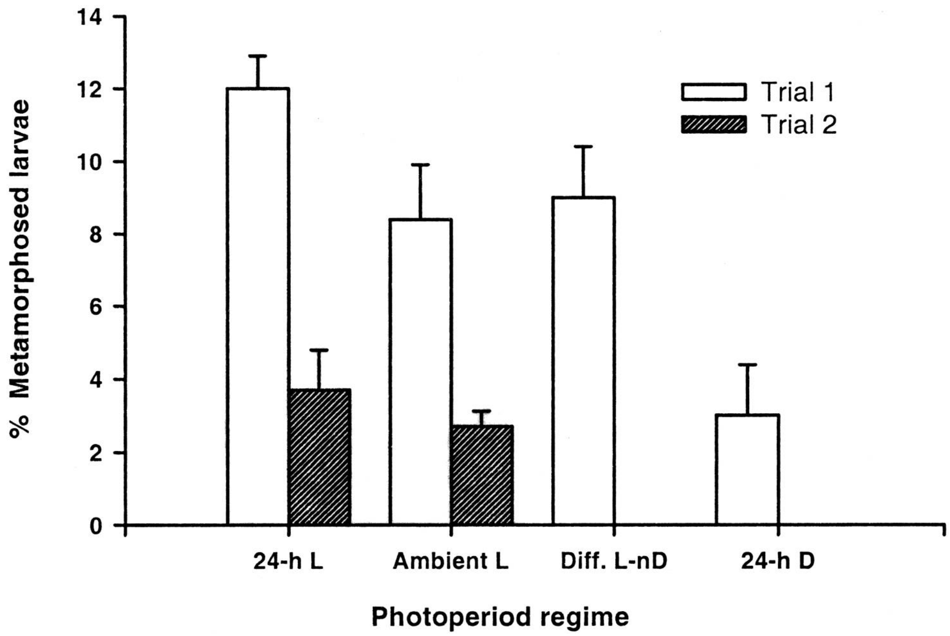

Fig. 3. Composite numbers of veliger from spontaneously spawned eggs of wild-caught and hatchery-bred abalone broodstock held in tanks. Asterisk (*) above bar means percent survival was not determined as veliger mixed with eggs during collection (Data from Fermin *et al.*, In press)

sizes ranging from 5 to 10 mm SL. At this size, weaning of juveniles on seaweed *G. bailinae* did not hamper their growth and survival, which appeared similar to those on an extended feeding on diatoms for 15 days (Fermin et al., in press b). Growth and survival of juveniles reared at varying stocking densities ranging between 183 and 687 individuals per m^2 in perforated plastic baskets did not vary significantly. Juveniles grew at daily growth rates of 170-181 μm and 54-64 mg to attain a final body size of 32-33 mm SL and 6.7-7.9 g body weight with a 96-99 % survival rates during 120 days of culture (Fermin *et al.*, in press b).

Abalone nursery culture in outdoor tanks proved better than indoor. Outdoor tank-reared juveniles had faster growth rate at 170 mm and 65 mg per day compared with juveniles reared indoors at daily growth rates of 111 mm and 35 mg per day (Fermin *et al.*, in press b). Higher growth rates of juveniles reared outdoors were due to higher feeding rates (26-33% per day) than juveniles reared indoors (14-18%) during the first 44 days of culture. After 65 days, juveniles reared in outdoor tank attained a final body size of 28 mm SL and 5 g body weight, which were significantly higher than abalone reared in indoor tanks with 24 mm SL and 3 g body weight. However, survival rates of 98-100% did not differ between groups.

Grow-out culture

Culture of juvenile abalone (25-30 mm SL) to marketable-size (50-60 mm SL, 40-55 g body weight) is carried out within 180-290 days in tanks or in sea cages using seaweed as feed. Although artificial diets promoted the best abalone growth rates during the first 90 days, its long-term use did not sustain culture up to marketable size (Capinpin and Corre, 1996). Abalone fed seaweed *G. bailinae* in excess maintained growth over an extended period until 360 days. The red alga *Kappaphycus alvarezii* was not suitable as feed for abalone.

Table 1. **Daily feeding rates of various sizes of abalone *H. asinina* on seaweed *G bailinae*[a] (Capinpin *et al.*, 1999)**

Shell length (mm)	Body weight (g)	Feeding rate (% body weight per day)[b]
16-20	0.8-1.7	35-40
21-25	1.7-3	30-35
26-30	3.1-6	25-30
31-35	6.2-9	20-25
36-40	10-15	15-20
41-45	16.5-21	12-17
46-50	22.5-30	10-15
51-55	35-45	8-12
56-60	50-60	6-10
>61	>65	5-9

[a]Fresh weight basis.
[b]Calculated as (amount of feed consumed/biomass)/time in days, usually every 7 days.

Density-dependent growth of abalone reared in sea cages (Capinpin *et al.*, 1999) and in tanks has been demonstrated (Fermin and Buen, submitted manuscript). During the first 150 days of culture in sea cages, abalone juveniles of 20 mm initial SL and stocked at 100 per m^2 grew to a size of 45 mm SL (Capinpin *et al.*, 1999). Stocking density was reduced to 40 per m^2 during final rearing to 60 mm SL within 180 days. Generally, smaller juveniles had higher daily feeding rates (DFR) than larger individuals so that a 16-20 mm-juvenile had a DFR of 35-40% while a 41-45 mm- individual can feed only as much as 12-17% of their body weight (Table 1, Capinpin *et al.* 1999).

Under tank conditions, abalone stocked at 25-50 per m^2 grew faster than those held at 100 per m^2 (Fermin and Buen, submitted manuscript). From an initial shell length of 32 mm, abalone stocked at 25 and 50 per m^2 grew to a final size of 60 mm SL and 59 g BW after 290 days of culture.

Feed development

To improve the growth rate of juvenile abalones, practical diets were formulated to contain graded levels (22, 27, and 32%) of animal and plant proteins and compared with natural food using seaweed *G. bailinae* having 17% crude protein as control feed (Bautista-Teruel and Millamena, 1999). Abalone fed diets with graded levels of animal and plant proteins had higher weight gain, daily growth rates, and specific growth rates compared to those fed seaweed. A feed conversion ratio (FCR) of 1.5-2.3 was obtained among animals fed artificial diets, which were higher among seaweed-fed abalone. The optimum protein level for juvenile abalone was 27% with an energy level of 3,150 kcal per kg metabolizable energy. In addition, preliminary results of artificial feeding to improve the reproductive performance of abalone broodstock indicated no significant difference in the spawning frequency of abalone fed the diets or seaweed (M Bautista-Teruel, personal communications). However, instantaneous fecundity and fertilization were higher in the diet-fed abalone than the seaweed-fed group.

Leaf meals from terrestrial plants and freshwater aquatic fern containing 27% crude protein and 5% lipid were evaluated as major protein sources in the diets for grow-out culture of abalone (O Reyes, personal communication). Abalone fed "malungay" (*Moringa oleifera*)-based diets showed a 90% weight gain compared with seaweed (*G. bailinae*)-fed abalone, which had a 75% weight gain. However, highest crude protein (70.3%) in the carcass was obtained from abalone fed papaya (*Carica papaya*) leaf meal-based diet while seaweed fed-abalone had the lowest carcass protein level (60%).

Window-pane oyster Placuna placenta

Broodstock development

The effects of feeding algae given at high density on gonadal maturation of *Placuna placenta* were investigated. Gonad development was rapid in broodstock fed a combination of *Isochrysis galbana* and *Tetraselmis tetrahele* at a 3:1 ratio with cell densities of 2 x 10^5 cells per ml (Madrones-Ladja, in press a). Broodstock fed high-density algae showed a higher gonad index (GI) of 330 compared with animals fed low-density algae (GI: 250).

Male and female window-pane oyster were induced to spawn by intra-gonadal injection of 0.5 ml of a 2-mM serotonin or by UV light (925-1395 mW h/l) irradiated-seawater (Madrones-Ladja, 1997). Spawning occurred 15-30 min after serotonin injection, and 30-60 min after exposure to UV light irradiated seawater. The latter method seemed more practical for spawning individuals as well as for groups of broodstock.

Seed production

Studies on feeding various algal species, i.e. *I. galbana, T. tetrahele,* and *Chaetoceros calcitrans* singly or in combination, to oyster larvae were conducted. Larvae fed *I. galbana* showed the best growth with 12.5% survival, but larvae reared on *Chaetoceros calcitrans* exhibited lowest growth (Madrones-Ladja, in press a). Survival rates were not different among larvae fed *C. calcitrans, T. tetrahele* either alone or in combination with each other or with *I. galbana.* Generally, setting stage was reached at day 14 (Madrones-Ladja, 1997).

In other experiments, the effects of various salinities on survival of oyster larvae were examined. Larvae reared at 34 ppt showed the highest survival of 13% whereas, larvae held at varying salinities ranging from 10 to 40 ppt had low survival rates (range: 4.5-7%). Larvae reared at the lowest (10 ppt) and highest (40 ppt) salinity tested had the lowest growth rate. Settling stage of larvae held at 34 ppt salinity was attained at day 14 while those at 16 ppt on day 19.

Stock enhancement

To rehabilitate depleted natural beds of the window-pane oyster, immature *P. placenta* adults (72 mm SL and 14.5 g body weight) were stocked at 75 individuals per m^2 in a 40 m^2 muddy area along the Tigbauan coastline in Iloilo, Philippines (Madrones-Ladja, in press b). Juveniles measuring 40 mm SL were also stocked. One month after stocking, veliger larvae were observed in plankton samples. An assessment of broodstock survival showed a 51% recovery 91 days after stocking. SL and body weight increments were 15 mm and 13 g, respectively. About 40% of recovered broodstock were induced to spawn by UV light irradiation of surrounding seawater.

Seaweeds

Seaweed research at SEAFDEC/AQD for the past several years focused on three economically important genera, namely: *Gracilaria, Gracilariopsis,* and *Kappaphycus.* Areas of studies for these genera were mainly on life history, optimization of biomass production, bio-remediation, and socio-economic.

Life history

To determine the viability of sporelings grown under laboratory conditions for possible outplanting, the life history of various species of *Gracilaria* (*Gracilaria changii*, *G. coronopifolia*, *G. firma*) and *Gracilariopsis bailinae* was examined. Mass production of sporelings from fertile cystocarpic plants grown at 12L:12D photoperiod and 25°C was conducted by using a dry-immersion method using Grund's medium. Sporeling development of all species were of the 'immediate discal type' like the other species of *Gracilaria* (Guimarães *et al*. 1999). Young plants (80-100 mm long) were obtained after 6 months of culture. Large scale mass production of sporelings will soon be attempted.

Optimization of biomass production

The amount of seaweed biomass produced in a given area at a particular time is significant since it determines the technical, environmental, and economic viability of the culture activity. Approaches to meet this objective were made on *Gracilaria, Gracilariopsis* and *Kappaphycus* on the following areas: (1) nutrient environment, (2) biomass density, (3) harvested biomass, and (4) crop quality for the conversion to agarose and carrageenan.

