Shrimp Farming and the Environment

Can Shrimp Farming Be Undertaken Sustainably?

A discussion paper designed to assist in the development of sustainable shrimp aquaculture

CONTENTS

EXECUTIVE SUMMARY

Shrimp farming has developed rapidly in recent years in many developing countries. Although it has brought significant benefits to some areas, it has also been associated with environmental degradation and social conflict. Many have questioned the sustainability of the industry on both social and environmental grounds. Widespread disease incidence has also raised questions relating to its sustainability in purely practical terms. The large areas of land required for extensive and semi-intensive farming have led to significant natural habitat loss through conversion of wetlands into ponds.

These issues are the focal points of this study. The overriding question addressed here is: Can shrimp farming be undertaken sustainably?

Current status and potential of shrimp farming

Several primary forces have driven the rapid expansion of shrimp aquaculture. They include potentially high profits, buoyant demand for high-value seafood products, increasing demand for farmed shrimp due to limitations and fluctuations in supplies from capture fisheries, and the industry's capacity to generate foreign exchange and employment in poor coastal areas of tropical and subtropical developing countries. Efforts are being incorporated into some projects to provide access to the benefits of shrimp farming to poor coastal communities, thereby reducing poverty and preventing the communities' interests being overtaken by external parties.

Shrimp farming has become a major aquaculture activity and attractor of investment over the past two to three decades. Currently, shrimp farming accounts for some 30% of total world shrimp production, and this share is growing. In the face of stagnating or declining catches from the wild, shrimp farming is expected to play an even more important role in the future.

Farmed shrimp has become a significant factor in world shrimp markets over the past five to six years. Worldwide farmed shrimp production has risen significantly since 1985, from 213,000 metric tons (MT) to 931,788 MT in 1995, although it has since declined slightly. The market for shrimp has grown in most parts of the world, and demand is likely to remain high, assuming that major markets continue to have overall economic growth. However, the current downturn in the southeast Asian and Japanese economies has affected price, and prices may settle at a level somewhat lower than in recent years, at least in the short to medium term. Nonetheless, shrimp remains a high-value product with a very large international market. It is expected that any future growth in the market and shortfall from capture fisheries will be covered by increased aquaculture production.

Crop failures due to disease outbreaks have occurred in several shrimp farming countries, and, along with other macroeconomic factors, have introduced an element of uncertainty in the market, with resulting price fluctuations. These fluctuations may be detrimental to the sustainability of shrimp farming.

Today, over 50 countries farm significant quantities of shrimp. Most production takes place in Asia. In India, Indonesia, and Thailand, national industry revenues range from $300 million to over $1.6 billion per year. The largest producers in 1995 were Thailand (281,000 MT), Indonesia (139,000 MT), India (97,000 MT), the Philippines (90,000 MT), and Ecuador (90,000 MT). Taiwan, Republic of China; Bangladesh; and Vietnam also have considerable shrimp farming production, ranging from 34,000 to 78,000 MT in 1995.

Shrimp farming systems and intensity

Shrimp farming production systems are technically diverse; the different systems and some of their implications are discussed in Chapter 3. They are commonly classified as traditional, extensive, semi-intensive, intensive, and superintensive (although there are very few commercial examples of the latter). Various other intermediate designations such as "improved extensive" are also used. In practice, these terms are ill-defined, reflecting a broad and continually changing spectrum of systems that vary according to how intensively they use different resources (capital, labor, skills, land, water, seed, feed, fuel, and equipment). Most shrimp farming in the world is still extensive or semi-intensive.

The more extensive farming systems require large areas of land, and therefore have a heavy impact on natural habitat and on other land uses. Indeed, one of the most important limiting factors in shrimp farming development today is the availability of land. In many countries, land costs have now risen to the point that constructing extensive shrimp farms is unprofitable. In addition, construction of shrimp farms in mangrove areas in some countries is now prohibited, rendering such land unavailable. The lack of, or high cost of, available space may therefore push the development of shrimp farming in the direction of more intensive systems in the future.

While more intensive shrimp farming methods may be beneficial (they require less land and can have high output), they are more difficult to manage, and their risks are greater. They also require higher inputs that may cause upstream and downstream environmental impacts. However, from an economic point of view, more intensive systems may be the only viable option in the future in those countries where suitable land is scarce or expensive. The environmental problems associated with intensive systems, and the need for greater skill, adequate finance, and improved technology, will therefore have to be addressed in detail when evaluating proposed intensive shrimp farming projects.

Environmental impacts

As with most development activities, including agriculture, shrimp farming is associated with a number of negative environmental impacts. These include habitat conversion; conversion of land from other valuable uses; nutrients and organic matter in effluent; chemicals used in soil, water, and disease treatment; salinization; and the introduction of non-native species or genetically distinct varieties.

The causes of environmental impacts are multiple, although seldom present all at once: poor planning and management of water supply and effluent; poor siting; poor design and technology; poor management practices and lack of knowledge about potential environmental damage; high disease incidence and associated use of chemicals; insufficient legal frameworks and regulatory instruments; weak law enforcement; and the prospect of rapid, high profits. The profit potential may undermine long-term planning and far-sighted farm management, which can contribute to environmental conservation if allowed to govern decisions.

It is extremely difficult to address most of these problems through conventional farm- or project-level environmental impact assessments (EIAs). Many shrimp farm developments, especially in Asia, are small scale, and their impact is insignificant when considered in isolation. However, very large numbers of such small-scale developments have serious cumulative environmental effects when concentrated in high densities in some locations. Therefore, project EIA is neither useful nor feasible for such developments, and to date has had limited positive effect on the development of the sector.

These cumulative impacts can be addressed only through sector environmental assessment (EA), undertaken for a specific estuarine, watershed, or coastal zone, which assesses the actual and potential impacts on the whole sector and seeks to mitigate adverse impacts through a range of planning, regulatory, economic, and infrastructure incentives and constraints. Ideally, such an EA would form part of a broader regional EA covering other sectors and activities.

It is possible to farm shrimp with minimal environmental impact. A wide range of practical measures for significantly reducing the potential damage from shrimp aquaculture, and making it more sustainable against a variety of criteria, are presented in Chapter 4. There is a pressing need for a strong set of incentives and constraints to promote implementation of these measures at farm level. Furthermore, some impacts can be reduced only through better siting and improved planning of the development of the whole sector in a defined area. All of these issues should be addressed in sector EA.

The discussion of environmental impacts and mitigation measures in Chapter 3 provides a broad basis for the development of more detailed and practical guidelines for project- or farm-level environmental assessment.

Social impacts

Shrimp farming is one of very few options for economic development in poor coastal areas with saline soils, and has the potential to enormously enhance smallholder income, or to provide relatively well-paid employment at larger operations. Despite claims to the contrary, it appears that shrimp farming can create relatively high levels of employment per unit area of land when compared with most feasible alternatives.

However, the risks associated with shrimp farming are considerable, and some extreme cases of negative social impacts have been reported. Some interest groups have shown a tendency to focus exclusively on these negative cases and have turned significant media attention on them. The result has been that the general public, as well as environmentally concerned groups, have the impression that shrimp farming represents a danger to the socioeconomic development of a country or region. Unfortunately, very few studies exist that have thoroughly and objectively assessed and presented the balance of social and environmental costs and benefits.

Although shrimp farming has sometimes been associated with increased inequity, resource appropriation, and resource use conflict, it should be emphasized that these problems are related less to the nature of shrimp farming itself than to the social, economic, and political contexts in which it has developed. The financial attractiveness of shrimp farming has been exceptional, and this has exaggerated and drawn attention to what are common development problems. Shrimp farming has become the victim of its own success. Further studies are required to gain a better and more objective understanding of these issues.

It is clear from the nature of the social impacts and related experiences that—just as with the environmental impacts—much more attention must be paid to proper planning. Social as well as environmental impact assessments should be undertaken for the sector as well as for individual projects.

Practical measures for minimizing social impacts are presented in Chapter 4; these may serve as a basis for developing practical guidelines for social impact assessments at project and sector levels.

Financial risk

Chapter 5 presents the main sources of risk in shrimp aquaculture and ways to minimize such risk through careful planning, feasibility analyses, and prevention measures. Although shrimp farming can be extremely profitable, the more intensive systems require high levels of investment in each crop. Furthermore, the returns from shrimp culture rarely match expectations in the long term. Although the risks can be reduced through good siting, design, technology, and management, serious disease outbreaks can be a problem on all types of farms, including the more extensive systems. Short-term losses can be considerable, and difficult to absorb, especially on smaller farms.

The risk of disease should be appraised thoroughly in any proposal for shrimp farm development. Such an effort requires study of existing disease incidence, industry and government measures to prevent and manage disease, and assessment of the risks from contaminated water supply, contaminated seed, or the cumulative effects of exceeding carrying capacity in any given ecosystem. In addition, disease incidence will generally be higher on less suitable soils, such as acid sulphate (or potentially acid sulphate) soil.

A well-documented feasibility study, supported by thorough and reliable market studies, soil and water analyses, assessments of the risks related to disease, raw material supplies studies, and other research should be undertaken before starting any shrimp farm project. Such research reduces uncertainty and financial risk, and safeguards the sustainability of the project. Adequate, appropriate, and accessible credit facilities or reserve funds must be available to the project, and cost recovery mechanisms should be considered in the project's financial design.

Generous safety margins, guided by a precautionary approach, should be included in all calculations for input, operational, and output factors. As such, sensitivity calculations must be performed, using less favorable conditions than the base case. Often, several negative factors will occur at the same time, and the sensitivity analysis should include calculations that reduce favorable inputs simultaneously, rather than individually.

Planning and management of the sector

Given the nature of the social and environmental effects of shrimp aquaculture, and the risk of disease outbreaks, the development of sustainable shrimp culture will be possible only with some form of government intervention, perhaps involving different levels of government. Such intervention needs to focus on issues such as land use planning and socioeconomic development, the development and adoption of powerful incentives and constraints to promote more efficient and environmentally friendly practices, and awarding operating licenses and permits contingent upon operators' using such better practices.

In most cases, this implies the development of an integrated coastal management (ICM) plan supported by appropriate national and state/provincial legislation. However, since developing an ICM can be an extremely lengthy process, and since shrimp farming has a tendency to develop rapidly in certain circumstances, some more immediate and practical approaches are required.

Shrimp farm development should be promoted only on the condition that a thorough sector environmental assessment is conducted first—that is, an EA incorporating best current practices for an estuarine or lagoon system (or some other usefully defined coastal area with aquaculture potential). This EA should feed into an aquaculture development plan, which may serve as one component in—and in some cases a starting point for—a broader natural resource management or integrated coastal management plan. Such a plan would address, at minimum, issues of land use zoning, chemical use, nutrient enrichment of nearby waters, hydrology and salinization, environmental capacity, habitat protection, equity and social issues, disease prevention and management, farmer organization, and product marketing.

Any development and management plan must be supported, facilitated, and in some cases enforced, with a comprehensive set of incentives and constraints. Constraints in the form of regulations are notoriously difficult to enforce in most developing countries; therefore, serious consideration should be given to economic incentives, including grant aid and credit, infrastructure provision, environmental certification and marketing initiatives, and tax incentives. In most cases, the implementation of these provisions will require a thorough review and revision of the legislative framework, which is commonly inadequate for aquaculture development. Recommendations for the minimum content of such plans and associated incentives are presented in Chapter 6.

Planning and management of individual projects

Large-scale farms or shrimp farm development projects should be subject to more thorough project assessment and planning than has occurred to date, including best-practices feasibility studies and project environmental impact assessments. Recommended minimum requirements for environmental assessment, and broad guidance for feasibility studies, are presented in Chapter 7. More detailed guidance for feasibility studies' content is included in Annex 1.

Project design should be modular, with engineering cost-effective for the planned scale. New areas should be developed in a phased manner over several years, with monitoring to assess whether estimates of environmental impact and carrying capacity are correct, as well as to determine whether mitigation measures are being implemented and are effective.

It can also be argued that individual projects should not be approved or considered for financial support in the absence of an adequate sector-level environmental assessment. Ideally, a comprehensive integrated coastal management plan should guide the process. However, it should be emphasized that it is more critical that any plan conform to certain minimum requirements for sustainability (as presented in Chapter 6). In contrast, what the plan is called is less important (likely names include coastal zone management plans and integrated coastal management plans).

Disease poses a major threat to the financial sustainability of any shrimp farming venture. Shrimp farms should be planned and designed with the assumptions that they will probably be hit by a devastating disease at some point, and that a switch to alternative species (normally less profitable) or a fallow period will be required.

Can shrimp farming be undertaken sustainably?

Chapter 8 evaluates the prospects for sustainability under different conditions and recommends practices to maximize the chances of designing and maintaining sustainable operations. Shrimp farming is one of the few activities possible in the coastal zone that offers real potential for greatly improving the living standards of poor and often landless people in developing countries. Although profits may be somewhat lower in the future than in the recent past, shrimp can be farmed very profitably. But can shrimp be farmed sustainably?

It is impossible to answer this question in absolute terms, because sustainability itself involves a wide range of different—and in some cases contradictory—elements, which are given greater or lesser weight according to cultural values and stage of development in any given country. However, the question may be answered in relative terms. There is no technical reason why raising shrimp should not be as sustainable, or in some cases more sustainable, than agriculture, fisheries, or other kinds of development.

Sustainability is often discussed in relation to intensity; there is a common presumption that more intensive systems are less sustainable. This can be misleading. As with agriculture, there is a trade-off between the conversion of large areas of natural habitat (or alternative land uses) for extensive cultivation with lesser use of inputs, and the conversion of smaller areas for more intensive cultivation with higher use of inputs. It is impossible to say which of these is more sustainable without reference to local circumstances and the relative scarcity of different resources (land, water, material inputs, and skilled labor).

Efficient resource utilization is sometimes used as a practical criterion or objective for sustainability. In practice, and especially in relation to agriculture and aquaculture, efficiency is usually measured in terms of resource utilization per unit of production by *weight*. For many developing countries, a more rational and practical sustainable development objective may be to maximize the *value* of production relative to the resources consumed. On this basis, both extensive and intensive shrimp farming score relatively well.

Disease may pose the greatest threat to the sustainability of the shrimp farming industry. Whether shrimp are particularly susceptible to viral diseases—or whether the severity and incidence of disease is more related to poor siting, design, and management—is not clear. But there is little doubt that improvements in siting, design, and management, coupled with comprehensive measures to minimize disease spread, will significantly reduce disease incidence, and make shrimp farming more sustainable. Even where disease is a recurrent problem, shrimp farming may still be profitable and sustainable in the longer term, but the farmer must be in a position to weather one or more lost crops, leave the ponds fallow for a period of time, and/or switch to an alternative species.

Further actions

Chapter 8, and the report as a whole, conclude with recommendations for further studies regarding legislation, regulations, tax incentives, enforcement instruments, social impact studies, and pilot projects that should be undertaken to support the planning and management of sustainable shrimp aquaculture development. Many studies of this type are currently under way around the world. The World Bank, the Food and Agriculture Organization of the United Nations (FAO), NACA (Network of Aquaculture Centres in Asia), and World Wildlife Fund (WWF) have created a consortium to take the lead in supporting such research (see Annex 4) and disseminating it to a broad audience of stakeholders (see Annex 5).

ABBREVIATIONS

MT	Metric tons
kg	Kilograms
m	Meters
cm	Centimeters
ha	Hectares
oz	Ounces
PUD	peeled, undeveined
FOB	free on board
CIF	cost, insurance and freight paid
C&F	cost and freight paid
C&P	cooked and peeled
ICM	Integrated Coastal Management
EIA	Environmental Impact Assessment (project level)
EA	Environmental Assessment

ACRONYMS COMMONLY USED IN THE INDUSTRY

ADB	Asian Development Bank
BAP	Bureau of Aquatic Production of the Ministry of Agriculture (China)
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
BFFEA	Frozen Food Exporters Association (Bangladesh)
CARP	Comprehensive Land Reform Program (Philippines)
DGF	Directorate General of Fisheries (Indonesia)
DOF	Directorate of Fisheries (Bangladesh) Department of Fisheries (Thailand) Federal Department of Fisheries (Malaysia)
EEC	European Economic Community
EU	European Union
EEZ	Exclusive Economic Zone
FAO	The Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration (USA)
FRG	Federal Republic of Germany
GDP	Gross Domestic Product
ICLARM	International Center for Living Aquatic Resource Management
IFC	International Finance Corporation (part of the World Bank Group)
IQF	Individually Quick Frozen
MBV	Monodon Baculo Virus
MPEDA	Marine Products Export Development Authority (India)
MSY	Maximum Sustainable Yield
NACA	Network of Aquaculture Centres in Asia
NGOs	Non-Governmental Organizations
SPF	Specific Pathogen-Free
SPR	Specific Pathogen-Resistant
USA, U.S.	United States of America
USDA	United States Department of Agriculture
USMSFP	United States Marine Shrimp Farming Program
WWF	World Wildlife Fund

PREFACE

There has been much controversy in recent years about the sustainability of shrimp farming. This study was therefore commissioned to analyze and discuss these issues objectively, with a goal of developing some preliminary guidance for the World Bank and other multilateral and bilateral agencies in addressing issues and opportunities related to the development of shrimp farming.

The present study, constituting Phase I of a larger study, identifies problem areas, good practices, and minimal requirements for environmentally safe and sustainable shrimp farming. Proposed activities for Phase II, some of them now under way, are presented in Chapter 8. Case studies undertaken by the consortium (World Bank, Network of Aquaculture Centres in Asia, World Wildlife Fund, and Food and Agriculture Organization of the United Nations) are presented in Annex 4. Discussion of the approach and dissemination of the results have been presented to a number of different stakeholders, as presented in Annex 5.

This report is intended primarily as a discussion paper, to serve as the basis for informed dialogue and policy development to encourage more detailed guidelines following further study and consultation. It seeks, in particular, to answer three commonly posed questions: Is sustainable shrimp farming possible? Can poor coastal communities benefit from it? And, if so, what role can agencies like the World Bank play to ensure that basic minimal requirements to achieve this are met?

This document was originally prepared for the World Bank by KPMG Center for Aquaculture and Fisheries (by Erik Hempel and Ulf Winther) and subsequently revised by John Hambrey (of the Asian Institute of Technology and Econeco), in close collaboration with the World Bank.

ORGANIZATION OF THE REPORT

In Chapter 1, a general background for the study is given, including some characteristics of the shrimp farming industry and some of the problems this industry is facing today. The chapter also reviews the development and current status of the shrimp aquaculture industry in detail. Chapter 2 provides an overview of shrimp farming systems and technology, in all their considerable diversity. In Chapter 3, the environmental impacts of shrimp farming are identified and described; the main impacts are reviewed and discussed in terms of both causes and effects. Technical measures to minimize these impacts are also discussed and summarized. Chapter 4 focuses on the social effects of shrimp farming and, again, discusses how negative results can be prevented or minimized. Chapter 5 addresses the financial risks associated with shrimp farming, as well as how the benefits can be maximized and risks minimized.

Chapter 6 deals more specifically with what needs to be done in planning and managing the sector, or industry, as a whole, while Chapter 7 applies these guidelines in more detail to project assessment and planning for individual farms and development projects.

On the basis of the analysis presented in previous chapters, Chapter 8 addresses the question posed in the subtitle: "Can shrimp farming be undertaken sustainably?" In addition, it presents overall conclusions and major recommendations for increasing the sustainability of shrimp farming. After the conclusions, a brief discussion follows of research that needs to be done, emphasizing field work; some of this research has been started as a result of this report's recommendation.

Annex 1 contains a blueprint for a feasibility study, listing the analyses that such a study should include.

Annex 2 presents statistical tables on a range of topics.

Annex 3 lists the experts in different countries who were contacted to contribute information and review earlier drafts of this report.

Annex 4 identifies the authors and the titles of dozens of case studies, either currently under way or completed, that address many of the issues raised in this report and in Annex 1.

Annex 5 lists various stakeholder meetings and conferences where this approach and/or the findings have been presented. Included are the meetings' locations, groups represented and people in attendance, and number attending.

A comprehensive bibliography of the citations used in the report follows, at the end.

CHAPTER 1: THE DEVELOPMENT AND CURRENT STATUS OF SHRIMP AQUACULTURE

The driving forces behind the rapid expansion of shrimp aquaculture include potentially high profitability, buoyant demand for high-quality seafood, increasing demand for farmed shrimp due to limitations and fluctuations in supply from capture fisheries, and its capacity to generate foreign exchange and employment in poor coastal areas. For these reasons, many of the Bank's client countries, particularly those with suitable climates and coastlines, have expressed interest in the development of shrimp aquaculture. As a result, a number of World Bank–financed projects, though very small in number and scale relative to global shrimp aquaculture development, have included shrimp farming components, ranging in size from a few million US dollars to nearly US$100 million. In each instance, the most advanced shrimp aquaculture design principles were incorporated in the projects. On the social side, measures have been included in some projects to provide support to poor coastal communities that want to gain access to the benefits of shrimp farming, to prevent their being supplanted by external interests, and to reduce poverty.

Often, however, severe disease outbreaks have crippled these developments. Efforts are currently being made in many countries with significant shrimp farm activity to remedy these problems. Measures include:

- The development of specific pathogen-free or -resistant strains of shrimp broodstock;
- Shrimp seed health certification programs;
- Polyculture or alternating cropping cycles;
- Disinfection of source water and its reclamation and recirculation;
- Construction of seawater supply systems with pumping and water treatment; and
- Engineering of farms to be suitable for the culture of alternate species, should the need arise.

Shrimp aquaculture has also come under increasing criticism due to reported adverse social and environmental impacts, questionable sustainability because of disease outbreaks, and sometimes irresponsible development objectives or practices. The considerable amount of land required for extensive and semi-intensive farming has resulted in significant conversion of coastal wetlands into shrimp ponds, with local impacts on biodiversity and natural resource use. These problems are related mainly to overly rapid development of a fledgling industry with inadequate technical knowledge and development planning, and although they have been exaggerated in many instances, they must nonetheless be addressed.

Is sustainable shrimp farming possible?

Shrimp farming has recently been criticized by a number of environmental and other public interest groups for having a negative impact on the environment and on local communities. In addition, the environmental and financial sustainability of shrimp farming has been questioned.

These issues are the focal points of this study. The overriding questions are: (1) Can shrimp farming be undertaken sustainably and for the benefit of poor coastal communities, and (2) Could such initiatives benefit from Bank assistance?

One of the earliest, simplest, and most widely accepted definitions of sustainability is:

> "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987).

Sustainable development has been defined in relation to agriculture and fisheries in the following way:

> "Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (FAO 1997).

It should be emphasized that any new activity in an area will necessarily bring about change. Preservation of the natural resource base is the cardinal objective of sustainable development. At the same time, development is necessary in order to create human economic opportunity and increase food production. The overriding concern is that this development should be undertaken so that the future productive capacity of the environment is not put in jeopardy.

Environmental sustainability

The current debate on environmental issues and the negative impacts of aquaculture stems mainly from irresponsible practices used by some aquaculture entrepreneurs who risk bringing the whole sector into disrepute (Barg, Bartley et al. 1996). The opportunity exists for the aquaculture community to improve its public image. In many cases, irresponsible practices result not from dishonest intentions but from lack of knowledge or lack of proper regulations and guidelines by the responsible authorities, or both.

Social sustainability

Any development will by its very nature entail certain social changes, usually encompassing both the positive and negative. To achieve socially sustainable shrimp aquaculture, the balance of change must be positive and acceptable to the communities affected. Nor should any changes lead to conflict between various groups of a magnitude sufficient to create societal disruption. Social sustainability also implies a financial return to the farmer or community over a longer period than that which may be required for financial sustainability, thereby ensuring greater social and economic stability.

Economic sustainability

Although an activity may bring in an adequate return on investment from the perspective of the owner or investor, it may not be viable in the longer term if the operation at that site does not have a real comparative economic advantage.

Financial sustainability

Without the prospect of adequate financial return, investors (including poor farmers) will not engage in shrimp farming at all. Thus it is a prerequisite that the activity be able to generate profits sufficient to repay investments and satisfy the investors' profit demands or expectations.

Preconditions for sustainable aquaculture development

Pillay (1997) lists a number of factors that are required to ensure long-term sustainability:

- Adequate planning of farming enterprises and responsible siting of farms;
- Sufficient involvement of local communities;
- Effective environmental impact assessment of farming projects;
- Effective design of farms, including irrigation and drainage systems;
- The pursuit of increased yields over time, rather than the largest possible returns in the short term;
- Adoption of appropriate technologies for production and waste disposal; and
- Measured use of chemicals and therapeutic agents (only when and in the amounts actually needed).
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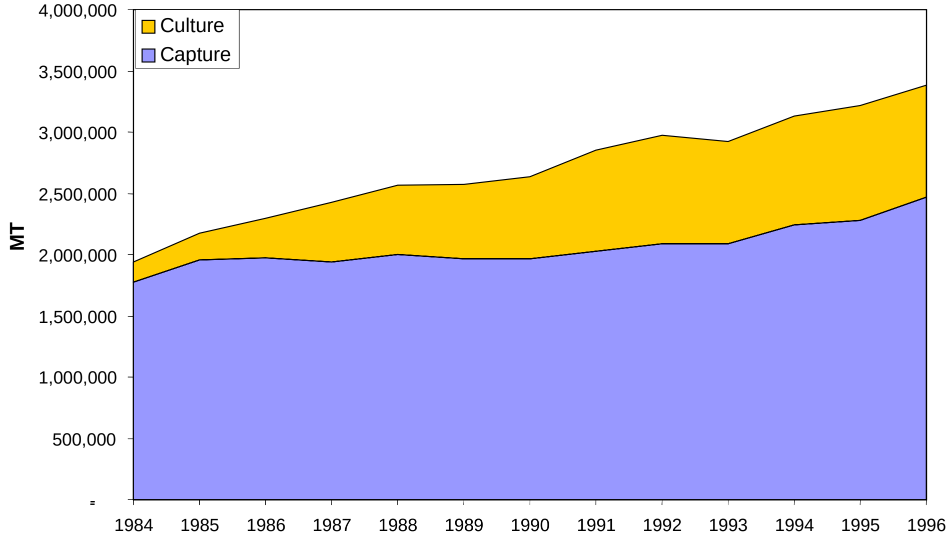
- More detailed discussions of sustainability as it relates to aquaculture can be found in a range of recent publications (for example, Barg 1992a; Folke & Kautsky 1992; Funge-Smith & Stewart 1996; Hambrey 1996c; Hargreaves 1996; Fegan 1996; Pillay 1997; Boyd & Clay 1998).

Development of shrimp aquaculture

Although shrimp farming has existed since the 1930s, it was not until the 1980s that it became an important factor in the shrimp industry (see Figure 1). Farmed shrimp production grew rapidly through the 1980s and into the 1990s, and by 1995 aquaculture accounted for some 932,000 metric tons (MT), or about 30% of the total supply. Despite a decline in 1996, this proportion is likely to continue to rise.

Figure 1. World Shrimp Production from Capture and Culture



Until the early 1980s, most of the shrimp sold in the world was captured by trawling operations. Since then shrimp farming has developed and spread rapidly, and by 1995 as much as 30% of total production came from farming. This section contains a brief history of the development of shrimp farming and an assessment of current production levels and market potential.

Modern shrimp farming was born in the 1930s when Motosaku Fujinaga succeeded in spawning the kuruma shrimp (*Penaeus japonicus*). He cultured larvae through growth stages to marketable size in the laboratory, and he succeeded in producing them on a commercial scale. Fujinaga shared his findings in published papers in 1935, 1941, 1942, and 1967, contributing greatly to the development of the industry.

Although the first successful shrimp farming efforts took place in Japan, that country never became a large producer of farmed shrimp. Major research on hatchery production and grow-out was undertaken in China; Taiwan, Republic of China; Europe; and the U.S. throughout the 1970s. From the mid-1970s to the mid-1980s, when fishermen and hatchery operators began supplying large quantities of juvenile shrimp to farmers, the production of farm-raised shrimp exploded. In the period from 1985 to 1995, several new producing countries entered the scene. As shown in Figure 2, worldwide production grew from 213,647 MT in 1985 to 914,706 MT in 1996 (FAO 1997). The main stages in the development and evolution of the shrimp farming industry are summarized in Table 2.

The phenomenal growth rate of shrimp farming resulted from a range of favorable characteristics and conditions:

- High market price for black tiger shrimp (consistently between US$5 and $8/kg farm gate price in Southeast Asia);
- Well-established distribution and marketing channels originally developed for capture fisheries;
- Development of hatchery technology (mainly in Asia);
- Shrimp tolerant of a wide range of pond conditions, including salinity; and
- Short cropping cycle (3–4 months).

Current shrimp farming practice incorporates several technical characteristics of particular relevance to a discussion of sustainability. These include:

- Dependence on wild seed in some countries but on wild broodstock in most countries;
- Extensive development in estuarine and mangrove ecosystems;
- Dependence on high-protein fishmeal-based diets for semi-intensive and intensive production; and
- Shrimp's susceptibility to disease.

The World Bank and the shrimp farming industry

The World Bank has received a number of applications for financing of shrimp culture projects in the past 10 years, and has approved some of these projects. Some observers (e.g., Bundell & Maybin 1996) have claimed that the World Bank has been the biggest promoter and funder among the international agencies. In terms of amounts loaned, this may be true. However, the total number of shrimp farming projects with World Bank financing is relatively small. From 1987 to 1997, only 13 projects received Bank funding (see Table 1). World Bank financing likely accounts for less than 10% of all public-sector assistance to the industry.

TABLE 1: WORLD BANK/IFC SUPPORTED SHRIMP FARMING PROJECTS 1980-1997

Country	Project	Year started	Bank funding (US$ Millions)
Bangladesh	Shrimp Culture Project	10/30/96	22.0
China	Rural Credit Project *	11/01/84	15.0
China	Rural Credit Project II *	04/18/86	90.0
China	Rural Credit Project IV *	03/22/91	75.0
China	Coastal Lands Development Project *	12/09/88	102.6
China	Shandong Agricultural Development Project *	01/29/90	109.0
China	Hebei Agricultural Development Project *	09/21/90	150.0
China	Songliao Plain Agricultural Development Project *	06/15/94	205.0
India	Shrimp and Fish Culture Project *	05/28/92	85.0
Indonesia	Fisheries Support Services Project *	05/07/87	24.5
Indonesia	Fisheries Credit Project *	01/08/75	6.50
Madagascar	Aquaculture de la Mahajamba (Aqualma) (IFC Project) – Phase I and II	05/92-05/95	5.40

Source: World Bank (ASTEN), June 1997.
* Shrimp farm and related support services and infrastructure development under these projects represented to varying degrees only a portion of the total investment for each.