Nutrient environment

Apical segments (5 cm) of *K. alvarezii* were tested in the laboratory for growth performance in various levels of ammonium phosphate and indole-acetic acid (IAA), applied either singly or in combination for 8 weeks. Plants grown in 1 mg per l IAA alone resulted in the highest specific growth rate (SGR, 2.1% increase in wet weight per day); however, it was not significantly different from those grown in 5 mg per l ammonium phosphate and the control. Dawes and Koch (1991) reported healthy explants of *K. alvarezii* when treated with 1, 5 and 10 mg per l of IAA under laboratory conditions. When the same plant was outplanted in cages using the bamboo raft method of culture, further addition of nutrients to the plants was not required. After 8 weeks of culture, plants previously grown in a single dose (5 and 10 mg per l) of ammonium phosphate had comparable growth (6.7-8.0%) with those grown in IAA (1 and 5 mg per 1; 5.7-8.3%). Growth of *K. alvarezii* was slightly better (7.1-7.5%) when grown in higher combination levels of ammonium phosphate/IAA (10/l and 10/5 mg per l) than in lower combination levels (5/1 and 5/5 mg per l; 6.8-6.5%). The addition of ammonium phosphate appears more practical than the addition of IAA, a plant growth regulator, because the latter is expensive.

Experiments in production ecology were conducted to establish an appropriate tank culture method for *Gracilaria.* Salinity tolerance, nitrogen source (ammonium-nitrogen and nitrate-nitrogen), and concentration were determined in relation to growth rate. Optimum growth was observed at 25 ppt. Growth was found to be more efficient when the seaweed was grown in a medium enriched with ammonium-nitrogen rather than nitrate-nitrogen. The addition of phosphate as di-sodium phosphate at 1 ppm did not significantly affect growth.

Biomass density

Stocking density in a culture system may result in the acceleration or stunting of growth of the organism, which in turn is dependent on several environmental factors. The culture of *Gracilariopsis bailinae* in tanks at various stocking densities (2, 4, 8, 12 kg per ton) was examined. A low stocking density (2 kg per ton) promoted growth even if water was not changed for 2 weeks. Higher stocking densities resulted in lower growth rates and harvested biomass (Chavoso and Hurtado-Ponce, 1995).

Harvested biomass

Vegetative thalli of brown and green *Kappaphycus alvarezii* were cultivated in Panagatan Cays in Caluya, Antique, Philippines for 60 and 90 days using hanging-long line (HL), fixed off-bottom (FB), and hanging long line-fixed off-bottom (HL-FB) method to determine daily growth rate and yield. After a 60-day culture period, daily growth rates and yields in all cultivation methods were lowest in July-August and highest in January-February. High growth rate (2.3-4.2% per day) and fresh wet yield (3.6-15.8 kg per m per line) were obtained from September to February. Significant differences in growth rate and yield were also determined between culture months. In a 90-day culture period, no significant differences in growth rate and yield were observed among culture months; however, significant differences were observed among culture methods. Higher estimated production (dry weight) was obtained from the brown strain (6.2-10.2 t per ha per yr) than the green strain (4.9-9.6 t per ha per yr) in all culture methods. The use of HL and HL-FB methods resulted in faster growth rate and higher biomass production than the FB method.

Crop quality for conversion to agarose and carrageenan

Harvested biomass either from a culture system or from a natural population determines the quality of the extracted phycocolloid. Such quality is influenced by the characteristic of the strain, environmental conditions, and the culture system used.

The quality of agarose extracted from wild populations of *Gracilariopsis bailinae* showed significant seasonality in yield and gel strength; however, gel strength was inversely proportional to carrageenan yield. Highest gel strength (296 g per cm) was recorded in April and lowest in December (108 g per cm). A slightly positive correlation existed between agarose yield and salinity. Water temperature, turbidity, and pH exhibited no significant correlation with gel properties.

Likewise, carrageenan gel strength of the brown and green strains of *Kappaphycus alvarezii* varied seasonally when grown by fixed off-bottom long line, hanging long-line, and a combination of the two cultivation methods. Seaweeds grown by a HL-FB method had higher gel strength compared with those grown by the two other methods.

Environment-friendly aquaculture

Earlier studies have shown that *Gracilaria* and *Gracilariopsis bailinae* have the capacity to absorb and store nutrients and to sequester heavy metals, making them useful in intensive aquaculture and in polluted coastal areas. However, heavy metals are retained in the tissues and in the extracted colloid. *G. bailinae* was grown in various concentrations (50, 100, 150, 200 and 250 µg per l) of copper, zinc, cadmium and lead for various periods (12, 24, 36, and 48 h). Copper was easily sequestered followed by zinc, cadmium, and lead similar to the report of Murugadas *et al* (1995). The same heavy metals were still detectable in the extracted agar. For example, unlike lead, copper showed greater affinity to the agar of the macroalga. The results demonstrate that gathering of seaweed like *Gracilariopsis bailinae* from heavy metal-polluted coastal areas should be discouraged.

When *G. bailinae* was integrated in the culture system of finfish broodstock, the seaweed recorded a specific growth rate of 10% per day. Ammonia concentration in tanks with seaweed was lower than in tanks without seaweed. Nitrogen in the tissue of *G. bailinae* became saturated after five days of culture, suggesting that the saturation of nitrogen pools in the plant tissue may stimulate growth.

Socioeconomics

The commercial farming of *Kappahycus alvarezii* in Sacol Island near Zamboanga City, which was originally called *Eucheuma cottonni*, started in the early '70s. The traditional fixed off-bottom line method was used in shallow waters until it was modified when cultivation was made in deeper waters.

The multiple raft long-line method, commonly called 'alu', was introduced in the mid-80s. A survey was conducted last May-June among seaweed planters of *K. alvarezii* in the three major production areas (Tictauan Island, Taluksangay, and Maasin) of Zamboanga City. A total of 30 respondents were interviewed based on: (1) personal background, (2) farming practices, (3) marketing system (4) economic impact, and (5) problems.

Seaweed farming in these areas shared common characteristics like: (1) family entrepreneurship, (2) labor hiring, and (3) capital sharing. Although farming of *K. alvarezii* by multiple raft long line method is expensive, return of investment is still high (59-226%) and payback period is comparable (0.4-1 yr) with the single bamboo raft method (0.4-0.9 yr) reported by Samonte *et al* (1993). Projected production of 21-38 t (dry weight) per ha per crop was higher in the multiple raft long line compared with single bamboo raft reported by Samonte *et al.* (1993). Problems like high moisture content (40-60%) and impurities, seasonal occurrence of 'ice-ice' (Alih, 1990) and poaching are common.

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Community-based Fishery Resources Management Project in Malalison Island: Institutional Arrangements for Fisheries Co-management

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Abstract

The paper discusses the monitoring mechanism of the SEAFDEC/AQD Community-based Fisheries Resources Management (CFRM) Project at Malalison Island in west central Philippines. The objective of the project was to learn from the collaboration of community organizations, biologists, and social scientists in adapting aquaculture and fishery management techniques and to assess the replicability of the experience to other fishing communities.

The monitoring mechanism used was Process Documentation Research (PDR), a way of recording the development process of a project focusing on the participatory model of the resource management strategy. A full-time, site-based process documentator gathered information. All activities, meetings, and consultations were tape-recorded. Informal talks or encounters with the people were also recorded.

The paper showed that PDR provided a better understanding and insight on the positive and negative perceptions of the project beneficiaries on the CFRM project. Unlike other research monitoring methods that match budget with accomplishments, PDR bares the feelings, hopes, and fears of the project beneficiaries regarding the impact of the project on their lives.

Introduction

The evolving development strategy of a democratic “bottom-up” approach in contrast to the highly centralized “top-down” approach has been given impetus by the government through decentralization of the decision-making process in development. A people-centered, community-based development model provides for the return of the decision-making to the people and recognizes their abilities to manage the resources to meet their needs. This development process will require the transformation of community institutions to enable them to manage and control resources in response to local needs and preferences (Korten, 1988).

In a community-based resource management system or co-management in a broader sense, the role of government is to facilitate and not control the development of resources. The enactment of the Local Government Code of 1991 and the new Fisheries Code of the Philippines provide the legal framework to empower fisherfolks and enable them to manage and control the fishery resources in close coordination with the government.

In order to help fisherfolks rise above their poverty and to regenerate and manage the marine and coastal resources, the Southeast Asian Fisheries Development Center/Aquaculture Department (SEAFDEC/AQD) with co-funding from the International Development and Research Center (IDRC) of Canada launched in 1991 the Community Fishery Resource Management (CFRM) Project in Malalison Island off western Panay Island, Philippines. The eight-year research project is development-oriented and integrates various disciplines in biology, economics, sociology, public administration, and engineering in its study of fishing communities and resources and in evolving interventions and strategies (Agbayani, 1995).

The overall objective of the project is to learn from the collaboration of community organizations, biologists, and social scientists in adapting recently developed aquaculture and fishery resource management techniques and to assess the potential replicability of the experience in other fishing communities. The framework of the project integrates the analysis of the socioeconomic condition of fisherfolks with the condition of the coastal resources, the types of fishing and aquaculture technologies, and the role of the institutions in setting up rules and rights in the use and management of the coastal resources. The framework is anchored on the fundamental principles of sustainability, equity, and efficiency.

The CFRM project implemented several interventions during the duration of the project. Development interventions focused on people empowerment through community organizing and capability building, implementation of livelihood activities (e.g., seaweeds farming and other family-based livelihood), deployment of concrete artificial reefs (ARs), implementation of territorial use rights in fisheries (TURFs), and searanching.

The third major development intervention was the deployment of concrete ARs in two reefs, one of which (Gui-ob reef) was declared a fish sanctuary by the community through its barangay (village) council. It was during this period that process documentation of the institutional arrangements for the fisheries co-management was performed. This stage of the project was critical since it included long-term policy considerations that were formulated and implemented by the community.

Process Documentation Research Methodology

Fishery co-management through community self-regulation of fishery resources is an alternative strategy to "top-down" policy making (Pomeroy, 1993). Process documentation research (PDR, de los Reyes, 1988; Veneracion, 1988; Borlagdan, 1988) was undertaken to test the usefulness of this methodology in documenting the self-regulation process or the institutional arrangements for fisheries co-management on Malalison Island.

PDR is both a learning and a blueprint approach. The overall goals and objectives of a project such as CFRM is the "blueprint. "How to do it" is the learning process component of the project. In a CFRM project, PDR records the development process by focusing on the participatory model of the resource management strategy. The participatory model includes: (1) the mass involvement in decision-making process through different consultation activities; (2) mass contribution in actual implementation of project activities; and (3) mass sharing of benefits from the project.

A full-time, site-based process documentor (PD) undertook the process documentation from January 1995 to November 1996. Most, if not all activities, meetings, consultations were tape-recorded. Informal talks or "encounters" with the village people were recorded later in the day.

Group discussions before and after meetings are more relevant than what actually transpires in formal meetings (Volante, undated). Some fishers who were too shy or not used to articulating their opinions in formal meetings expressed their honest opinions and perceptions concerning the project in informal conversations. Computer inputting of the data was done during weekends at SEAFDEC's main station in Iloilo. The local dialect ("Kinaray-a") was generally used during meetings and informal talks. The tape-recorded minutes were transcribed and translated to English by the PD, although literal translation was not always possible. The translated words and phrases retained the same style and sentence construction as the original statements since the translation, interpretation and analysis of data were done with the fishers.

The dynamics of the consultation process among the different stakeholders are vividly reflected or mirrored in the documentation process. PDR also reflects the articulation of relevant issues by the officers and members of the Fishermen's Association of Malalison Island (FAMI), Fisheries and Aquatic Resources Management Council (FARMC), and the barangay council on issues pertaining to resource management, livelihood, and the institutional arrangements.

Highlights of Institutional Arrangements (1995-1996)

The key institutions that played important roles in the institutional arrangements for fisheries co-management on Malalison Island are FAMI, Malalison Barangay FARMC, Malalison Barangay Council, Culasi Municipal FARMC, Culasi Sangguniang Bayan (local legislative assembly), PROCESS Foundation (the non-government organization or NGO that organized the Malalison community into a cooperative), national government agencies (such as DA or the Department of Agriculture, DENR or the Department of Environment and Natural Resources, DILG or the Department of Interior and Local Governments), SEAFDEC, and the local radio station. A total of 45 meetings and consultations were documented from 9 January 1995 to 17 November 1996.