Figure 2. Farmed Shrimp Production by Country, 1984–1996
(producers>10,000 MT)

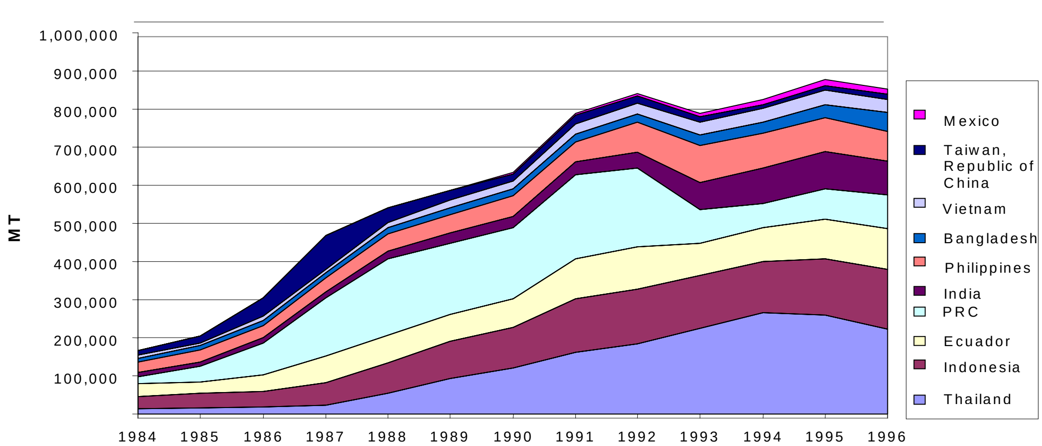


Table 2. Development stages in the shrimp farming industry

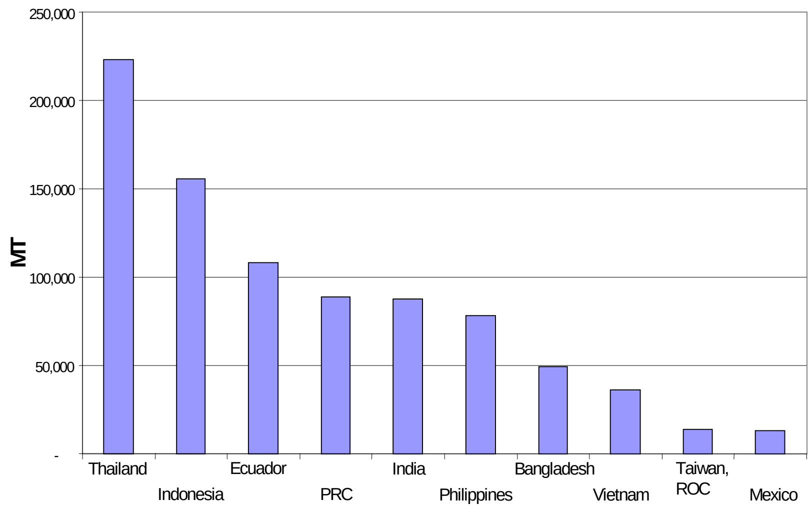
Phase 1: Rapid Growth	Phase 2: Problems

• Traditional coastal ponds. Shrimp a by-product of milkfish or mullet production in Taiwan, Republic of China; the Philippines; Indonesia
• Expanding high-value international seafood markets led to increased price
• Static, and in some cases declining, wild catch reinforced price rises
• High value and biological interest stimulated intensive research on hatchery techniques in '60s and '70s, building on earlier Japanese work
• High value stimulated greater specialization with shrimp in existing coastal ponds in Asia, and active stocking with wild seed in some cases
• High value stimulated new development of coastal ponds specifically for shrimp in both Asia (especially China*,* Thailand) and South and Central America
• In South and Central America abundant wild seed allowed steady development of the industry; low competition for land encouraged extensive and semi-intensive farming
• Shortage of wild seed in SE Asia led to practical development of hatchery technology
• Consistent supplies of hatchery seed, and continuing high prices for product, resulted in the entry of a wide range of entrepreneurs from small farmers to multinational corporations
• Rapid development in Taiwan, Republic of China, and both South America (mainly Ecuador) and Southeast Asia
• Production dominated by two species in Asia (*Penaeus monodon, P. chinensis*) and one species in America (*P. vannamei*)
• By 1991:
    • more than 1 million ha of ponds worldwide
    • more than 4,000 hatcheries
    • about 37,000 shrimp farms
    • small- to large-scale
    • wide range of production rates:
      - 40kg/ha/crop to 10t/ha/crop
      - average in 1990 still only 730kg/ha/yr.
	• High capital investment costs and/or competition for suitable land stimulated intensification
	• Very high returns in the early stages of intensification led to rapid development in both traditional pond areas and new (often converted mangrove) areas, where land was readily available
	• Shortage of land resulted in increased land prices
	• Higher land costs stimulated further intensification
	• In the rush to make money, little attention was paid to site suitability, water supply, and effluent disposal
	• Governments encouraged development, especially in mangrove areas, which were considered of low value for other uses
	• In practice, lost mangrove was an actual or potential loss of
	    • natural wastewater treatment;
	    • wild shrimp nursery areas;
	    • biodiversity;
	    • resources and livelihood of other users.
	• Acid sulphate conditions commonly associated with mangrove created water quality problems, especially in more intensive systems, and these exacerbated disease
	• Poor pond conditions related to site selection and poor management led to disease
	• In South and Central America, upstream pollution (pesticide use in banana plantations) was blamed for lowered resistance and spread of Taura Syndrome to shrimp
	• Poor water supply/effluent design and high density of farms led to rapid spread of disease as well as pollution (organic, inorganic, chemical)
	• In the late '80s, the industry crashed in Taiwan, Republic of China, and has still not completely recovered; in the early '90s, major problems were also experienced in China and Indonesia; in recent years Thailand has suffered substantial falls in production
	• Disease is now a major problem in all producer countries
	• Many operators have abandoned ponds and relocated to areas unaffected by disease
	• Shortage of wild broodstock has led to higher prices and in some cases reduced quality through repeated spawnings

Current status of the industry

Today, more than 50 countries have shrimp farms. The largest producers of farmed shrimp are found in Asia, concentrated in Southeast Asia. In 1996, Thailand accounted for 223,000 MT, valued at US$1.6 billion; Indonesia for 155,500 MT, valued at US$0.9 billion; and Ecuador for 107,920 MT, valued at US$0.65 billion (FAO 1997). Other major producers include China, India, the Philippines, Bangladesh, Vietnam, and Mexico (Figure 3).

Figure 3. Production of Farmed Shrimp by Country: 1996



Nicaragua and Cuba have shrimp farms, among other nations throughout Central and South America. Honduras, Mexico, and Colombia have substantial industries, while smaller industries exist in Panama, Peru, Guatemala, and Brazil. The U.S. also produces farmed shrimp.

The shrimp-consuming nations, primarily the U.S., Western European countries, and Japan, specialize in high-tech intensive shrimp farming, but so far production from this technology has been small.

Production of black tiger shrimp (*Penaeus monodon)* has grown steadily since 1985, and it is now the most important shrimp aquaculture species. In 1996, black tiger accounted for 532,232 MT (58% of the world's total farmed shrimp production). Whiteleg shrimp (*Penaeus vannamei*) is also an important species in aquaculture. The growth of fleshy shrimp, also called China white shrimp (*Penaeus chinensis*), was steady until 1992–1993, when disease problems led to sharp declines in production, first in China and then elsewhere.

Figure 4. Map of Eastern Hemisphere Shrimp Farming

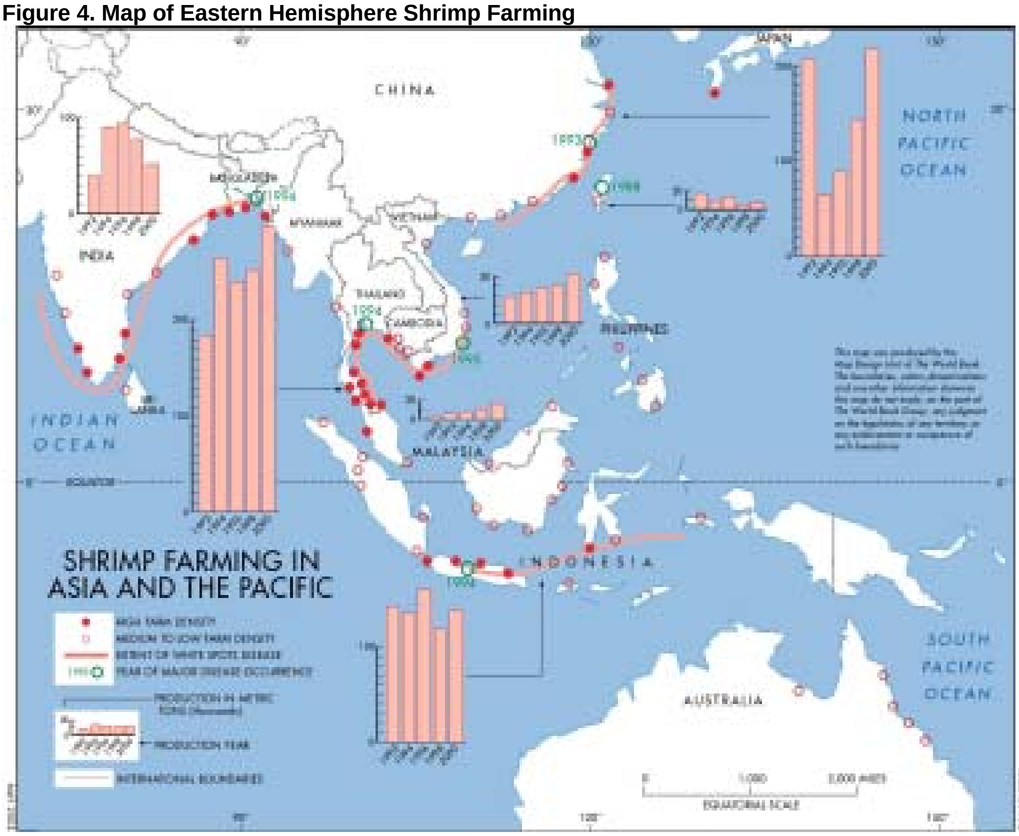
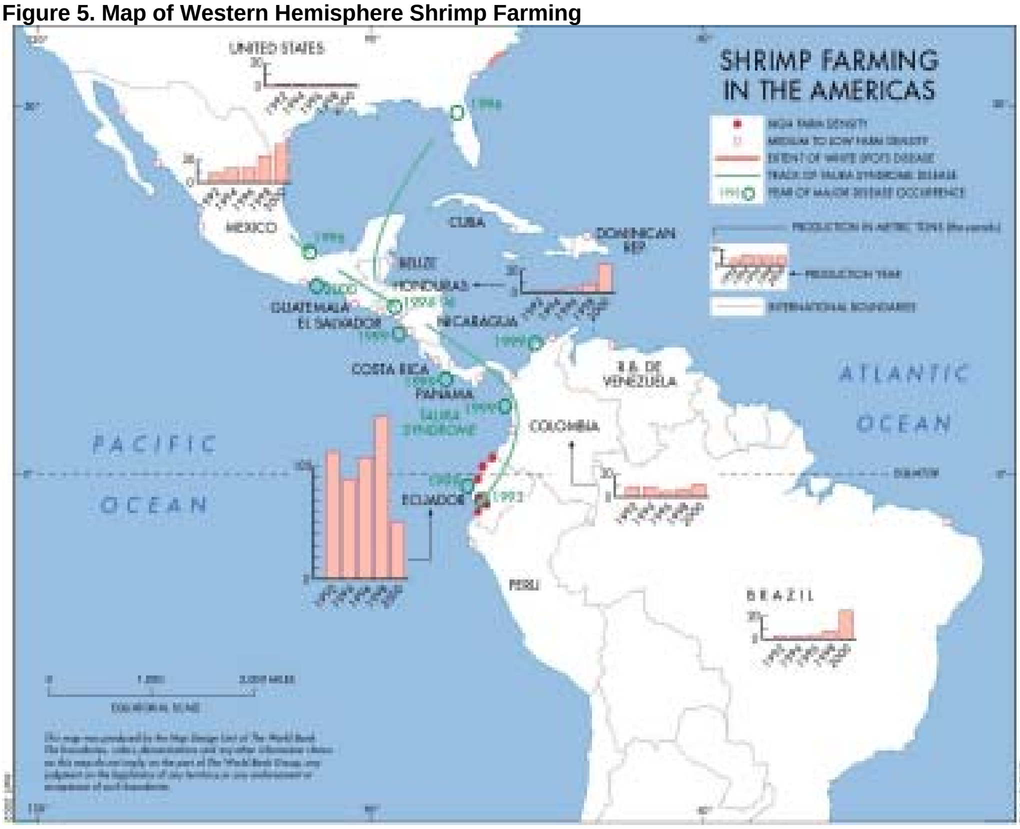


Figure 5. Map of Western Hemisphere Shrimp Farming



In recent years, several major crop failures have occurred in the Asian region. The first such failure occurred in Taiwan, Republic of China, in 1987–88 and led to a flight of investors. The conversion of many ponds to other forms of aquaculture, such as marine finfish, followed—and in some cases ponds were abandoned. Problems have also been experienced by China, which lost a large proportion of its production due to disease outbreaks in the early 1990s. India had a major crop failure in 1995. Other major producers such as Indonesia, Vietnam, and Bangladesh have also suffered crop failures due to disease and environmental problems. Following a period of continuous growth, farmed shrimp production declined in 1996, mainly due to disease in major producing nations, and in particular in Thailand. In spite of this, Asia has been able to maintain its position as the world's leading shrimp-producing region.

Markets

Since the late 1980s, farmed shrimp has become a major contributor to overall shrimp supplies, making up for the declining wild catch and meeting the steadily increasing demand. It is now a major factor in world markets. In particular, farmed shrimp now makes a major contribution to the high-value tropical *Penaeid* shrimp market (Figure 6). Consequently, the unpredictability of supply, resulting partly from disease over the past few years, has introduced some uncertainty into the market, with significant local and short-term price fluctuations. Limited supply may also have constrained the growth in consumption. For example, shrimp consumption declined in the U.S. in 1996, mainly due to lower imports and higher prices, which were a result of declining supplies from Asian countries.

These price uncertainties can have a significant impact on the financial performance of shrimp farms, and may in some cases lead to bankruptcy and closure. In extreme cases, the sustainability of the industry may be threatened in areas where physical or economic conditions are suboptimal for shrimp farming.

Figure 6. Show the extend of shrimp farming in terms of people involved and value of the product (Based on comments from Clay J. 2002).

Actors in the marked chain	Number of people involved	Value of product (in US$)
PL and Feed Providers		
Hatchery PL	100,000	US$ 1 billion
Wild Caught PL	> 1,000,000	5,000,000
Feed	Few thousands	US$ 1 billion
Producers		
Farmers	300,000	> US$ 4 billion
Processor to Port		
Processing plants	Several thousands	US$ 6 billion
Exporters/Importers	Few thousands	US$ 7-10 billion
Importing Countries		
Distributors	Few thousands	Add 3-7% to product
Wholesalers	Several thousands	Add 5-12% to product
Retailers	> 100,000	Add 15-50% to product
Consumers	>1,000,000,000	US$ 50-60 billion

Export markets

Aquaculture has been the major force responsible for increased shrimp trading during the last six to seven years. In the boom years, foreign sales reached record heights. Retail sales increased dramatically: 30% in the U.S., and 50% in Japan. Unexpected fluctuations in Asian shrimp supplies since 1993 have made the market unpredictable and volatile. Most recently, the downturn in price (late 1998) was related more to a downturn in demand in Japan than to supply fluctuation.

Emerging markets

Southeast Asia and the Far East have emerged as the fastest-growing markets for all kinds of seafood. Shrimp is one of the major items enjoying good demand in this area. In 1994, seven major economies in Southeast Asia (Taiwan, Republic of China; Singapore; Hong Kong; Malaysia; South Korea; China; and Thailand) imported more than 100,000 MT of fresh or frozen shrimp. The total consumption in these countries is estimated to be twice this figure (head-on weight). Domestic consumption in Thailand, for example, is more than 50,000 MT annually. More than half of Malaysia's cultured shrimp is destined for domestic consumption in households and restaurants. Similar scenarios are also seen in Singapore, Indonesia, China, and other countries. In 1996, China alone imported seafood products worth more than US$1 billion.

Overall industry status

Towards the end of 1988 there was a significant price drop for *Penaeid* shrimp, related mainly to the state of the Japanese economy. However, prices have strengthened again since then, reflecting strong demand from the U.S. market, and the outlook for the moment is good. The decline in production in recent years will also tend to lead to a strengthening in price. Clearly, however, the market for luxury seafood products will be sensitive to changes in the global economy, and these, coupled with variability in supplies, will cause continuing price fluctuations. However, it should be remembered that the global market remains large and generally buoyant, and capture fisheries for shrimp are unlikely to expand significantly. In the medium to long term, therefore, prices are expected to average at least at the current levels. As with other agricultural products, however, producers must be able to bear significant short-term fluctuations.

Future outlook

Judging from the present investor interest in shrimp farming, together with assumptions about the future demand for shrimp, shrimp farming is expected to continue to expand for some years, although constrained to some extent by disease. Eventually, site limitation, markets, and the probable long-term increase in the cost of fishmeal or fishmeal substitutes will together constrain further growth of the industry.

As with most emerging industries, shrimp farming will become more business-oriented and scientific as time goes on. The profit margins will become slimmer as competition increases, and more attention will be paid to marginal improvements in production methods and economies. As the industry matures, it will have to pay more attention to detail and effective management. As this happens, the "fortune hunters" will disappear from the industry, as may some of the less efficient small-scale producers, while more serious operators remain in business. These producers will naturally focus on their long-term investment and do their utmost to make sure that operations can be maintained over time. Consequently, financial returns will be considered over longer periods, and more attention will be paid to environmental and social issues.

Once the current unpredictability of production has lessened, the market and prices should stabilize. While this will reduce the opportunities for massive short-term profits, it will be positive for the industry as a whole, benefiting the majority of operators and investors. Some market fluctuations are unavoidable, as the shrimp market depends on a number of interrelated factors as well as on unrelated factors outside the influence of the industry. However, the long-term outlook is for more stable demand than in the short term.

Summary and conclusion

Shrimp farming has become a major aquaculture activity and object of investment over the past two to three decades. Shrimp farming currently accounts for some 30% of total world shrimp production, and this share is growing. In view of stagnating or declining catches from the wild, and the continuing high demand for high-quality seafood, shrimp farming is expected to play an even more important role in the future, despite the recent downturn in the market.

CHAPTER 2: SHRIMP FARMING SYSTEMS

Shrimp farming is an extremely diverse activity, currently undertaken in a wide range of physical, social, and economic circumstances. This chapter provides an overview of shrimp farming technology and the various forms that are practiced in different parts of the world.

Nomenclature and classification of shrimp farming systems is varied and inconsistent. So-called "traditional" systems rely on the passive entry of wild seed into intertidal ponds during the normal tidal cycle. Feeding and fertilization is uncommon in such systems. However, most farmers now stock ponds with shrimp seed (post-larvae, or PL) and provide feed and fertilizer to promote rapid growth. Depending on the stocking rate (which commonly varies between <1 and >100 PL/m^2) and the intensity of feeding, these systems are usually referred to as extensive, semi-intensive, intensive, and superintensive. In practice these terms are ill-defined, reflecting a broad and changing spectrum of systems that vary according to how intensively they use different resources. Super-intensive systems in tanks or raceways, with stocking rates well above 100 PL/m^2, have been successful in several experiments and trials, but commercial production at these levels is as yet insignificant (Liao 1996).

Most production in Central and South America, India, and Bangladesh still uses wild seed (although hatchery production has increased rapidly in Ecuador in recent years), while production in Southeast Asia is based almost exclusively on hatchery-reared post-larvae, produced from the spawning of wild-caught broodstock. In some countries there is a special nursing phase, either of zoeae larvae to post-larvae, or of small post-larvae to older post-larvae, or sometimes both.

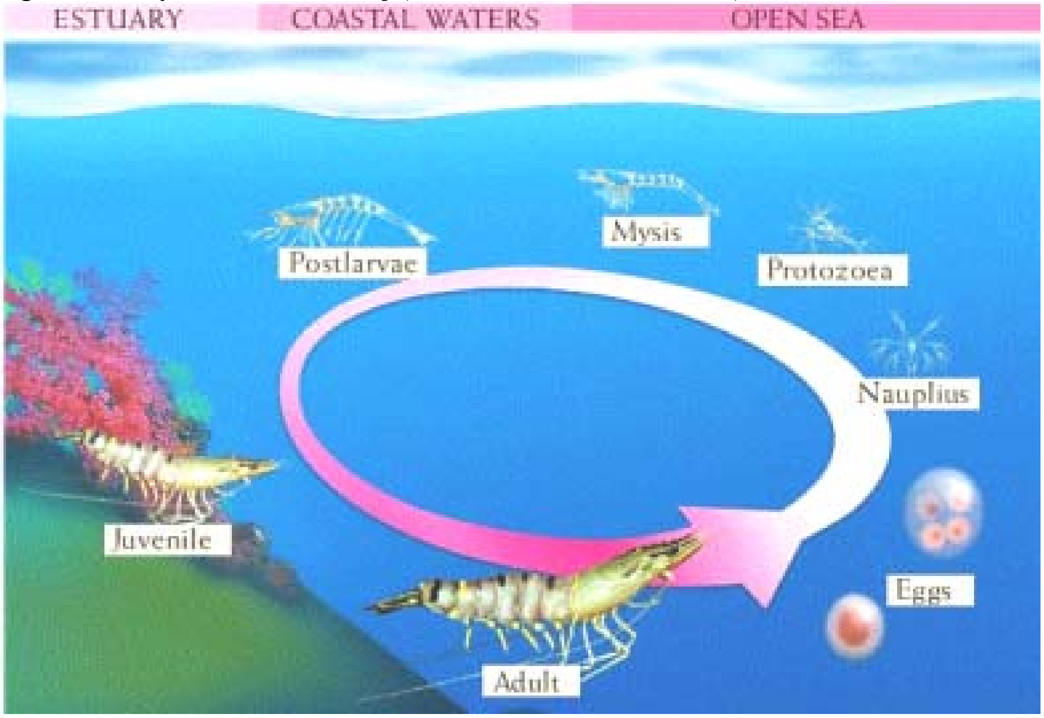
Grow-out typically takes between three and five months, mostly occurring in coastal brackish-water ponds. Some shrimp culture is also undertaken in the sea in pens and creeks (Hutchings & Saenger 1987; IUCN 1987; Nittharatana 1995). The high tolerance of *Penaeus monodon* to low salinity has also allowed shrimp culture to spread inland in Thailand in recent years (von Post & Åhman 1997; Christensen 1982; Hamilton & Snedaker 1984; Gilbert & Janssen 1997; Ruitenbeek 1991). Two crops (occasionally more) can be grown per year in the tropics, one to two in subtropical areas, and one crop in temperate areas.

Hatcheries

Most shrimp farmers still rely on wild shrimp for the production of seed. They either capture wild juveniles that are stocked directly into nursery or grow-out ponds, or they spawn wild females in a hatchery. Although most of the commonly grown shrimp species can be matured and spawned in captivity, production and quality of eggs and larvae is usually lower than from wild-caught spawners. However, the current shortage (and high price—up to $2,000 each in Vietnam) of wild spawners, particularly of *Penaeus monodon*, is stimulating further research on maturating shrimp in captivity. The quality of farm-raised broodstock is expected to increase steadily over time. Eventually, this source should replace wild-caught spawners.

Shrimp go through several stages during their development (Figure 7). Hatcheries sell two products: *nauplii* (tiny, newly hatched, first-stage larvae) for between 20¢ and $1 (in U.S. currency) per thousand, and *post-larvae* (juveniles that have passed through three larval stages, also called PL) for $5 to $20 per thousand. Post-larvae production costs may range from $2 to $7 per thousand. Post-larvae are stocked in nursery tanks and nursery ponds or directly in grow-out ponds. Nauplii are sold to other hatcheries, which grow them into the post-larval stage.

Figure 7. Life cycle of *Penaeid* shrimp (FAO and Multimedia Asia 1999)



The hatchery cycle

In Southeast Asia most broodstock of *P. monodon* are caught in the wild by offshore trawlers specially equipped to hold live shrimp. In some cases high-speed "collector" boats pick up broodstock when a skipper reports a catch. These are then transported to a hatchery, where they are held and conditioned using high-quality feeds (such as marine worms and squid). Some broodstock are now sourced from extensive ponds (e.g., in Vietnam). Many trials are now under way on the maturation of captive *P. monodon* in ponds or tanks.

Whether gravid (pregnant) shrimp are captured in the wild or matured in the hatchery, they invariably spawn at night. Depending on a number of variables (temperature, species, size, wild/captive, and number of times they have previously spawned), they produce from 20,000 to more than 1 million eggs.

The next day, the eggs hatch into nauplii, the first larval stage. Nauplii, looking more like tiny aquatic spiders than shrimp, feed on their yolk sac for two to three days. They then metamorphose into *zoeae*, the second larval stage, when they have feathery appendages and elongated bodies but otherwise few adult shrimp characteristics.

Zoeae feed on algae (usually diatoms) for about six days and then metamorphose into *myses*, the third and final larval stage. Myses have many of the characteristics of adult shrimp, such as segmented bodies, stalked eyes, and shrimp-like tails. They also feed on algae and zooplankton. This stage lasts another three days, and then the myses metamorphose into post-larvae.

Post-larvae, looking like adult shrimp, feed on zooplankton (usually brine shrimp), detritus, and commercial feeds. After one to four weeks with almost daily molts, the post-larvae are stocked into nursery or grow-out ponds. The larval period lasts for about two weeks and the post-larval period for another four weeks, so from spawning to stocking in grow-out ponds takes about six weeks.

Hatcheries come in a range of sizes and levels of technical sophistication, from small, simple, family-run systems to major industrial-scale installations employing managers, scientists, and technicians. All operate on the principles of maintenance of high water quality, health monitoring, and appropriate feeding (mainly diatoms followed by brine shrimp and micro feeds).

The following section provides a brief overview of some typical systems. "Hatchery" is commonly used to describe installations that specialize in rearing zoeae, as well as those that actually spawn shrimp and hatch the eggs. "Nursery" generally refers to those operations that nurse post-larvae to a size suitable for stocking in large ponds.

Small-scale (backyard) hatcheries

Small-scale hatcheries are usually operated by a family group. Their chief advantages are low construction and operating costs and their ability to open and close quickly in response to the season and the supply of wild seed. They work with small tanks, little if any pumping, and usually concentrate on just one phase of production, such as nauplii or post-larvae. They usually operate with low densities and use untreated water. Stock cultures of algae are commonly bought from larger operations, and brine shrimp (used to feed the growing product) are hatched and reared in small tanks. Disease and water quality problems often wipe out production, but it is a relatively simple matter to disinfect and restart operations.

Survival rates of the developing larvae in small-scale hatcheries ranges from close to 0 to 90%, depending on a wide range of variables, such as water quality, stocking densities, temperature, and the experience of the hatchery operator. Small-scale hatcheries have achieved great success in Southeast Asia, particularly in Thailand; Taiwan, Republic of China; Indonesia; the Philippines; and southern China.

Medium-scale hatcheries

Some medium-scale hatcheries are based on a design developed in Japan and popularized by the Taiwanese, and therefore are called "Japanese/Taiwanese" or "Eastern" hatcheries. They use large tanks, low stocking densities, low water exchange, and encourage a mixture of plankton to bloom within the tank using appropriate nutrient media. The larval shrimp feed on this bloom. Bacteria (probiotics) may be added in an attempt to promote the growth of more favorable bacteria and suppress the growth of those that are harmful. This "ecosystem" approach aims to produce stronger post-larvae by more closely approximating natural conditions. The survival rate, from stocked to harvested post-larvae, is typically around 50%.

Large-scale hatcheries

These are multimillion-dollar, high-tech facilities that produce large quantities of seed in a controlled environment. Developed at the Galveston Laboratory (Texas) of the United States National Marine Fisheries Service, they are referred to as "Galveston hatcheries," or "Western" hatcheries. They usually have more than 500 m^3 of tank capacity. In the Western Hemisphere, particularly in Ecuador, these hatcheries are the dominant type. In northern China as well, large-scale hatcheries supply the farms around the Gulf of Bohai. Large hatcheries can be found in all major shrimp farming countries and are generally owned by corporations with substantial capital.

Hatcheries of this kind require highly paid technicians and scientists; the hatcheries work with high densities, high water exchange, large tanks, and filtered water. They attempt to take advantage of the economies of scale by producing seed throughout the year. They grow algae and brine shrimp in separate tanks for feeding the developing shrimp. High survival rates, often up to 70–80%, are possible with these systems. However, large-scale hatcheries often experience problems with disease and water quality, and it can take them a long time to recover from production failures.

When wild females and juveniles are readily available, large-scale hatcheries may have a difficult time competing with smaller hatcheries and fishermen who supply wild post-larvae to the farms.

Maturation facilities

Some large-scale hatcheries maintain captive broodstock for the production of seed. These "maturation facilities" are by some experts considered to represent the future of the industry but have so far been only marginally successful. They require special live feeds like bloodworms, squid, and mollusks. Dry formulated feeds are also popular, but they do not work on an exclusive basis.

Feeds

Hatcheries use a combination of live feeds, such as microalgae, brine shrimp nauplii (*Artemia*), or rotifers, with one or several prepared diets either purchased commercially or prepared at the hatchery. The principal algal species used are *Skeletonema, Chaetoceros, Tetraselmis, Chlorella,* and *Isochrysis*. Some hatcheries (especially in Vietnam) introduce formulated feeds at a very early stage.

Hatchery trends

In the Western Hemisphere, most hatcheries are large-scale and associated with a large farm. They frequently supply nauplii to smaller hatcheries in other regions and sometimes other countries. The smaller hatcheries raise the nauplii to post-larvae, which are sold to farms for stocking in nursery or grow-out ponds. Large centralized hatcheries open the door to a wide range of possibilities, such as the development of disease-free broodstock and seedstock, perhaps using genetic manipulation.

In the Eastern Hemisphere, small and medium-scale hatcheries continue to produce most of the seed. Worldwide, the once-clear distinction between Galveston-style hatcheries and the Japanese/Taiwanese-style hatcheries is increasingly blurred as a large number of hybrid operations, borrowing the best from both systems, are adapted to local conditions and experience. The advent of the very small backyard hatchery has further blurred this distinction. Success has not been the exclusive domain of any one style, and it is clear that hatcheries must be adapted to local conditions. Moreover, management is at least as important as the technology chosen.

Nurseries

The nursery phase of shrimp farming, when juveniles are cultured at high densities in tanks or small earthen ponds, occurs between the hatchery and grow-out phases. It has some of the characteristics of the hatchery phase, but more closely resembles grow-out. Since hatchery-produced and wild-caught juveniles can be stocked directly into grow-out ponds, the nursery phase is not always necessary. Some farmers skip it, while others believe that it contributes to better survival rates during grow-out. In the Western Hemisphere, acclimation stations, where post-larvae are held in tanks for a few days before stocking, are replacing nursery ponds.

Farmers commonly stock post-larvae in nursery ponds (0.1 to 1.0 hectares) at densities of 150 to 200 per square meter. They feed a crumbled diet once a day. Protein levels in these feeds range from 30 to 45%. In high-density tank and raceway systems, live brine shrimp larvae are also used for feed. Most farmers think the nursery phase should not exceed 25 days.

Proponents of nursery ponds argue that they improve inventory, predator, and competition control; increase size uniformity at final harvest; better utilize farm infrastructure; permit more crops per year; improve risk management; produce stronger juveniles; and decrease feed waste. Because low salinity levels are lethal to newly stocked juveniles, nursery ponds provide an opportunity for acclimation during this critical period. Nurseries are also useful in temperate climates, where it is important to get a jump on the grow-out season.

The main criticism of nursery systems is the stress that the juveniles experience when they are harvested for stocking into grow-out ponds. This stress can be avoided if nursery ponds connect directly with grow-out ponds, or if PL are nursed in part of a larger pond using net barriers. Nonetheless, nursing at grow-out sites adds complexity to the production system and is thus being phased out by many shrimp farmers today.

Grow-out phase

Once a grow-out operation is stocked with juvenile shrimp, it takes from three to six months to produce a crop of market-sized shrimp. Northern China produces one crop per year, semitropical countries produce one to two crops per year, and farms closer to the equator produce two or more crops per year. Factors such as warm temperatures, beneficial site conditions, high water quality, low labor costs, good feed, government support, know-how, and capital all contribute to grow-out success and comparative economic advantage.

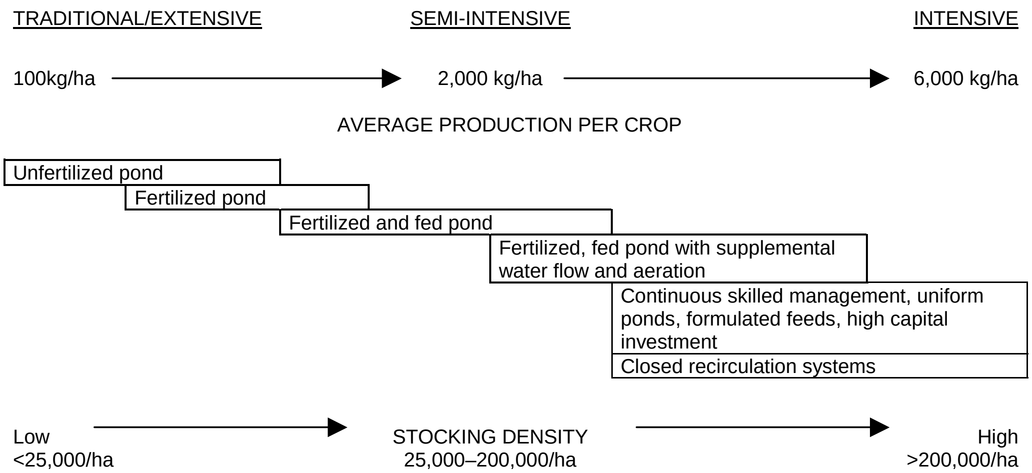
Models of shrimp farms

In the following paragraphs, details relating to some typical shrimp farming models are given. A summary of the main characteristics of each model is provided in Figure 8.

Shrimp farms are commonly referred to as extensive, semi-intensive, and intensive. Other designations such as traditional, semi-extensive, and improved extensive are also to be found in the literature. Although there are no universally accepted and clear definitions of these types, traditional shrimp farming generally refers to systems that rely on the natural entry of wild seed into tidal ponds; extensive shrimp farming generally means low stocking density (typically <3PL/m^2), semi-intensive means medium density (typically 3–15 PL/m^2), and intensive means high density (typically>15PL/m^2). However, other features, such as intensity of use of feed or chemicals, may also be used to define these different types.

As stocking densities increase, the farms tend to be smaller, the technology is more sophisticated, capital costs go up, production and income per unit of space increases dramatically, and financial risks increase. If badly sited or managed, or if workers' skills are inadequate, the risks of disease and crop losses also increase with growing intensity. However, disease can strike at any level of intensity. Recent disease outbreaks in Asia have affected all farms, irrespective of intensity.

FIGURE 8. CONTINUUM OF DIFFERENT SHRIMP FARM PRODUCTION SYSTEMS



Source: Clay 1996.

In practice, different people use intensity classifications in different ways, and generalizations—such as "intensive shrimp culture is not sustainable"—are often misleading. "Intensity" relates to resource utilization (land, water, capital, labor, seed, feed, fertilizer, and fuel), and different systems may be more or less intensive depending upon which resource is considered. It is important to understand the use of all of these resources if a thorough assessment of the sustainability of different kinds of shrimp culture is to be made. For example, so-called traditional or extensive systems are generally low on capital, labor, seed, and feed intensity, but use a great deal of land and water. "Intensive" systems, on the other hand, are generally low on land intensity, but high on labor, seed, and feed intensity. Traditional intensive systems were also high on the intensity of water use, but many producers (in Thailand, for example) now use closed or low water-exchange systems. The desirability and sustainability of different systems depends to a great degree on the cost and availability of these different resources, and these vary tremendously between countries.

Traditional/extensive systems

"Traditional" shrimp farming is still conducted in some parts of the tropics (e.g., West Bengal and Kerala in India; see Clay 1996) and in low-lying impoundments along bays and tidal rivers, often in conjunction with crab and finfish. Impoundments range in size from a few hectares to over 100 hectares. When local waters are known to have high densities of young shrimp, the farmer opens the gates, impounds the wild shrimp, and then grows them to maturity or whenever they are marketable. The shrimp (along with assorted crabs and finfish) feed mainly on natural food in the pond. Stocking density depends on the abundance of wild seed but rarely exceeds 10,000 per hectare. Production is commonly from continuous or semicontinuous harvesting, and ranges from about 50 to several hundred kg/ha/yr (head-on weight).

Some farmers stock wild juveniles that they themselves have caught or purchased from fishermen. There may also be some limited fertilization and supplementary feeding. The tides provide water exchange, dependent on the height of the intertidal zone and the local tidal regime. Construction and operating costs are low. Cast-nets and bamboo traps are used to produce the harvests.

Various forms of polyculture and mixed cropping are practiced. Shrimp can be grown in the same pond as other species such as milkfish. Ponds may be used for rice production during the wet season, and for shrimp production during the dry season. Examples of salt production (dry) and shrimp farming (wet) also occur. Such alternating use of the ponds has certain advantages, increasing the farmer's self-sufficiency and overall production. In addition, polyculture reduces the financial risk involved in shrimp farming. However, it is only feasible in very specific climatic and hydrological regimes.

Semi-intensive systems

Typically conducted at the upper end of the tidal range, or above the high tide line, semi-intensive farming usually involves carefully laid-out ponds (0.1 to 25 ha), feeding, and diesel- or electrical-powered pumping. Pumps typically exchange 5 to 15*%* of the water each day. With stocking rates ranging from 25,000 to 200,000 juveniles per hectare, there is more competition for the natural feed in the pond, so the farmers augment production with shrimp feed (commercial formulated compound feed, "trash" fish, or locally collected mollusks). Construction costs vary from $10,000 to $25,000 per hectare. Wild or hatchery-produced juveniles are sometimes stocked at high densities in nursery ponds until they are large enough to be stocked at lower densities in grow-out ponds. The farmer harvests by draining the pond through a net, or by using a harvest pump. Farmers usually renovate their ponds once a year. Yields range from around 500 to 10,000 kg (head-on) per hectare per year.

Intensive systems

Intensive shrimp farming usually involves small ponds (0.1 to 5 hectares), high stocking densities (more than 200,000 juveniles per hectare), around-the-clock management, intensive feeding, waste removal, and mechanical aeration. Mechanical aeration—the addition of oxygen to the water—permits much higher stocking densities and feeding levels. Water exchange rates for such systems used to be very high—up to 30% a day, but in recent years (stimulated mainly by a fear of introducing disease through the water supply) many farmers in Thailand have begun to use low water-exchange systems. These involve zero or minimal water exchange in the early part of the grow-out cycle, with water exchanged only as required for water-quality management toward the end of the cycle. In some cases, water may be recycled through a storage reservoir, allowing for the development of completely closed water systems, so that the only water required is to make up water lost to seepage and evaporation**.**

Intensive shrimp culture is also practiced in raceways and tanks, which may be covered or indoors, although this method remains relatively unimportant commercially.

Construction costs range from $10,000-$25,000 for simple pond systems in developing countries to as much as $250,000 per hectare for sophisticated concrete pond, tank, or raceways systems. Sophisticated harvesting techniques and easy pond cleaning after harvest permit year-round production in tropical climates. Yields of 5,000 to 20,000 kg (head-on) per hectare per year are possible, although the sustainability of higher rates is questionable. Production costs range from $4 to $8 per kg of live shrimp. Experience from Taiwan, Republic of China; Thailand; and Vietnam has shown that intensive shrimp farms can be converted relatively rapidly and without major additional investments to other species such as grouper, seabass, and milkfish, although these are generally less profitable.

Super-intensive systems

Superintensive shrimp farming takes even greater control of the environment and can produce yields of 20,000 to 100,000 kg/ha/year. A superintensive shrimp farm in the U.S. once produced at the rate of 100,000 kg/ha/year, but it was wiped out by a viral disease. Thus far, superintensive shrimp farms have achieved only marginal success. Generally, they require highly skilled managers and run the risk of disease, which leads to crop failures. They can also harm the quality of surrounding water by releasing pollutants in effluent, and must take steps to prevent other environmental damage. It seems that annual production levels above 10,000 kg per hectare are risky.

Owing to the high density of stocking, superintensive operations require far less land area to produce large amounts of shrimp. This fact may act in favor of superintensive operations in the future, if and when some of these other problems are solved.

TABLE 3. COMPARISON OF INPUTS FOR THREE SHRIMP GROW-OUT METHODS

Characteristics	**Extensive**	**Semi-intensive**	**Intensive**
Impoundment/pond area	1–100 ha	5–25 ha	0.01–5 ha
Pond shape	Irregular	More regular	More regular
Stocking density (/ha)	5,000–30,000	25,000–200,000	200,000+
(/m^2)	0.5–3	2.5–20	20+
Water exchange rate (/day)	5–10% (tides)	10–20% (pump)	0–30%+ (pump)
Water depth (m)	0.4–1.0	0.7–1.5	1.0–2.0
Aeration	None	Sometimes	"Moderate amount", especially towards the end of production cycle
Shrimp feed	Naturally occurring organisms (sometimes supplemented w/organic fertilizer)	Shrimp feed or agricultural by-products (e.g., rice bran, oil seed cake) augments naturally occurring organisms	Primarily formulated feed (less than 5% naturally occurring foods) and/or "trash" fish
Survival rates	<60%	0–80%	0–90%
Crops/yr	1–2	2–3	2–3
Potential energy requirement (hp/ha)	0–2	2–5	15–24
Labor needs (persons/ha)	< 0.15	0.10–0.25	0.5–1
Management	Minimal attention	Continuous, skilled	Continuous, skilled
Disease problems	Can be serious	Can be serious	Can be serious
Production costs (/kg)	\$1–\$3	\$3–\$5	\$5–\$7
Construction costs (/ha)	Low	\$15,000–\$25,000	\$25,000–\$100,000
Yields (kg/ha/yr)*:			
Weidner 1992c; Lambregts	50–500	500–5,000	5,000–10,000
Muir	Up to 1,000	1,000–10,000	10,000+
Potential profit (/kg)	Moderate	High	Moderate
Potential profit	Very low	Moderate	High

Source: Clay 1996
*Statistics vary by source; examples from three sources are given here.

Farming strategies

Much of the world's production still comes from extensive farms. India, Vietnam, Bangladesh, the Philippines, and Indonesia are good examples of countries with vast areas of extensive farms (Table 4).

Indonesia has developed the largest area for shrimp farming (350,000 ha); approximately 70% of the farms there use the extensive model. About 90% of the farms in Bangladesh consist of extensive farms that seasonally alternate between shrimp and rice or shrimp and salt. Corresponding figures for other major producers are: India, 60% extensive (total area 200,000 ha); Ecuador, 60% extensive (130,000 ha total area); and Vietnam, 80% extensive (200,000 ha total area).

In the countries surveyed, some 1.3 million ha have been developed into a total of some 111,000 shrimp farms. Of this total, extensive farms constitute 59.0% (by number of farms), semi-intensive 29.5%, and intensive farms 11.5%.

TABLE 4. OVERVIEW OF SHRIMP FARMING IN MAJOR PRODUCING NATIONS: 1996

Country	No. of farms	Total area (ha)	Production (head-on, MT)	Extensive	Semi-intensive	Intensive
Belize	6	600	2,000	0%	90%	10%
Costa Rica	4	800	1,000	0%	100%	0%
Ecuador	1,200	130,000	120,000	60%	40%	0%
Honduras	55	12,000	10,000	5%	95%	0%
Mexico	240	14,000	12,000	25%	65%	10%
Nicaragua	20	4,000	3,000	0%	100%	0%
Peru	40	3,000	5,000	5%	90%	5%
USA	30	700	1,300	0%	80%	20%
Venezuela	7	800	2,000	0%	100%	0%
Australia	33	400	1,700	0%	20%	80%
Bangladesh	13,000	140,000	35,000	90%	10%	0%
China	6,000	120,000	80,000	10%	85%	5%
India	10,000	200,000	70,000	60%	35%	5%
Indonesia	60,000	350,000	90,000	70%	15%	15%
Malaysia	400	4,000	4,000	40%	50%	10%
Philippines	1,000	60,000	4,000	40%	40%	20%
Sri Lanka	900	2,500	2,000	10%	20%	70%
Thailand	16,000	70,000	160,000	5%	15%	80%
Vietnam	2,000	200,000	30,000	80%	15%	5%
Total	110,935	1,312,800	633,000			

Source: Rosenberry 1996. NB: Figures are approximate only and do not include all shrimp farming nations.

Ecuador is making the transition from extensive to semi-intensive farming. Northern China pursues its own model of semi-intensive farming. Japan; Taiwan, Republic of China; the U.S.; Australia; Thailand; Sri Lanka; and some European countries concentrate on intensive shrimp farming, and intensive farms occur in all major shrimp farming areas of the world, but especially in Thailand, Sri Lanka, and Australia.

Scale

Shrimp farms vary enormously in scale, in terms of both area used and production. Small farms in Southeast Asia may be half a hectare or less, while semi-intensive farms in South and Central America may cover thousands of hectares. Small-scale operations are characterized by low investments and an interplay with other operators, often more sophisticated and larger-scale, in their vicinity.

Small farms are often thought to have limited impact on the environment. This is misleading; the cumulative impact of a large number of contiguous small farms (or those in close proximity) can be as environmentally damaging, or more so, than single large-scale developments. It is therefore important to take into account the density of development, especially in relation to carrying capacity, when considering the environmental impact of aquaculture.

The procurement of post-larvae (PL) for larger operations is often undertaken by small-scale operators, sometimes from the wild-capture fishery. The danger involved in such operations is that the small-scale operator often lacks the ability to take on responsibility for this ecosystem because of a poor economic situation and lack of training. Small operators therefore tend to focus on short-term survival of their own operations at the expense of the environment, even when they understand the local ecosystems. Thus, such operations tend to be detrimental to the environment, and particularly to the sustainability of both shrimp farming and capture fisheries.

Summary and conclusions

A wide range of shrimp farming technologies, production systems, and scale of enterprise are found throughout the world, from highly extensive systems based on passive stocking and little if any fertilizer or feed inputs, to highly intensive systems using high stocking densities, formulated feeds, and intensive aeration. They may be located in marine, brackish, and even inland waters, but typically use earthen ponds. Although the use of hatchery-produced seed is increasingly common, almost all hatcheries still depend on wild broodstock.

Shrimp farming systems vary greatly according to the intensity with which they utilize resources (such as land, capital, labor, fuel, water, feed, and fertilizer). The economic desirability of different systems and their environmental impact depends to a large degree on the local scarcity or abundance of such resources, and the way in which they are managed under the farm operation. Other specific circumstances such as site conditions and the socioeconomic status of the operator will determine the relative desirability of different systems.

High technology may produce high yields (measured in both production volumes and profitability), but they require close monitoring and a great degree of knowledge on the part of the farmer. While intensive and superintensive shrimp farming technologies may be beneficial both by using little land and producing high output, these technologies are in general more difficult to manage, and the risks are high. The collapse of intensive shrimp farming in Taiwan, Republic of China, is a case in point.

CHAPTER 3: ENVIRONMENTAL IMPACTS OF SHRIMP AQUACULTURE

For centuries, the coastline has been the most important human habitat, and, as a result, has been subject to a wide range of development pressures. Shrimp farming represents additional pressure on these areas, at least potentially. While shrimp farming *per se* does not necessarily have a significant adverse impact on the coastal environment, inappropriate practices and unplanned development have led to a number of problems.

The main environmental impacts associated with shrimp aquaculture, and ways in which specific impacts can be reduced or mitigated, are discussed below. The means by which these mitigating measures can be facilitated, promoted, or enforced at the farm level are discussed further in Chapter 7, but these vary greatly according to the particular kind of shrimp farming, the socioeconomic status of the farmers, and other local circumstances. More detailed guidance will be developed in Phase II of this study.

The actual or potential environmental impacts of shrimp farming fall into the following categories:

- Destruction of natural habitat (through direct conversion);
- Abstraction/contamination and salinization of groundwater;
- Organic matter and nutrient pollution;
- Chemicals;
- Disease;
- Harvest of broodstock and wild post-larvae (PL);
- Introduction of exotic species;
- Abandonment; and
- Use of fishmeal in feeds.

The emphasis of this report is on ways to make shrimp farming *more* sustainable. As a result, the emphasis of this chapter is on mitigation measures to address negative impacts. In some instances, such measures have already been adopted widely by the industry; in others, the suggestions are based more on theory than on practical application. In either case, more research needs to be undertaken to document the effectiveness of the proposed mitigation measures in addressing the impacts.

From the outset, however, it should be emphasized that many of the impacts from shrimp aquaculture are not unique to that industry. Rather, they are typical of agricultural practices in general, especially where land is in short supply. It should also be noted that shrimp farms suffer a great deal from pollution caused by other activities, including agriculture and industry. Indeed, while many other activities are relatively careless of their environment, experienced shrimp farmers realize that long-term benefits result from maintaining environmental quality. When establishing new farms, water quality is one of the most important factors to consider; sites where industry, agriculture, or other activities are polluting the water should be avoided.

Destruction of natural habitat

Extensive shrimp farming takes place in the intertidal zone, commonly in or adjacent to estuarine systems. Semi-intensive and intensive shrimp farming usually takes place in the upper intertidal or just behind/above the intertidal zone, often in adjacent wetlands. Some shrimp farming now takes place in inland areas. Most tropical estuarine systems are dominated by mangrove, an intertidal ecosystem of tree and shrub species specially adapted to saline habitats, that support a wide range of other organisms.

In the early part of the 20th century, many estuarine systems and wetlands remained relatively free from development because of their unsuitability for agriculture and the costs of clearance and drainage for urban development. In the 1960s, ’70s, and ’80s, they were regarded as wasteland by many, and governments and international agencies actively encouraged private sector development for aquaculture and other enterprises. It is only relatively recently that their biodiversity and ecological value has been widely recognized. It should be emphasized that while the most attention has been paid to mangrove in recent years, estuarine systems in general, including salt flats, mud flats, lagoons, creeks, and sea-grass beds, fulfill a wide variety of functions. It is important not to ignore the non-mangrove components of these ecosystems, which in some cases may be at least as valuable as the mangrove.

Estuarine and lagoon systems fulfill the following major functions:

- Provide nurseries for inland, coastal, and offshore fisheries, including shrimp, fishes, and crabs; and
- Assimilate nutrients and use organic matter, turning some of it into sediment.

Mangrove probably enhances these functions, and in addition:

- Produces a range of wood and other forest products (firewood, poles, wood chips, charcoal, bark for tanning and dyes, honey, etc.);
- Protects shoreline against flooding and inundation in storms; and
- Increases sedimentation and accretion, and reduces erosion.

It is also commonly claimed that mangrove has high biodiversity value. In fact, most mangrove forest itself is rather impoverished, consisting of few species due to its varying water level, salinity, anaerobic conditions, and low light. However, mangrove forests are important to the overall biodiversity of its wider estuarine systems, as a source of nutrients and detritus and as shelter for a variety of species. Mature mangrove also harbors many rare or unique species. These and other values and functions have been widely reported and described in the literature, and it is now widely accepted that mangrove conservation should be a high priority.

Reduction of mangrove forests

Mangroves constitute an important part of the tropical coastline. At one time, as much as 75% of tropical coastlines were likely covered with mangroves. The United Nations Environmental Program (UNEP) now estimates that about half of the world's mangrove areas have been destroyed. Some mangroves have become established due to poor upland management practices, especially from extractive industries such as forestry, agriculture, and mining, over the past few centuries (Clay 1998, personal communication).

Mangroves are under intense pressure from a suite of development activities, including over-exploitation for firewood, poles, and charcoal production; conversion to agriculture, salt farming, and coastal aquaculture; and urban development. The relative contribution of these different activities to mangrove destruction varies widely from country to country and region to region. Although the data are incomplete and often contested, there is no doubt that shrimp farming has been a significant cause of destruction in some areas (Asian Development Bank/Network of Aquaculture Centres in Asia [ADB/NACA] 1995; Primavera 1991; Clay 1998; Boyd 1997.) In the countries that are the largest producers of farmed shrimp, NACA reports that 20–50% of all current mangrove deforestation is due to shrimp farming. In areas of Ecuador and Thailand, for example, large areas of mangrove may have been destroyed for shrimp ponds. In many instances, however, shrimp farms were constructed in mangrove areas that had previously been deforested for wood products, making it difficult to attribute the original cause of mangrove loss.

Although mangroves are now widely recognized as being unsuitable for market-oriented shrimp aquaculture development for a variety of reasons (discussed below), primary or secondary mangrove forests are still converted to shrimp ponds in many countries. In Thailand, for example, government agencies have had little success in preventing the clearing of protected mangrove forests (MIDAS 1995). Even in wetlands under consideration as RAMSAR sites, illegal shrimp farmers seeking new land have established their ponds (Anon. 1997a). Major shrimp producers from Thailand are reported to have expanded into Koh Kong Province of Cambodia, where the environment minister has expressed concern for the mangrove forests of the province.

It should be remembered, however, that coastal resources, and in particular mangrove and estuarine systems, have been under intense pressure from increased population and development demands for many years. Displaced and migrant people have often been forced into coastal areas, where they find opportunities to collect wood for fuel, charcoal, and poles, to make salt, and to fish. Significant area has also been converted to agricultural land. It is precisely because these resources are often on public-access property that settlers have been able to do this. However, much of the wood extraction and fishery activity has been unsustainable—and, coupled with the conversion activities, this has led to significant degradation of mangrove and estuarine resources in some countries. In other words, controlling shrimp farm development alone will not save mangrove, and may not even slow the rate of destruction in some areas. A much broader policy, planning, and regulatory framework will be required to stem the degradation of coastal resources.

Suitability of mangrove areas for shrimp farming

Mangrove forests are not considered to be the best sites for semi-intensive or intensive shrimp farms. Boyd (1997) lists the following problems associated with shrimp farming in the intertidal zone:

- Soils are often highly acidic and contain large amounts of organic matter;
- Water exchange is incomplete, so pond effluents may not be washed completely away; and
- Crabs and other possible carriers of shrimp diseases are abundant.

In addition to these reasons for not establishing shrimp farms in primary or secondary mangrove areas, Boyd notes that it is in the farmers' interest to preserve the mangroves, since these forests are capable of efficiently removing solids and nutrients from shrimp farm effluents (Robertson & Phillips 1993). In addition to cleaning discharges from shrimp ponds, mangrove can stimulate the productivity of coastal areas, thereby improving coastal fisheries, minimizing pollution of the coastal environment, and providing higher water quality for shrimp farming. However, these positive effects can be overridden by discharging amounts of nutrients greater than the carrying capacity of the local ecosystem, by discharging concentrated pulses of nutrients and organic matter, and by introducing chemicals and antibiotics (used to treat diseases and improve pond quality), all of which can be locally harmful.

Despite this general warning about avoiding shrimp culture farms in mangrove forests, the severity of the constraint should not be overemphasized. A NACA/ADB survey (ADB/NACA 1995) of shrimp farms in 12 countries in Asia showed that while an average 31% (range 0–88%) of intensive farms were sited in what was previously mangrove, soil acidity was reported as a significant problem in only 5% of them overall (range 0–6%). While these low figures may in part reflect ignorance on the part of the farmers as to the causes of water quality problems, they do suggest that some mangrove soils are indeed suitable—or at least acceptable—for shrimp production. Furthermore, most mangrove soils are potential acid sulphate soils that may not become acidic if disturbance is limited and the soil is not dried out, as is often the case with more extensive systems.

Mitigation of threats to habitat

There are three possibilities for minimizing the conversion of natural habitat to shrimp farms. First, shrimp farms can be constructed away from mangrove areas altogether. The (large-scale) shrimp farming industry organizations, several NGOs, other international organizations, and most governments in the largest producer countries of farmed shrimp now agree that shrimp farms should not be established in mangrove forests. Unfortunately, such avoidance may result in destruction of other natural habitats (such as other wetlands, forests, salt marshes, mud flats, salt flats) with their own natural functions and biodiversity value, or conversion from other uses, such as rice farming, coconut plantation, or other forestry/agriculture. Whether such changes are desirable will depend on local circumstances and priorities. It should be noted, however, that in some countries (for example, Vietnam), the only land available to poor, displaced migrant and minority groups is in fact mangrove. Given the high population density of such areas and the limited sustainable productivity of natural mangrove (Hambrey 1993), such settlements are inevitably resulting in overexploitation or conversion to agriculture and/or aquaculture. In these circumstances, carefully planned and limited conversion to aquaculture may be the best option, perhaps reducing the overall development pressure on mangrove and other valuable natural habitat.

Second, shrimp farms can be constructed on the landward fringe of mangrove. In some circumstances, this may be an attractive option, since such land is often partially saline and of low value for alternative uses. If mangrove is present, it may be highly degraded as a result of human pressure or in natural decline as part of the mangrove cycle of colonization, accretion, and stabilization. Ponds may be constructed so that a belt of mangrove forest is maintained along the coast, with the ponds located immediately behind the mangrove belt (Barg 199b). There are operating examples of such an arrangement in Thailand, for example the Kung Krabaen Bay Royal Development Project in Chantaburi.

The third approach is to reduce the total area of shrimp farming, and/or ensure that any future increases in production come from the same or a lesser area of land, so that no further destruction of mangrove is allowed. This implies intensification of production. It is essential that appropriate skills, improved water management and technology, strategies for disease management, and appropriate infrastructure are developed in parallel with intensification, if this approach is implemented.

Whatever approach is taken, the value of natural habitat and productive land must be assessed within an appropriate natural resource planning framework, and some form of rational land use allocation and/or zoning must be introduced. If effectively implemented, such policies should minimize habitat destruction by coastal aquaculture and other activities, and protect the most valuable remaining natural habitat. Approaches to resource assessment and land use planning in relation to aquaculture have been recently reviewed by GESAMP (1999). Where shrimp farms are developed on acid soils, pond water acidity may be countered through regular flushing and treatment with lime, or in some cases with oxidation and flushing. Alternatively, ponds may be lined with concrete, laterite, or PVC, although there may be some disadvantages in using PVC pond liners in terms of water quality (Wanuchsoontorn 1997). However, all these practices will increase the cost of operation and the risk of failure, compared to farms constructed in nonacidic or low-acid soils.

Contamination and salinization of groundwater

Contamination of groundwater

Water use in shrimp farming is extremely variable, ranging from little more than make-up water to compensate for evaporation and seepage to very high rates of exchange. For example, for each metric ton of shrimp produced, intensive farms require 50 to 60 million liters of water, according to Gujja and Finger-Stich (1995). Recent trends in Thailand, however, have intensive farms using minimal water exchange, relying on intensive aeration and skilled management to maintain water quality.

While extensive farms often rely on exchanging water by using tidal ebb and flow, some semi-intensive and intensive farms use large amounts of freshwater to mix with seawater, or to make up for evaporation in ponds, in order to maintain what is thought to be an optimum salinity of 15–20 ppt.

Pumping freshwater from groundwater is reported to have significant environmental effects, contributing to problems such as:

- Saltwater intrusion into groundwater reservoirs;
- Land subsidence; and
- Loss of water supplies for agricultural and domestic purposes.

These effects are reported in a number of countries and regions, including Taiwan, Republic of China; Thailand; Indonesia; the Philippines; and Ecuador (Primavera 1994; Clay 1996; Dierberg & Kiattisimkul 1996). In Taiwan, Republic of China, such problems contributed to the shrimp crisis in the late 1980s.

Some experts claim that the practice of mixing water to obtain a salinity of approximately 15 ppt is not necessary, and that this practice is rare even in Asia (Boyd 1997). New management practices that use low water exchange rates have probably reduced this problem substantially worldwide.

Shrimp farming in freshwater

Penaeus monodon is highly tolerant of low salinity and, if given time to acclimatize, can be grown in water of close to zero salinity (Ullah 1995). This adaptability has allowed the spread of shrimp farming into inland waters (Ponza 1999). Concentrated seawater is trucked inland and added to small ponds or nursery enclosures to provide an initial salinity of 7–10 ppt. Passive water exchange with a partially filled grow-out pond results in a steady reduction in salinity. Finally the ponds are filled, and salinity is reduced to close to zero for the bulk of the grow-out cycle. Water management is usually based on the semiclosed system, in which water is added to the system, but effluent is not discharged until the end of the cropping cycle. In recent years shrimp farming has become a significant industry in predominantly freshwater rice-growing areas in Thailand, and has resulted in some social conflict which has recently led to a ban on shrimp farming in some areas (Flaherty & Vandergeest 1998).

Seepage through pond bottoms, discharge of pond water into freshwater areas, and seepage of salt from sediment disposal sites can salinize freshwater reservoirs (Boyd 1997), canals, and adjacent rice paddies (Funge-Smith & Stewart 1996). The severity and significance of salt's impact is little researched and is highly variable, depending on local hydrology and salinity regimes, as well as pond soils and management practices. Clearly, this topic warrants further research, but generalizations should be avoided. In some slightly brackish and even freshwater areas, shrimp farming may represent the best long-term economic option, but potential social, environmental, and land-capability impacts must be thoroughly researched and assessed, and adequately planned for, if implementation is to be sustainable.

Mitigation of water contamination

Boyd (1997) claims that if ponds are built on sites with soils of adequate clay content, seepage will not be a factor, and he suggests that the practice of discharging pond water into freshwater bodies should be prohibited.

Research on the nature of the local aquifer, hydrology, and soils, along with knowledge of water management practices, is required if this issue is to be adequately addressed. In addition, the relative benefits and costs to the various stakeholders resulting from the introduction of shrimp farming needs to be assessed. Results from such research might then contribute to a land-use planning or zoning scheme to minimize conflict between users as well as long-term impact on the environment, and to maximize social benefits.

In effect, a precondition for mitigation of this kind of impact is effective research capacity linked to a natural resource planning system. In the absence of such a system, a precautionary approach should be taken. Shrimp farming should not be allowed to operate in ways or in locations where it may disrupt the aquifer and salinity regime.

Organic matter and nutrient pollution

The water in shrimp ponds is high in nutrients and organic matter, especially towards the end of the production cycle. These nutrients are derived mainly from waste food and metabolic products, as well as from the small quantities of fertilizer added at the start of the cycle to stimulate plankton blooms (Institute of Aquaculture 1996). Poor feeding practices, particularly over-use of feed, allows feed to sink to the bottom of the pond. This pollutes the pond and significantly increases the cost of operation, since feed comprises approximately 40 to 60% of operational costs (Lin 1995). A survey in Thailand showed that larger operations achieved higher feed conversion ratios than smaller operations, on average, suggesting greater commitment and more effective monitoring of feed consumption in family-run and -operated farms (Asian Shrimp Culture Council 1994; Lin 1995).

When pond water containing high concentrations of nutrients and organic matter from a large number of shrimp farms is discharged into coastal waters, the effects can be negative, depending on the ecosystem's capacity to receive the discharges. Potential negative effects include (Clay 1996; Dierberg & Kiattisimkul 1996; Lin 1995):

- Unusual rates of sedimentation;
- Eutrophication, with increased risk of harmful algal blooms;
- Change in the nutrient cycle;
- Oxygen depletion;
- Toxicity from sulfide compounds and ammonia following degradation of organic matter; and
- Increased incidence of disease, stemming from poor water quality and stress on marine life.

These impacts may be detrimental to the farm itself, to neighboring farms, and to the wider environment. It should be noted, however, that increased levels of nutrients and organic matter may be desirable for some coastal ecosystems. Indeed one valuable function of mangroves is their capacity to absorb and use the detritus and nutrients that arrive in estuaries and coastal waters. So long as carrying capacity is not exceeded, the nutrient and organic matter discharges from shrimp ponds may actually be beneficial. Some increase in the production of shellfish resources in southern Thailand has been tentatively related to increased shrimp farming activity (Menasveta 1996). Similar experience exists in China for shrimp and caged fish farming combined with adjacent culture of seaweeds and mollusks (Zweig 1999).

Although there are examples of lake eutrophication as a result of fish farming, few examples are reported in coastal waters. Other than at harvest, the concentration of nutrients and organic matter in effluents from shrimp farms are relatively low compared, for example, with treated sewage or wastes associated with food processing (Table 5). However, when pond effluent is added to other sources of nutrients (e.g., from agricultural and domestic wastes), the risks of algal blooms or suffocation of marine organisms may become significant. At that point, nutrient discharge should be minimized.

TABLE 5. QUALITY OF INTENSIVE SHRIMP POND EFFLUENT COMPARED WITH DOMESTIC WASTEWATER, THAILAND

Component (mg/l)	Shrimp effluent	Domestic wastewater (*untreated*)	Domestic wastewater (*primary treated*)	Domestic wastewater (*secondary treated*)
BOD	4.0–10.2	300	200	30
Total N	0.03–3.40	75	60	40
Total P	0.01–2.02	20	15	12
Solids	30–225	500		15

Source: Beveridge, Phillips, & Mackintosh 1997.

The significance of the impacts of organic matter and nutrients from aquaculture depend on management practices on the one hand, and environmental capacity on the other. Good management practices can radically reduce the export of nutrients to the environment, and where farms are well dispersed, or carrying capacity is high (e.g., because the local environment is effectively flushed), effects are likely to be minimal. The most severe impacts arise at the time of harvest, when accumulated and concentrated organic matter and pond bottom sediments may be discharged to the environment either passively, following re-suspension during the harvesting process, or through active flushing with high-pressure hoses (Table 6). Examples of environmental damage, including damage to mangrove, have been reported to follow harvest effluents (Clay 1996). The effects of such effluents will be most significant where farms are located in the vicinity of more sensitive marine habitats, such as coral reefs. Fortunately, most shrimp farms are located in estuarine systems, which tend to have relatively high environmental capacity.

TABLE 6. VARIATIONS IN EFFLUENT QUALITY FROM AN INTENSIVE SHRIMP FARM IN SOUTHERN THAILAND

mg/l	Routine discharge	Draining & harvest
Total N	0.5–3.4	1900–2600
Total P	0.05–0.4	40–110

Source: Lin 1995

Mitigation of organic pollution

The quantity of waste nutrients and organic matter produced in a shrimp farming system is directly related to the feed conversion efficiency, and this in turn depends on feed quality and feeding practice. High-quality feed, and feeding the right amounts at the right time, can radically reduce nutrient and organic matter wastes, while at the same time reducing costs. Low-pollution diets (specifically low-phosphorus diets) can also be manufactured specifically to reduce this type of pollution. Some authors have also suggested greater use of feeding trays to minimize waste (Viacava 1995), but this may not be cost-effective in more intensive systems where the shrimp are already extremely densely packed.