The PDR study period was Stage 3 of the CFRM project. Stages I and II consisted of the implementation of territorial users' rights in fisheries (TURF) and construction and deployment of concrete ARs. The concept of TURF as a fishery management strategy has been found to be acceptable among the fisherfolk of Malalison Island (Siar *et al.* 1992). The implementation of TURF referred mainly to the planning and formulation of specific resource management strategies such as a creation of fish sanctuary and the rules and rights embodied in the provisions of the policy on fish sanctuary. At this stage of the project, the members of FAMI, FARMC, and the Barangay Council have already undergone social preparation (training, exposure trips, membership in provincial federations, etc.) and have fully understood the importance of formulating the set of rules and rights in the use and management of their coastal waters.

Manifesto by FAMI on TURFs

The FAMI manifesto written in "Kinaray-a" defines TURF as the proper utilization, management and control by FAMI of the body of water surrounding Malalison Island as provided for by Municipal Ordinance 5-90. There are two components of TURF: (1) creation of a fish sanctuary; and (2) deployment of concrete ARs. Fish sanctuary is defined as the habitat of fish and other aquatic species and where fishing of any type is prohibited. Artificial reefs are man-made structures to serve as fish habitat. These structures rehabilitate the natural reefs that have been destroyed by illegal fishing practices. Fishing in areas where ARs are deployed is regulated in terms of types of gears and fishing season. Specifically, commercial fishers are banned. Illegal fishing practices such as dynamite, cyanide, fine-mesh net and other destructive gears are also not allowed in the TURF area.

In enforcing TURF, FAMI agreed on the following guidelines: (1) a fine of P1,000, confiscation of fish catch, and filing of charges against those caught fishing inside the fish sanctuary; (2) charging of a fishing fee for those fishing in areas where ARs are deployed at the rate of 5% of the value of their catch for non-Malalison fisheries and 1% for Malalison fishers; (3) no fishing activities during the spawning season of selected fishes. FAMI and the Malalison Barangay Council designate the fish wardens. DA has been requested to train the fish wardens to ensure full enforcement of the policies set by FAMI and the Barangay Council.

Consultation with Neighboring Coastal Barangays

In 1995, the Antique Integrated Area Development (ANIAD) Project, funded by the Netherlands Government, implemented a community-based coastal resource management (CBCRM) in all of Culasi's coastal barangays except Malalison. ANIAD contracted the assistance of SEAFDEC researchers in undertaking a resource and social assessment of the coastal barangays. In the process of assessment, consultation meetings with barangay leaders and residents of 16 barangays were done to discuss the principles, methods, and benefits of CBCRM to communities. The role of SEAFDEC researchers was to explain the status of Malalison CFRM project and its impact on other coastal barangays. A focus of the consultation was the TURF interventions (fish sanctuary and concrete ARs). The consultation process provided the fora for fishers of nearby coastal barangays to discuss the principles, process, and benefits of CBCRM and their role as co-managers of coastal resources.

The results of resource and social assessments done by SEAFDEC for ANIAD became the basis for the creation of barangay FARMCs and a municipal-wide FARMC in Culasi. Another positive impact of the assessment and consultation process was that leaders of two other barangays (Lipata and Batonan Sur) initiated the move to declare fish sanctuaries in their respective coastal waters similar to Barangay Malalison.

The entry of ANIAD in Culasi to implement CBCRM was a "bonus" for SEAFDEC's project in Malalison. The replication of the CFRM project in other coastal barangays of Culasi was hastened at no cost to SEAFDEC. ANIAD, on the other hand, benefited from the experience of SEAFDEC researchers and scientists at minimal cost. This type of linkaging and networking among research and development institutions should be harnessed in order to share manpower and financial resources for the benefit of more communities.

Construction and Deployment of Concrete ARs

The construction and deployment of concrete ARs was a major intervention to regenerate the corals destroyed after years of destructive fishing practices. In areas where ARs have been deployed, fishing activities are not allowed (as in fish sanctuaries) or are regulated as in the TURF area at Kawit reef.

The engineering designs of the ARs took into consideration the transport and deployment methods. Two prototypes of pre-fabricated modules, building blocks and pipe culverts, were deployed in May 1994 (Tenedero, 1995). The ARs were designed according to the capability of the community to fabricate and deploy. The experience in this experimental deployment resulted in reduction of time and cost in actual deployment in 1995. Techniques of transporting, hauling and deploying, and assembling of ARs were improved.

In 1995, fabrication and deployment of ARs were undertaken in Gui-ob reef (26 modules) and in Kawit area (26 modules). SEAFDEC and FAMI entered into an agreement to share the cost of deployment in selected areas. The deployment cost was P58,740. The Barangay Malalison Council agreed to share P5,000 from their Internal Revenue Allotment (IRA) as provided for by the Local Government Code. Although the share of the community was minimal (8.5% of cost), the willingness to share the cost as "co-owners and co-managers" of coastal resources was notable.

1995 Malalison Forum

The holding of an annual forum in Malalison became a tradition. It was an effective venue to assess and evaluate the CFRM project and discuss problems and issues affecting the project. Forum participants were representatives from neighboring coastal barangays, local government officials, NGO representatives, SEAFDEC researchers and staff, and the community as a whole.

The issue of putting into operation TURF was one of the major concerns discussed during the forum. There were apprehensions on the efficiency of law enforcement, especially policing or preventing the entry of commercial fishers in the TURF area. There was a suggestion of putting up markers.

Another problem discussed was the inadequacy of capital to add more livelihood activities aside from the present seaweeds farming and consumer store operation. FAMI had intended to tap other funding sources such as ANIAD and to implement more land-based livelihood activities. The possibility of getting the island supplied with electricity from the mainland was also proposed.

The annual forum became an occasion for socializing with the members of the community, government representatives, and NGOs. The day usually ended with disco dancing in the evening.

Creation of Barangay Malalison FARMC

As mentioned earlier, the Barangay Malalison FARMC was created on June 24, 1995 in compliance with Executive Order (EO) No. 240 of the President of the Philippines dated April 27, 1995. There was, however, already an existing Barangay Coastal Resource Management Council (CRMC) created in 1994 to plan, formulate and implement rules and rights in the management of the coastal resources. The new FARMC took over the functions of the previously organized CRMC. Election of officers of the newly created FARMC was done immediately.

Specifically, the functions of the FARMC are to: (1) prepare fisheries management plans and policies based on sound assessment and socioeconomic characteristics and, (2) recommend to local government units and other agencies the issuance of licenses and permits for appropriate use of fishery resources. It is worth noting that EO 240 gives value to research, i.e., resource and socioeconomic assessments in making policies related to fishery resource management. Participatory type of research involving members of the community is also encouraged.

Declaration of Gui-ob Reef as a Fish Sanctuary

After the creation of the Barangay Malalison FARMC, the officers together with the Barangay Council members held a series of meetings and consultations with the residents of Malalison Island regarding the plan of declaring Gui-ob reef as a sanctuary. The choice of the sanctuary site was based on several factors, such as the use of the area as a fishing ground, the presence of various species which must be conserved, and the distance from the island for surveillance purposes.

On 5 July 1995 or about 10 days after the creation of Barangay Malalison FARMC, a joint meeting between the FARMC and the Barangay Council was held. The outcome was the promulgation of Malalison Barangay Council Resolution No. 01, Series of 1995 declaring Gui-ob reef a fish sanctuary and adopting a barangay ordinance necessary for its preservation, protection, control, and supervision. The sanctuary covered 28.27 hectares and had a radius of 300 meters. The Malalison FARMC promulgated on the same day a resolution (Resolution FARMC No. 01, Series 1995) requesting the Barangay Council to approve the rules and regulations regarding the "strictly no fishing" policy in Gui-ob. Copies of the Barangay Resolution were submitted to the offices of the Mayor of Culasi, Sangguniang Bayan, DILG, DENR, Philippine National Police, Coast Guard, and the Association of Barangay Captains.

In support of the resolutions, the Barangay Council promulgated Barangay FARMC Ordinance No. 01, Series of 1995 dated July 19, 1995 prohibiting fishing in Gui-ob. The Ordinance penalized violators as follows: (1) first offense - barangay captain to summon the violator and ask him to explain why he violated the ordinance; (2) second offense - warning and his catch would be confiscated; and, (3) third offense - fine of P1,000 and the catch to be confiscated. The ordinance also provided that fishers from Malalison Island and from other areas could fish in Salangan reef area east of Malalison, Balabago reef south of the island, Nablag reef to the west, and Layag-layag reef to the north. However, only Malalison fishers could fish in the fringing reefs surrounding the island.

The ordinance was favorably endorsed by the residents of Malalison Island in a general assembly meeting on 12 July 1995 as attested by their signatures.

Lobbying for the Approval of Malalison Barangay Resolution No. 01

Malalison FARMC and Barangay officials wasted no time in working for the approval of the Barangay Resolution by the Culasi Sangguniang Bayan or Municipal Council. On 14 July 1995, a meeting was arranged by the Malalison officials with the Vice Mayor (who acts as Chair of the Sangguniang Bayan), municipal councilors, and a local radio announcer. Two important issues regarding the Resolution were discussed, namely: (1) penalties imposed on violators and (2) consultation process with Malalison residents. The radio announcer promised to support the Malalison cause by broadcasting the information on Malalison fish sanctuary. The Culasi municipal officials assured support and made arrangement for DENR and municipal officials to visit the site.

Succeeding lobbying activities were undertaken to hasten the approval of the fish sanctuary resolution. The Sangguniang Bayan deliberated on the resolution in almost every regular session but could not get approval for the Malalison resolution. Some of the Sangguniang members together with Malalison consulted with national government officials (DENR and DILG) regarding the resolution as it relates to the Local Government Code. At that time, even the representatives of the concerned national government offices could not provide advice that would help the Culasi and Malalison local officials legislate or approve resolutions and ordinances related to coastal resource management.

Need for Scientific Data to Support the Fish Sanctuary Ordinance

In support of the Malalison Municipal Ordinance on the fish sanctuary, SEAFDEC provided the officials of the barangay and FAMI with the biological resource data of Gui-ob reef. The information included: (1) number of families (27) and species (172) of reef fishes; (2) estimated and relative annual yield of reef fishes at Gui-ob reef (2,646.1 kg/ha/year); (3) list of coral species (12 families and 63 species); (4) average cover of benthic lifeforms; and (5) average frequency of benthic lifeforms. The list included scientific and local names of fishes.

The value of scientific data for policy-making has been demonstrated in the formulation of the fish sanctuary ordinance. This partnership between policy-makers and scientists could upgrade policies that would ensure sustainability of the coastal resource. This linkage should be encouraged in all levels of governance from the barangay to the national level because it is consistent with the provision of E.O. 240 on the use of sound scientific assessment for policy-making.

Approval of the Malalison Resolution on Fish Sanctuary

Barangay Malalison Resolution No. 01, Series of 1995 was approved by the Sangguniang Bayan by default. According to one local legislator, the parliamentary procedure is for the Council to act (approve or disapprove) on a resolution within the statutory period of 30 days upon submission of the resolution. Failure to act would mean automatic approval. The Malalison fish sanctuary ordinance has been technically approved one month after 13 July 1995 when the Malalison Barangay Council submitted the ordinance to the Culasi Sangguniang Bayan. This was due to the lack of experience of the municipal council regarding the parliamentary procedures on ordinances emanating from the barangays using the Local Government Code as a legal framework. This was the first time the Sangguniang Bayan of Culasi received a community-initiated resolution related to the declaration of a fish sanctuary based on the provisions of the Local Government Code. On record in the municipal council, however, was the approval of the ordinance, which was effected during a regular session on 3 July 1995.