Poor water quality affects not only the shrimp in the concerned ponds but also those in neighboring ponds, as well as life in adjoining water bodies. The eruption and spread of disease often occurs in connection with poor water quality; disastrous outbreaks affecting entire regions can result.

Heavy aeration/effective water circulation can help break down organic matter and minimize the quantity of anaerobic sediments that accumulate at the bottom of shrimp ponds. Some direct removal of ammonia may also occur during intensive aeration.

A large proportion of the nutrients are in suspended solids, and it is relatively easy to remove about half of these in simple settling ponds. It is particularly effective—and particularly important—to settle effluents released at the time of harvest. If water exchange is relatively low during most of the culture period, the area of settling ponds relative to production ponds need not be very high (Boyd 1988). Settled solids can be removed and dried to oxidize organic matter, and may be suitable for other uses. In most circumstances, settling ponds are likely to be the simplest and most cost-effective approach to making effluents of acceptable quality.

Completely closed recycling systems, incorporating settling and water treatment, are now being used commercially in several countries (Muir 1994), including Taiwan, Republic of China; and Thailand, and offer the prospect of minimal impact on the environment. However, it should be remembered that even with closed systems, the need to dispose of accumulated solid wastes effectively remains.

If discharges from shrimp farms are passed through mangrove areas, depending on hydrology and the extent of the mangrove system, much of the residual suspended solids will settle out, and nutrients may be absorbed by the mangroves (Barg 1992a. 1992b; Robertson & Phillips 1994). It is important to ensure that nutrient or organic matter pulses are not excessive; otherwise the mangrove itself may be adversely affected. Such an event is very unlikely if the effluent has been settled prior to discharge, as described above. However, more research is needed on the impact of different nutrient loadings on different mangrove species.

If the natural mangroves or wetlands are incapable of performing this natural process of "cleaning," or in cases where it is undesirable to use a mangrove forest to receive effluent, constructed wetlands may be installed to take over the functions of sedimentation, filtration, and soil absorption (Schwartz & Boyd 1995). Some examples of areas required for "natural" treatment with mangrove, and design parameters for constructed wetlands, are provided in Box 1. The economic attractiveness of various approaches will depend on issues such as land value, the costs associated with alternative treatments, and the environmental cost of no treatment. The main problem with constructed wetlands is the large amount of (relatively) low-value plant matter generated that needs to be removed to maintain the efficiency of the process.

Research is being conducted on the potential for using mollusks (e.g., oysters, mussels) or plankton-eating fish (such as *Tilapia*) to remove excess plankton, and for using seaweed (such as *Gracilaria*) to remove residual or recycled nutrients (Chandrkrachang, Chinadit, Chandayot, & Supasiri 1991; FAO 1989; Jones & Preston 1996; Ryther, Goldman, Gifford, et al. 1975). Despite the substantial potential of these approaches, they have not been adopted by farmers. It is difficult to balance the production of very different products with different values and with different market outlets. Most farmers will be far more interested in maximizing

Box 1: Potential for removal of waste nitrogen using natural or artificial wetlands

Nitrogen content of feed (example)	7%
Nitrogen content of shrimp (ca.)	3%
Food conversion efficiency (example)	1.5

Then, waste nitrogen
= (0.07*1.5*1000) – (0.03*1000)
= 75kg/MT shrimp produced

Nitrogen removal

Water hyacinth:	8t/ha/yr
minimum area required	*0.009 ha/mt/yr*
Mangrove:	219kg/ha/yr
minimum area required	*0.34 ha/mt/yr*
Constructed wetland:	
loading 77-91 l/m^2/day	*45-61%*

Notes:
These figures assume no alternative source of nitrogen.
They also assume that wastewater will be evenly available to all the plant matter in the treatment area or zone (unrealistic in the case of natural mangrove).
Sources: Robertson & Phillips 1994; Boyd 1995

shrimp or high-value finfish production and reluctant to invest effort in maintaining healthy and productive culture of lower-value species.

Chemicals

In addition to the use of fertilizers discussed above, shrimp farmers now use a wide range of chemicals to prevent and manage disease, to manage water and pond soil quality, and to facilitate harvesting and transportation. They include the following:

- Soil and water treatments (e.g., EDTA, lime, zeolite);
- Disinfectants (e.g., sodium or calcium hypochlorite and chloramine, benzalkonium chloride (BKC), formalin, iodine, ozone);
- Pesticides and herbicides (e.g., saponin, rotenone, anhydrous ammonia, Gusathion, Sevin, organophosphates, organotins);
- Antibacterial agents (e.g., nitrofurans, erythromycin, chloramphenicol, oxolinic acid, various sulphonamides, oxytetracycline);
- Other therapeutants (e.g., formalin, acriflavine, malachite green, methylene blue, potassium permanganate, Trifluralin);
- Feed additives (e.g. immunostimulants, preservatives and anti-oxidants, feeding attractants, vitamins);
- Anesthetics (e.g., benzocaine, quinaldine); and
- Hormones.

In addition, chemicals may be leached from plastics and other structural materials used in shrimp farming.

The most commonly used chemicals in shrimp culture are chlorine for disinfecting tanks, ponds, and (increasingly) the water supply; quick lime, saponin, and rotenone for pond soil disinfection; formalin for disinfecting broodstock and larvae, and as a general disinfectant and disease treatment; BKC and EDTA for pond water management; and various antibiotics for disease treatment. Relatively small quantities of anesthetics may be used in the transportation of broodstock. Hormones are not widely used in the shrimp industry. The overall use of chemicals in aquaculture has recently been reviewed by GESAMP (1997).

As with agriculture and other forms of aquaculture, the use of some of these chemicals raises a variety of environmental concerns. Perhaps the greatest is the indiscriminate use of antibiotics to control or prevent disease outbreaks, and in particular the use of antibiotics that affect human health, such as chloramphenicol. Several bacterial and viral diseases have plagued the shrimp farming industry in recent years, and large quantities of antibiotics and other drugs have been used to reduce shrimp mortality. Some of the medicine will eventually end up in the environment, exposing other organisms. One report notes that approximately 70 to 80% of the administered antibiotics will ultimately end up in the environment as a result of uneaten food and contaminated excrement (Greenpeace 1995, cited in Clay 1996). Three primary environmental concerns are associated with the use of antibiotics:

- The proliferation of antibiotic-resistant (and thus more dangerous) pathogens as a result of incorrect or continual use of antibiotics, and/or their persistence in sediments;
- The transfer of antibiotics to wild fish and other organisms in the vicinity of farms using medicated feeds; and
- The effect of antibiotics on natural bacterial decomposition in bottom sediments, and their influence on the ecological structure of benthic microbial communities.

Drugs and other chemicals are commonly overused, since the costs of possible losses from disease are very high compared with the costs of treatment. Furthermore, when instructions specify a certain dosage, operators sometimes believe that doubling the dosage will double the effect of the drug, so they use more than the recommended dosage. Lack of training and knowledge can therefore lead to poor production rates, or even disasters.

Excessive or improper use of many antibacterials, especially those that persist in the environment, may lead to the development of resistance, to the long-term detriment of the shrimp industry itself and human health generally. For example, *Vibrio* species have already become resistant to oxytetracycline in many countries, and resistance to oxolinic acid has also been reported.

The effect of most of the chemicals used in shrimp farming depends on the amount used, exposure time, and dilution. Even if a compound does not cause harmful effects in moderate amounts in an environment with good dilution properties, the effects might be severe if large amounts of the same compound are discharged in coastal environments with poor water exchange.

Chlorine is used to disinfect ponds between generations of shrimp. It is used to disinfect water for use in hatcheries, and increasingly to disinfect water in reservoir ponds (used to fill production ponds). The most common compounds used are sodium and calcium hypochlorite. Chloramine is sometimes used to disinfect tanks and equipment. In the presence of organic matter, both hypochlorite and chloramine are rapidly reduced to nontoxic compounds, and it is the remaining available chlorine that causes inactivation of viruses (Hedge et al. 1996). Neither hypochlorite nor chloramine are bioaccumulative, and they are likely to have only localized biological effects. Research is currently under way to explore the possibility of creating complex persistent chlorinated organic compounds, but these could have serious environmental impacts.

Formalin (aqueous solution of 40% formaldehyde) is used extensively against fungus, viruses, bacteria, and ectoparasites in shrimp farming. Formaldehyde has low persistence, with a half-life of 36 hours. Along with sodium hydroxide ($NaOH$), formalin exists in nature and should not have a significant impact on the wider environment under normal farm usage (Tobiesen & Braaten 1995).

The effect of the chemicals on humans who handle them should also be considered (GESAMP 1997). For example, organophosphates and malachite green are respiratory enzyme poisons. Rotenone can cause respiratory paralysis. Ingestion of chloramphenicol may cause aplastic anemia. Formalin can cause cancer and severe allergic reactions in people through long-term exposure. Even though some of the most frequently used chemicals in shrimp farming are only moderately toxic, they can have severe effects on the environment and people working at the shrimp farms, depending on amounts used, dilution, repeated measures, and preventive measures.

Many of the chemicals used in shrimp farming (e.g., formalin, furazolidone, dichlorvos) are not persistent, with half-lives ranging from 36 to 200 hours. Oxytetracycline, oxolinic acid, and flumequine, on the other hand, are relatively persistent and can be found in pond sediments six months or more after treatment.

Organisms in the wider environment may be susceptible to some of the chemicals used in aquaculture, especially those used to combat ectoparasites. In practice, their use is rather less common in the case of shrimp than in finfish farming. Other organisms in the local environment may take up chemicals directed at the aquaculture enterprise. Mollusks, for example, may take up chemotherapeutants, especially if grown in polyculture. Mollusks may then pose a hazard to humans who eat them, although there is little evidence of this to date.

There is widespread concern among consumers relating to chemical residues in farmed products. Most shrimp destined for export are now tested for antibiotic and other residues. However, such testing may result in consignments that fail the tests being marketed locally, where regulations are less stringent.

Mitigation of chemicals' effects

Two basic rules should apply to the use of chemicals in aquaculture: minimal use and correct use. Use can be minimized if disease incidence can be reduced by other means (see discussion below). Correct use depends upon effective information dissemination and communication, including agricultural extension and other training. Shrimp farming generates substantial profits, and the industry itself is therefore well capable of funding improved information and training. However, the role of companies that market chemicals in providing advice at the grassroots level in many countries is of concern, since their interests are inevitably biased toward greater chemical usage. These issues are dealt with more fully in Chapter 6.

In more immediately practical terms, the safe and effective use of chemicals in aquaculture has recently been reviewed by GESAMP (1997) and is also presented in relation to specific diseases by AAHRI (Chanratchakool, Turnbull, et al. 1996).

Disease

Some of the diseases that trouble the shrimp farming industry are directly caused by environmental problems, while a number of other diseases are triggered or spread more effectively by the stress induced by environmental problems. None of the shrimp diseases are known to be pathogenic to humans. In recent years, shrimp farming has been afflicted with outbreaks of viral diseases that have greatly undermined profitability and sustainability of operations. Based on a detailed survey conducted in 1993–94, the Network of Aquaculture Centres in Asia estimated the total losses in 12 countries in South and Southeast Asia to amount to U.S.$143 billion dollars (ADB/NACA 1995).

Disease outbreaks have led to the collapse of shrimp farming in some places, including Taiwan, Republic of China; parts of Thailand; the east coast of India; and China. In China, the collapse has led to a shift away from shrimp to other species such as finfish, mollusks, and crab, some of which are grown in polyculture.

Viral diseases

More than 15 different viruses have been identified for *Penaeid* shrimp over the past 20 years. Many of the known viruses infect larvae and juveniles, and they can be species-specific. Shrimp may become less resistant under conditions of stress, such as overcrowding, water temperature fluctuation, low oxygen levels, or high levels of pollutants (Lundin 1996).

Taura Syndrome

In the Western Hemisphere, the most damaging disease at present is Taura Syndrome Virus, referred to as TSV or just TS (Rosenberry 1996). Attacking shortly after shrimp are stocked, it kills from 40 to 90% of the juveniles in a pond. It is called “Taura Syndrome” because it first appeared on the Taura River, about 25 km southeast of Guayaquil, Ecuador. It has also been called “Little Red Tail” (La Colita Roja) because the fan tail and body of affected shrimp turn pale pink.

Although TSV may have been active for a number of years earlier, it was first noticed in shrimp farms in Ecuador in 1992. Several farms were affected by it, then it disappeared quickly but reappeared in March 1993. At that time, it became a major epidemic, killing farm-raised shrimp throughout the Gulf of Guayaquil.

Taura spread from Ecuador to Colombia as early as 1993. In 1994, most farms in Honduras and Guatemala were affected as well, and by 1995 there were reports of the disease in Mexico. In May 1995, TSV hit Texas shrimp farms and killed 90% of the crop.

In 1993, 1994, and 1995, Ecuadorian shrimp farmers continued to produce large amounts of shrimp, although many areas were infected with TSV. Profits were lower, because the farmers stocked the ponds with twice the ordinary number of juveniles.

There is now evidence that the white-leg shrimp (*Penaeus vannamei*) has become resistant to TSV. In mid-June 1995, survival of wild-caught seed ranged from 50 to 60%, while survival of hatchery-produced seed was 20 to 30%. This was still double the survival rates experienced in 1993–94.

There have been no reports of Taura in Costa Rica, Panama, Venezuela, or Nicaragua.

White Spot Virus Disease

In the Eastern Hemisphere, White Spot Virus Disease is the most common and serious shrimp disease affecting shrimp farms (Rosenberry 1996). In Thailand, attempts to eradicate the disease have so far failed. White spot was also probably responsible for the major shrimp farming disasters in Taiwan, Republic of China, in 1987–88 and in China in 1993. It has caused problems in Bangladesh, India, and Vietnam, and is probably established everywhere in Southeast Asia.

The virus causing the white spot disease has been given different names by various research groups. Among these names are *Penaeus monodon* Occluded Baculovirus 2 or 3 (PmNOBII and PmNOBIII), and Systemic Ectodermal and Mesodermal baculovirus (SEMBV). Lately, the virus is referred to as either the White Spot Virus (WSV) or White Spot Baculovirus (WSBV).

Post-larvae from 20 days of age and up are susceptible to White Spot Disease. Mass mortalities of up to 100% occur within 3 to 5 days of the first clinical signs. Outbreaks are now more sporadic than the widespread epidemics that hit the industry in 1993, but they are more common in areas with dense concentrations of shrimp farms. Environmental factors like poor water quality and deteriorating pond bottoms have been implicated as the stresses that trigger outbreaks. Thus far, White Spot Disease has affected *Penaeus chinensis* and *P. monodon* most significantly, but recently has devastated shrimp in ponds on the Pacific coast of Central and South America.

Among the other important viral diseases is Yellow Head Virus (YHV), which has been a problem particularly in Asia (for a detailed discussion of viral diseases in shrimp farming, see Flegel 1997 and Flegel, Boonyaratpalin, & Withyachumnarnkul 1997).

Bacterial diseases

Many different forms of bacteria can affect shrimp, frequently as opportunistic follow-ups to viral infection or environmental stress (Lundin 1996). The short-term strategy for dealing with bacteria has been to use antibiotics as well as improving pond cleaning and increasing water exchange.

Vibrio species, in particular *V. harveyii* (luminescent bacteria), have posed significant problems in many Asian countries, including the Philippines, Indonesia, and Sri Lanka, affecting hatcheries and grow-out ponds.

Other diseases

Other diseases affecting shrimp include rickettsia, such as the Texas necrotizing hepatopancreatitis (TNHP) in *Penaeus vannamei*, and rickettsia-like infection of *Pandalus*. Fungi also occasionally infect shrimp. Protozoa can cause considerable damage to shrimp as well, particularly under poor farming conditions.

Disease and environmental problems

Outbreaks and spread of shrimp diseases cause serious environmental problems, including:

- Increased risk of infections in wild populations of shrimp and other crustaceans;
- Widespread use of antibiotics and chemicals that can harm wild populations and human health;
- Large amounts of dead shrimp; and
- Large areas abandoned by shrimp farmers.

The use of antibiotics and chemicals is discussed above, and land abandoned by shrimp farmers is discussed further below.

The diseases caused by specific agents like viruses, bacteria, and fungi originate in wild shrimp and other crustacean populations. Although the frequency and impact of diseases in wild populations is poorly understood, concentrated outbreaks of an infectious disease in shrimp farms are likely to increase the risk of infecting wild stocks locally, as well as farther away from the farms. This could cause increased mortality in wild stocks, resulting in alterations to the ecosystem and reduced production of shrimp biomass.

Post-larvae and broodstock are often transported within countries and exported to other shrimp farming countries. These are practices that can increase the spread of disease. If dead shrimp are not removed quickly from shrimp ponds and properly disposed of, their presence increases the spread of disease in the pond.

Disease prevention and management

Disease has made shrimp farming unsustainable in many areas of the world. To date, the responses have been reactive and ad hoc—based largely on disease identification and treatment, coupled with efforts to promote improved management practices on individual farms. In practice, this approach has failed to prevent major losses to the industry, and in some cases the losses have led to abandonment. If shrimp farming is to become more sustainable, a much more strategic and integrated approach will be needed. In practice, this will require countries, and specific shrimp farming areas, to develop comprehensive disease prevention and management strategies. These strategies, and other components of better planning of shrimp farm development, are discussed in Chapters 6 and 7. They will require significant government intervention.

Such strategies should include measures to promote, facilitate, or require the following:

- Improved understanding of disease epidemiology;
- High-quality, low-pathogen water supply to major farming areas, and to individual farms;
- High-quality, low-pathogen, or pathogen-resistant seed supply;
- High-quality, pathogen-free feed supply;
- Optimal grow-out conditions;
- Farmer competence in the rapid identification and correct treatment of disease;
- Increased species diversity; and
- Cautious intensification and implementation of different system models in response to local conditions.

Improved understanding of disease epidemiology

Diseases affecting shrimp and other aquaculture organisms may originate from local wild stock or other carrier organisms, from infected seed, from infected broodstock, and possibly from infected feed. Information on the incidence and spread of disease can help identify the source and may allow for more effective disease prevention. A disease inspection system is required to monitor and control the movement of organisms, to test for disease and keep detailed records for epidemiological purposes, and to take action as appropriate when disease problems arise. To maintain effective prevention, such inspectors must undertake regular analysis of data collected.

High-quality, low-pathogen water supply to major farming areas and to individual farms

The exchange of water between shrimp farms through the mixing of influent and effluent is a common problem in areas where shrimp farming has developed overly rapidly and in an unplanned manner. Improved design and management of water supply and disposal is required if disease spread is to be minimized. This may require major initiatives, such as seawater supply systems with pumping—developed in major shrimp producing countries in Asia—or more modest agreements between farmers relating to canal design and use. Clearly, managing water supply is far easier to accomplish if undertaken before the majority of farms are developed, and should be considered in any planning initiatives related to aquaculture development.

High-quality, low-pathogen seed supply

Infected seed is commonly blamed for the introduction of disease to shrimp ponds. Regular inspection and testing of seed from hatcheries, coupled with epidemiological information collected as above, may provide the basis for hatchery or seed certification schemes. Certification might be based on adherence to best management practices, or hatcheries producing "consistently disease free" shrimp seed.

"High health" strains of post-larvae, or so-called SPF (specific-pathogen-free) strains, have recently been introduced in shrimp farming (Pruder 1994). The term "high health" has been suggested to replace terms such as specific-pathogen-free (SPF) and specific-pathogen-resistant (SPR) strains of shrimp. It has now been adopted by the US Marine Shrimp Farming Program (USMSFP) to describe shrimp stocks judged, on a best-professional-effort basis, to be free of certain viruses, protozoa, and parasites.

"High health" shrimp stocks have been presented by some analysts as the solution to preventing disease in shrimp farming (Pillay 1997), while others (Pruder 1994) are more cautious in their assessments of the high health programs. Pruder (1994) recommends that the marine shrimp farming industry worldwide adopt a “high health” shrimp system similar to that advocated in the United States, but both Pruder and Chamberlain (1994) conclude that “high health” shrimp systems alone do not appear to be a solution for preventing outbreaks of Taura syndrome. Both conclude that to reach sustainable production and financial performance goals, there are no substitutes for good husbandry and effective management.

In general, there is a danger in relying on SPR or SPF strains of shrimp. Experience shows that other illnesses may infect such animals when they are exposed to pond environments which are less sterile than where they were bred. The use of SPF or SPR strains requires close follow-up by a well-established veterinary service. It may in fact be more important to implement such follow-up than to focus on development of SPFs or SPRs. A cautious and broader-based approach is recommended, since it has not been convincingly documented that SPF or SPR strains of shrimp have a long-term advantage over “natural” shrimp.

High-quality, pathogen-free feed supply

Feed has also been blamed as a source of infection in shrimp ponds. This may be a particular problem if “trash” fish and shrimp are used in feed. In general, this practice should be discouraged or, at a minimum, procedures for sterilizing feed components should be set in place.

Optimal grow-out conditions

As noted widely in the literature, poor husbandry and management make a significant contribution to the susceptibility of shrimp to disease, and hence to its rapid development and spread. Of particular importance are the maintenance of suitable water quality and the provision of high-quality feed in the correct quantities at the correct times. Effective training and information dissemination, coupled with appropriate incentives, are required to achieve this. A review of practical measures to prevent and treat disease in shrimp ponds can be found in AAHRI’s book (Chanratchakool, Turnbull, et al. 1996).

Farmer competence in the rapid identification and correct treatment of disease

Early identification and treatment of disease is essential to prevent disease spread. Correct and timely treatment will also reduce the environmental impact of many of the chemicals and medicines used in disease control. Farmers need the knowledge to identify diseases themselves, as well as ready access to laboratory diagnostic and advisory services. Although companies may play a role, there is a clear need for government intervention to ensure quality control and to reduce the overuse of antibiotics and other compounds.

Increased species and system diversity

Disease is likely to spread more rapidly, and its impact on local economies will be more severe, if monocultures of shrimp are grown. Mixed cropping (i.e., different species in different ponds), alternate cropping of different species in the same pond, and polyculture and integrated farming systems may all contribute to this objective, and may be suited to different development contexts. In practice, many farmers will prefer the simplicity and the potential high returns from monoculture of shrimp, and economic incentives or regulations may be needed to encourage greater diversity in culturing.

Cautious intensification

Disease has been widespread in all shrimp farming systems, from extensive to intensive. However, it is likely that the risk of disease increases in more intensive systems, especially if knowledge and husbandry skills are inadequate. The economic incentives to intensify may be extremely strong, and intensification is desirable in several respects. It is therefore essential that governments, shrimp farmer associations, and corporations ensure that skills keep pace with intensification by providing appropriate training, information dissemination, and access to expertise through local aquaculture extension agents. If such measures cannot be implemented, it may be necessary to restrain intensification using suitable disincentives.

Vaccination

It is generally assumed that it is not possible to vaccinate shrimp against disease (Subasinghe 1995). One reason is that the immune systems of shrimp appear to have a “short-term memory,” which renders the vaccine ineffective after just a few hours (Söderhäll & Cerenius 1992). However, recent research

(Raa 1996) indicates that it is possible to stimulate a shrimp's immune system to withstand certain diseases.

Harvest of broodstock and wild post-larvae

Many farmers in South and Central America, Bangladesh, and India still depend on wild-caught post-larvae, usually caught by local fishermen. Some shrimp farmers prefer wild-caught PL because they believe that these are more resistant to disease, and in general more robust, than artificially produced PL.

The intensive collection of wild PL may lead to a decline in wild stocks. If this happens, the same local fishermen who collect wild PL are the ones most likely to suffer. However, the impact of collecting wild broodstock and post-larvae is controversial. Some authors report that intensive seed-stock fishing has reduced the capture of mature shrimp and other species (Clay 1996), while others claim that there is no convincing evidence that shrimp farming has depleted the native shrimp in any country (Boyd 1997).

Using wild broodstock or post-larvae makes it difficult to control their disease status. By comparison, the Norwegian salmon industry has succeeded in reducing disease outbreaks by controlling the health status of broodstock, eggs, and smolts, as well as by developing and using effective vaccines.

Dependence on wild seed is therefore undesirable in the longer term. However, the seed capture industry provides income and employment for poor coastal people in many parts of the world, and any strategy to promote replacement with hatchery-reared seed must take this into account.

Introduction of exotic species

In general, introduction of exotic or non-native species into an area is considered undesirable because of the risk of competition with native species and because non-natives may transfer pathogens and parasites to which native organisms are not adapted. In a number of countries, this threat is considered so serious that introduction of non-native species is prohibited by law, for example in Norway and some other European countries.

While it is documented that importing living non-native shrimp has introduced new pathogens (import of *P. monodon* to Latin America brought White Spot Virus), there does not appear to be any documentation of uncontrolled proliferation of new shrimp species resulting from importation. The spread of new diseases and uncontrolled reproduction of new species should be regarded as ecological risks unless it is firmly demonstrated that no harmful effects on native shrimp or other populations will result from introduction of a non-native species. In general, the export and import of non-native shrimp across borders and continents should be discouraged and international protocols strictly followed.

Abandonment of ponds

Significant areas in some of the most important producer countries have been abandoned by shrimp farmers. Usually, disease has made production unprofitable in these locations, so the farmers have been forced to quit. In many cases, these ponds will be put into shrimp production again, as has happened in Thailand and China, when disease incidence declines or when improvements in management practices make production profitable once again. Sometimes the resumed production intensity is lower and, in some instances, shrimp are grown in polyculture.

In Thailand, the National Economic and Social Development Board reports that 24% of the shrimp farms established in mangrove areas are abandoned after 2–4 years because of disease and production problems, and that these sites are unsuitable for other purposes such as agriculture (Anon. 1997b). Other estimates for pond life expectancy range from 5–15 years (Flaherty & Karnjanakesorn 1995). It has been suggested that the life span of shrimp culture ponds depends on the stocking density, food and feeding regime, quality of the bottom soil, and water temperature (Matsusato 1993). In certain instances of extensive shrimp culture, farm life spans of up to 50 years may be observed.

In practice, this analysis may be misleading, especially about the relationship between abandonment and intensity. If badly planned and sited with inadequate or poor water supply, extensive ponds may be abandoned rather quickly, as has happened in parts of Vietnam. On the other hand, some well-managed intensive ponds have been in operation for many years and are likely to continue for many more. Critical factors are soil and water quality, and the balance between husbandry, management skills, and the level of intensity. Markets also play a role and may interact with other factors. For example, production is likely to cease if disease is widespread and prices are relatively low.

Many areas chosen for shrimp farms are simply not well suited for this activity. A classic example of improper groundwork in site selection occurred in Malaysia in the early 1980s, when a large commercial investor (one of the old plantation companies) selected a site for shrimp farming without undertaking a proper examination of soil and water quality. The venture was a failure, and the corporation left the shrimp farming business altogether.

Mitigation and restoration

In practice, most shrimp farm sites are chosen on the basis of availability rather than suitability, and government intervention in the form of land use policy and planning may therefore be required to address this issue. Similarly, matching skills with local circumstances and production intensity will require government support in the form of training and information dissemination. The dangers of allowing this function to be undertaken by the private sector (input suppliers) have already been noted.

If ponds are nonetheless abandoned, the question arises of whether to restore to natural habitat or convert to alternative productive use. Rehabilitation of mangrove areas that have been cleared for shrimp farming has been undertaken in some areas. This process is neither difficult nor costly (Mackintosh 1996) so long as an appropriate tidal/hydraulic regime can be re-created. However, that step is not always easy, especially if development activities have occurred, including canal and road construction and other infrastructure activities. At a minimum, however, effective breaching of dikes is required (Stevenson 1997; Stevenson, Lewis, & Burbridge, in press). Where natural mangrove is sparse, there may also be a shortage of mangrove propagules, in which case nursery production will increase overall costs.

Conversion of such areas to alternative productive use is more difficult, since mangrove soils are commonly unsuitable for agricultural purposes.

Where ponds have been developed on land previously used for rice, rubber, coconut, or similar crops, restoration may be more difficult, depending on the extent to which the hydraulic regime has been disrupted and soils salinized.

The use of fishmeal in shrimp feeds

Compound shrimp and finfish feed typically contain a significant proportion of fishmeal and fish oil, which contribute to a high nutrition diet. There is a concern that aquaculture will put significant demands on the supply of fishmeal in the future (Tacon 1996) and that this will increase pressure on capture fishery resources, leading to depletion. Furthermore, it has been argued that the conversion of one form of fish into another is necessarily inefficient and wasteful. Shrimp farming is therefore bad for the environment and questionable for food security (Naylor et al. 1998).

There is little doubt that dependence on fishmeal poses a long-term financial risk to shrimp farming and the culture of other species (including intensive livestock production of all kinds) that require high-quality protein feeds. It is also the case that many fisheries, including some of those for “trash” fish, are not being managed sustainably, and that a truly environmentally responsible industry will seek to minimize its use of inputs from unsustainable sources.

However, the issue is extremely complex. The argument that aquaculture will be responsible for the demise of these fisheries, or that aquaculture actually decreases food security, is questionable. Aquaculture represents only one of many sources of demand for industrial fish and fish products, and whatever course aquaculture takes in the future, it is likely that the demand for fishmeal and fish oils will remain strong. In any case, fishmeal and fish oil are produced mainly from species that are not suitable for human consumption or for which there is limited demand, or from waste products from fish processing for human consumption (Pike 1998).

Only where locally sourced "trash" fish is used for aquaculture, in areas where a poor population relies on such fish as a source of cheap high-quality nutrition (such as Vietnam), may the use of fishmeal lead to a reduction in food security or availability to poor people. Ironically, in these places, using fishmeal imported from developed countries such as Scandinavian nations, Japan, and Chile rather than locally sourced fishmeal for aquaculture is the best way to maintain food security, maximize cheap food availability for the poor, and minimize pressure on local fish stocks in developing countries. Much fishmeal is produced in Ecuador, Peru, and Chile because of the abundance of coastal anchoveta in the southern/central eastern Pacific Ocean. However, much of the high-quality fishmeal used in aquaculture comes from Northern European countries.

The argument that the conversion of fish from one form into another is fundamentally wasteful is also open to question. The logic of this argument implies that to eat anything other than primary production is wasteful. Is there any fundamental difference between eating wild or farmed carnivorous fish in this respect? In practice, the basis of much economic activity is the conversion of low-value materials into higher-value materials—with, ideally, a recycling of waste back into primary production.

Notwithstanding these points, it is in the industry's interest to seek cheaper alternatives from more sustainable sources. Although there is no clear consensus on how much fishmeal can be substituted with other protein sources from a technical or nutritional point of view, there is little doubt that it can be reduced substantially. As the price of fishmeal and oils rises, the incentive to replace them will increase rapidly. Ultimately, it may be fish oils that are limiting, but progress in biotechnology may provide solutions in this area (Tacon 1994; Wijkström & New 1989).

It can also be argued that fishmeal may not become a limiting factor, at least for some time. Today, a vast resource of unused marine biomass is discarded at sea, thrown away as offal, or wasted in other ways. This biomass has been estimated by the FAO to constitute some 25 to 30 million MT per year (FAO 1997). Much of this waste could be converted into fishmeal, if it were technically and economically feasible. Also, alternatives to fishmeal as a protein source should be researched for shrimp diets, such as single-cell proteins. In China, fishmeal used in the feed formulated for freshwater fish has been greatly reduced, much of it replaced with yeast. There is great scope for research in all of these areas.

Conclusions and recommendations

Like most human activity, shrimp farming has created many different environmental impacts. The severity and significance of these impacts is extremely variable both within and between countries, depending on factors as diverse as hydrology, management practices, and the nature of the local economy. In general, these impacts are similar to those caused by agriculture; they are mainly related to habitat conversion (more serious with extensive shrimp farming); increased nutrient loads added to the environment (usually more severe in the case of intensive farming); and use of chemicals to combat disease (generally used more in intensive systems). Particular attention has been drawn to the environmental impacts of aquaculture because its financial attractiveness has encouraged extremely rapid, and in most cases unplanned and unregulated, development; and because it has been developed (and was originally widely promoted) in mangrove and estuarine systems, which are already under severe development pressure.

The environmental impacts of shrimp culture can be greatly reduced through a range of practical measures, as discussed in this chapter. Some of these are relatively simple to implement, while others are much more difficult. It is likely that rather few will be adopted without significant government intervention and/or market incentives, discussed further in Chapter 7.

The various measures for reducing environmental impacts may be classified as follows:

- Site selection;
- Scale and extent;
- Design;
- Technology and research;

- Farm-level management; and
- Industry-level management.

Recommendations for each of these are summarized on the following pages.

Site selection

Site selection is of great importance, not only for ensuring appropriate soil and water regimes for the farm, but also because of broader issues such as the proximity of other farms and the carrying capacity of the environment. If carrying capacity is exceeded and water quality and ecological degradation ensue, this will affect both shrimp farmers and other users.

Appropriate siting of shrimp farming can help:

- Minimize critical natural habitat destruction;
- Minimize destruction of, or adverse effects on, otherwise productive land;
- Minimize the impacts of shrimp farm effluents (for example, by siting adjacent to areas with high assimilative capacity—such as mangrove or well-flushed coastline);
- Minimize the spread of disease (by maintaining adequate separation between farms and adequate separation between influent and effluent waters);
- Prevent saline contamination of groundwater, agricultural land, and freshwater irrigation systems—which can result from withdrawal, discharge, or seepage; and
- Maximize the productivity of shrimp farming itself (by siting on suitable soils and in locations with access to high-quality water supply).

While rational site selection may be possible—and is indeed an essential part of project planning and feasibility studies for large shrimp farming projects—smaller and poor farmers generally choose sites on the basis of availability rather than suitability. Some form of government intervention may therefore be required to restrain development in unsuitable areas and/or to facilitate development in suitable areas. If the issues discussed above are to be fully addressed, this will require a comprehensive assessment of natural resources and land use potential, leading to land use planning policies, possibly incorporating zoning, and implemented through a set of powerful incentives and constraints.

Extent of shrimp farming

Impacts on the natural environment may be reduced by limiting the area that shrimp farming can occupy. If the objective is to maximize production with minimal habitat destruction or land use conversion, then the intensification of existing farms rather than the development of new farms may be an appropriate strategy (Hambrey 1996b; Menasveta 1997), if the other potential problems associated with more intensive systems can be addressed. Where shrimp production is seasonal, total production per unit area may be increased by growing an alternative crop in the less suitable season (e.g., rice, finfish, *Macrobrachium*, *Artemia*, or salt depending on local circumstances).

Design

Good design of shrimp ponds—in particular, design of water supply and discharge systems—can have a major impact on sustainability. Good design can:

- Ensure high-quality water supply and optimal pond water conditions;
- Reduce the likelihood of disease and the use of undesirable chemicals;
- Minimize effluent quantity and/or maximize effluent quality; and
- Prevent salinization of adjacent agricultural lands, groundwater, or freshwater irrigation systems.

Principles of pond design can be found in many standard texts (Fast & Lester 1992). However, to minimize the environmental impact of semi-intensive and intensive shrimp farming, the following principles should be adhered to wherever feasible:

- Settling ponds suitable for both routine and harvest effluents should be constructed;
- Reservoirs for water storage and treatment should be included; and

- Supply and effluent canals should be isolated as far as possible from each other, and from other farms.

In practice, the last of these will be difficult to achieve in the absence of a broader planning framework, including water supply/disposal infrastructure.

In all cases of new farm construction or existing farm rehabilitation, farms should be designed and engineered to allow other economic activities to surface should there be shrimp crop failures, as has happened over the last decade or more in all of the major shrimp-producing countries. This is a particularly important issue in poor coastal communities, whose residents derive their livelihoods from coastal aquaculture. If an operation fails, a plan and the infrastructure should exist for the culture of other species, which often will usually have a much lower market price. If this is not possible, a "fallow" period may be planned to allow recovery of soil quality and decline of disease organisms, as is commonly practiced in agriculture. Thus, investment in the farm should be based on the assumption that culture of lower-value species, or a fallow period, would follow failed shrimp culture, and that even with repayment of the amortized investment, the profitability of the farm would remain sufficiently high to justify continued operation. Sustainable seed supply and nutritional needs should be considered in the selection of alternate species so as to reduce their overall impacts.

Technology and research

Improved technology should allow for significant reductions in the environmental impact of shrimp farming. In particular:

- Increased supply of seed from hatcheries and breeding of pond-reared shrimp should reduce the potential risk of depleting wild stocks and allow for greater control of disease;
- Breeding may also produce disease-resistant strains;
- Adoption of semiclosed, closed, and recycled systems should reduce environmental impacts—if well designed and managed;
- New technologies for water treatment and management should improve pond water and effluent quality;
- Lining of ponds or dikes may reduce seepage and, in some cases, saline contamination;
- Techniques for identifying disease in broodstock and seed, and for the early identification of disease in ponds, should reduce disease incidence and allow for more effective treatments;
- Development and adoption of low-fishmeal diets should protect shrimp farmers from the likely rise in prices of fishmeal in the future, as well as reducing pressure from aquaculture on these prices; and
- Development of higher-quality, low-pollution diets will reduce feed-associated wastes in pond water and thus improve effluent quality.

Promoting these developments in technology will require collaboration between government, shrimp farmers, and feed manufacturers. Some changes in technology may be advanced through a set of incentives and constraints, which might include regulation, taxation, grants, and marketing schemes. These are discussed further in Chapter 6.

Management

Poor management is a major contributing factor to the environmental effects of shrimp farming. Relatively simple changes in management practices can lead to significant reductions in environmental impact:

- Careful management of soil, in particular soil acidity, through appropriate treatment including regular flushing, liming, or lining with laterite soils, may improve pond water quality and reduce shrimp stress and disease;
- Treatment of influent water supply (for example with chlorine) to eliminate pathogens and carriers may reduce disease incidence and associated use of chemicals;
- Skilled assessment of seed health prior to purchase should reduce disease risks;
- Modest stocking rates—combined with knowledge, skills, and technology—should reduce the risk and severity of losses from disease;

- Reductions in water exchange coupled with increased aeration and careful pond water management can reduce the quantity of routine effluents, and may reduce the rate of disease spread;
- Intensive aeration may itself serve as a form of water treatment;
- Careful management of water at the time of harvest, and effective use of settling ponds, can greatly reduce nutrient and organic matter loadings on the environment;
- Careful disposal of pond sediments (rather than simple flushing) to allow for oxidation and decomposition will greatly reduce the nutrient and organic matter loading to the environment;
- Providing the right amount of high-quality food at the right time throughout the production cycle can greatly reduce feed and metabolic wastes;
- High-quality husbandry, knowledge and skills in identifying and treating disease will greatly reduce the incidence of disease and the associated use of chemicals; and
- Observance of an adequate withdrawal period when chemicals and therapeutants have to be used, to clear the shrimp of residues, will improve their marketability and raise their market value.

Implementation

The implementation of these varied approaches to reducing environmental impact and promoting sustainability will depend upon managers and staff having adequate skills and access to information, and in many cases some form of government—or market-initiated incentives or constraints. Furthermore, some of the mitigation measures (for example, restrictions on siting, provision of infrastructure, or development of disease prevention and management strategies) will require direct government intervention. The key roles for central and local government in facilitating, promoting, and in some cases directly implementing these mitigation measures is discussed in Chapter 6.

Further discussion and detailed guidelines for measures to reduce the environmental impact of shrimp farming can be found in several recent publications (Barg 1992; SEACAM 1999; Hambrey 1996c; Pillay 1997; Clay 1996; Global Aquaculture Alliance 1998; GESAMP 1999; Institute of Aquaculture 1996).

CHAPTER 4: SOCIAL AND ECONOMIC IMPACTS OF SHRIMP FARMING

This chapter reviews the main reported negative impacts of shrimp aquaculture and considers ways to reduce or overcome such effects, as well as to spread the benefits of shrimp aquaculture more widely. Many of the social impacts follow directly from environmental impacts discussed in the previous chapter, and possible mitigation measures are therefore often the same.

Although less thoroughly researched than environmental impacts, discussion and analysis of social and economic impacts can be found in a range of recent publications (Bailey 1988; Bailey 1992; Bailey & Skladany 1991; Primavera 1994; Funge-Smith & Stewart 1996; Clay 1996; Asian Institute of Technology 1996; Adger, Kelly, Ninh & Thanh 1998; Gilbert & Janssen 1997; Holland 1998). Many of these articles, and others in publications read more by the general public, have focused on negative impacts. Only the studies by Clay (1996) and Kelly, Ninh & Thanh (1998) have attempted to present the overall balance of costs and benefits to specific areas or communities. More balanced and thorough assessments in a range of different circumstances are required if the true picture is to emerge.

Shrimp aquaculture is undertaken in coastal areas that are used for a variety of other activities, such as fishing, hunting, agriculture, salt making, and wood and charcoal production. The impacts of shrimp farming are therefore felt not only by those who are directly involved in it but also by others who live and work in the area. Several social, economic, and secondary environmental impacts are associated with shrimp farm development and deserve consideration (see Table 7).

Negative social and economic impacts may include:

- Impacts on fisheries;
- Competition for resource rights and equity issues;
- Impact on agricultural production;
- Employment;
- Redistribution of wealth;
- Displacement of local populations;
- Human rights violations;
- Social disturbances;
- Corruption; and
- Public income expenditures.

Shrimp aquaculture is becoming big business in some countries, with large corporations involved in the investment in, development of, and operations of the shrimp farms. In such circumstances a relatively small part of the benefits of shrimp farming are shared by the local population, while a number of problems arising from shrimp farming may affect them. Those who are directly involved as employees of large corporations may be said to benefit directly from the venture, and others may also benefit indirectly through trade, secondary employment, and the growth of associated service industries. However, others may be negatively affected by the degradation of the environment, the erosion of common resource rights, and the like.

In large parts of Thailand and Vietnam, on the other hand, shrimp farming is dominated by small-scale family enterprises (Lin 1995; Hambrey & Lin 1996), and there is no obvious trend toward larger-scale enterprises yet. With small-scale farms, a more significant proportion of benefits accrue to local communities (Asian Institute of Technology 1996) so long as farming can be sustained over a reasonable period. Much more research is required in different parts of the world to document and assess the distribution of positive and negative social and economic impacts of shrimp farming.

TABLE 7. SOCIAL AND ECONOMIC IMPACTS OF SHRIMP POND CONSTRUCTION AND PRODUCTION

Action	Impacts	Results
Shrimp products are exported	Most benefits do not accrue locally	No improvement in local diet, perhaps net protein loss "Flight" of mariculture protein and earnings to foreign banks Local communities do not develop employment or improve infrastructure
Coastal wetlands are declared "national patrimonies"	Claims outstrip government's capacity to manage resources or even ensure that claims are honored	Widespread encroachment on public-sector property leads to displacement of artisanal fishermen and others dependent on fisheries resources, and land use conflicts ensue
Excessive collection of post-larvae and egg-laden female shrimp	Declining shrimp population along coastline	Loss of income for fishermen
	By-catch is reduced (Example: estimated that 10 kg of finfish and shrimp larvae are killed for every 1 kg of *Penaeus monodon* post-larvae captured)	Reduction of natural shrimp and fish stocks, massive loss of recruitment stocks
Clearing mangroves	Loss of natural mangrove products (fuel wood, poles, fish and game, etc.)	Loss of income and subsistence products for local population
	Destruction of shrimp and fish nursery grounds	Lower productivity, lack of seed stock
Construction of shrimp ponds in former mangrove areas	Displacement of rural coastal communities	Loss of income for those who traditionally depend on mangrove resources

Source: Clay 1996.

Impacts on fisheries

In many areas where shrimp farms have been constructed, this new activity has created new markets and opportunities for the local population. However, these new opportunities may be associated with threats to existing activities, especially traditional fishing.

Although hatchery seed supply is the norm in Southeast Asia and use of hatcheries is increasing generally, the majority of shrimp farms in the Americas, Bangladesh, and to a lesser extent India, still depend on wild-caught post-larvae (PL) for stocking the ponds. Local fishermen capture wild PL in nursery grounds and sell them to shrimp farmers. Some shrimp farmers prefer wild-caught PL because they believe that they are more resistant to disease, and in general more robust than artificially produced PL (Clay 1996).

Special-interest groups have claimed that excessive collection of wild PL can endanger wild shrimp reproduction and lead to a decline in the wild stocks and their associated capture fisheries. The very local fishermen who collect wild PL are among those most likely to suffer from such a development. However, scientific evidence of this effect has been not been found, and it appears that little has been done to document these allegations.

Nevertheless, if statistically valid evidence is documented showing that shrimp seed collectors are having an adverse impact on biodiversity and fisheries productivity, constraining this activity would have major social implications. For example, in Bangladesh, it is estimated that about 300,000 people derive a significant part of their annual incomes from shrimp seed collection. Alternative employment opportunities would need to be identified for these people—in an area where extreme population pressure upon natural resources already exists.

Shrimp farming may also result in direct conversion of nurseries for commercially valuable inshore and offshore capture fisheries. Estuarine systems including mangrove are often important nursery grounds for commercially valuable fish and crustacean species, including shrimp (Robertson & Duke 1987; Baran & Hambrey 1998). Construction of shrimp ponds may disrupt these nurseries. In the case of widespread extensive farming, this problem may be compounded by intentional entrapment of juvenile shrimp and other crustacean and finfish species in traditional ponds. In practice, rather little is known about the microhabitat requirements of the juvenile stages of commercially important crustaceans and finfish, and in particular the extent to which they move into, or depend on, extensive upper tidal mangrove forest. A recent study in the Philippines (Gilbert & Janssen 1997) showed that a mangrove forest reserve supported a small on-site fishery but contributed minimally to off-site fisheries. The value of particular estuarine systems and associated mangrove in supporting marine nurseries varies widely; effective valuation and (where appropriate) developing protection schemes will require local studies.

Mitigation of harm to fisheries

Primary fishery nursery areas must be identified and conserved. This is a standard fishery management tool but has been little used to date in tropical developing countries. Identification and location of the more important of these areas should be possible using local knowledge, at least for the more valuable and abundant species. More detailed ecological surveys will be needed in the longer term to ensure overall habitat conservation to maximize fisheries yield. Clearly, there is a need for strong incentives and constraints to protect such areas, recalling the value of effective land/resource use planning, and ideally integrated coastal management.

Competition for resource rights and equity issues

Resource ownership or use-rights for land, water, fisheries, forests, and intertidal areas (including mangroves) are notoriously ambiguous in the coastal zone. Many areas have had traditional use rights or common access, and these are now under pressure from a variety of development interests. Other areas are classified as government land but with little legal clarity on use rights.

Privatization or appropriation of common resources

In many cases, shrimp farming has been able to develop in mangrove and other coastal areas when a government issues permits, rights, or ownership to individual farmers or entrepreneurs. In other cases, previously common access land has simply been appropriated and developed illegally by farmers and small-scale entrepreneurs. In either case, the extent of common access resources has been reduced, often to the detriment of the poorest sectors of society. Displaced and poor migrant people are frequently marginalized in coastal lands, and depend at least in part on these common resources. The loss of common resources has sometimes led to increased pressure on, and degradation of, remaining common access resources (Adger, Kelly, Ninh & Thanh 1998). Remaining resources may also be affected by the externalities of shrimp farming, in particular the disruption of hydrological regimes and salinization.

Loss of land security

Where ownership rights are more clearly established, land value often rises in areas suitable for shrimp farming. Such market change may encourage poorer farmers, or in some cases indebted shrimp farmers, to sell their land. While this may bring short-term benefits and financial relief in the absence of alternative employment opportunities, it may ultimately lead to increased poverty and inequity.

In a number of countries, conflicts have arisen over the use of land and coastal areas by different industries and activities. For example, there are conflicting interests between agriculture and aquaculture in regions of India (Murthy 1997; Patil 1998), and tourism is in conflict with finfish aquaculture in parts of Malaysia (Ferdouse 1997). However, no documented examples of conflicts between shrimp farming and tourism interests were found during preparation of this study.

Loss of access to resources

There have been reports, in particular from India and Bangladesh (Murthy 1997; Bashirullah et al. 1989), of loss of access to beaches or creeks for local farmers and fishermen. This was a significant factor contributing to the Supreme Court's ban on shrimp farming in India.

Mitigation of resource rights issues

Although such conflicts can rarely be solved to everyone's satisfaction, it is now widely agreed that effective land/resource use planning, and ideally integrated coastal management, are the best ways to tackle these issues.

It may also be possible to utilize a single area for two or more purposes, growing two products together or changing production with the seasons. For example, in Asia, the production of rice and fish in the same fields has been practiced, using special deep-water rice species (Choudhury 1995). Shrimp are also grown with rice in some parts of Vietnam that have slightly brackish waters (Lin 1998). Growing agricultural produce (such as rice) during one season and raising shrimp during another season can also be done under some hydrological and salinity regimes. The combination of shrimp farming and salt production has also been practiced in some areas.

Impact on agricultural production

The possible effects of shrimp farming on land and water quality has already been dealt with in Chapter 3. Conflicts may relate to competition for water (Clay 1996), or salinization of water. Conflicts arising from saline discharge into irrigation canals have been reported in Thailand (ADB/NACA 1995). Although contamination with chemicals is also possible, there are no substantiated reports.

The actual impact on agricultural production has been studied little, although there is some preliminary data from the Mekong Delta in Vietnam (Bhe 1998), and there is also some evidence from Thailand (Flaherty & Vandergeest 1988; Ponza 1999). The impact is likely to be extremely variable, depending on soils, hydrology, design of water supply/effluent channels, water management practices, and the type of agriculture.

Mitigation of impacts on agriculture

In recent years, trends in shrimp farming have favored semi-closed systems with intensive aeration and minimal water exchange, or recirculation of water in intensive systems, particularly in some countries, such as Thailand and Taiwan, Republic of China. Boyd (1997) claims that the problem of using large quantities of fresh water in shrimp aquaculture is being reduced over time.

The issue of saline contamination of soils or water has been discussed in the previous chapter. Three approaches are possible: technical solutions to minimize seepage or disposal of saline or otherwise contaminated water; management solutions to minimize seepage and effluents; and resource/land use planning (ideally as part of integrated coastal management) to separate shrimp farming from other activities, possibly in "aquaculture zones."

Employment

One of the reasons given by governments for promoting shrimp farming is that it creates jobs. It is difficult to estimate how many people are directly employed in the practice of shrimp farming, but the total is estimated at over one million, and people employed in related activities are several times that figure. In Thailand alone, direct employment by aquaculture has been estimated at more than 80,000 (ADB/NACA 1995). If processing, packaging, and distribution is done in the area, the need for employees rises considerably.

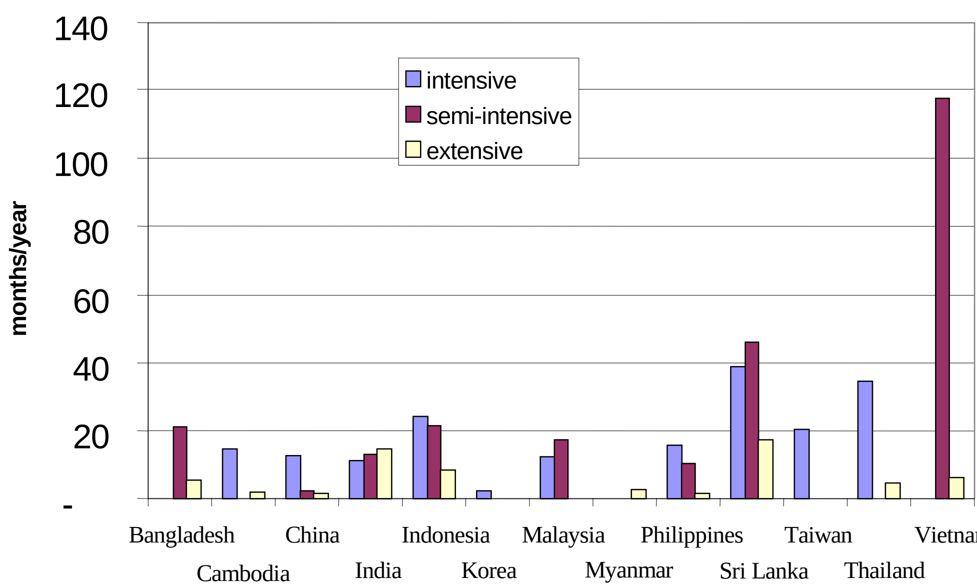
Some critics have suggested that shrimp farm operations require far fewer workers than, for example, rice farming, which in some instances is an alternative to shrimp farming. According to one report (Bundell & Maybin 1996), rice farming requires ten times as many workers as shrimp farming. Another study, from Indonesia, reported that rice production employed people for an average of 76 workdays per hectare per crop cycle. In the same area, a semi-intensive shrimp farm employed about

26 workdays per hectare, and an extensive shrimp farm about 45 workdays per hectare per cycle (Clay 1996).

These findings conflict with other reports on Asia, which show that in general, semi-intensive and intensive shrimp farming require more labor per unit area of land than competing activities, including rice farming. Furthermore, it generates far higher wages for labor (Hambrey 1993; Hambrey 1996a). Funge-Smith & Stewart (1996) report labor requirements in southern Thailand of between 2.5 and 4 persons per hectare. NACA undertook a comprehensive ADB-funded survey of shrimp farming in Asia in 1994; the survey included 869 intensive farms, 1,017 semi-intensive farms, and 2,944 extensive farms across 13 countries in South and Southeast Asia and China (ADB/NACA 1995). Labor use across types of farms (extensive, semi-intensive, and intensive) was highly variable in this report, probably reflecting the inconsistent use and recording of family labor. Total labor use on intensive farms ranged from 2.3 person months/ha/yr (Korea), to 39 (Sri Lanka), with an average of 19 (Figure 9). For semi-intensive farms the figures ranged from 2.4 in China to 117 in Vietnam, with an average of 31. Extensive farms used between 1.5 person months/ha/year (Philippines) and 17.1 (Sri Lanka) with an average of 6.4. These figures are based on labor *use* rather than labor *requirements* and are probably rather high, reflecting the inefficient use (or inaccurate recording) of family labor, and the very small size (and therefore low labor productivity) of many of the enterprises in Asia.

Figure 9. Labor use on shrimp farms in Asia

(data from NACA 1995)



Source: NACA 1995.

Experience from large numbers of intensive shrimp farms in Thailand, Indonesia, and Vietnam suggests that intensive farms (of more than 1 ha) generally require between 6 and 18 person months total labor per hectare per year. Smaller farms may require higher rates. Whatever figure is actually used, semi-intensive and intensive shrimp farming may require at least as much labor as rice farming (which typically requires 6-12 months/ha) or other feasible alternatives on poor, usually brackish coastal soils. All forms of shrimp culture also require significant labor during construction.

Figure 9 also shows that more intensive farming requires more labor than extensive farming, although India provides an exception to this general rule. This reflects the need to feed the shrimp often, as well as careful water quality management and other husbandry practices required on intensive farms. Harvesting and pond preparation in more intensive ponds is also a labor-intensive activity. Extensive shrimp farming, on the other hand, is largely passive, with labor required merely to control water exchange and entry of seed at appropriate stages of the tide, with only occasional feeding. Harvesting is typically done by capture in traps.

Redistribution of wealth

Power relationships and social change

As has been seen in many areas of the world, the social structure of a local community may change when aquaculture is developed. Many poor farmers have become rich, large fortunes have been made in some cases, and political and financial relationships and relative power have shifted. Such developments are not necessarily harmful or unnatural; they have occurred in all societies through history. However, if such changes are very rapid and substantial, the local community may have difficulty in adapting, and, in extreme cases, social disorder may result. Disorder is most likely to take place when land becomes concentrated in a few hands, especially if these landowners are non-local speculators.

Since local elites generally have more influence and greater access to credit, subsidies, and permits, they are better able to take advantage of new opportunities than poorer sectors of society, and to further consolidate their positions of power and wealth. Thus, the gap between the elite and the general population tends to widen rather than narrow (Adger, Kelly, Ninh & Thanh 1998). Whether or not this is a necessary or acceptable stage in the development process is a matter of debate, but it should certainly be addressed as a policy issue by those who promote shrimp aquaculture.

A takeover by large companies of extensive tracts of land for shrimp farm development may have a severe negative effect on the local community. If smallholders fail in their efforts at shrimp farming, they tend to change their land use to other activities. If, on the other hand, a corporate-owned shrimp development fails, after having bought up the land from smallholders, the area may be abandoned and all economic activities discontinued, and the people who formerly owned the land have neither employment nor the right to use the land. In these cases, the negative impacts on the local community may be devastating and permanent.

Scale, intensity and suitability of shrimp culture for poverty elimination

Modern shrimp farming is often incorrectly characterized as the domain of large corporations. On a global scale, and especially in Southeast Asia, small-scale shrimp farmers are the dominant sector of the industry, in terms of numbers and production. However, more intensive forms of shrimp farming are often not easily accessible to the poor, who may also be at a disadvantage in product quality and marketing.

To date, national governments, sometimes supported by bilateral development agencies, have often been oriented towards large-scale shrimp aquaculture, while international aid agencies and financing institutions have tended to support smaller-scale projects. A number of attempts have been made to establish shrimp farming ventures that have as their main objective improving the lives of the poor coastal population. The most common approach in the past has been cooperative farming, in which the activity is undertaken as a community cooperative.

During the first few years of such cooperative shrimp farming, which was characterized by extensive or semi-intensive methods, results were generally good. However, as more intensive methods of farming were adopted, problems arose, and in some cases there was complete failure. Failure was mainly caused by lack of proper training, particularly in preventing and controlling disease outbreaks, which are most likely in intensive shrimp farming. Intensive shrimp farming is a high-risk, high-reward activity that requires significant investment as well as access to credit during the first period of operation.

But even in areas where cooperative semi-intensive and intensive farming have failed, small-scale shrimp farming has sometimes survived, using mostly extensive and semi-extensive methods. Extensive and semi-intensive small-scale farming does not require as much capital as intensive shrimp farming, but neither does it generate the large rewards associated with intensive shrimp farming.

One of the key elements for success in cooperative semi-intensive or intensive shrimp farming seems to be access to credit. However, the danger with making credit available to people who have little experience in managing credit is that they can easily fall into the trap of spending available money during grace periods and thus failing to meet payment deadlines. Also, the risk, particularly of a first crop loss, can place the poor and small-scale shrimp farmer in a precarious debt situation from which he/she may find it difficult if not impossible to recover. Risk issues are discussed further in Chapter 5.

In addition to access to credit, training and extension expertise are important factors for the poor small-scale farmers. Extension work can be set up in the community, with experts looking after a moderately large number of small-scale operations and helping the farmers adjust their operations to various conditions.

Mitigation of lack of credit access

The lack of credit availability to the poorer sectors of society in developing countries is a major constraint to their becoming shrimp farmers (Holland 1998). However, easy credit may encourage both unsustainable practices and indebtedness, so credit should not be extended lightly. There are examples from Thailand of easy credit availability to promote small-scale shrimp aquaculture in the early ’90s that resulted in extremely rapid intensification, and in some cases environmental degradation, disease, financial collapse, and indebtedness.

As with other incentives, credit should not be used in isolation but rather as one element in a suite of incentives and constraints designed to ensure the sustainability of the sector in a particular area or region. Conditionalities related to credit (in terms of farm operation or intensity) will be hard to enforce, and it will generally be more appropriate to strictly limit the amount available, and relate it to the scale of enterprise and skill of the farmer. Such practices should help ensure that intensification is not overly rapid, and that skills can develop steadily as the use of inputs and production levels increase. Very small amounts of credit, coupled with effective extension-based support and infrastructure, can lead to highly significant increases in income for shrimp growers as well as their employees.

Displacement of local populations

Displacement of local populations as a result of some of the impacts described above has been reported, but there are few well-documented and thoroughly researched examples. In many cases, it is unclear whether shrimp farming was the major factor, a contributory factor, or merely incidental to communities’ displacement. However, these are serious issues and deserve further research.

Human rights violations

There have been reports of human rights violations in connection with the development of shrimp farms. Such cases are usually associated with large corporations that invest in a local area and resort to physical force to intimidate protesters. In the course of this study, no conclusive evidence of human rights violations was found. Secondary information is commonly reported and presented as “evidence,” without any attempt to obtain a firsthand, objective description of the situation. Once again, these issues are serious and warrant objective study.

Social disturbances

Disruption to local livelihoods and communities has sometimes been sufficient to provoke social disquiet, and in some cases serious social disturbances, e.g., in Bangladesh, India (Murthy 1997), and other countries. The 1994 NACA survey reported wide variations in Asia, with rather few (<10%) farms reporting conflict in most countries, but with significant incidence in India (29%) and very high levels in China (94%). The reasons behind these conflicts, and the differences among countries and locations, warrant further investigation.

Although insufficiently documented, the case history presented by Bundell & Maybin (1996), supported by reports from other sources, highlights an extreme impact stemming from large-scale shrimp aquaculture. Large areas in the states of West Bengal, Tamil Nadu, and Andhra Pradesh in India were developed for shrimp aquaculture in the 1990s. These projects appear to have come into conflict with other economic activities to the extent that social unrest erupted in the region in 1996 (Khor 1997).

It is clear that there have been social conflicts, and in some cases more widespread social disturbances, associated with shrimp farming, but there is very little well-documented information about these issues, the real nature of the conflicts, and the role that shrimp farming has played in them.

Corruption

In many developing countries with areas suitable for shrimp farming, corruption among the central and/or local authorities has become a problem. Corruption occurs in several ways. First, officials in charge of giving permits may be "bought" (persuaded by bribes) to ignore rules and regulations, or to misinterpret these rules in favor of a certain party. In other cases, law enforcers may be paid to ignore nonadherence to environmental requirements. It has also been claimed that illicit funds, for example from narcotics trading, have been laundered by being channeled into shrimp farming. One reason for the prevalence of these practices may be that officials with responsibility for the distribution of shrimp farming permits and other rights are often underpaid, in some cases grossly so.

Though corruption has been noted in shrimp farming, such problems are by no means unique to the shrimp farming industry. Rather than ignoring the possibility of corruption, it should be taken into account when designing the regulatory system that is to govern shrimp farming. Rules must be made so simple and clear that they leave little or no room for individual interpretation or discretion by the official.

Public income and public spending

The foreign currency earnings from shrimp aquaculture make it extremely attractive to national authorities in developing countries. Several major shrimp farming countries have significantly increased their export earnings as a result of shrimp farm development. Cases in point are Ecuador, Indonesia, Thailand, China, and Vietnam.

Local and national incomes derived from shrimp farming operations may also be considerable. Taxation of such enterprises and their employees is usually a relatively straightforward matter. However, in many developing countries, governments have given companies a tax moratorium for the first few years (for example, up to 10 years in Thailand) in order to make the investment attractive. In some cases, this has meant that by the time the operation was liable for the usual taxes, it may already have been discontinued due to disease and reduced profitability. In these cases, public income from shrimp farming may be negative, if significant public works have been undertaken to support the activity.

Public works expenditures may include a number of infrastructure investments such as roads, water facilities, and electricity distribution. Sometimes, such expenditures are necessary to induce investors, and the public outlay may be considerable. Although other economic sectors may also benefit from such expenditures, the price may in some cases be too high from a national budget allocation perspective.

Conclusions

The social and economic impacts of shrimp farming have been extremely variable throughout the world, reflecting enormous social, economic, and political differences, as well as the wide range of shrimp culture technologies and the variety of habitats or land types on which it has been developed. Very few studies that objectively balance the costs and benefits at a district, regional, or indeed national level have been conducted. A program of such studies covering a range of development and natural resource contexts is urgently needed.

However, it is clear that shrimp farming has had significant negative social impacts in some areas, and equally clear that it has brought social and economic benefits to others. If shrimp culture is to be a significant force in development and poverty alleviation in coastal areas, these benefits must be continued over time and distributed more equitably.

Minimizing negative social repercussions and maximizing the positive ones will require government intervention and political will. As with environmental impacts, the solution to these problems cannot be applied on a case-by-case basis. Rather, a planned approach to issues of resource access and degradation must be developed, involving some form of land-use planning or zoning. Issues of equity and wealth distribution can only be tackled through interventions in the form of tax policies, grant aid, credit, and other economic instruments. But any such interventions must take account of the inherent risks associated with aquaculture—risks that are greater for those with fewer financial resources, skills, and education.

There are two main components to making shrimp aquaculture more socially and economically desirable:

- Reducing the negative externalities of resource appropriation or degradation; and
- Increasing participation of the poor in shrimp farming activities, or distributing the benefits more widely, or both.

The first of these will require effective land and resource use planning. The second will require government intervention in the form of grant aid, credit, tax incentives, or some form of redistributive taxation (e.g., taxing successful shrimp farmers to generate funding for services or development initiatives for the poor). The risks associated with shrimp culture must be taken fully into account when considering promoting shrimp farm development among poorer sectors of society. Ideally, measures relating to both of these strategies should form part of a local resource management or integrated coastal management plan, although provisions regarding taxation and other economic instruments will depend critically on compatibility with national policy and legislation. Given the rate of resource degradation in coastal areas of developing countries, and the significant levels of social conflict associated with shrimp aquaculture in some countries, initiatives along these lines are urgently required. These approaches are difficult and costly but cannot be avoided if shrimp farming is to be made more sustainable. They are analyzed more fully in Chapter 6.