There is a need for training of local legislators on the provisions of the Local Government Code and other pertinent laws related to the decentralization of authority to manage the coastal resources. The performance of the participating institutions, especially local legislative bodies in fishery co-management, can be enhanced through formal training courses and sharing of experiences with other local legislators.

Enforcement of the "No fishing" Ordinance in the Sanctuary

The enforcement of the ordinance requires physical, financial, and manpower resources. The first priority is to define the boundary by setting-up markers. The second requirement is a reliable boat for mobility in doing monitoring and surveillance work. The third is the dissemination of information to fishers and residents of Malalison and neighboring coastal barangays who traditionally fish in the area.

With financial support from SEAFDEC, Malalison officials purchased, fabricated, and installed markers in the Gui-ob fish sanctuary. FARMC through its members from neighboring coastal barangays disseminated the information to their constituent-fishers who fish in Malalison waters.

A very effective partner in information dissemination and advocacy on sustainable management is the local radio station. The radio announcer, a resident of Culasi, actively informed the public by broadcasting the provisions of the ordinance and the long-term benefits which the fishers from Culasi would gain. The announcer was also effective in exposing violations especially by Malalison fishers and even one involving a Malalison barangay official. The radio is an effective medium in relaying information in rural areas like Malalison. In spite of the absence of electricity in the island, most households have battery-operated radios for news and entertainment. The radio announcer was always present during investigations of violations done in the municipal hall.

Community-initiated Survey on TURF

As mentioned earlier, the Municipality of Culasi granted to FAMI a TURF area covering 1 km^2 located between Culasi mainland and Malalison Island as early as 1990 before the start of the CFRM project. There were, however, no rules and rights defined in the use and management of the TURF area especially in Kawit reef where 26 modules of concrete ARs have been deployed.

There was a need to gather information and know the perception of fishers from different coastal and island barangays regarding TURF and the rules and rights that go with it. A community-initiated survey was done in October-December 1995 to determine: (1) whether fishers agreed to the concept, (2) the types of fishing gears that should be allowed in the TURF area, and (3) amount of fee as percentage of value of catch that fishers were willing to pay FAMI to defray operational expenses in overseeing the fishing activities in the TURF area. A total of 146 respondents from Malalison and 6 coastal barangays facing Malalison were interviewed.

The survey revealed that 61 were in favor and 5 were against the implementation of TURF. The rest (80) had no idea about TURF. A great majority of the respondents were against net fishing especially destructive ones such as "pamo" and "muro-ami." Respondents were also against the use of compressor in spear fishing ("hookah"). This practice is similar to spear fishing using SCUBA where even spawners can be easily caught. This practice, however, is tolerated in the island as long as it is done by Malalison fishers. Any kind of hook-and-line fishing gears are acceptable. The survey revealed that fishers were aware of destructive gears that should not be allowed if further destruction of fishery resources is to be prevented.

Draft of Policies on Excursionists and Visitors in Malalison Island

In late 1996, Barangay Malalison officials drafted an ordinance to regulate the activities of excursionists and visitors on the island. They encouraged tourists to visit Malalison. Salient provisions of the draft ordinance are: (1) designated docking area is only the Kawit area; (2) visitors will pay an entrance fee of P10 (foreigners) and P1 (locals); (3) visitors must log-in before going around the island and log-out before leaving the island; (4) cleanliness will always be observed in the island; (5) picking of "pitcher" plant is not allowed; (6) religious camping is not allowed; and (7) foreigners and local tourists are not allowed to stay for more than three days.

There has been no follow-up meetings or consultations regarding this proposed ordinance. This action, however, shows that the community residents are now enlightened on their power and responsibility in the co-management of fishery and land resources.

The provisions of the proposed ordinance on tourism reveal the conservatism of the Malalison people. In spite of the promise of economic benefits from tourism, they fear a "Boracay" situation happening in their community. The "Boracay" scare refers to the adverse social and environmental effects of tourism on the community and its environment. They fear that foreign tourists would wear skimpy swimsuits or go topless and "tempt the husbands and sons" residing on Malalison Island. Boracay Island resort is one-and-a-half hour drive from Culasi.

Conclusions

Community-based projects will benefit from the use of PDR. The dynamic field level interactions in a participatory development process are complex and dynamic, requiring "blow by blow" (so-to-speak) documentation. It provides a systematic "ringside" view of field experiences.

Overall, PDR provided a better understanding and insight on the positive and negative perceptions of the project beneficiaries on the CFRM project. Unlike the traditional monitoring of status of development projects, which matches budget versus accomplishments, PDR as a monitoring mechanism bares the "inner" feelings, hopes and fears of the project beneficiaries regarding the project's impact on their lives.

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Mangrove-friendly Aquaculture Studies at the SEAFDEC Aquaculture Department

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Abstract

The SEAFDEC Aquaculture Department studies on mangrove-friendly aquaculture (MFA) can be categorized under two models: a) mangrove filters where mangrove forests are used to absorb effluents from high-density culture ponds, and b) aquasilviculture or the low-density culture of crabs, shrimp and fish integrated with mangroves. In a study using the first model, shrimp pond effluents were retained in an enclosed mangrove area prior to release to receiving waters. Nutrients and other water quality parameters, and bacterial levels were monitored in the untreated effluents and post-mangrove water.

In the second MFA model, mangrove pens and ponds installed in old growth and newly regenerating mangrove sites in Aklan, central Philippines were stocked with mud crab *Scylla olivacea/S. tranquebarica* and shrimp *Penaeus monodon.* Investment costs, survival and production, and cost-return analysis for the pens and ponds are reported in the paper. Aside from the aquasilviculture trials in collaboration with local government units, other activities in the Aklan mangrove sites are the survey and mapping of the 75-ha area in Ibajay, construction of a treehouse, and the educational use as field site by Coastal Resource Management trainees of SEAFDEC Aquaculture Department and field biology students of the University of the Philippines in the Visayas.

Introduction

Amidst the growing concern of international environmental non-government organizations (NGOs) over the ecological impacts of aquaculture, in early 1996 the SEAFDEC Council proactively mandated the Aquaculture Department to conduct studies on environment-friendly shrimp culture and to build up its expertise on mangroves. Under this initiative, a Mangrove-Friendly Aquaculture (MFA) Seminar-Workshop was organized in July 1999. The Workshop identified two MFA levels or models: a) mangrove as filters where the absorbing function of mangroves is used to process or treat effluents from high-density culture ponds, and b) aquasilviculture (or silvo-fisheries) where low-density culture ponds/pens are physically integrated with mangrove trees.

This paper reports on studies that fall under both MFA models.

Mangroves as Filters

The study site is located in Barangay Alacagan in the municipality of Banate, Iloilo. A second run (April-August 1999) of 15,000 *P. monodon* gave 41.2% survival rate, 6.98 g average body weight and 43 kg total production. Extraneous species such as *Metapenaeus/Penaeus* spp., tilapia, mudcrab and ambassids were abundant and contributed around two-thirds of total biomass, due to a lack of teaseed application. During the culture period, effluent water from a high-density (10 per m^2) shrimp pond of 1500 m^2 was made to pass through a 1200 m^2 mangrove 'pond' for a few days prior to draining to Banate Bay. Water quality was measured inside the shrimp pond (pre-treatment of pond water) and in the mangrove pond (post-treatment) every two weeks.

Water in the shrimp pond (SP) showed significantly higher levels of NO_2, PO_4 and COD and lower dissolved oxygen compared with the mangrove pond (MP) (Figs. 1-2). Similar levels in the SP and MP were observed for temperature, salinity, NH_3, COD (sediment) and pH (Figs. 1-3). Levels of presumptive *Vibrio* and luminous bacteria increased throughout the culture period in the SP and in cultured shrimp (Table 1). In contrast, total bacterial counts remained constant in SP water but increased in the shrimp population. On the single date (29 April 1999) that the MP was monitored, luminous bacteria levels were one order of magnitude lower than in the SP. Overall, the lower levels of nutrients, COD, and luminous bacteria, and higher DO levels in the MP compared with the SP indicate nutrient assimilation and less organic matter, which are features related to the filtration function of mangrove trees.

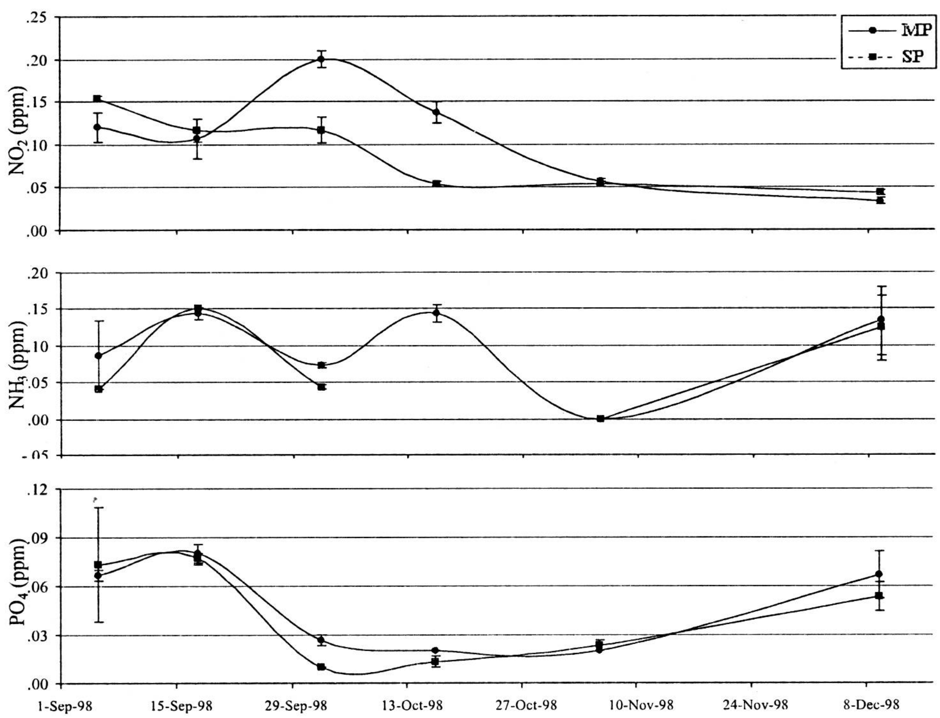

Figure 1. **Nutrients in shrimp pond (SP) and mangrove pond (MP) water in Banate, Iloilo**

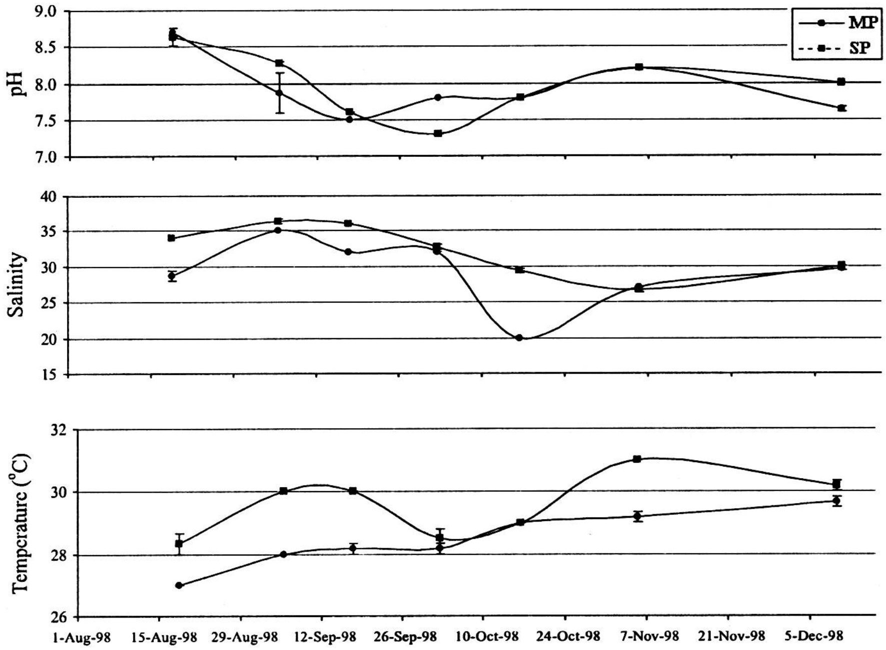

Figure 2. **Physico-chemical measurements of shrimp pond (SP) and mangrove pond (MP) water in Banate, Iloilo**