It is notable that neither of these issues can be addressed effectively through project-level environmental impact assessment (EIA)—whether or not social impact assessment is included—except in the case of large isolated developments. The social problems associated with shrimp culture, as with the environmental problems, are generally cumulative and incremental in nature, and therefore require a broader resource use planning approach.

Sector EIA, on the other hand, incorporating social impact assessment, may have an important role to play in developing appropriate sector or natural resource development plans, which may serve as the building blocks for broader-based integrated coastal management plans.

Summary of measures to reduce social impacts

All those measures discussed in the previous chapter, insofar as they reduce environmental impact and resource degradation, are likely to help reduce social impacts, as well. In addition, specific measures will be required to address issues of resource appropriation, income distribution, and equity. These are political issues and will require political will and political solutions at the national and local levels. However, the following specific measures may be appropriate, depending on local circumstances:

1. Sector EIA incorporating comprehensive and cumulative social impact assessments as well as participatory approaches to problem identification and solution;
2. An aquaculture development plan, preferably developed as part of a wider natural resource or integrated coastal management plan, drawing on the findings of the sector EIA. In addition to those provisions discussed in the previous chapter, this plan should include:
   - Social and economic objectives of aquaculture development;
   - Measures to protect the interests and rights of existing resource users;
   - Measures for facilitating access of relatively poor local people to shrimp farming on suitable sites (conditional on the measures presented in the previous chapters for ensuring more sustainable production). Depending on local circumstances, these might include:
     - Preferential access to licenses, permits, use-rights, or ownership for local people;
     - Modest grants and limited credit for farm development and initial operations;
     - Tax exemptions or “holidays” during start-up;

    - Training and agricultural extension support;
    - Infrastructure (e.g., canals, water treatment, marketing/supply services); and
    - Assistance in the establishment and organization of farmer representative groups;
- Provisions for monitoring and analyzing social and economic impact, to inform policy formulation; and
- Provisions for adapting the plan and associated incentives and constraints in the light of findings of the monitoring program;
- Project or program EIA for major shrimp farming initiatives, incorporating comprehensive social impact assessment and participatory approaches to problem identification and solution;
- A suite of incentives and constraints, appropriate to local circumstances, drawn up to support plan implementation.

CHAPTER 5: FINANCIAL RISKS ASSOCIATED WITH SHRIMP FARMING

As for any agriculture and mariculture activity, there are significant financial risks associated with shrimp production. These risks fall under four main categories (Hempel 1993):

- Input factors (price of PL, water quality, availability of broodstock, credit, etc.);
- Output factors (shrimp price, future supply to the market, etc.);
- Design factors (site selection, etc.); and
- Factors based in nature (naturally occurring risks, such as shrimp disease, typhoons, floods, etc.).

Most analysts will agree that shrimp disease, discussed in detail in Chapter 4, is the single most important risk factor. We will focus in this chapter on the financial risks to both the farmer and the investor.

In general, financial risks increase with increasing intensity. In more intensive systems, the probability of loss, and cost of such losses if they do occur, are likely to be higher. Although average returns may be higher, they are subject to larger fluctuations in response to factor prices, market prices, and losses from disease or environmental factors. However, the relationship is neither simple nor universal. Well-planned, -designed, and -managed intensive systems may be less vulnerable to disease than poorly planned, designed, and managed extensive systems. Disease has not been limited to semi-intensive and intensive systems, for it has also become widespread in extensive systems in the Mekong and Ganges/Bramaputra deltas in recent years.

The financial risks also differ substantially with the size and organization of the farms, and the financial status of the operator. For example, a small-scale extensive shrimp farmer whose crop is wiped out by White Spot Disease Virus could lose all his/her working capital and might never restart. Such a disastrous end could have significant negative social consequences. On the other hand, the farmer might be lucky and able to change to different species, start or return to rice culture, or start extensive polyculture. For a large investor with thousands of hectares of shrimp ponds, such as those operating in Guatemala, many of the risks may lead only to a routine fluctuation in annual profits. A medium-scale intensive farm in Thailand, on the other hand, with significant permanent staff and generally high overhead costs, might be unable to weather two or more years of poor production. When the development does not give the expected return, investors can pull out. This was all too clear in the case of Taiwan, Republic of China, where investors pulled out of the industry as disease problems started to occur and losses mounted (Liao 1996). In all cases of loss, and particularly abandonment, the financial loss may have social and environmental consequences.

Financial risk can often be reduced by relatively simple actions, once the risk and its implications are well understood. Evaluating the financial risk of a shrimp farming project requires a thorough financial analysis, based on a sound grasp of technical issues and thorough knowledge of aquaculture in practice. Financial analysis should accompany the design and planning of the project from the very beginning. In a sense, it becomes the focal point of all other decisions, for all aspects of the design are related to their financial consequences. From a financial and economic point of view, investment can be defined as a long-term commitment of economic resources made with the objective of producing and obtaining future net gains exceeding the total initial investment (Behrens & Hawranek 1991). Thorough and informed financial risk assessment should prevent high-risk shrimp farming projects from being implemented, thereby avoiding abandoned shrimp ponds, social unrest, and environmental problems in the future.

Input factors

Price of raw materials

The availability of raw materials and the costs of procuring them can vary according to location and time of year. The raw material for a shrimp farming project will include items such as supply of PL, feed, labor, fuel, and transportation. The consistent provision of such inputs is crucial to the success of the project. It is also important that the supply costs used in calculations are correct, or at least that they encompass the likely range. Deviations from the costs used in these calculations may jeopardize the financial performance of the project.

Risk factors to evaluate include the competition for supplies, and what this may do to cost levels. Many authors have pointed out potential risks to the industry and the environment of dependence on fishmeal and fish oil for shrimp feed (Tacon 1994; Wijkstrom & New 1989). Marine by-products suitable for shrimp feed represent an expensive and finite commodity. The competition for fishmeal supplies comes not only from the shrimp and fish farming industries, but also from other industries, such as farm livestock production. Rising costs of fishmeal and fish oil may undermine the long-term viability of shrimp culture unless cheaper alternative protein and essential nutrient sources can be found. This is particularly the case given the long-term tendency for the price of cultured species to fall as production increases.

Quality of raw materials and water

Shrimp disease and low productivity are both influenced by a number of factors, such as feed quality, disease prevention measures, hygiene, water quality, and general management practices. The genetics of the broodstock and PL used are also important factors. In general, there is a lot to be gained in productivity by introducing breeding programs. Genetic engineering may in the future play an important role, but this is judged to be a long-term option at the present time. Selective breeding programs are far simpler to implement, and hold good potential for improvement of broodstock in the short to medium term. The feed conversion factor is used by many as a measure of productivity. Although much research has been undertaken on feed development and feeding practices, especially in relation to salmonids, carps, and tilapias, rather less research has been done in relation to shrimp, and there is ample room for improved and more efficient feeds.

Box 2: Scale, Risk Exposure, and Poverty
An example from Thailand

Different kinds of farmers operating at different scales and intensity have very different exposure to financial risk. For example, Scura et al. (1996) classified shrimp farmers in Thailand in terms of their access to credit as follows:

Corporate shrimp farms: larger shrimp farms owned and operated by commercial producers who run fairly vertically integrated operations including hatchery, feed mill, grow-out ponds, and possibly also processing plants. Because of this integrated approach, they achieve a higher stability in their operations, and their fixed and liquid assets easily give them access to credit.

Shrimp farming entrepreneurs: this category of shrimp farmer may not be integrated, but they still engage in shrimp farming as a speculative commercial venture. Their assets allow them access to credit, but they usually have less stability and are more exposed to crop failures. Usually, they operate ponds close to the corporate shrimp farms, and tend to minimize their investments and operating costs. In the event of crop failures, they usually have enough capital to carry them over to the next harvest.

Small-scale shrimp farmers with other sources of income: these farmers may be poor and have limited access to credit, but they engage in other activities which give them an alternative source of income. Furthermore, they may be able to convert their land back to other uses, such as for example salt production, if crop failures occur repeatedly.

Small-scale shrimp farmers with no alternative sources of income: this group is typically the landless farmers who were original members of the land settlement co-operatives. They have small shrimp farms in former mangrove areas, where few or no alternative uses of the land are possible. They depend on tidal water exchange, and can rarely afford to install and operate pumps to exchange the water in their ponds. They typically earn less than US$100 a month, and their access to credit is practically nil.

Credit risk

Access to credit at fair market rates is a prerequisite for a successful sustainable shrimp farming operation, as has been stressed by several authors (Cesar 1997; Zweig and Braga 1996; Holland 1998). Shrimp farmers commonly need access to credit for infrastructure and working capital during operations. This need is generally greater for small- and medium-size operations than for larger corporate enterprises, which have easier access to the credit they need.

In order to secure a financial basis for small- and medium-scale shrimp aquaculture, it is therefore necessary to ensure that credit facilities are available locally and/or nationally, and that the private investor/operator qualifies for such facilities. Credit could be channeled directly to the individual farmer or through cooperatives where the individual members share the risk. The credit system should ideally be set up in a way that helps the farmers survive at least one episode of shrimp disease, possibly through some form of insurance or joint liability system that creates a crop protection fund in which individual farmers invest. Such systems already exist in some countries.

By way of example, Box 2 presents profiles of different types of shrimp farmers in Thailand with differing exposure to risk and credit needs.

Labor

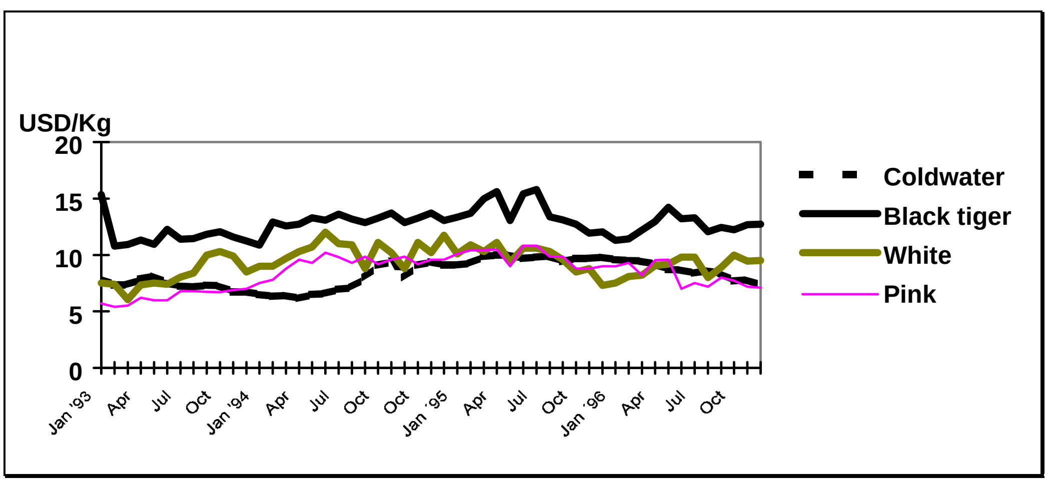
Lack of specialized know-how on the part of farm managers and workers is a major risk factor. The investor should make sure that the staff employed have solid experience in shrimp farming and proper management practices. The proper training of personnel is important and may significantly reduce the financial risk of a shrimp farming project. Management procedures should include safety margins that are realistic given past experience and industry averages, while also taking into account the degree of know-how on the part of employees and managers.

Output factors

Shrimp price

One of the most important factors influencing the economic performance of a shrimp farming project is the farm-gate price of the shrimp. Furthermore, experience shows that in many cases of farm failure, the price estimates used in feasibility studies were overly optimistic. Shrimp prices fluctuate greatly, especially in the short run. When planning shrimp farming projects, actual prices over a number of years, coupled with assessments of future supply and demand, should be used to determine the prices for the financial calculations. The lowest prices observed during the period examined could be used as the base case input, and sensitivity analysis should include at least a 30 percent drop from these prices, to be on the safe side. Figure 10 illustrates the wide range of prices over a relatively short period of time.

Fig 10: Shrimp price development



Source: Seafood International, INFOFISH Trade News, 1993–1996

Also, more recently, the Asian financial crisis resulted in a 20 percent drop in the unit prices of shrimp, from the last quarter of 1997 to last quarter 1998. However, prices have since strengthened again, mainly because of strong demand from the U.S. market. Shrimp still have high sales prices compared to most other farmed species, and the long-term outlook remains bright.

Future supply

A main factor in determining long-term supply projections for shrimp is aquaculture growth, which has certainly influenced the market in recent years (Ruckes 1994; Ferdouse & Hempel 1996). During the boom years, it was estimated that shrimp farming was responsible for a 40 percent drop in prices in 1989, when China's cultured shrimp came on the market in great quantities (Josupeit 1995). Similarly, prices collapsed as Thai shrimp flooded the market in 1991[1]. The present outlook projects that aquaculture will provide an increasing part of total world shrimp production. According to Ruckes (1994) and FAO aquaculture production statistics, aquaculture accounts for some 30 percent of total shrimp supplies, and that share is increasing. This trend is likely to continue, because several major shrimp capture fisheries are now in decline.

It is reasonable to assume, therefore, that farmed shrimp will have an increasing effect on market price. If supply cannot meet demand, price is likely to rise; if the industry suffers from over-investment and over-production, as has taken place in the salmon farming industry, price may decline significantly, leading to lower profit margins, increased efficiency, and greater rationalization of ownership and more centralized control of the industry. In the case of salmon, production was increasing faster than demand in 1991, creating the oversupply situation that led to falling prices. A number of salmon farms went out of business. If the market had not continued to grow and expand (stimulated in part by vigorous marketing efforts), those farms would not have been re-activated. As it happened, they were sold to other operators, and most of the closed farms are today back in operation, albeit under new ownership. A similar situation could arise in the shrimp farming business. However, the "boom and bust" syndrome is well known in most industries, and is usually the sign of a new and immature industry. In practice disease has restrained production of farmed shrimp, allowing the development of marketing channels and market demand approximately in balance with production. It remains to be seen whether this balance will continue. Short-term price fluctuations can have a significant impact on farm gate prices and farm viability in more isolated areas, where producers have more limited access to harvesting, distribution, and processing infrastructure.

Design factors

Site selection is crucial to reducing the risks in shrimp farming. To the extent possible, the local environment must be surveyed prior to the final decision to construct the farm, and every precautionary measure necessary to prevent degradation of the environment must be taken during design and construction. It is in the interest of the investor to make sure that environmental conditions do not deteriorate as a result of the shrimp farming operation, as that would render the farm inoperable after a short period. Unless local conditions are properly surveyed before the planning and design stage, unforeseen needs may increase construction costs to the extent that the project's profitability and financial performance suffers greatly. It is, therefore, very important to have a precise and thorough understanding of the local physical conditions affecting the farm before the design is done.

Unfortunately, as discussed elsewhere in this report, many small-scale operators do not have the luxury of site selection but simply develop what is available to them (their own land or some form of allocated land). It must be the role of government to ensure that sites that are *available* for shrimp aquaculture are also *suitable* from all perspectives. In addition, construction codes for proper shrimp farm design and engineering can also be created and enforced, similar to other development activities, such as housing and commercial urban and rural development. These codes should include environmental guidelines.

1 Josupeit 1995. One might add to Josupeit's argument that other factors also influenced the demand, such as the death of Japanese Emperor Hirohito. In the year following his death, entertaining was greatly reduced in Japan out of respect for the late emperor, and consumption of shrimp declined as a result. This coincided with the rise in Thai supplies.

Natural factors

Shrimp disease

The outbreak of disease is the most prominent nature-based risk factor in shrimp aquaculture, sometimes wiping out entire crops. The more spectacular examples of this were found in Taiwan, Republic of China, in 1988, and in China in 1993. In the former country, disease led to investor flight from shrimp farming, and many operations were either closed down or converted to other uses.

Disease occurrences can be roughly divided into the ones that are environmental and opportunistic in origin, and that mainly occur in poorly managed farms; and the outbreaks that seem to spread to almost all farms regardless of management. The first category is the easiest for the individual farmer to address, but outbreaks require concerted efforts, as described in Chapter 4.

The risk of disease outbreaks is related to the capacity of the individual farmer to manage the farm, which can obviously be improved as knowledge of shrimp farming improves. There is also a collective risk that arises as soon as one farmer mismanages a farm or introduces disease via seed or feed. Once the disease has been established in a region, it can affect relatively well-managed farms just as those less well managed. Managing this collective responsibility in an industry that is immature, as it is in most shrimp farming countries, requires good insight by regulators, as well as farmer associations with sufficient knowledge to limit the risk of disease introduction. One of the main challenges at this time is to prevent shrimp disease spreading to new frontiers for the industry, such as Africa, from the main growing regions. In the medium term, there is also a risk of new African diseases spreading the other way. However, few of the farming countries are taking precautions to limit these risks.

Weather

Adverse weather and other climatic conditions can be a risk factor and should be considered in the design of the project. For example, seasonal floods may wipe out production unless the construction of the ponds takes that risk into account. Low winter temperature, or high summer temperature, can also stress shrimp. This is a particular problem where farmers attempt two shrimp crops per year, thereby subjecting the beginning of the first crop and the end of the second crop to suboptimal conditions and increasing the risk of disease. While extreme weather conditions may occasionally affect production, to a large extent the design, construction, and operation of the farm can be adjusted to weather conditions observed over the recent past. By taking these conditions into account, the financial risk of the project can be assessed and, in some cases, significantly reduced. For example, in China some shrimp farmers have two crops of shrimp that bracket the hottest summer weeks, when production is suspended and ponds are fallow.

Discussion and conclusions

Shrimp aquaculture is an inherently risky activity, subject not only to the unpredictability of climate, input prices, and product value, but also to the possibility—indeed the likelihood—of disease and production failure. The extent and incidence of disease depends on both the management of individual farms and the management of the industry as a whole. Minimizing disease risk is therefore only partly in the hands of the individual operator. Government can play a major role in reducing some of these risks.

In general, financial risks increase with increasing intensity, and decrease with improved siting, design, technology, husbandry, and management. The relationship between intensity, returns, risk, access to credit, and skills requirements should be given careful consideration in the planning and design of any shrimp culture project or program.

In the case of individual projects or aquaculture development programs, the most important safeguard against financial risk is a proper and well-documented feasibility study, supported by thorough and reliable market studies, raw material supply studies, and similar analyses. It should also address in detail the probability and costs of disease. The objective of the feasibility study is to reduce financial risk as much as possible, in order to safeguard the sustainability of the project (Behrens & Hawranek 1991). Appropriate credit facilities must also be available to the project, and cost recovery mechanisms should be considered in the project's financial plan.

In order to reduce financial risk, realistic—even generous—safety margins should be included in the calculation of the project's main input, operational, and output factors. No operation will perform according to plan and, most often, it is better to err on the side of safety. In addition, sensitivity calculations must be performed, using less favorable conditions than the "base case." Often, several negative factors will occur at the same time, and the sensitivity analysis should include calculations that reduce favorable inputs simultaneously, rather than one by one.

Finally, an analysis of possible project alternatives is important in the design phase of a shrimp farming investment. One option to consider is crop diversification, in order to reduce the financial risk associated with shrimp disease. For instance, in areas where diseases occur mainly in the rainy season, a polyculture farm with tilapia, crabs, and sea bass in the rainy season, combined with shrimp culture in the dry season, might be an option. Alternatively, farmer cooperatives or government agencies could keep broodstock of tilapia, milkfish, sea bass, and other fish to be distributed once a shrimp disease or another natural calamity hits an area, in order to safeguard farmers' incomes.

Chapter 6: Planning and Management for Sustainable Shrimp Aquaculture

An examination of all the issues related to the sustainability of shrimp aquaculture has highlighted the need for better planning and management of the industry as a whole. Planning for any land-use activity is notoriously difficult; from impressive policy documents that cannot be effectively implemented to excessively top-down and centralized control. This chapter discusses various needs and approaches to meeting them, and presents some preliminary guidance for planning shrimp culture.

Legal frameworks

Examination of existing literature about the negative impact of shrimp farming has repeatedly brought to light the general lack of, or inadequacy of, legal frameworks and regulatory instruments in shrimp farming countries. Aquaculture commonly falls between legislation relating to land use, water use and fisheries management.

Inadequacy of existing frameworks

Ownership, use, and access rights

Land/water ownership and access or use rights in coastal areas are notoriously ambiguous in many countries. Such ambiguity has been identified as contributing to many of the social problems stemming from shrimp-farm development (Chapter 4). The legal aspects of resource rights are often not fully understood and legislation may be lacking or confusing. Traditional rights have broken down or been revoked by national governments in most shrimp farming countries, but governments often lack the capacity, or the will, to enforce new property rights or implement a new system of equitable resource allocation. Government-designated conservation zones are often subject to continuing illegal development or exploitation by landless, migrant, and minority groups on the one hand, and “officially sanctioned” development from more powerful commercial interests on the other. Shrimp farming, along with many other activities, has developed rapidly in high-priority conservation areas through both of these routes, and traditional users of these resources have sometimes suffered as a result. Lack of enforcement instruments and personnel makes it impossible for authorities to control use. However, more and more countries are now focusing on this problem and seeking to gain control over areas that should be protected.

Claridge (1996) has identified a number of legal factors that may contribute to the negative impacts of shrimp farming. Although his work is based on the case of Thailand, his observations can be generalized to other locations.

Inappropriate, ambiguous, or lacking legislation

In many shrimp-farming countries, there has been no comprehensive review of natural resource management legislation in order to improve its effectiveness for sustainable coastal and marine resource management. When such a review is undertaken, it should consider not only legal aspects but also implementation and monitoring of any newly proposed controls.

Inappropriate or lacking environmental standards

Although regulations or laws may contain general standards, or at the very least indicate the need for such criteria, few provide the specific standards needed. This is not surprising, as the specification of standards may vary over time, and is therefore often left to administrative institutions to provide and modify. Often, however, the intentions noted in the law or in the regulations enacted by the legislature are not translated into measurable, specific standards or criteria with which the industry can comply, or to which enforcement authorities (if any are identified or in existence) can refer.

Lack of effective land use and resource allocation controls

Land (or coast) use controls are often nonexistent or ineffective. The problems associated with shrimp farming, particularly those related to land use, siting, and resource access, imply the need for integrated coastal management plans, which would provide an appropriate planning and administrative framework for central and local authorities, as well as for investors and operators in shrimp aquaculture (Post & Lundin 1996). This issue is discussed further below.

Conflict between law enforcement and other government functions

Problems may arise when government officials are simultaneously responsible for law enforcement and industry development. In their role as industry development promoters, the government officials' success is measured by their ability to promote and expand activities like shrimp farming, and to discuss issues such as marketing, pond management, and financing successfully with private sector farmers. The farmers are unlikely to discuss such matters with officials who are also responsible for law enforcement. District fisheries officers in Thailand are currently in such a situation, as one example. On the other hand, it is important that the promotion and control functions of government are closely coordinated and do not work in opposition to each other.

Ineffective or nonexistent law enforcement

There is a significant lack of necessary legislation to prevent or mitigate the impact of shrimp farming, and those laws that do exist are generally not enforced. There are many reasons for this, including lack of personnel and proper enforcement instruments, or insufficient motivation or skills on the part of law enforcement officers. Regulations may also be well intended but have side effects that render compliance impossible. Furthermore, law enforcement requires at least a general absence of corruption in the government, particularly among the administrative branch employees.

Selected examples of legal intervention by government

In India, the Supreme Court has upheld the coastal zone regulations that restricts shrimp farming, as one example of governmental action (Murthy 1997). Among the proposed guidelines are requirements that no shrimp farms be built in mangrove areas, in sensitive wetlands, or on productive agricultural lands; and water from underground aquifers cannot be used in the aquaculture process. However, there is considerable political disagreement on this issue, and in April 1997 the upper house of the legislative assembly passed the Aquaculture Authority Bill, which would virtually nullify the Supreme Court decision. The legislation is still pending in the lower house, and the industry remains in limbo. One of the problems in this case was that shrimp farming had not been specifically taken into account in drawing up the original Coastal Zone Act.

The Government of Ecuador has taken steps to address the environmental effects of shrimp farming. For example, mangroves have been designated as woodland to be protected, two reserves have been created covering approximately 55,000 hectares of mangroves, and rules were established for the conservation and protection of mangroves (Anon. 1996k).

As early as 1991, the Thai Cabinet made several decisions to control the shrimp farming industry (Anon. 1996a). The cabinet:

- Banned the use of mangrove areas for shrimp farming;
- Encouraged participation of local authorities and people in preserving mangroves;
- Planned documentation of all the mangrove areas in Thailand;
- Initiated a periodic monitoring system for delineating borders and documenting them on maps and day-to-day monitoring of mangrove areas;
- Restricted loans for shrimp farming through the Royal Bank of Thailand;
- Promoted zoning plans for coastal aquaculture; and
- Initiated a pilot project to test a seawater irrigation system to supply offshore seawater for use in treating shrimp pond discharges.

In addition, in 1996 the government completed a 20-year sustainable development plan that included an environmental plan for shrimp farming. The Thai government has also committed U.S.$40 million to conserve remaining mangroves. However, despite government will to improve regulation, lack of law enforcement resources (untrained personnel and limited capacity of governmental agencies) is severely limiting the effect of the regulations (MIDAS 1995).

Planning and resource management

Inadequacy of existing procedures

There are few examples of well-planned shrimp farming to draw on. Although many countries have planning systems that have been applied to aquaculture, they have usually been unable to apply procedures thoroughly and consistently while facing the sheer pressure for rapid development that springs from the initial success of aquaculture. Sri Lanka, for example, has relatively well developed legislation and planning procedures applicable to aquaculture development, including coastal planning and environmental assessment procedures, but unregulated development has nonetheless taken place, and major shrimp disease problems have occurred. One of the main problems (in Sri Lanka and many other shrimp farming countries) has been the inadequacy of environmental assessment procedures. These have been undermined through illegal developments on the one hand, and the inadequacy of conventional EIA to cope with large numbers of small- or medium-scale developments on the other. When taken in isolation, such a development is unlikely to have a significant impact on the environment, but a large number of such projects (typical in estuarine and lagoon systems suitable for shrimp culture) is likely to have a significant cumulative impact.

Planning frameworks

Sector-level environmental assessment (as opposed to project- or individual farm-level) linked to a sector plan and a set of appropriate incentives and constraints appears to be the only way to address the problems associated with these cumulative impacts (SEACAM 1999; GESAMP 1999). However, if the planning and regulatory framework is to address social, economic, and environmental issues in a comprehensive manner, it will need to include all elements of integrated coastal management (ICM). ICM has been widely promoted as a suitable framework for addressing the problems and issues presented in previous chapters (Chua 1992; Chua 1997; Olsen & Coello 1995; Barg 1992; Holland 1998) and should be pursued as a long-term ideal. Unfortunately, developing comprehensive ICM plans is typically a difficult and lengthy process (see, for example, Robadue 1995), and shrimp farming may require more immediate action. Sector environmental assessment of coastal aquaculture, leading to the development of a provisional sector plan, may be an effective first step toward more comprehensive ICM.

Whether central or local government bodies should initiate such policies is a question that various countries have been grappling with. There is an increasing consensus that the main initiative must come from local government, facilitated through an appropriate national policy and legal framework. Where such a framework is lacking, the development of local initiatives may stimulate and provide the basis for national policy and legislation.

A detailed discussion and guidelines for the planning and environmental management of the aquaculture sector, and its integration within broader ICM frameworks, will be published shortly by GESAMP (1999). Comprehensive guidelines for both sector and project environmental assessment of coastal aquaculture have recently been developed by SEACAM (1999). More general reviews and guidance on the development of integrated coastal management plans may be found in many recent publications. (Recent examples include Cicin-Sain, Knecht, & Fisk 1995; UNEP 1995; GEF/UNDP/IMO MPP-EAS & CMC 1996; Post & Lundin 1996; and Sorensen 1997).

Economic and market incentives and disincentives

Legislation and planning measures for aquaculture development commonly have a significant regulatory component. However, the difficulties of applying regulatory approaches in many countries should not be underestimated, and there is a need to consider alternatives. Economic incentives and disincentives offer a potentially simpler and cheaper approach to guiding or modifying development activity with minimal intervention and conflict; incentive methods should generally be given more consideration (van Houtte 1996).

Government incentives

Economic incentives to modify location, design, and operation of shrimp farms rely upon the reality or perception that higher net profits will be made if the farmer behaves in certain ways.

There is little published information about successful tax incentives and other government-instituted incentives with the specific objective of furthering sustainable shrimp farming. However, a broad range of more general measures is now a key feature of, for example, the European Common Agricultural Policy, where a range of grants, cheap credit, and tax incentives are available to farmers in special areas who farm in traditional ways or in a manner designed to enhance biodiversity or conserve rare or important natural habitat.

Examples of tax incentives to promote the development of shrimp farming, and in particular to attract foreign investment in shrimp farming, do exist (Anon. 1988). However, these incentives seem to have been directed more towards pushing rapid growth of the industry and of exports, rather than safeguarding against negative impacts on the environment.

Government can manipulate net profits in a variety of ways, and these may be linked to specific conditions or circumstances. Profit can be increased if farmers receive:

- Grant aid;
- Cheap credit;
- Free or subsidized land purchase or rental;
- Free or subsidized inputs;
- Tax exemptions or holidays;
- Production and marketing infrastructure; and
- Subsidized research, training, and extension services.

These benefits could be linked to location (e.g., the incentives are only available in designated shrimp culture zones), or to design and technology (e.g., grant aid or tax exemption is available for waste treatment equipment). However, any differential benefits or taxes should be used with great caution, especially if they are likely to give new farmers an advantage over existing farmers.

One option is to introduce tax incentives for particular applications and procedures in order to avoid negative impacts on the environment. For example, tax incentives and exemption from import (or other) duties on equipment needed for proper water treatment may be introduced to ensure that such treatment is installed. In some countries, government investment grants are in use to encourage investment in environmentally friendly technology or designs.

The establishment and operation of a government-financed veterinary service would improve shrimp health conditions and help prevent the spread of disease. Government-supported training and extension programs on proper management practices can help alleviate or prevent both disease and environmental problems. Government support for research in sustainable aquaculture and environmental impact studies would encourage operators to undertake such studies. Financial grants for undertaking appropriate environmental impact assessments would encourage investors to comply with the regulations. In such situations, such EIAs must be required to comply with certain specifications.

Some examples of these approaches already exist. Cheap credit is a common tool used in aquaculture development programs, but to date it has only rarely been linked to siting or design conditions. Land, infrastructure (research, training, water supply), credit, and free seed have been provided for some small shrimp farmers in several countries, and recently substantial seawater irrigation systems have been built in Thailand. To date, however, these incentives have rarely been comprehensively linked to plans and strategies for sustainable aquaculture development.

Market incentives

Shrimp farming is an international business: trade, namely export, of a high-quality processed product. Processing is relatively centralized since processing and freezing must be done rapidly while the product is very fresh. This requirement has also led to a centralization of harvesting, done by specialist contractors in major producing countries. Product inspection and certification is already in place, for example, for antibiotic residues. Furthermore, the product is high-value, purchased in bulk by large retailing chains, and eaten by increasingly discriminating consumers. These conditions are ideal for the establishment of environmental quality labeling initiatives.

Such initiatives have been or are being developed for agricultural products (some of them well established), forestry products, and, more recently, fishery products. The time is ripe for environmental certification for shrimp production. Such schemes will require the establishment of generally accepted practices for siting and operating farms (ideally, developed through collaboration between industry, government, consumer groups, and environmental interests); impartial certification procedures; specific, easy-to-understand steps for monitoring the distribution and marketing chain. The potential for these initiatives is discussed in more detail by Clay (1996; 1997) and GESAMP (1999). Success will depend critically on four factors:

- The willingness of the consumer to pay a premium for more sustainably produced shrimp;
- The capacity to track product from producer to retailer;
- The capacity to monitor and certify sustainable production and management practices; and
- The allocation of a reasonable proportion of the premium to the producer.

However, some preliminary initiatives that use certification conditional only on siting, and the existence of a credible local sector development and management plan (based on a thorough sector environmental assessment), may offer a first step in developing more sophisticated initiatives (e.g., the Thai Code of Conduct 1998, the GAA Code 1999).

Government constraints

A variety of economic constraints have been proposed for shrimp aquaculture. In general, they are less likely to be effective than incentives, since people can generally find ways to avoid them. Nonetheless, they may be appropriate in some circumstances.

Many authors have proposed the use of environmental performance bonds. These require that would-be shrimp farm developers make a payment or bond redeemable only if environmental quality in the vicinity of the farm is not degraded, or only if the environment is restored should the operation be abandoned, or both. Such bonds are generally considered only for large-scale operations with external investors. However, they may be applied more widely to small operations if local government includes the requirements and necessary guidance as part of a farm licensing policy. A pool of funds from small and large operations would be used to restore failed and abandoned shrimp farms, where necessary.