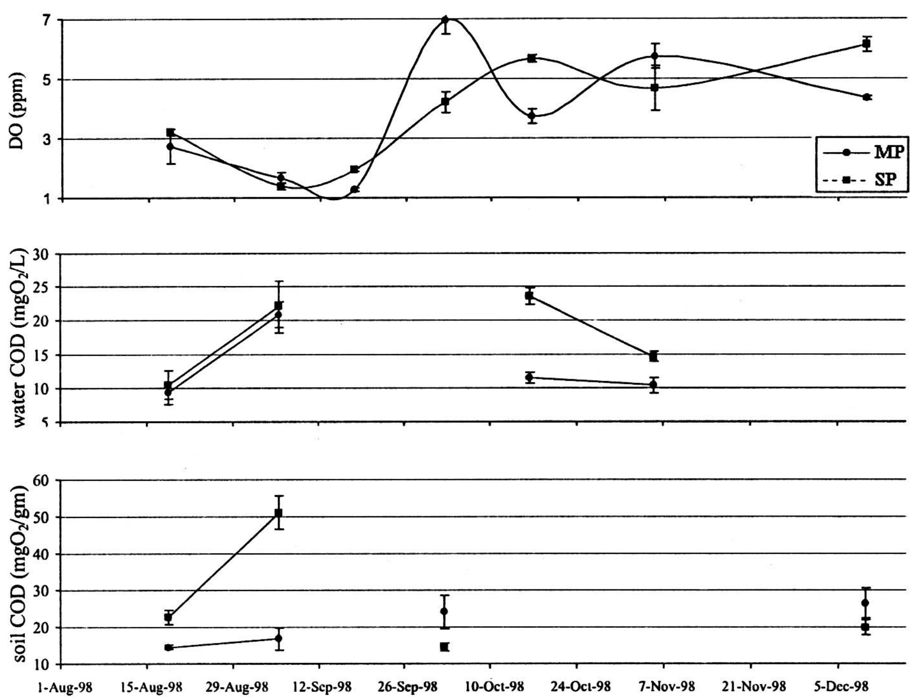

Figure 3. **Physico-chemical measurements of shrimp pond (SP) and mangrove pond (MP) water and sediment in Banate, Iloilo**

Table 1. **Bacterial levels (cfu per ml) in pond water (shrimp pond and mangrove pond) and in shrimp in Banate, Iloilo**

	Total plate count	**Presumptive *Vibro***	**Luminous bacteria**
Shrimp pond water			
07 April 1999	3.2×10^3	1.0×10^1	0.0
29 April 1999	2.0×10^3	1.8×10^3	3.1×10^2
17 May 1999	3.6×10^3	6.9×10^2	2.1×10^1
09 June 1999	1.2×10^3	5.3×10^2	2.5×10^1
01 July 1999	3.9×10^3	7.1×10^2	3.0×10^1
12 Aug 1999	3.8×10^3	1.4×10^3	8.5×10^1
Mangrove pond water			
29 April 1999	7.4×10^2	2.0×10^2	2.0×10^1
Shrimp *P. monodon*			
10 April 1999	5.6×10^3 to 1.4×10^4	5.7×10^3	0.0
01 July 1999	3.6×10^6	4.0×10^5	7.0×10^4
12 August 1999	1.3×10^7	4.1×10^6	1.9×10^4

Table 2. **Growth of *Rhizophora* seedlings in mangrove pond and in control pond in Banate, Iloilo**

	Mangrove pond		**Control (natural mangrove)**	
	Mean height (cm)	**Mean no. leaves**	**Mean height (cm)**	**Mean no. leaves**
05 June 1998	26.81	—	18.86	—
10 July 1998	50.48	8.28	25.14	—
03 September 1998	50.41	7.17	41.55	5.13
02 October 1998	56.63	—	48.77	—
12 November 1998	60.67	9.60	54.97	6.38
09 December 1998	63.75	11.79	58.86	7.17
28 July 1999	78.82	—	71.77	—

Rhizophora propagules were planted inside the MP and in adjacent natural mangrove areas. As shown in Table 2, seedlings had significantly higher growth in the MP (55.4 cm height, 9 leaves) compared to the SP (45.7 cm height, 6 leaves). The faster growth of mangrove seedlings inside the MP compared with control areas provide indirect evidence of utilization of nutrients (drained from the SP effluents) by the seedlings.

Aquasilviculture

Aquaculture that is integrated with the mangrove ecosystem may be located in the sub-tidal waterways as in the farming of seaweeds, bivalves and fish in netpens or cages, or in the intertidal mangrove forest itself as in mangrove ponds and pens. This report will be limited to the latter as the culture of seaweeds and fish is covered elsewhere in this volume.

In collaboration with the local government or people's association, the SEAFDEC Aquaculture Department has mangrove pond and pen culture study sites located in old growth and regenerating

Table 3. **Comparison between New Buswang, Kalibo and Bugtong Bato, Ibajay mangrove-aquaculture sites in Aklan**

Trait	New Buswang, Kalibo	Bugtong Bato, Ibajay	
Mangrove growth	Regenerating	Old growth	Old growth
Culture system	Pen	Pen	Pond
Compartment size (m^2)	200	300	1400
Culture species	Mud crab	Mud crab, milkfish	Mud crab, shrimp
Linkage	People's organization	Local government	Local government

Table 4. **Investment cost for 200 m² pens of mud crab *Scylla serrata* in Kalibo, Aklan (1 Philippine Peso, ₱ = 40 US Dollar)**

	Stocking density		Feed	
	0.5 / m²	**1.5 / m²**	**Salted fish**	**Mixed**
Total variable cost [a]	₱ 5,275	₱ 5,275	₱ 5,275	₱ 5,275
Capital cost [b]	1,822	4,900	3,423	3,153
Interest in capital	211	211	211	211
Depreciation [c]	26	26	26	26
Total fixed cost	237	237	237	237
Total operation cost	2,059	5,137	3,660	3,390
Total investment	7,334	10,412	8,935	8,665

[a]seed, feed, etc., [b]bamboo, nylon, PVC, etc., [c]8% per annum

Table 5. **Production and cost-return analysis per crop for mud crab *Scylla serrata* in 200 m² pens in Kalibo, Aklan**

	Stocking density		Feed	
	0.5/m²	**1.5/m²**	**Salted fish**	**Mixed**
Survival (%)	56	33	44	45
FCR	5.30	7.60	6.70	6.20
Mean body weight (g)	317.40	316.40	310.00	324.00
Production (kg per pen)	17.80	31.30	23.60	25.60
Total revenues (₱)*	5,509	9,715	7,313	7,924
Less: Operational cost (₱)	2,059	5,137	3,660	3,390
Net revenue (₱)	3,450	4,578	3,653	4,534
Production cost per kg (₱)	116	264	155	133
ROI (%)	65	87	69	86

* Price per kg: ₱ 350.00 female, ₱ 270.00 male, ₱ 310.00 mixed sexes (in Philippine Peso, ₱)

Table 6. **Investment cost for 300 m² pens of mud crab *Scylla tranquebarica* in Ibajay, Aklan (in Philippine Peso, ₱)**

	Male	Female	Mixed
Total variable cost[a]	P 10,704	P 10,260	P 10,221
Capital cost[b]	9,011	9,011	9,011
Interest in capital	360	360	360
Depreciation[c]	45	45	45
Total fixed cost	405	405	405
Total operating cost	11,109	10,665	10,626
Total investment	20,120	19,676	19,637

[a]seed, feed, etc., [b]bamboo, nylon, PVC, etc., [c]8% per annum

Table 7. **Production and cost-return analysis per crop for mud crab *Scylla tranquebarica* in 300 m² pens in Ibajay, Aklan**

	Male	**Female**	**Mixed Sex**
Survival (%)	69	60	52
FCR	7.70	7.30	7.20
Mean body weight (g)	190.20	191.30	216.70
Production (kg per pen)	79	69	68
Total revenue (P)	15,800	16,560	15,640
Less: Operation cost (P)	11,109	10,665	10,626
Net revenue (P)	4,691	5,895	5,014
Production cost per kg (P)	141	155	156
ROI (%)	52	65	56

mangrove sites (Table 3).

Mangrove pens, Kalibo, Aklan - In a regenerating mangrove site (a few naturally growing *Avicennia* and *Sonneratia*, planted *Rhizophora),* 200 m² pens made of nylon net on a bamboo framework were installed. Investment costs are found in Table 4.

Mud crab *Scylla serrata* juveniles were stocked in a 2x2 factorial experiment (two densities: 0.5 and 1.5/m² and two feeds: salted fish and mixed 25% salted fish plus 75% salted brown mussel). Survival, production and cost-return analysis are found in Table 5 (statistical analysis showed no interaction between stocking density and feed so data were pooled). Although 1.5 per m² density gave a lower survival rate and higher FCR compared with 0.5 per m², it has a higher production, gross and net revenue and ROI (Table 5). On the other hand, feeding with salted fish alone and mixed salted fish-mussel gave similar survival, food conversion (FCR) and production rates.