An example of such an approach comes from India, where eco-restoration taxes were included in the regulations passed by the State Assembly in Tamil Nadu in 1996 to regulate shrimp farming. The tax was intended for use in restoring abandoned farms to their pre-implementation condition.

The interplay between regulations, negative and positive taxes, and other incentives should be carefully considered in order to achieve optimum shrimp farming practices. The use of tax incentives and other government-instituted incentives to advance sustainable shrimp farming appears to be little used and not well documented. This obviously is an area that requires further investigation.

Design and implementation of operational codes

Government is well placed to initiate the development of codes and standards for the industry, and devise means to encourage their adoption (such as using licenses or access rights conditional on their adoption). These standards, however, must be practical and capable of wide adoption—in other words, they need to be developed in close collaboration with farmers and others involved in the industry. The codes may be broadly based on the mitigation measures discussed in Chapters 3–5, and also on existing general codes and guidelines such as the FAO Technical Guidelines for Responsible Fisheries (No. 5: Aquaculture Development) and others. (Codes of design and practice for sustainable aquaculture can be found in documents including UNEP 1990; FAO 1997; Global Aquaculture Alliance 1998; SEACAM 1999; Australian Prawn Farmers Association 1998; and Government of Belize 1997.) Codes will need to be adapted to suit the needs of specific countries, and indeed specific zones within them, as well as different types of production systems.

NGO initiatives

Several NGOs have addressed the environmental problems caused by shrimp farming. In all the main producer countries of farmed shrimp, NGOs are actively working for stronger regulation of the industry. In 1996 an NGO Statement Concerning Unsustainable Aquaculture was given to the UN

Commission on Sustainable Development, listing a number of points to which governments were invited to agree. These opinions were further formalized in the Choluteca declaration of October 1996, made by NGOs from Latin America, Europe, and Asia in Choluteca, Honduras. A Resolution on Mangrove Forests was made by several NGOs in December 1996, urging governments to "take immediate action to halt the expansion of industrial shrimp farming which is destroying mangrove forests."

In addition, the first Shrimp Tribunal was held in April 1996 and included a government-NGO dialogue on the sustainability of shrimp trawling and farming. Representatives from the major producer countries were present, together with a number of NGOs. The second Shrimp Tribunal was held in April 1997.

The Industrial Shrimp Action Network (ISANet) was formally established in 1997 as an umbrella organization of dozens of NGOs in both the South and the North who are concerned about the uncontrolled expansion and negative impacts of industrial shrimp aquaculture and are working together to oppose it. No single strategy has been developed by this confederation. Some groups within it have opposed the industry, while others have attempted to engage it.

Farmer and industry initiatives

In recent years, farmers in both the Americas and Asia have recognized the need for improved environmental management of the industry at local, national, and international levels. At the local level, farmers have organized to cooperate on issues such as wastewater management. Farmers in Surat Thani in southern Thailand cooperate to ensure that they minimize both pollution of each other's water supply and the spread of disease. Farmers in Ecuador are working with the NGO Fundacion Natura to promote mangrove conservation.

At the international industry level, traders, processors, and farmers (mainly large-scale) established the Shrimp Council in 1996. In February 1997, the Shrimp Council presented a four-point initiative that addresses environmental concerns. It has since spawned the Global Aquaculture Alliance, a broader-based industry alliance that has developed, in collaboration with scientists, its own code of practice for sustainable shrimp culture which is available on the Internet (Global Aquaculture Alliance 1998).

Farmer organization is extremely important to facilitate the processes of sector environmental assessment and integrated coastal management. Typically, organizing and training farmers is more effectively carried out by NGOs, experts, and consultants than by government, whose involvement may be mistrusted (Robadue 1995; Ochoa 1995).

Scientific research

Even a casual observation of the world's aquaculture industry reveals the importance of scientific research, for improving production techniques as well as for environmental protection. Many developing countries have no resources to engage in such research, and must, therefore, either rely on research done by others or do without the results of modern science. The failure to invest in research and systems to disseminate findings efficiently has resulted in a lack of knowledge about the issues that pose the most serious threats to the industry and to the environment.

Key areas for research at the local level include the assessment of natural resources, their functions, dependencies, and value; and the assessment of environmental capacity in relation to economic developments, including aquaculture in the coastal zone.

For most developing countries, economic priorities determine whether they engage in scientific research. Often, research related to the negative effects of a booming industry is ignored because of the substantial immediate returns from the industry, while funds available are spent on other, apparently more urgent, matters.

Conclusions and recommendations

Recommendations for government- and industry-initiated measures to promote and manage sustainable shrimp culture have been made in several recent reports and papers (Barg 1992; GESAMP 1996b, 1997; Chua 1992, 1997; Clay 1996; SEACAM 1999). The main common features of these recommendations are listed below, modified and supplemented on the basis of this analysis. While some elements may be inappropriate in particular development contexts, governments and industry representative bodies should consider all of these issues carefully and seek to adopt and promote a broad range of measures, with the goal of implementing more sustainable shrimp culture, and in particular the technical recommendations made in previous chapters.

Central government policy

It is now generally recognized that in order to ensure that shrimp aquaculture is sustainable and will increasingly contribute to food security, government policies have to be established and implemented that are responsive to the main issues of sustainable development.

In general, it is advisable to plan the development of shrimp farming as part of an integrated coastal management plan, taking into consideration the many different uses of the coastal area. Where this is not possible (from lack of time or resources), a sector (coastal aquaculture) environmental assessment, leading to a sector development and management plan, may be adequate.

In general, sustainable development of shrimp aquaculture is most likely where the following pre-conditions can be met:

- A legal, regulatory, and enforcement framework specifically designed or adapted for coastal aquaculture development;
- The existence of, and compliance with, an aquaculture development and management plan, or an integrated coastal management plan for the area;
- Sector environmental assessment as a key element in the drawing up of such a plan;
- In the case of large projects, environmental assessment studies, adhering to current best practices, undertaken during the project planning; and
- Proper law enforcement instruments, supported by the resources necessary for enforcement.

An appropriate framework and process for establishing these conditions is summarized below, including an indication of appropriate roles and responsibilities in this process.

Legal and regulatory frameworks

Legal and regulatory frameworks must be country-specific and will often build on or add to existing legislation. Nonetheless, some common components that serve to promote sustainable shrimp culture should be included:

- Principles, values, and definitions relating to sustainable coastal aquaculture development;
- Provisions for the development, implementation, monitoring, and adaptation of sector plans, natural resources management plans, and/or integrated coastal management plans at provincial and/or district levels;
- Provisions for the application and use of both sector environmental assessment (EA) and project or individual farm environmental assessment;
- Responsibilities and procedures for the development and implementation of such plans, and for the conduct of EA, including in particular the need to use a participatory approach;
- Requirements for the minimum content of such plans, possibly based on the content outlined below;
- Requirements for setting environmental quality standards, and provisions for the promotion or regulation of activities in order to meet such quality standards;
- Allocation of authority and responsibility for implementation and enforcement of plans and associated incentives and regulations;
- Clarification of ownership and use rights of coastal lands and water (including provision for access and title to coastal and aquatic resources), taking full account of the needs and

traditional rights of local users, and avoiding where possible one-time cash compensation settlements;
- Assignment of legal liabilities for environmental damage; and
- Provisions for regular environmental monitoring and reporting.

Sector EA and coastal aquaculture development and management plans

Whether they are stand-alone or part of a wider ICM initiative, sector plans for coastal aquaculture development and management are likely to be a prerequisite for sustainable shrimp farming. They should be based on thorough *sector* or regional environmental assessment. The following issues might be addressed in a thorough sector assessment and plan:

- Identification of suitable areas for shrimp culture development, taking into account the needs of other resource users, the need for biodiversity conservation, the technology likely to be used, and environmental capacity;
- Procedures for resolving any resource use conflicts that may arise (for example, between aquaculturists and fishermen or rice farmers);
- Incentives and constraints to promote development in suitable areas in line with the carrying capacity. This might include, for example, zoning schemes with associated infrastructure (e.g., water supply and disposal, processing and marketing facilities or services), exclusion zones, registration/licensing requirements and associated economic or regulatory incentives and constraints, limits on production or new entrants;
- Criteria for the application of project or farm EA, and environmental standards against which impacts can be assessed. Ideally, these standards should be developed as part of sector EA and be based specifically on local ecological and hydrological conditions in shrimp-farming areas;
- A water supply and management strategy, incorporating provision for appropriate infrastructure (e.g., seawater irrigation and pre-treatment systems, wastewater treatment);
- Effluent standards and/or protocols for wastewater management; incentives and/or constraints for complying with standards or procedures;
- A code of practice for siting, design, technology use, and management of individual farms or operations, and a set of incentives and constraints (economic, market, or regulatory) to ensure compliance with such codes;
- A training, extension, and information dissemination strategy to further promote sound practices;
- A disease prevention and management strategy (see Chapter 3) incorporating provisions for monitoring, diagnosis, and epidemiological analysis; disease testing and certification, especially for any seed or stock moved in or out of the planning zone; training and extension on health management in shrimp ponds; incentives for diversification (alternate/mixed cropping, polyculture); and codes of practice for the use of chemicals in disease prevention and management;
- Provision for farmer representation and participation in the planning process, whether this be limited to sector-level or comprehensive ICM;
- Methods of ensuring that the benefits from aquaculture development are shared as widely as possible. This might include, for example, provision of credit and training, and allocation of suitable sites to poorer groups or individuals;
- A research program to explore issues such as environmental capacity, environmental impacts of specific aquaculture developments, seed supply, environmentally friendly feeds, improved design and technology; and
- A monitoring and evaluation process to assess the success and problems of the development with provision for plan modification as appropriate.

A detailed discussion and guidelines for the development of coastal aquaculture management plans was produced by GESAMP (1999). In addition, guidelines for sector and project EA of coastal aquaculture are provided in SEACAM (1999). Reviews and guidance on the development of integrated coastal management plans may be found in these two publications, as well.

Roles and responsibilities for implementing the recommendations

It is clear from Chapters 3 and 4 that shrimp farm development, left to itself, is unlikely to be undertaken sustainably. It is also clear from previous chapters that the measures and conditions required to promote sustainability are wide ranging and complex, and require much collaboration and integration. How can this be done, and what might be the roles of the various stakeholders?

Central governments have been rather ineffective to date in implementing and enforcing constraints on shrimp farmers or promoting better practices, and they are increasingly unwilling to provide funds. However, there is a wide range of necessary functions for central government, including these:

- Create the necessary legislative framework;
- Promote and facilitate planning initiatives at provincial and district levels;
- Monitor the success or failure/problems of various local initiatives;
- Encourage coordination and collaboration between industry, agencies, NGOs, farmers, local government, scientists, extension workers, and others;
- Support research, training, and extension activities;
- In collaboration with district and local government examine the opportunities for using government sponsored economic incentives and constraints; and
- Working with all of the industry and other stakeholders in the vicinity, facilitate formulation of “codes of conduct for sustainable shrimp farming” and certification programs.

Provincial or district government can play a crucial role in promoting sustainable development, since it is well placed to integrate the work of different sectors and to address the needs of the various stakeholders with respect to practical issues. Specifically, district/provincial government can:

- Undertake sector (i.e., coastal aquaculture) environmental assessment to provide an objective, technical basis for the development of plans;
- Actively develop sector, natural resource, and integrated coastal management plans (including the minimum content suggested above);
- Pressure the central government to develop or adapt legislation to meet the needs identified in the assessment and planning process;
- Facilitate, promote, and require the development of farmer representative organizations;
- Facilitate links among local producers, and among producer organizations and importing, processing, or retailing outlets, in order to develop environmental labeling initiatives; and
- Create an adequately strong capacity to enforce national and local regulations.

Shrimp producers must begin to take responsibility for their actions and effects, not least in order to maintain an acceptable market image. Producers can:

- Organize themselves at various levels so that they have greater input in, and take greater responsibility for, environmental and social initiatives;
- Develop guidelines and codes of practice for their own conduct (see GAA 1998);
- Collaborate with consumer and environmental groups and government to develop operating standards and codes of practice that may form the basis for developing environmental labeling initiatives, perhaps on an industrywide or pilot project basis; and
- Tithe some proportion of profits to support local community services.

International aid donors and development banks are well placed to apply pressure to promote sustainability at a range of levels, from central government to individual projects. They can:

- Support a range of initiatives to establish the necessary preconditions for more sustainable shrimp culture discussed in this report and elsewhere—in particular, initiatives related to sector environmental assessment, sector planning, and integrated coastal management incorporating such plans;
- Support pilot projects that aim to promote sustainable shrimp culture development;
- Require aspiring shrimp farmers who seek development aid to meet a set of conditions that could be developed from the guidelines and recommendations presented in this and other reports, particularly those relating to the assessment and planning of coastal aquaculture development;
- Support the establishment of environmental labeling programs; and
- Promote and facilitate continuing debate and discussion on these issues.

Major retailing chains have the opportunity to benefit from an environmentally responsible image for the shrimp industry. They should therefore**:**

- Explore the opportunities and potential for social and environmental labeling for shrimp aquaculture products.

CHAPTER 7: PROJECT PLANNING AND ASSESSMENT

Where major aquaculture development projects are proposed, it is essential that project assessment and planning is done thoroughly, taking full account of the general mitigation measures presented in chapters 3–5, as well as incorporating thorough environmental assessment. It is important that these considerations be addressed as early as possible in the investment project's timeline.

The investment project cycle

Investment projects, including shrimp farming projects, go through a cycle consisting of three main phases: preinvestment, investment, and operations. Each of these phases includes a number of actions, or steps, that must be taken to finish the project. The time schedule or time horizon for each phase may vary greatly depending on the size and type of project. Table 8 provides a general illustration of the steps in each phase.

TABLE 8: THE INVESTMENT PROJECT CYCLE

PHASE	PLACE IN APPROXIMATELY 3-YEAR CYCLE	DURATION
Preinvestment phase		
Opportunity study		1-3 months
Prefeasibility study		1-3 months
Feasibility study		2-12 months
Appraisal report		1-3 months
Preparation		3-6 months
Evaluation		1-2 months
Investment phase		
Negotiation/ contracting		3-24 months
Engineering design		3-12 months
Construction		6-12 months
Pre-production marketing		1-12 months
Training		2-12 months
Implementation		2-6 months
Evaluation		1-2 months
Operations phase		
Commissioning and start-up		1-4 months
Replacement and rehabilitation		3-12 months
Expansion and innovation		3-12 months

Note: This table is based on World Bank literature describing large projects. Smaller projects will, of course, have shorter time spans than represented here.

Based on experience with previous World Bank–funded aquaculture projects, Zweig & Braga (1996) have identified a set of guidelines for the planning and implementation of such projects, particularly those in developing countries. The main recommendations from this document are highlighted below, supplemented with conclusions from the current study.

Project identification and preparation

Projects should be based on sound concepts, using already implemented technology and institutional frameworks. Aquaculture projects must be designed on the basis of well-founded market analysis and technical information about fish resources, environmental conditions and legislation, suitable technology, and prevailing market conditions.

- Demonstration projects should be modest, simple, closely monitored, and involve only proven technologies;
- A pilot phase should be mandatory for any projects that seek to introduce new technologies or credit and institutional arrangements;
- All communities affected by the project should be involved in the preparation and planning process from the beginning; and
- Project preparation and appraisal are fundamental stages for successful implementation; they should not be skipped or shortened, particularly for big projects covering large and/or diverse areas.

Projects must incorporate some degree of flexibility to be able to adjust to changes in market and environmental conditions, development of better technologies, and disease outbreaks. Attention should be paid to possible shifts in government policies, particularly during long preparation and implementation periods. As a rule, the simpler the project, the less difficult it is to respond to changing conditions.

Technical aspects

Full account should be taken of the siting, design, and technology recommendations to minimize environmental impacts, discussed in Chapter 3:

- A primary requirement for a successful aquaculture project is a reliable and adequate water supply;
- The choice of site must take into consideration technical, managerial, marketing, and social constraints;
- Aquaculture projects should avoid dependence on wild-caught seed supply;
- The bidding process for equipment acquisition should give greater weight to technical considerations and quality of equipment, and less to price;
- When using contractors in a project, the selection process should consider both competence and experience in the type of work to be done; and
- Adequate time for completion of work in advance of contract awards, as well as for unexpected events, should be factored into planning.

Institutional aspects

- Project organization could be kept as simple as possible and the roles and responsibilities of people and agencies involved in the project, both existing and newly required ones, should be clearly defined. There must be a clear consensus among the Bank and all parties involved about the nature (public and private), objectives, organization, financing, and operating principles of the various bodies;
- Agencies tend to work more closely together at lower levels of government; placing responsibility for meeting requirements at the district or local level rather than at the central level usually improves performance; and
- The agencies responsible for technical aspects of the project should work very closely with those responsible for providing credit for project implementation.

Implementation issues

- Thorough project preparation is the best insurance against occurrence of technical problems during project implementation; preparation should include a good set of initial technical designs, and detailed water and soil analysis;

- Appraisal and supervision missions should not always be conducted by the same experts, although there should be at least one person who follows the project from beginning to end;
- Governments need to provide adequate incentives to keep staff working on the project for long periods of time;
- Project directors should hire and train enough staff with expertise in relevant matters as soon as possible; and
- Good training of extension officers is essential.

Socioeconomic issues

- A good understanding of the socioeconomic and environmental characteristics of the proposed side is fundamental, especially of the land titling situation in areas involving small landholders;
- Private sector participation should not only be anticipated but encouraged, and whenever possible it should be specified in the original project design; and
- It is a requirement that a social impact assessment study (SIA) be undertaken before the project plans are submitted for approval.

Environmental issues

- Possible environmental impacts, both positive and negative, must be thoroughly addressed in all phases of aquaculture project development and implementation;
- A coastal zone management plan (Post & Lundin 1996; Asian Development Bank 1991; World Bank 1996) for the region should be a prerequisite, and an environmental impact assessment study must be undertaken prior to approval and licensing of any project.

Sustainability issues

Sustainability is highly correlated with overall project quality, including technological and institutional aspects, and more specifically with whether farmers have access to credit, good training, and extension support to ensure adequate managerial and technical capabilities of the pond operators. Full account must be taken of the recommendations made in Chapters 3 and 5 on siting, design, technology, and management.

Financial issues

- The project needs to make sure that farmers will have access to credit as required for construction and operations.
- Cost-recovery mechanisms should be a factor considered in the original project design.

Guidelines for feasibility studies

An opportunity study, prefeasibility study, and feasibility study are the responsibility of the promoter/investor to conduct. This section presents guidelines for the investor in preparing these studies. A more comprehensive discussion of these issues can be found in Behrens & Hawranek (1991), and Zweig & Braga (1996).

Opportunity studies

The identification of investment opportunities is the starting point in a series of investment-related activities. Once an idea has been hatched, it needs to be described and documented to a certain extent in order for investors to reach a decision on whether to continue and to commit financial resources to the further development of the project.

The instrument used for this documentation is the *opportunity study*, which specifies the idea and the social, commercial, and (to some extent) physical environments in which this idea may materialize.

The opportunity study usually describes and analyzes the following:

- The natural resources and conditions that appear to support the idea;
- The market demand for shrimp and the supply situation, in order to determine the potential of the shrimp farm;

- Commercial and market conditions, such as availability and cost of production inputs, domestic production and imports, and trends in total demand in the most appropriate markets (including foreign markets);
- The risk of disease and the nature of any industry or government strategy to prevent or manage disease;
- The environmental impact;
- The social impact;
- Similar projects in other regions or countries and their success;
- Possible linkages to other critical industries;
- The general investment climate;
- Industrial policies and other legal/regulatory aspects;
- The extent to which the project fits with existing development, natural resource development plans, and integrated coastal management plans.

Opportunity studies are rather sketchy in nature and rely more on aggregate estimates and readily available information than on detailed analysis. The key limiting factor at this stage is cost: the cost of producing an opportunity study is by nature very limited. The purpose of the opportunity study is to determine whether the idea is worth pursuing and whether it is worthwhile to commit further resources.

Prefeasibility study

If a decision has been reached that it is worth pursuing, the project idea must be elaborated in a somewhat more detailed study. However, the formulation of a full-scale feasibility study is such a costly and time-consuming undertaking that a more limited exercise is usually initiated: that of a prefeasibility study.

The prefeasibility study should therefore be viewed as an intermediate stage between a project opportunity study and a detailed feasibility study. A prefeasibility study presents less detailed information and discusses and analyzes project alternatives less intensively, but the two types of studies should share the same structure and include the same sections.

In a prefeasibility study, the information used will be that which is easily available and reasonably reliable, whereas in a feasibility study, all relevant data should be documented. The prefeasibility study more resembles a “desk study” in this regard, while the feasibility study usually necessitates field visits and empirical observation to document the information.

Feasibility study

The purpose of the feasibility study is to arrive at definite conclusions about all the basic aspects of the project and to consider alternative conditions under which the project may have to operate. The conclusions and recommendations resulting from the feasibility study must be supported and documented by hard and convincing evidence, in order to minimize any uncertainty.

Whereas a prefeasibility study will often be based on the “best known” facts and assumptions, the feasibility study should be based on confirmed facts, to the extent possible. This means that all input data for the study must be documented and proven. (This requirement is restricted to observable and documentable facts, of course, such as physical, legal, and economic conditions.)

There will nevertheless be some element of uncertainty, even in a feasibility study. One cannot with 100% certainty predict for example market conditions in the future or price levels of the products. But even these assumptions should be researched and documented to the extent possible, and they should be based on reliable and accepted expert opinions. The uncertainty is reduced as the promoter moves through the various stages of a project development, from opportunity study through prefeasibility study to feasibility study.

For convenience of presentation, the feasibility study should start with an executive summary outlining the project data (both actual and assumed) and the conclusions and recommendations. The executive summary should cover all critical aspects of the project, such as the business environment, the reliability of the assumptions and the documented data, the margin of error (uncertainty and risk) in market forecasts, supply trends, technological trends, and project design.

The structure of the executive summary should follow the structure of the main body of the study. An outline or blueprint for a feasibility study is presented in Annex 5.

Impact assessment and monitoring

It is important when planning a shrimp farming venture that an environmental impact assessment be undertaken. The discussion of impacts and mitigation measures in Chapters 3–5 of this report provide a broad outline of the kinds of impacts that should be addressed, and the mitigation measures that might be proposed in such assessments. Detailed guidelines for the environmental assessment of aquaculture projects and related development programs have been produced recently by SEACAM (1999).

These assessments must be undertaken with maximum public and stakeholder participation and, in addition to the more usual technical issues, should address, at a minimum:

- Siting;
- The potential for cumulative or additive impacts;
- Environmental capacity of the surrounding area;
- Social impact (including loss of access to communal property and water);
- Alternative technologies; and
- Employment opportunities.

Once the project is initiated, ongoing monitoring and reporting should be assured, either by a government mechanism or by the project proponent, with government oversight. In either case, shrimp farmers should be required to provide regular reports to confirm that they are operating within accepted standards. Deviations from the norm by one operator can have disastrous effects on a number of other shrimp farmers.

Environmental assessment should be integrated fully with project planning and investment appraisal, so that it can make a positive contribution to project planning, design, and operation. This means that the EIA team should work closely with economists and engineers from the outset. In this way, EIA becomes a positive tool to promote sustainable development, rather than a restrictive (and in some cases destructive) set of administrative procedures.

Summary of minimal requirements

In summary, any proposal for the development of a major shrimp farm or shrimp farm development project must include provision for a comprehensive feasibility study (based on earlier opportunity and prefeasibility studies). A more complete outline for a typical feasibility study for a shrimp aquaculture project is included in Annex 1. However, at a minimum, an assessment should address:

- The natural resources and conditions available to support the project;
- The risk of disease and the existence of industry or government strategies to prevent or manage it;
- Commercial and market conditions, such as availability and cost of production factors, domestic production and imports, and trends in total demand in the most promising markets (including foreign markets);
- Similar projects in other regions or countries and their success, and possible linkages to other industries;
- The general investment climate;
- The likely environmental and social impacts;
- Industrial policies and other relevant legal/regulatory aspects; and
- The extent to which the project fits with existing development, natural resource development plans, and integrated coastal management plans.

In addition, the proposal should include a comprehensive environmental impact assessment that addresses and evaluates, at a minimum, the following areas:

- Alternative siting opportunities, designs, and technologies;
- Alternative management practices and levels of intensity;

- Conversion of natural habitat and of land with alternative productive uses;
- Pollution issues such as organic matter production and disposal; nutrient production and disposal; chemical use and disposal;
- Upstream impacts on capture fisheries (shrimp broodstock and seed supply, fishmeal and other feed sources);
- Genetic pollution (species, races, and associated organisms);
- Disease spread and disease management;
- Social impacts related directly or indirectly to any of the above;
- Mitigation measures;
- An environmental management plan; and
- Provisions for monitoring, reporting, and executing a planned response to any social or environmental problems.

Details of existing relevant plans (aquaculture development plans, natural resource management plans; integrated coastal management plans) should be provided, and the ways in which the project complies with, or furthers, the provisions of these plans should be described.

At all stages of the project, the proponents should collaborate with governments and NGOs as guardians of the public interest.

CHAPTER 8: CONCLUSIONS, RECOMMENDATIONS, AND FURTHER COURSES OF ACTION

It is clear from the foregoing chapters that shrimp farming has been a tremendous development success in many ways, generating very high returns to relatively poor coastal areas, in addition to generating much-needed foreign revenue. It is one of the few feasible activities in the coastal zone that offer real potential for greatly improving the living standards of poor and often landless people in developing countries. But can shrimp be farmed sustainably?

Relative sustainability

There is no simple answer to this seemingly simple question about sustainability. If asked in relation to the use of cars, or the production of crops using fertilizer and pesticides, or the conversion of raw materials in industrial processes, the answer would be equally difficult and controversial. This is because there is no such thing as absolute sustainability, and because the idea of sustainability involves a wide range of different, and in some cases contradictory, elements, which in practice are given greater or lesser weight according to culture and development status. The analysis and discussion in the preceding chapters shows just how complex this issue is, and how unrealistic it is to offer a simple answer.

Sustainability can be discussed in relative terms, however. Overall, shrimp farming is very similar to many other forms of agriculture, insofar as it involves conversion of significant areas of natural habitat, nutrient and organic enrichment, and the use of chemicals of various forms. It may be more or less sustainable than capture fisheries, depending on how well the two industries are managed. It is probably rather more sustainable than many industrial activities, measured against a wide range of criteria.

The efficiency of resource utilization is sometimes used as a practical criterion for measuring sustainability, or maximizing such efficiency may be an objective of sustainable projects. In practice, and especially with regard to agriculture and aquaculture, resource utilization is usually measured in terms of resources used per unit of production *by weight*. For many developing countries, a more rational and practical sustainable development objective may be to maximize the *value* of production relative to the resources consumed. On this basis, both extensive and intensive shrimp farming score relatively well. Furthermore, most forms of shrimp farming use limited amounts of nonrenewable natural resources, although energy use is sometimes significant in highly intensive systems. Atmospheric pollution is insignificant, and most forms of aquatic pollution can be reduced to low levels with appropriate design and management practices.

Sustainability is often discussed in relation to intensity, and there is a common assumption that more intensive systems are less sustainable—but such an assumption can be misleading. As with agriculture, there is a tradeoff between, on the one hand, the conversion of large areas of natural habitat (or alternative land uses) for extensive aquaculture with lesser use of inputs and, on the other, the conversion of smaller areas for more intensive cultivation with higher use of inputs. It is impossible to say which of these is more or less sustainable without reference to local circumstances and the relative scarcity of different resources (land, water, inputs, and skills).

Disease so far appears to pose the greatest threat to the sustainability of the shrimp farming industry. Whether shrimp are particularly susceptible to viral diseases—or whether the severity and incidence of disease among cultivated shrimp has resulted more from poor siting, design, and management—is not clear. But there is little doubt that improvements in siting, design, and management, coupled with comprehensive measures to minimize disease spread, will significantly reduce disease incidence.

In conclusion, shrimp farming—both in general and in its various forms—is more or less sustainable than other activities depending on the criteria used, and the weighting they are given. The policy question should not be, "Is shrimp farming sustainable?" but rather, "Can shrimp farming be made more sustainable?" and in particular, "Can it be made to reach specific standards of sustainability?" that are set by governments, agencies, NGOs, and others.

The answer to these questions, as shown in previous chapters, is a *conditional* "yes." The conditions are complex and difficult to implement; thus shrimp farming should be promoted or facilitated by governments, banks, and international agencies with caution. However, the potential benefits to be derived from shrimp farming are so great that every effort should be made to meet these conditions.

Reasons for unsustainable shrimp culture

Shrimp farming has often turned out to be unsustainable in practice. It is important to understand why if we are to make it more, or "acceptably," sustainable. The lack of sustainability to date has resulted mainly from the following factors:

- It is a relatively new activity that can be extremely profitable; it has therefore tended to develop overly rapidly, without adequate planning or regulation;
- Since it generates significant foreign currency earnings, many governments are keen to promote rather than restrain the shrimp industry (thus promoting environmental conservation) by offering generous tax incentives and other inducements;
- Disease, and the use of chemicals associated with disease prevention and treatment, are major problems in the industry, related partly to the unplanned and unregulated development already noted;
- It is possible to farm shrimp in areas where resource use rights or ownership are often unclear or lacking; this situation can contribute to resource appropriation by more powerful sectors of society, which may in some cases lead to corruption, social unrest, and violence;
- It is possible to farm shrimp in areas (such as salt marshes, sand-flats and mud-flats, and mangroves) that have been little developed because of their unsuitability for agriculture or urban /industrial development; and these areas often have high environmental value;
- It is possible to farm shrimp in inland areas where it may compete with agricultural activities such as rice farming; this may result in accidental or irresponsible practices which result in salinization of land with agricultural potential, and lead to social conflict;
- Shrimp aquaculture generally requires significant investment in either land and water (for more extensive systems) or inputs (for more intensive systems); the need for investment funds makes the activity less accessible to the poorer sectors of society, and it may therefore increase inequity; and
- Intensive shrimp farming still depends heavily on fishmeal in formulated feeds; given the state of capture fisheries and the increasing demand for fish products, the price may increase significantly in the future, undermining the profitability of intensive aquaculture.

Conditions for improved sustainability

It is clear that more sustainable shrimp farming will be difficult to achieve without a comprehensive and integrated set of interventions and initiatives by government, development agencies, planners, extension agents, farmers, NGOs, processors/traders, and researchers. Together, these parties should promote or facilitate:

- More rational and appropriate land and water use;
- More rational and equitable resource access or allocation;
- Conflict resolution;
- Protection of the environment;
- Improved monitoring and regulation related to disease incidence; and
- Improved water management, supply, and wastewater disposal.

The role of national and local governments in coordinating and promoting appropriate interventions will be crucial to the future sustainability of shrimp culture. Legal and planning frameworks may need to be adapted and improved to take account of the specific requirements for the industry's sustainability. Ideally, these frameworks would specifically address the needs of coastal aquaculture (FAO 1998), and would include:

- Provision for sector environmental assessment, leading to the creation of provincial or district-level coastal aquaculture development and environmental management plans;
- Provisions for the development of national guidelines or codes of practice for the design and operation of coastal aquaculture, and/or procedures for developing such guidelines at provincial or district levels; and

- Requirements and guidance for feasibility studies, project planning and design, and project environmental impact assessment.

Government coastal aquaculture development strategies may be a useful step toward developing such frameworks.

In addition, government, banks, and international agencies should seek to facilitate a range of other initiatives, perhaps including marketing and environmental labeling schemes; farmer organization and representation; research, pilot, and demonstration projects (design, technology, and management at farm level; environmental management at district or provincial level); and more detailed codes of design and practice appropriate to specific circumstances.

The technical basis for most of these interventions now exists and has been thoroughly reviewed in this and other recent publications. It is now up to national and local government, in close collaboration with the industry itself, to take the responsibility and initiative to facilitate the development and management of sustainable shrimp culture.

The present study has revealed a number of issues that are not properly documented and about which too little is known. In particular, very few studies have thoroughly assessed both the positive and negative social and environmental impacts of shrimp aquaculture.

The Bank now has an opportunity to assist with, and contribute to, the ongoing processes of generating reliable information and building consensus. In particular, there is a need to organize a series of expert consultations on key issues raised in this report. Recent meetings and consultations that have been held are listed, along with the types of participants, in Annex 5.

There is also a clear need for capacity building, especially in relation to aquaculture development planning integrated with coastal management initiatives. These may in turn lead to a need for specific technical assistance and investment.