Mangrove pens, Ibajay, Aklan - Located in a primary forest in Barangay Bugtong Bato, the pens have similar construction as in Kalibo but the dikes were higher, the canals deeper (to

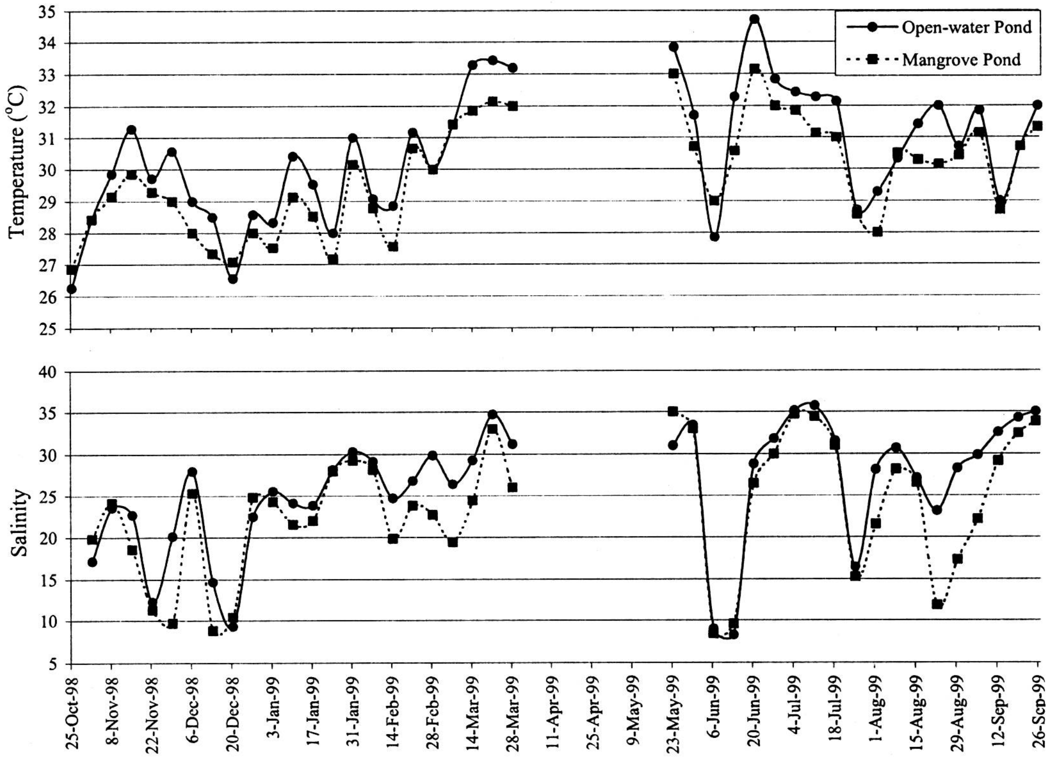

Figure 4. **Weekly means of water temperature and salinity in Pond B (open water) and C (mangrove pond) in Bugtong Bato, Ibajay, Aklan**

Table 8. **Mud crab *Scylla olivacea/S. tranquebarica* culture in 1,400 m² mangrove pond in Bugtong Bato, Ibajay, Aklan**

	Run 1	**Run 2**	**Projected**
Total pond area (m²)	1,400	1,400	5,000
Stocking density (number per m²)	0.65	0.40	0.50
Initial stock (number)	910	580	2,500
Final stock (number)	366	213	1,250
Survival rate (%)	40.2[a]	36.7[b]	50.0
Mean body weight (g)	210	142	220
Production (kg per crop)	76.9	30.2	275
FCR	8:1	7.4:1	6:1

[a]Leaking gate, [b]Chelipeds removed

Table 9. **Projected investment cost of mud crab culture in 5,000 m² mangrove pond in Ibajay, Aklan (in Philippine Peso, P)**

Capital cost			
Diking (675 m^3 x P40 per m^3)		P 27,000	
Gate		10,000	
Net enclosure		5,000	
Miscellaneous		500	
	Total capital cost	P 37,775	P 42,500
Operating cost			
Variable cost			
Crab juveniles, 2500 x P3.50		P 8,750	
Feed (*kohol*), 825 kg x P7.00/kg		5,775	
Feed (fish), 825 kg x P15.00/kg		12,375	
Lime, teaseed, etc.		1,000	
	Subtotal	P 27,900	
Fixed Cost			
Interest on capital[a]		P 633	
Depreciation[b] 40			
	Subtotal	P 673	
	Total operating cost	P 28,573	
	Total investment	**P 71,073**	

[a] 8% per annum, [b] 0.5% per annum

Table 10. **Partial cost-return analysis of mud crab culture in 5,000m² mangrove pond in Bugtong Bato, Ibajay, Aklan (in Philippine Peso, P)**

Total harvest (kg)	275
Total revenues (kg x P250 per kg)	P 68,750
LESS: Operating cost	28,573
Net revenues	40,177
Total investment	71,073
Revenue per kg	250
Production cost per kg	241
ROI (%)	57

hold 0.8-1.0 m water depth), and the compartments bigger at 300 m^2. Tables 6 and 7 show investment costs, and production and cost-return analysis, respectively, for all-male, all-female and mixed sex stocking of *S. tranquebarica.*

Although mixed sexes have lowest survival (52%), the highest body weight (216.7 g) gave a production similar to the all-female treatment (Table 7). All-male treatment has the highest survival and production but the lower price for males (P270 per kg vs. P350 per kg for females) gave lower net revenue and ROI compared with the other treatments.

Mangrove pond, Ibajay, Aklan - A mangrove "pond" was constructed in a patch of old growth forest in Barangay Bugtong Bato by deepening the natural canals and piling the excavated soil to mounds created by the mud lobster. Dikes enclosed an area of 1400 m^2 and a wooden gate was installed for tidal water exchange. Interestingly, water temperature and salinity levels were consistently lower in the mangrove pond because of the canopy shading compared to an adjacent open-water pond (Fig. 4).

Locally sourced crab juveniles of the species *Scylla olivacea* and *S. tranquebarica* were stocked at 0.4-0.65 per m^2 and fed the golden apple snail *Pomacea canaliculata* (*kohol*) or chopped salted fish sometimes combined with copra meal. Low survival (37-40%) in the first two runs may be traced to a leaking gate (and escape of small juveniles) and removal of whole chelipeds, respectively (Table 8). The smaller size and production in Run 2 compared with Run 1 (142 vs. 210 g body weight; 30 vs. 77 kg per crop) can be traced to the total removal of both chelipeds prior to stocking. Hence, energy was first diverted to limb replacement before growth.

Based on capital cost of P42,500 for a 5,000 m^2 pond and operating cost of P28,573 at 0.5 per m^2 stocking density, 50% survival rate and 6:1 FCR based on Run 1 and 2 (Tables 8 and 9), partial cost-return analysis gave a total revenue of P68,750, net revenue of P40,177 and ROI of 57% for the 5,000 m^2 mangrove pond (Table 10).

Conclusion and Recommendations

Results of the Banate, Iloilo study indicate some mitigating effects of passing effluents from shrimp ponds through mangrove forests (before draining to receiving waters) in terms of assimilation of nutrients from the effluents. There is a need for follow-up studies in sites with a wider mangrove area (compared with the 20-m band found in the Banate site) that incorporate regular monitoring of luminous bacteria in shrimp ponds and in the receiving waters of mangrove forests.

The aquasilviculture trials in Ibajay, Aklan had some un-intended "negative", albeit valuable, results. Mortality of some *Avicennia* and *Sonneratia* trees and saplings in the pens, and to a lesser degree in the pond, was traced to a) stress from prolonged flooding or inundation (of the pnuematophores or mangrove roots), and b) direct cutting of the major mangrove roots during pond/ pen construction. In contrast, both the natural *Avicennia* and *Sonneratia* and planted *Rhizophora* in the Kalibo, Aklan pens were healthy and fast-growing. In this latter site, very little of the hydrology was altered. These results point to the double challenge of aquasilviculture - to meet the biophysical needs not only of the cultured animal (e.g. crabs, shrimp) but the mangrove trees as well.

Nevertheless, the promising ROI, net revenues and other financial indicators point to a way by which local villagers can obtain fishery products for sale or domestic consumption while conserving the mangrove trees. The aquasilviculture project is in collaboration with local government units (Barangay Bugtong Bato and Ibajay municipality) in Aklan. Aside from this project, a treehouse has also been constructed on old growth *Avicennia* trees in the site. The Ibajay mangroves have been an educational tool as site for the practical exercises of Sustainable Aquaculture and Coastal Resource Management trainees of SEAFDEC and field biology students of University of the Philippines in the Visayas.

Technology Verification and Extension Program of SEAFDEC AQD

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Realizing the urgent need to package technologies generated through the years of R&D, the SEAFDEC Aquaculture Department through the Technology Verification and Extension Section (TVES) launched in June 1996, a technology transfer and commercialization program to test aquaculture technologies in actual production systems. On-site trials were implemented to verify sustainability, social-equitability, and profitability of aquaculture technologies. Going into real-life situations using aquaculture farms, TVES collaborated with fishfarmers and other institutions in bringing technology to the end-users to enhance widespread interest in aquaculture. This way, TVES can hasten adoption of these technologies and intensify information dissemination to the rest of the aquaculture industry. Once found viable and profitable, extension manuals derived from verification studies are published, with the hope that AQD can contribute to the country's concern for increasing livelihood opportunities and food production from the aquaculture sector.

Objectives

1. To intensify technology verification activities by field-testing specific culture systems in selected farm sites and determine their economic and commercial viabilities;
2. To package technology that are found to enhance productivity and/or profitability;
3. To prepare extension materials for dissemination to SEAFDEC Member Countries and the Philippine government through the Department of Agriculture, Bureau of Fisheries and Aquatic Resources (BFAR); and
4. To network with other related local and international research/educational institutions and fish farmers association.

The TVES continued to verify, package and extend aquaculture technologies. The following activities have been accomplished as of 1999:

Technology Verification

Igang Marine Substation (IMSS)

Cage culture of economically important marine fishes such as red snapper (*Lutjanus argentimaculatus*), grouper (*Epinephelus* spp.), siganids (*Siganus* spp.), scat (*Scatophagus argus*), and tilapia (*Oreochromis* spp.) is ongoing at IMSS. Additional validation tests will be undertaken in cages to determine the optimum stocking density, growth performance, and acceptability of formulated commercial grouper feeds.

Grouper. Grouper broodstock development is also being undertaken with 32 broodstock being maintained in three cages. These fish are fed trash fish at 5% of the total biomass every other day. These will be cannulated to determine their sex and stage of gonad development.

Red snapper. One hundred fifty six of cage cultured red snapper with an average weight of 300 g are ready for harvest. Two other batches having 200 g and 10 g average body weight, respectively, are being cultured in two separate cages. Four red snapper weighing 1.5-25 kg are also being maintained for broodstock development.

Scat ("kikiro"). Eighty scat with weights ranging from 180 to 200 g are being grown in a cage. A separate stock of forty fish weighing about 2.2 g is being grown in another cage. Both stocks are fed daily fish pellets and *lumut* (filamentous green algae) at a rate of 5% of the total biomass.

Siganid. In a similar activity, siganids of three different size-groups (450 pieces, 36g; 377 pieces, 95g; and 413 pieces, 15g) are being cultured in three cages. The fish are fed daily commercial pellets at 5% of the total biomass. Growth measurements are taken regularly. Siganids are also used to check or minimize fouling in cages where other species are cultured.

Tilapia. High-saline tilapia (1600 pieces) with an initial average weight of 20 g are also being grown in a 4x4x3m cage at a density of 33.3 pieces per m^3. Mortalities that may be due to transport and post-stocking stress were observed occasionally during the first two weeks of culture.

Seaweeds. The bi-culture of grouper and seaweeds (*Eucheuma* spp.) using the hanging method in cages was discontinued due to poor growth of the seaweeds. This may have been caused by heavy freshwater run-off during the rainy season.

***Shrimp** :* The larval rearing of shrimp and other commercially important fishes was discontinued due to power supply problem at IMSS. Hatchery operation will be resumed as soon as reliable power supply is restored.

Dumangas Brackishwater Station (DBS)

Pond rehabilitation at the Dumangas Brackishwater Station (DBS) is ongoing for high density culture of milkfish and grouper, red snappers, and verification of the use of environment-friendly schemes in shrimp farming.

High-density milkfish culture. The initial result of the high-density milkfish culture in ponds was encouraging. One pond stocked 1.5 milkfish per cm^2 had a survival rate of 90% after 37 days of culture. The culture is still ongoing.

Grouper culture in brackishwater ponds. Groupers stocked at 9 per m^2 had a survival rate of 85% after 120 days of culture with average body weight of 144.3 g. In another pond, grouper stocked at 9 per m^2 had a survival rate of 90% with average body weight of 76.5 g after 92 days of culture. The groupers fed on tilapia fry with trash fish as supplemental feeds. Paddle wheels were installed to provide additional aeration and PVC pipes to serve as hiding places.

Environment-friendly schemes in prawn farming. Reservoir ponds are also maintained at DBS to verify the use of tilapia, siganids, scat, mollusks and seaweeds as bio-manipulators and bio-filters. Siganids stocked in a pond at 66 per m^2 gave a survival rate of 80% with average body weight of 707 g after 70 days of culture.

In another pond, tilapias stocked at 1.8 per m^2 gave a survival rate of 85% with 80.5 g average body weight after 70 days of culture. Water analysis was regularly done to determine the levels of luminous bacteria. The ponds serve as reservoir of quality water for the shrimp grow out culture. On the other hand, one pond was stocked 3,000 tilapia to act as bio-manipulator. The pond has a sludge collector at the center to prevent shrimps from getting in contact with pond sludge. After water has attained a desired quality, the pond was stocked with 130,000 shrimp fry at 20 per m^2. Another pond filled with quality water was stocked 170,000 shrimps at 20 per m^2. Luminous bacterial analysis in the two grow-out shrimp ponds and reservoirs is done regularly.

Aquasilviculture in Aklan, (northern Panay Island, west central Philippines). Shrimp culture in coastal tidal flats with existing mangroves showed very low survival and low growth for shrimps stocked at 5 and 15 per m^2. Shrimps stocked at 15 per m^2 attained an average body weight of 19.16 g and a survival rate of 1.7%. Shrimps at 5 per m^2 had an average body weight of 14.61 g and a survival rate of 9.1%. For crabs, the growth and survival rates were affected by the high influx of freshwater into the culture site.

Tilapia culture in small freshwater reservoirs or SFRs (Bingawan, Iloilo). Hybrid tilapia in net cages experienced slow growth due mainly to pollution from run-offs from rice fields near the reservoir and also from domestic discharge, making the culture water turbid during the rainy days.

Environment friendly schemes in prawn farming (Sum-ag, Bacolod City, Negros Occidental). Shrimps were cultured using schemes such as probiotics as bio-manipulators, installation of sludge collector at the center of the pond to prevent shrimps from getting in contact with pond sludge, stocking of milkfish, tilapia and oysters in reservoir ponds to act as bio-filters, and installation of long-arm paddle wheels for cleaning the pond bottom and improving aeration. The shrimps, after 157 days of culture, had an average body weight of 33 g. Part of the study was intended to verify the SEAFDEC-formulated feeds. Formulated feed enhanced growth of cultured shrimps, but feed stability in ponds needs to be improved.

Technology Extension

Panay Gulf Development Program (PGDP)

SEAFDEC/AQD together with government agencies such as the Department of Environment and Natural Resources, Department of Agriculture, Department of Science and Technology, Department of Labor and Employment, the University of the Philippines in the Visayas, and the Land Bank of the Philippines agreed to assist the PGDP in its effort to develop the marine resources and protect marine life in Panay Gulf. PGDP, spearheaded by the Iloilo's first district representative, is intended to benefit the communities of the First District of Iloilo where the Tigbauan Main Station of SEAFDEC/ AQD is located. The program makes use of idle or unproductive brackishwater ponds, small freshwater impoundments, and protected coastal waters. The technologies suitable in these coastal areas are: grouper culture in ponds, culture of all-male genetically improved farmed tilapia (GIFT) in small freshwater reservoirs, cage culture of grouper, siganids or milkfish, and improvement of the indigenous methods of fish traps, and fry and fingerling collection. The program also intends to implement a rehabilitation project for *the Placuna placenta* industry in the coastal towns of Oton, Tigbauan, Guimbal, Miag-ao, and San Joaquin.

Seed production of **Placuna placenta** *(lampirong)*

About 1200 *lampirong* (window-pane oyster) broodstock obtained from the island of Negros have been made to mature and spawn at the laboratory of SEAFDEC/AQD in Tigbauan and in the sandy beach in front of the Tigbauan Main Station. Seedlings produced in the laboratory were also stocked along the area to enhance existing stocks. Breeding sites included Barangay Trapiche in Oton, Barangay Namocon in Tigbauan, and Barangay Nalundan in Guimbal.

Tilapia culture in small freshwater reservoirs

Some 3000 all-male GIFT tilapia were distributed to villages with potential SFRs in Miag-ao and Tubungan in Iloilo. In addition, 250 SEAFDEC-strain of a fast-growing tilapia broodstock were also stocked in a Miag-ao SFR for breeding in order to insure sustainability of the project.

Orientation and training of wild fry gatherers

An orientation and training of gatherers of wild fish fry was conducted at Tigbauan. Wild fry gatherers were trained on the identification and the methods of catching fry of groupers, siganids and other economically important fish. The three-part training series was attended by about 200 fry gatherers from Oton to San Joaquin in Iloilo.

Philippine Reef and Rainforest Conservation Foundation, Inc. (PRRCFI)

The Southern Negros Coastal Development Program of the PRRCFI sought the assistance of SEAFDEC/AQD in their efforts to provide alternative livelihood to local fisherfolk cooperatives in five coastal communities of Negros Occidental extending from Cauayan to Sipalay. Mangrove-friendly aquaculture and fish cage culture projects in potential sites have already been started.

Concepcion Polytechnic College (CPC)

A joint technology demonstration and extension project is being implemented by BFAR, SEAFDEC/AQD, and CPC at the school's pond facilities. The project aims to demonstrate in commercial scale, the technical and economic viability of grouper culture and pond culture of milkfish using hatchery-bred fry. The project also intends to provide CPC students in fisheries and aquaculture hands-on training on SEAFDEC-generated technologies and to update the technical know-how of its faculty.

Central Panay Economic Unification, Inc. (CPEU)

SEAFDEC/AQD has collaborated with BFAR to provide technical assistance to CPEU on the culture and seed production of tilapia in a 24 ha dam in San Julian. Some 25,000 fast-growing and 580 SEAFDEC strain tilapias have been stocked in 14 floating cages. The rebel returnees of Capiz also maintain separate cages of tilapia in the same dam under the supervision of a TVES technician.

Philippine Business for Social Progress (PBSP)

AQD is collaborating with PBSP Technology Management Program in assessing mariculture-based livelihood projects for coastal beneficiaries in Western Samar, Quezon, and the Davao Gulf area. Four units of floating net cages have been installed by PBSP in Maqueda Bay, Western Samar and stocked with grouper collected from the wild. AQD researchers also provided technical assistance to PBSP coordinators of Western Samar, especially in the breeding and grow-out culture of grouper. TVES is also supervising the construction of four units of grouper cages in Samal Island in Davao.

Food and Agriculture Organization-United Nations Development Programme (FAO-UNDP)

AQD is providing technical assistance to the FAO-UNDP aimed at providing alternative livelihood to Moro National Liberation Front (MNLF) regulars and rebel returnees in Mindanao. Ten units of floating cages for grouper culture have been constructed in identified sites in Basilan and Jolo provinces, southern Philippines.

Western Visayas Technology Promotion Center (WVTPC)

The Land Bank of the Philippines (LBP) initiated the establishment of the WVTPC with members from SEAFDEC/AQD, University of the Philippines in the Visayas, and the Iloilo State College of Fisheries in response to the government's thrust on food security and poverty alleviation. The Center will fast track countryside development, including the adoption of sustainable fishery technologies. The WVTPC's initial activities include the validation and assessment of environment-friendly, sustainable and profitable aquaculture technologies by LBP for commercial (collaterized) and livelihood (non-collaterized) loaning programs. A hands-on aquaculture training at AQD has been envisioned as a prerequisite for the granting of loans by LBP. Aquaculture technologies being considered by LBP for funding are grouper culture in ponds and cages, pen culture of mud crab in mangroves and in ponds, and high-density milkfish culture in ponds.

Region IV (Palawan and Batangas)

Shell Philippines, the Provincial Governments of Palawan and Batangas, and the Center for Renewable Resources and Energy Efficiency (CREE) have sought the technical assistance of SEAFDEC/AQD in the implementation of their aquaculture projects in Palawan and Batangas, two provinces in Region IV. Through the Shell Foundation, Shell Philippines has exerted efforts to provide livelihood options to displaced residents of Batangas City where Shell has put up an oil refinery. In Palawan, a fish sanctuary has been set up in Malampaya Sound in Coron Island where Shell Foundation is also committed to provide alternative livelihood to fisherfolk in the island. CREE has also started a grouper cage culture project and has planned to implement a mud crab project in Coron and Busuanga, Palawan. Shell Foundation and CREE are seeking the technical assistance of SEAFDEC/AQD in this province-wide joint aquaculture venture and hope to formalize the collaboration for the development of Palawan and Batangas.

The Local Government of Tigbauan, Iloilo

SEAFDEC/AQD has committed itself to provide technical assistance to the Municipality of Tigbauan, the host of the Tigbauan Main Station. Suitable aquaculture sites are currently being identified by barangay captains and local government officials. After the site suitability study, appropriate livelihood projects will be established to showcase viable SEAFDEC-developed aquaculture technologies for the benefit of the the municipality.

ADSEA '99 Priorities and Recommendations

These recommendations were forwarded during the six simultaneous workshop sessions, which focused respectively on six major aquaculture systems. The species listing under each system has not been prioritized; however, specific research areas under each species were. The list also considered areas of concern, which are important to responsible aquaculture development in the region. In implementing these priorities for research, training and information, the SEAFDEC Aquaculture Department shall further review such recommendations to consider 1) its existing manpower and physical resources; 2) possible collaboration with other SEAFDEC Departments, research institutions, government sector, and the private sector to preclude duplication of efforts, 3) do-able research areas within an appropriate time frame, and 4) market demands of aquaculture products and choice of species as a means for poverty alleviation in farming communities.

I. Priorities and Recommendations for Research

A. Mariculture

No specific recommendations were offered for some of the invertebrates identified during the workshop, particularly the sea urchin (*Tripneustes gratilla*), green mussel *Perna viridis,* giant clam *Tridacna* sp., pearl oyster *Pinctada* sp., blood cockle *Anadara* sp., and hard corals, since the culture technology is either already in place or in an advanced stage. Hence, workshop participants generally rated as least critical the various concerns in responsible aquaculture development for these invertebrates. Nonetheless, it is strongly recommended that existing culture systems for these invertebrates be improved, with particular consideration for technologies appropriate for coastal fishing communities and its impacts on economic viability, environmental integrity, and social equity in this impoverished sector of society.

Seaweeds

Kappaphycus sp.
- Improvement of farming technology

Eucheuma gelatinae
- Development of seed production and grow-out techniques
- Economic viability of farming

Gracilaria sp./*Gracilariopsis* sp.
- Economic viability of farming
- Refinement of existing farm production technology
- Social equity of farming - is farming viable as an alternate livelihood option?
- *Gracilaria* sp./*Gracilariopsis* sp. as biofilter in mariculture

Sargassum sp.
- Development of farming techniques
- Regeneration of *Sargassum* beds to mitigate natural resource depletion
- Market studies to address low value of produce

Caulerpa lentilifera
- Verification of farming technology
- Development of criteria for site-selection of farms

Halymenia sp.
- Development of farming techniques

Porphyra sp.
- Adoption of existing Japanese farming technology

Gracilaria eucheumoid.es
- Development of farming techniques
- Assessment of economic viability of farming

Fishes

Rabbitfish *Siganus guttatus*
- Refinement of hatchery and grow-out techniques
- Development of economically viable culture methods

Seahorse *Hippocampus* sp.
- Improvement of hatchery and development of nursery and grow-out techniques

Blue tang *Paracanthurus hepatus*
- Development of seed production techniques

Humpback wrasse *Cheilinus* sp.
- Development of seed production techniques

Grouper *Cromileptis altivelis*
- Development of seed production techniques

Crustaceans

Sea mantis
- Assessment of farming potential

Ranina ranina ("curacha")
- Assessment of farming potential

Blue crab *Portunus* sp.
- Adoption of nursery and grow-out techniques

Spiny lobster *Panulirus* sp.
- Development of methods for management of wild stocks

Other invertebrates

Donkey's ear abalone *Haliotis asinina*
- Development of formulated diets as alternative to seaweed diet

Window-pane shell *Placuna placenta*
- Improvement of seed production techniques

Nylon shell *Paphia* sp.
- Development of seed production and farming techniques

Top shell *Trochus* sp.
- Adoption of seed production technology

Angelwing clam *Pholas orientalis*
- Improvement of hatchery and grow-out techniques

B. Brackishwater Farming

Milkfish *Chanos chanos*
- Development of techniques to increase yield using deep and shallow water farming methods
- Determination of fate of antibiotic residues from chicken manure applied to enhance natural productivity in ponds
- Improvement of farming thru minimal water exchange in ponds
- Refinement of polyculture techniques
- Economic viability for different farming systems (e.g., land use)
- Genetic selection of broodstock
- Development of techniques for off-season and year-round spawning
- Analysis of the ecological footprint of milkfish farming

Grouper *Epinephelus coioides*
- Improvement of broodstock management and hatchery techniques
- Development of formulated diets as alternative to fish by-catch diet and reduction in fish meal requirement
- Development and standardization of techniques for nursery and grow-out techniques
- Documentation of treatment and control of diseases in groupers

Mangrove red snapper *Lutjanus argentimaculatus*
- Improvement of broodstock management and hatchery techniques
- Development of formulated diets as alternative to fish by-catch diet (e.g., cowpea as fish meal substitute)
- Development and standardization of techniques for nursery and grow-out techniques
- Analysis of prey-predator relationship in developing farming techniques

Mullet *Mugil* sp.
- Biology of species
- Assessment of market demand
- Development of cost-effective farming system

Rabbitfishes *Siganus* sp.
- Development of nursery techniques
- Research documentation of growth rates in various culture systems

Mud crab *Scylla* sp.
- Broodstock development
  - Improvement of handling and holding conditions
  - Development of reliable criteria for larval quality assessment
  - Development of improved broodstock through genetic selection
- Development of hatchery and nursery techniques
  - Improvement of health management techniques in the hatchery
  - Development of *Artemia* substitutes

    - Improvement of fertilization schemes for in situ production of natural food
    - Optimization of stocking density
    - Practical diet development
- Development of grow-out techniques
    - Improvement of feeds and feeding management
    - Comparative evaluation of farming various species of *Scylla*
    - Polyculture with fish or shrimp in semi-intensive system

Giant tiger shrimp *Penaeus monodon*
- Revision of criteria for assessing fry quality (i.e., documentation and compilation of screening criteria for postlarvae)
- Management and genetic selection of broodstock
- Further validation and evaluation of the ecological footprint of shrimp farming

C. Freshwater Fish Aquaculture and Integrated Fish farming

As in the other commodities, the development of aquaculture technologies for each of the freshwater fishes listed here need also to consider economic viability, environmental impacts, social equity, and integration of culture systems.

Tilapia *Oreochromis* sp.
- Broodstock management and seed production
    - Environmental influence (season, water temperature) on spawning
    - Health management of broodstock and seed
    - Identification of critical stages of development to increase seed survival
    - Interaction of genetics and environment during culture
    - Establishment of standard protocol for accreditation of hatcheries producing quality seeds
    - Development of disease control measures during stock transfers
- Integrated fanning
    - Effects of antibiotic residues from chicken manure applied to enhance natural productivity in ponds
    - Red tilapia in "green water" culture of shrimp in ponds

Catfish *Clarias macrocephalus*
- Integration of catfish culture in farming systems
- Environmental impacts of catfish farming
- Live food in catfish seed production
- Prevention, monitoring, and regulation of introduction of exotic species in natural waters
- Feeds and feeding management

Catfish *Pangasius* sp.
- Characterization and elimination of off-flavor in pond-reared catfish
- Water quality management
- Feeds and feeding management

Catfish *Arius manilensis*
- Biology and breeding for resource conservation

Freshwater lobster *Macrobrachium rosenbergii*
- Collection and characterization of various strains and varieties
- Genetic improvement
- Enhancing productivity of freshwater lobster culture in ponds

Carps (common, Chinese, Indian, and silver carps)
- Genetic improvement of stocks for fast growth
- Polyculture in various culture systems
- Impact monitoring of genetic variability of introduced carps
- Improvement of post-harvest techniques

Eel *Anguilla* sp.
- Assessment and identification of wild elver stocks
- Increase survival of elvers in the farm

Rice eels *Monopterus* sp. and *Fluta alba*
- Broodstock development
- Health management in grow-out culture (e.g., epizootic ulcerative syndrome)
- Social equity in rice eel culture

Freshwater ornamental fishes
- Development of culture techniques for indigenous species

Giant gourami
- Development of broodstock
- Nutrition studies for growth acceleration
- Development of appropriate culture systems
- Identification of strains

Snakeheads *Channa* sp.
- Development of breeding techniques

D. Coastal Resource Management and Mangrove-friendly Aquaculture

Coastal resource management
- Income diversification
  - Promotion of sea ranching and protective management
  - Development of environment-friendly aquaculture
  - Promotion of non-coastal resource based enterprises
  - Market studies on selected products (e.g., mud crabs)
  - Alternative aquaculture systems and techniques to integrate fish, molluscs, seaweeds and other species
- Property rights and collective action in technology adoption by coastal communities
- Co-management schemes and institutional arrangements (e.g., marine sanctuaries)
- Community-ecological modelling
- Strategies for organizing community groups and institutions for coastal resource management
- Review of coastal resource management strategies in Southeast Asia to focus on specific culture commodities (e.g., milkfish) or ecosystems (e.g., mangrove)

Mangroves
- Ecological footprint of intensive brackishwater pond culture (mangrove-to-pond ratio)
- Aquasilviculture
  - Mangrove pens and pond culture, particularly water management, appropriate animal and plant species
- Mangrove zonation
- Processing and use of pond sludge
- Valuation of mangroves and other coastal resources
- Research on the biology and distribution of commercially important invertebrate and aquatic plant resources in mangrove areas (e.g., *Paphia,* mangrove clams, etc.)

E. Intensive Aquaculture

Giant tiger shrimp *Penaeus monodon*
- Development of cost-efficient diet appropriate for a particular farming system
  - Alternative protein sources with good digestibility
  - Improvement of feed-conversion ratio
  - Development of water-stable feeds (i.e., good binders)
  - Improvement of feeding practices
  - Establishment of standards for shrimp feeds
  - Definition of nutrient requirements

- Improvement of culture systems
  - Evaluation and improvement of existing pond engineering designs
  - Research on nutrient dynamics
  - Development of integrated farming systems for shrimp
  - Establishment of standards of water quality

- Environmental impacts
  - Sludge disposal and effluent treatment
  - Reduction of water change
  - Phytoplankton profile in intensive culture ponds
  - Impacts of pollutants on resource valuation
  - Tolerance level of cultured shrimps to various agricultural chemicals
  - Carrying capacity of culture area

- Disease management
  - Molecular genetics of causative agents of shrimp diseases

- Social equity of intensive shrimp farming
  - Comparison of social structure of shrimp farming vis-a-vis other Southeast Asian countries
  - Analysis of social benefits of shrimp farming (e.g., employment, etc.)
  - Documentation of farms as point-sources of water pollution and its impacts on nearby coastal communities

- Tilapia *Oreochromis* sp.
  - Carrying capacity of inland freshwater bodies related to farming tilapia in cages
  - Development of saline-tolerant tilapia strains

F. Farming in Marine Cages

Fishes

Milkfish *Chanos chanos*

- Adoption and improvement of off-shore culture
- Feed development
- Nursery management

Grouper *Epinephelus coioides*

- Feed development
- Disease management
- Nursery management

Mangrove red snapper *Lutjanus argentimaculatus*

- Feed development
- Broodstock management, particularly elimination of mass-mortalities

Rabbitfish *Siganus guttatus*

- Feed development
- Improvement of seed transport and handling

Sea bass *Lates calcarifer*

- Evaluation of marketing strategies to create demand

Jack *Caranx* sp.

- Broodstock development
- Development of grow-out techniques

Seahorse *Hippocampus* sp.

- Broodstock development
- Development of nursery and grow-out techniques

Blue tang *Paracanthurus hepatus*

- Broodstock development
- Development of nursery and grow-out techniques

Seaweeds

Caulerpa sp.

- Development of grow-out techniques to provide social benefits to coastal communities

Ulva lactuca

- Development of grow-out techniques to provide social benefits to coastal communities

Donkey's ear abalone *Haliotis asinina*

- Improvement of nursery techniques
- Improvement of grow-out techniques

II. Priorities and Recommendations for Training and Information

A. Mariculture

- Documentation of existing technologies of other aquaculture species in the region

B. Brackishwater Farming

- Increased collaboration with other institutions' extension activities
- Enhancement of funding to expand the range of readership of extension materials and the number of trainees from various countries in the region
- Evaluation of the benefits of training and information activities
- Reduction of aquaculture training cost to be of reach to small stakeholders
- Modification of the duration and location of training activities to suit the needs of fish farmers

C. Freshwater Fish Aquaculture and Integrated Fish Farming

- Conduct of freshwater aquaculture training appropriate for specific countries in the region
- Translation of existing extension materials in freshwater aquaculture into a common language, such as English

D. Coastal Resource Management and Mangrove-friendly Aquaculture

- Environment education at the community level (e.g., curriculum development for grade and high schools in collaboration with education agencies)
- Formulation and evaluation of guidelines on the management of marine protected areas
- Integration of coastal resource management in aquaculture books to be published by SEAFDEC
- Mangrove education plan for children (e.g., mangrove day as a special event)

E. Intensive Aquaculture

- Development and promotion of training and education programs for environment-friendly aquaculture technologies, particularly shrimp farming
- Dissemination of information on the impacts of pollutants on coastal resource valuation
- Dissemination of information to local governments and fish farmers on the provisions and implications of the FAO Code of Conduct of Responsible Fisheries, particularly the provisions on Aquaculture Development

F. Farming in Marine Cages

- Provide easy access to farmers of faming technologies in marine cages

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The Southeast Asian Fisheries Development Center (SEAFDEC) is a regional treaty organization established in December 1967 for the purpose of promoting fisheries development in the region. Its member countries are Japan, Malaysia, the Philippines, Singapore, Thailand, Brunei Darussalam, the Socialist Republic of Vietnam, Union of Myanmar, and Indonesia.

Representing the Member Countries is the Council of Directors, the policy-making body of SEAFDEC. The chief administrator of SEAFDEC is the Secretary-General whose office, the Secretariat, is based in Bangkok, Thailand.

Created to develop fishery potentials in the region in response to the global food crises, SEAFDEC undertakes research on appropriate fishery technologies, trains fisheries and aquaculture technicians, and disseminates fisheries and aquaculture information. Four departments were established to pursue the objectives of SEAFDEC.

- The Training Department (TD) in Samut Prakan, Thailand, established in 1967 for marine capture fisheries training
- The Marine Fisheries Research Department (MFRD) in Singapore, established in 1967 for fishery post-harvest technology
- The Aquaculture Department (AQD) in Tigbauan, Iloilo, Philippines, established in July 1973 for aquaculture research and development
- The Marine Fishery Resources Development and Management Department (MFRDMD) in Kuala Terengganu, Malaysia, established in 1992 for the development and management of the marine fishery resources in the exclusive economic zones (EEZs) of SEAFDEC Member Countries.

SEAFDEC/AQD is mandated to:

- promote and undertake aquaculture research that is relevant and appropriate for the region
- develop human resources for the region
- disseminate and exchange information on aquaculture

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