Further investigation

As a follow-up to the present report, it is proposed that field studies in different countries be undertaken in order to obtain primary data on issues where present knowledge is incomplete. (Studies that have been undertaken by the consortium, including proposed titles, are listed in Annex 4.) Areas for research focus should include:

- Sustainability;
- Legislation and experience with existing regulations and procedures;
- Regulatory and enforcement instruments;
- Tax incentives;
- Socioeconomic impacts of shrimp farming; and, specifically,
- Employment effects.

Sustainability

The question of whether sustainable shrimp farming is possible, and under which conditions, has been answered in part through this study. However, a number of issues need to be identified, and measures taken, in order to formulate a comprehensive policy for sustainable shrimp farming in a country. The following issues and measures, in particular, are important:

- An appropriate institutional and legal framework for aquaculture needs to be established;
- Integrated management of catchment and coastal areas in which aquaculture is contemplated must be taken into account;
- Appropriate institutional mechanisms and human skills must be identified; and
- The devolution of management to the lowest level of responsibility should be instituted (while recognizing the responsibility of government to provide the appropriate legal and institutional framework), and the required technical support should be provided.

The field studies are examining these issues and experiences in countries included in this study in order to better document the preliminary conclusions drawn in this report.

Environmental capacity is often referred to in discussions of sustainability, but the concept has been used very little in developing countries. There is a need to clarify the nature of environmental capacity and how it can be used to promote the sustainable development of aquaculture and other activities in the coastal zone.

Social impact of shrimp farming

The issue of the social impact of shrimp farming has been mentioned by many authors, and several cases of social unrest have been reported. However, few, if any, attempts have been made to study the causes and the overall impacts of these incidents, or of aquaculture's social effects in general. Furthermore, very few studies have assessed comprehensively the overall social, environmental, and economic costs and benefits of aquaculture to particular areas or countries. Social impact is another component of the ongoing field studies.

Legislation, regulations, and existing experience

Legislation related to shrimp farming has been introduced in some countries, but little is known about the implementation and effects of the associated rules and regulations. In other countries, specific legislation has governed aquaculture development for many years. The field studies should focus on legislation related to shrimp farming and should draw on experience with other types of aquaculture, in countries where such legislation has been in place for many years.

Countries of specific interest in this regard include:

- Thailand (as a major shrimp farming country with limited legislation);
- Ecuador (as a major producer with very different scales and intensity of activities and land use controls);
- Sri Lanka (which has significant relevant legislation that has not always been effective);
- China (which in some cases has strong central or provincial government control, and has recently embarked on ICM initiatives);
- Vietnam (which has a rapidly expanding shrimp industry based mainly on very small-scale producers);
- Indonesia (because of the scale and dispersion of the industry), and
- Norway (as a salmon farming country with a long history of legislation related to aquaculture).

In addition to legislation proper, the associated and accompanying regulatory instruments should be examined in detail, and their effects should be identified. It would be practical and most effective to study regulations in the same countries where legislation is studied.

Economic incentives

While economic incentives to promote the development of shrimp farming (or aquaculture in general) have been introduced in a number of countries, speculation about their effects is rampant. There is consequently a need to establish reliable conclusions about the results of such incentives. Field studies should examine tax and other economic incentives introduced to promote aquaculture and particularly the results of these incentives. However, tax incentives to promote *sustainable* aquaculture seem to be less common and less widely understood. Field studies are needed to identify various forms of tax incentives and constraints that are expected to promote sustainable aquaculture, and, to the extent possible, the experiences and lessons learned from their use. It appears that countries of interest in this regard would include Thailand, Malaysia, Indonesia, and Norway.

Enforcement instruments

The present study has indicated that law enforcement instruments are either lacking or not used as intended, for a number of reasons. Field studies need to examine cases of failure and success in this regard and propose a general framework for establishing law enforcement instruments, particularly for developing countries, while taking into account such illicit practices as corruption.

Employment

As mentioned in the report, too little is known about the employment effects of shrimp farming. Arguments are made that aquaculture creates employment both directly and indirectly. On a global scale, it is estimated that at least 1 million people are directly employed in shrimp culture. Estimates suggest that the number of people employed in related activities is many times that figure. If processing, packaging, and distribution are done in the area, the local employment figures rise considerably.

In order to obtain better measures of the employment effects of shrimp aquaculture, field studies should examine labor statistics and other data at each of the farms and in each of the countries included in the present study. These data should be analyzed with regard to both the volumes and types of employment the aquacultural activities have created. This study should build on previous surveys, such as the one undertaken by NACA and the ADB (1994).

Particular attention should be paid to the overall organization of production systems that use labor in innovative ways. These practices could include such approaches as institutionalized perks and bonuses, incentives, joint ventures, spin-off businesses owned by workers, ESOPs (employee stock option programs), and others. While most shrimp farmers do not start their businesses in order to create innovative systems for using labor, many of them have in fact done just that. These experiences should be documented so that they can be shared with others.

Case studies

Case studies focusing on the above aspects of the industry should be undertaken to illustrate the issues and opportunities. Since this report was drafted, many such research studies have started, and some of them have been written up; they are listed in Annex 4. The case studies are intended to review and evaluate cases of both success and failure in shrimp farming and identify contributing factors. It is proposed that the study teams include and be supported by local experts in each country.

The field studies should focus on the social impact of shrimp farming in countries where extreme results have been observed, such as Bangladesh, India, Honduras, Thailand, Ecuador, and Madagascar. In these countries, special focus should be placed on social issues, regulations and corruption, government plans, environmental concerns, and implications for World Bank support.

The following nations should be studied, with research including the specified issues:

- **Thailand**: government initiatives to alleviate negative environmental impacts, including legislation, regulatory and enforcement instruments, tax incentives, employment effects;
- **India**: social impact of shrimp farming, violence, displacement, net employment effects;
- **Bangladesh**: social impact of shrimp farming, the role of women, violence, displacement, net employment effects, rural income;
- **Honduras**: social impact of shrimp farming, how conflicts led to a moratorium on new projects and zoning restrictions in others, net employment impacts, conflicts with other resource users;
- **Norway**: legislation, regulatory, and enforcement instruments; experiences and lessons learned from implementing this legislation; employment effects;
- **Ecuador**: social issues, regulations and corruption, government plans, environmental concerns; and
- **Madagascar**: social issues, regulations and corruption, government plans, and environmental concerns.

Expert consultations on shrimp farming and the environment

The present study suggests that a series of consultations and workshops be undertaken to help promote the issues and agendas identified here. These consultations would explore further the impact of shrimp aquaculture on the environment, in a more targeted way. The focus of such meetings could include, but not necessarily be limited to, identifying indicators, legislation and regulatory frameworks, disease, introduced species, mangroves and other fragile coastal wetlands, BMPs (better management practices), and social and equity issues. Other meetings and workshops could be undertaken with producers and producer groups that would help disseminate the more specific operational findings of the case studies.

Pilot projects in sustainable shrimp culture development

As noted repeatedly in this document, the key to sustainable shrimp farming is effective and informed planning, coupled with powerful incentives or constraints to site, design, construct, and operate farms in particular ways. One increasingly discussed incentive is environmental quality certification linked to labeling initiatives—associated, it is hoped, with a market premium. One case study should explore the implications of certification for shrimp aquaculture. A related study could explore the use of BMP-based screens for investors and institutional purchasers, as a way to send signals to producers from both ends of the market.

It might be interesting to test the feasibility of linking a retail labeling scheme to one or more groups of small-scale shrimp producers in a developing country who are all operating within some planning framework, set of best practices, or agreed-upon code of practices. If this practice worked, it might then be extended to other groups.

ANNEX 1: A BLUEPRINT FOR FEASIBILITY STUDIES

A typical feasibility study for a shrimp-farming project should cover, but not necessarily be limited to, the following content:

1. Summary of the project background and history

- Name and contact information for the project promoter/developer;
- Project background and history;
- Project objective and outline of the proposed strategy, including geographical scope and market share, cost leadership, differentiation, and market niche;
- Project location: proximity and access to the proposed market(s) and to supplies and raw materials; and
- Economic and industrial policies supporting the project (World Bank 1996).

2. Review of government regulations and legislation

- Licenses necessary and other restrictions; and
- Other relevant government regulations and requirements.

3. Summary of market analysis and marketing strategy

- A summary of the results of market research: business environment, target market and market segmentation (consumer and product groups), channels of distribution, competition, life cycle of the operation and of market demand (if any); expected project impact on local or regional markets for shrimp;
- List of annual data for demand (seasonal data if available), quantities and prices, and supplies; estimates of past, present, and future demand and supplies;
- Explanation and justification of the marketing strategies for achieving project objectives and an outline of the marketing concept;
- Indication of projected marketing costs, elements of the projected sales program and revenues (quantities, prices, market share, and other factors); and
- Description of impacts on raw materials, supplies, and the local environment; resulting effects on the production program, including capacity and the technology to be utilized.

4. Raw materials and supplies

- Description of the general availability of raw materials, feed, water, PL, chemical amendments, energy if applicable, and other physical inputs to production;
- List of annual supply requirements (PL, feed, etc.) and explanation of how each will be met; and
- Summary of the availability of critical supplies (for example water, PL and feed) and plans for responding to potential crises.

5. Location, site, and local environment

- Review of coastal zone plans and adaptation of the project to these plans;
- Ecological and environmental impact (including EIA studies);
- Socioeconomic policies, incentives, and constraints (including SIA studies);
- Identification and description of location and pond site(s) selected, including:
  - Infrastructural conditions
  - Review of water resources available (including water rights and supply)
  - Review and analysis of soil conditions
  - Review of temperature conditions and seasonal variations
  - Review and analysis of discharge options and the need for constructed pond settlement areas
- Summary of critical aspects and justification of site selection; and
- Outline of significant costs relating to the chosen location and site.

6. Technology and engineering

- Outline of the production program and production capacity;

- Evaluation and selection from different farming models (semi-intensive, intensive);
- Evaluation of planned stocking densities;
- Description and justification of technologies selected (including advantages and disadvantages), explanation of how the technology is adapted to local conditions (including social and physical environment), risk control, and costs, training, legal aspects;
- Description and evaluation of water treatment options and justification of selected method;
- Description of the layout and scope of the project;
- Summary of main aspects of the physical installations (ponds, pumps, equipment), availability of installations/parts, maintenance aspects, and costs; and
- Description of major required works to be built as part of the development of the operation.

7. Management, organizational structure, and human resources

- Description of basic organizational design, management plan, and measures required to implement;
- Estimate of overhead costs;
- Description of human resources availability, recruitment and training needs, and the reasons for the employment of foreign experts (if any);
- Indication of key personnel/skills required and total employment numbers, both during construction, during start-up, and during full operation, including use of construction workers after the construction period; and
- Description of local/regional socioeconomic and cultural aspects related to significant project requirements and impacts.

8. Project implementation schedule

- Indication of duration of construction;
- Indication of duration of production start-up period;
- Planned stocking and cropping schedules for the ponds; and
- Identification of any critical actions needed for successful implementation.

9. Financial analysis and investment appraisal

- Summary of criteria governing investment appraisal;
- Total investment costs:
  - Major investment data, showing local and foreign components
  - Land and site preparation
  - Structures and civil engineering works
  - Machinery and equipment
  - Auxiliary and service equipment
  - Incorporated fixed assets
  - Other preproduction expenditures and capital costs
  - Net working capital requirements
- Total costs of production:
  - Operating costs
  - Depreciation charges
  - Marketing costs
  - Financing costs
- Project financing:
  - Source of finance
  - Impact of cost of financing and debt service on project proposal
  - Relevant public policies on financing;
- Investment appraisal key data:
  - Discounted cash flow (internal rate of return, net present value)
  - Pay-off period
  - Yield generated on total capital invested and on equity capital
  - Yield for parties involved, as in joint venture projects
  - Significant financial and economic impact on the national economy
- Aspects of uncertainty, including critical variables, risks, possible strategies/means of risk management, probable future scenarios and possible impact on the financial feasibility of the project;

- Sensitivity calculations and analyses related to variations in input values; and
- Conclusions:
  - Major advantages of the project
  - Major drawbacks of the project
  - Assessment of chances of implementing the project.

ANNEX 2: STATISTICAL TABLES

TABLE A1: WORLD PRODUCTION OF SHRIMP: WILD CATCH AND AQUACULTURE (1000S OF MT)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Catches	1,947	2,043	2,107	2,149	2,361	2,440	2,554	2,629	2,749	3,034	3,081
Aquaculture	659	813	867	823	867	932	926	911	974	1,033	1,021
Sum	**2,606**	**2,856**	**2,974**	**2,972**	**3,228**	**3,372**	**3,480**	**3,540**	**3,723**	**4,067**	**4,102**

Source: FAO Aquaculture statistics, 2001

TABLE A2: WORLD SHRIMP PRODUCTION BY MAJOR SPECIES GROUPS (IN MT)

Species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Penaeid shrimp	1,436,278	1,662,876	1,704,452	1,707,237	1,869,986	1,936,381	1,913,524	1,945,956	2,066,037	2,372,413	2,314,437
Metapenaeid shrimp	56,502	57,071	56,221	63,709	66,765	73,088	71,706	95,893	83,552	75,612	85,535
Pandalus spp	279,454	285,311	310,605	308,212	301,426	328,164	343,015	340,224	364,483	393,019	415,459
Other	850,003	872,010	925,510	870,751	1,013,146	1,059,815	1,178,403	1,192,151	1,248,013	1,277,877	1,352,935
Sum	**2,622,237**	**2,877,268**	**2,996,788**	**2,949,909**	**3,251,323**	**3,397,448**	**3,506,648**	**3,574,224**	**3,762,085**	**4,118,921**	**4,168,366**

Source: FAO Aquaculture Statistics, 2001

TABLE A3: WORLD SHRIMP FARMING PRODUCTION BY COUNTRY (IN MT)

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Thailand	119,510	162,051	184,884	225,515	267,764	260,713	240,609	227,860	253,001	275,544	299,700
Ecuador	76,420	105,238	113,137	85,472	98,731	105,597	107,920	132,709	144,000	119,700	50,110
Indonesia	107,295	140,131	141,690	138,786	167,410	146,608	151,759	167,445	118,111	140,946	138,023
Philippines	53,989	51,434	78,397	95,816	92,647	90,179	78,067	41,610	37,798	35,573	41,803
India	29,985	35,500	40,000	72,200	91,974	97,539	95,152	65,581	78,709	71,072	52,771
China	184,817	219,571	206,866	87,856	63,872	78,416	88,851	102,923	143,086	170,830	217,994
Taiwan, ROC	18,126	23,318	17,693	14,378	9,242	12,234	13,472	5,926	5,549	6,065	7,237
Others	72,211	85,457	97,952	115,137	128,977	166,480	177,188	201,010	232,809	265,145	279,473
Sum	**662,353**	**822,700**	**880,619**	**835,160**	**920,617**	**957,766**	**953,018**	**945,064**	**1,013,063**	**1,084,875**	**1,087,111**

Source: FAO Aquaculture Statistics, 2001

Table A4: World shrimp farming production by species **(in MT)**

Species	Scientific name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Banana prawn	*Penaeus merguiensis*	30,473	32,211	33,491	39,201	43,522	44,994	44,994	41,497	43,109	37,150	45,717
Kuruma prawn	*Penaeus japonicus*	9,417	14,077	7,739	2,491	2,295	2,240	2,809	2,890	2,549	2,383	2,639
Blue shrimp	*Peaneus stylirostris*	8,080	11,582	12,741	9,739	11,973	9,796	10,758	14,787	15,773	12,338	-
Whiteleg shrimp	*Penaeus vannamei*	82,012	111,413	120,457	94,184	109,447	141,739	140,180	172,609	197,567	186,573	143,737
Black tiger prawn	*Penaeus monodon*	250,777	332,729	391,462	434,887	505,658	599,808	570,241	487,921	508,366	544,627	571,498
Eastern king prawn	*Penaeus plebeius*	0	0	0	0	0	1	1	0	0	0	0
Fleshy prawn	*Penaeus chinensis*	185,074	220,036	207,428	88,128	64,389	78,820	89,228	104,456	143,932	171,972	219,152
Caramote prawn	*Penaeus kerathurus*	0	0	0	0	0	1	1	1	1	1	1
Brown tiger prawn	*Penaeus esculentus*	7	0	0	0	0	1	1	0	0	0	0
Northern white shrimp	*Penaeus setiferus*	0	0	0	0	0	1	1	1	0	0	0
Indian white prawn	*Penaeus indicus*	1,060	1,350	1,500	1,874	2,244	3,429	3,124	3,209	3,201	3,672	4,370
Redtail prawn	*Penaeus penicillatus*	1,769	877	907	2,233	217	150	116	144	137	107	44
Penaeus shrimp nei	*Penaeus spp*	43,739	48,797	59,009	97,657	123,080	46,823	63,744	70,791	79,695	95,279	75,694
Eastern school shrimp	*Metapenaeus macleayi*	10	2	0	0	0	1	1	0	0	0	0
Endeavour shrimp	*Metapenaeus endeavouri*	5,619	4,249	1,640	9,490	1,843	-	-	-	-	-	-
Metapenaeus shrimp nei	*Metapenaeus spp*	23,641	21,920	22,747	23,907	25,894	26,193	28,422	42,090	22,017	20,575	20,916
Akiami paste shrimp	*Acetes joponicus*	1,389	3,735	104	228	200	1,392	673	328	264	93	544
Common prawn	*Palaemon serratus*	160	60	30	30	30	110	140	225	163	98	110
Nantantian decapods	*Nantantia*	19,091	19,612	21,319	31,066	29,775	429	330	323	329	904	605
Sum	**Sum**	**662,363**	**822,700**	**880,619**	**835,160**	**920,617**	**955,928**	**954,764**	**941,272**	**1,017,103**	**1,075,772**	**1,085,027**

Source: FAO Aquaculture Statistics, 2001

ANNEX 3: EXPERTS CONTACTED

Herbert Acquay	Global Environment Facility Washington DC, USA
Uwe C. Barg	FAO, Rome, Italy
Sofia Bettencourt	World Bank Washington DC, USA
Herman Cesar	IVM Amsterdam, Netherlands
Jason Clay	World Wildlife Fund Washington DC, USA
Marianne Damhaug	NORPLAN Oslo, Norway
Fatima Ferdouse	INFOFISH Kuala Lumpur, Malaysia
William B. Folsom	NOAA Washington DC, USA
Olav Kjorven	Consultant Oslo, Norway
Marja Lehtinen	FAO Rome, Italy
Audun Lem	FAO Rome, Italy
Stephen Lintner	World Bank Washington DC, USA
Carl Gustaf Lundin	World Bank Washington DC, USA
Jan Raa	Fiskeriforskning (Norwegian Fisheries Research Institute) Tromsø, Norway
Dale Sarver	Black Pearls, Inc. Hawaii, USA
Lou Scura	World Bank Washington DC
Tarlochan Singh	INFOFISH Kuala Lumpur, Malaysia
Albert G.J. Tacon	Consultant Hawaii, USA
Juergen Voegele	World Bank Washington DC, USA
Dennis Weidner	NOAA Washington DC, USA
Ronald Zweig	World Bank Washington DC, USA

ANNEX 4: CASE STUDIES UNDERTAKEN BY THE CONSORTIUM

Thematic Reviews
Thematic Review of Coastal Wetland Habitats and Shrimp Aquaculture Prepared by: *Donald J. Macintosh, Michael J. Phillips, Robin Lewis III and Barry Clough*
Codes of Practice for Marine Shrimp Farming Prepared by: *Claude Boyd, John Hargreaves and Jason Clay*
Thematic Review on Management Strategies for Major Diseases in Shrimp Aquaculture Report of the Workshop held in Cebu, Philippines from 28-30 Nov1999
Thematic Overview of Social Equity, benefits and Poverty Alleviation BMP's of the Shrimp Aquaculture Industry Prepared by: *Jason Clay*
An Analysis of Shrimp Aquaculture Legislation Prepared by: *Annick Van Houtte and William Howarth*
Innovation and the Implementation Deficit: Assessing Shrimp Producing Countries Based on Their Effectiveness in Implementing the FAO's Code of Conduct for Responsible Fisheries and Related Guidelines and Standards in the Context of Shrimp Aquaculture Prepared by: *David Barnhizer*
Chemical and Biological Amendments Used in Shrimp Farming Prepared by: *Claude E. Boyd*
Global Review of Feeds Management Practices in Shrimp Aquaculture Prepared by: G J Tacon

Country	**Asia-Pacific Countries**
Australia	The Environmental Management of Shrimp Farming in Australia Prepared by: *Nigel Preston, Peter Rothlisberg, Michele Burford and Chris Jackson*
Bangladesh	Social Aspects of Shrimp Aquaculture in Bangladesh Prepared by: *Anwara Begum and S.M. Nazmul* Case Studies on Shrimp Aquaculture Management in Bangladesh Prepared by: *Rahman M., P.P.G.S.N. Siriwardena and Wajed Shah*

China	Shrimp Farming in Rushan Country, China Prepared by: *Anantha Kumar Duraiappah*
India	The Role of Small Farmer Groups and Associations in Sustainable Shrimp Aquaculture Management Prepared by: *Kutty, M.N., P. Ravichandran, M. Krishnan, M. Kumaran and C.P. Balasubramanian*
Indonesia	Good Practices for Community-Based Planning and Management of Shrimp Farming in Sumatra, Indonesia Prepared by: *James Tobey, Hermawati Poespitasari and Budy Wiryawan*
Philippines	Mangrove Management and Aquaculture in the Philippines Prepared by: *Dioscoro M. Melana, E.E. Melana, C.E. Yao and Edgar L. Abuan*
Sri Lanka	Report on a Code of Good Management Practices for Shrimp Aquaculture in Sri Lanka Prepared by: *Siriwardena, P.P.G.S.N.*
Thailand	Case Study on Institutional Aspects of Shrimp Aquaculture in Thailand Prepared by: *Nissapa, Ayut and Somsak Boromthaanarat*
Thailand	Assistance and Issues in the Implementation of the Code of Conduct for Shrimp Aquaculture Prepared by: *Siri Tookwinas*

Country	**Latin American Countries**
Belize	Evaluation of Belize Aquaculture, Ltd. - A Super-Intensive Shrimp Aquaculture System in Belize Prepared by: *Claude E. Boyd and Jason Clay*
Brazil	Key Management Challenges for the Development and Growth of a Shrimp Farm in Northeast Brazil -- A Case Study of Camanor Produtos Marinhos Ltd. Prepared by: *Barbara Schwab, Michael Weber and Bernard Lehmann*
Brazil	Barriers to Investing in Shrimp Aquaculture – Lessons from Brazil Prepared by: *Patricia Moles..*
Colombia	The Integration of Mangrove and Shrimp Farming: The Case Study of Agrosoledad on the Caribbean Coast of Colombia Prepared by: *Dominique Gautier*

Colombia	The Adoption of Good Management Practices by the Shrimp Industry on the Caribbean Coast of Colombia Prepared by: *Dominique Gautier*
Ecuador	Case studies on shrimp aquaculture management in Ecuador covering: (I) Use of wild post larvae (II) Composition of shrimp pond soils in former mangrove versus non-mangrove areas (III) Farm management and concentration of potential pollutants in effluents (IV) Water exchange practices (V) Status of mangrove forests Prepared by: *Jorge Calderon, Stanislaus Sonnenholzner and Claude E. Boyd*
Honduras	Science and Society in the Gulf of Fonseca: The Changing History of Mariculture in Honduras Prepared by: *Denise Stanley, Carolina Alduvin and Amanda Cruz*
Honduras	Coastal Water Quality Monitoring in Shrimp Farming Areas with an Example from Honduras Prepared by: *Claude E. Boyd and Bart Green*
Mexico	Shrimp Aquaculture, People and the Environment in Coastal Mexico Prepared by: *Billie R. De Walt, Lorena Noriega, Jaime Renan Ramirez Zavala and Rosa Esthela Gonzalez*

Country	**Africa and the Middle East**
Regional	Review on Shrimp Farming in Africa and the Middle East Prepared by: *Rafael Rafael and Jason Clay*

ANNEX 5: MEETINGS AND STAKEHOLDER CONSULTATIONS

Location	**Appendix A--Meetings Held or Attended in 1999-2002 to further the Work of the Consortium.**	Participants	Producers	Govt. officials	Multi-lateral orgs	Bi-lateral orgs	NGOs	Researchers /universities	Community groups	Investors/ Funders	Buyers	Certifiers	Trade associations	Consultants
Vinh, Nghe Anh, Vietnam	Provincial level stakeholders workshop on shrimp aquaculture management in Nghe An province, Vietnam (NGOs in the Vietnam context = Women's union, Youth Union and non-aquaculture farming and community groups) (one day workshop, March 2000)	30	✓	✓			✓	✓	✓					
District and Villages in Nghe Anh, Hai Phong and Quangh Binh provinces, Vietnam	Stakeholder workshops in districts of Quynh Luu, Quang Thuan, Bang La, Quang Thuan, Quynh Bang, Quang Binh and Do Son, covering livelihood analyses, wealth ranking, social impacts of shrimp aquaculture and poverty. (7 workshops in total, in March-April 2000)	140	✓	✓			✓	✓	✓					
Hanoi, Vietnam	Scoping workshop on "Sustainable Aquaculture for Poverty Alleviation" ("SAPA"). National level workshop to present findings of research and broadly discuss the role of aquaculture in poverty alleviation in Vietnam. (23rd-25th May 2000).	60	✓	✓	✓	✓	✓	✓	✓					✓
Hanoi, Vietnam	Follow up workshop to approve a government policy document on "Sustainable Aquaculture for Poverty Alleviation" ("SAPA") (14th September 2000).	40	✓	✓	✓	✓	✓	✓	✓					✓
Khulna district, Bangladesh	Primary stakeholder workshops (women, shrimp cultivators, agriculture farmers, landless) in three "polders" in Khulna district (March 2000)	182	✓				✓	✓	✓					
Khulna district, Bangladesh	District, upazilla secondary stakeholders workshop on shrimp aquaculture in Khulna district (4 one day workshops, March 2000)	87	✓	✓			✓	✓	✓	✓	✓			
Dhaka, Bangladesh	Workshop on shrimp aquaculture case studies in Bangladesh (presentations of draft case study findings) (3rd July 2000)	51	✓	✓	✓	✓	✓	✓						✓
Nice, France	World Aquaculture Society meeting	2,500	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Thailand	Local workshops on the Thai Code of Conduct for Responsible Shrimp Aquaculture (Rayong and Hat Yai) (June/July 2000)	15	✓	✓			✓							
Bangkok, Thailand	Workshop to prepare the thematic review on coastal wetland habitats and shrimp aquaculture (14th-16th February 2000)	25	✓	✓			✓	✓						✓
Bangkok, Thailand	NACA/FAO/Government of Thailand Conference on Aquaculture in the Third Millenium. (20th-25th February 2000)	550	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓

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Negombo, Sri Lanka	Sri Lanka consultations on development of a Code of Practice (March 2000)	50	✓	✓			✓							
Various locations, the Philippines	Local workshops held at 4 coastal locations in the Philippines	60+	✓	✓		✓	✓		✓					
Cebu, Philippines	Management strategies for major diseases in shrimp aquaculture. (28th-30th November 1999)	40	✓	✓	✓		✓	✓					✓	✓
Puerto Vallarta, Mexico	Trans-boundary aquatic animal pathogen transfer and the development of harmonized standards on aquaculture aquaculture health management (joint APEC/FAO/NACA consultation) (24th-28th July 2000)	49	✓	✓	✓		✓							✓
Brisbane, Australia	FAO/Australia consultation on management practice and institutional and legal arrangements for shrimp aquaculture (4th-7th December 2000)	65	✓	✓	✓	✓	✓	✓				✓	✓	✓
Beijing, China	Final workshop on Asia Regional Health Management for the Responsible Transboundary movement of live aquatic animals (27th-30th June 2000)	45		✓	✓	✓								
Dhaka, Bangladesh	Regional workshop on "Primary aquatic animal health care in rural, small-scale, aquaculture development" (27th-30th September 1999) (participants from 12 countries)	48	✓	✓	✓	✓	✓	✓						✓
Hanoi, Vietnam	Meeting on a potential Code of Practice for shrimp aquaculture in Vietnam (December 2000)	17	✓	✓		✓		✓						✓
Hanoi, Vietnam	Workshop for drafting of EIA guidelines for government on coastal aquaculture developments in Vietnam (13th December 2000)	10		✓		✓	✓	✓						✓
London, UK	Meeting with the Marine Stewardship Council, December 1998	7										✓		
Guayaquil, Ecuador	Annual meeting of ISANet. December 1998	30					✓	✓	✓					✓
Guayaquil, Ecuador	Meeting with the Ecuadorian Shrimp Industry. January 1999	20	✓				✓	✓			✓		✓	✓
Washington, DC	Meeting with Oceanographic Institute and World Bank, 24 May 1999	5			✓			✓						
Washington, DC	Meeting with US-based NGOs on Shrimp Aquaculture, 25 May 1999	5					✓	✓						
Washington, DC	Meeting on Economic Analysis of Shrimp BMPs	3					✓	✓						
Caracas, Venezuela	Meeting with WWF Latin American Marine Program staff to discuss shrimp aquaculture. May 1999	20					✓							✓

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Auburn University, USA	Presentation to Auburn U. Aquaculture Staff. June 2, 1999.	26						✓						✓
Los Altos, CA, USA	Met with Packard Foundation to advise on the priorities for their expanded marine program	15						✓		✓				✓
San Diego, CA, USA	Spoke about consortium's work at Coastal 99 meeting sponsored by Sustainable Resources Division of NOAA in light of US goal to increase aquaculture output 5-fold in 20 years. July 1999	125	✓	✓			✓	✓	✓		✓		✓	✓
Washington, DC, USA	NOAA meeting to discuss implications of reaching goal of increasing aquaculture production 5-fold in 20 years. August 1999.	250	✓	✓			✓	✓	✓				✓	✓
Salzburg, Austria	Salzburg Seminar on sustainable development in the humid tropics. Aquaculture featured. Clay gave keynote. August 1999.	90			✓	✓	✓	✓		✓				✓
Guayaquil, Ecuador	Bi-Annual Meeting of the National Shrimp Producers Association. October 26-31.	500	✓	✓			✓	✓			✓	✓	✓	✓
San Francisco, CA, USA	Meeting of the Marine Program of the Packard Foundation on fisheries (including shrimp) market chain analysis. November 18-19, 1999.	10					✓	✓			✓			✓
Belize	Met with Belize Aquaculture and other producers to tour operations and discuss BMPs for shrimp aquaculture. December 12-15, 1999.	12	✓				✓	✓						✓
Bangkok, Thailand	NACA/WWF/WB/FAO meeting to discuss BMP work and the role of the consortium. April 20-23, 1999.	40	✓	✓	✓		✓	✓	✓					✓
Sydney, Australia	World Aquaculture Society Meetings. Session on shrimp aquaculture and the environment. April 27-30, 1999.	150	✓	✓			✓	✓						✓
Maputo, Mozambique	Meeting on Threats to the East African Marine Ecoregion. Discussion on shrimp aquaculture. January 14-21, 2000.	25			✓		✓	✓	✓					✓
New Orleans, LA, USA	Aquaculture America 2000. Talk on NGOs and Aquaculture and the identification and use of BMPs to improve performance. February 4, 2000.	125	✓	✓			✓	✓	✓					✓
New Orleans, LA, USA	Aquaculture America 2000. Session on Environmentally Sound Aquaculture. February 3, 2000.	150	✓	✓			✓	✓						✓
San Francisco, CA, USA	Marine Working Group, Consultative Group on Biodiversity. Talk on Promoting Sustainability through Certification, Marketing and Consumer Awareness. February 10, 2000.	45					✓	✓		✓		✓		✓

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San Francisco, CA, USA	Marine Working Group, Consultative Group on Biodiversity. Talk on the Consortium's work on BMPs for shrimp aquaculture. February 10, 2000.	50					✓	✓		✓		✓		✓
Bangkok, Thailand	ISANet Annual Meeting. February 19, 2000.	40					✓	✓	✓	✓				✓
Bangkok, Thailand	Meeting with ISANet to discuss the work of the consortium. February 20, 2000.	12					✓	✓	✓					✓
Bangkok, Thailand	Meeting on Organic Shrimp Certification with Agro-Eco. February 24, 2000.	7	✓	✓			✓	✓				✓		
Bangkok, Thailand	Expert consultation on the Proposed Sub-Committee on Aquaculture of the Committee of Fisheries to advise the FAO on the mandate of an aquaculture subcommittee. February 28-29, 2000.	35	✓	✓	✓	✓	✓	✓						✓
Washington, DC, USA	Gulf of Mexico shrimp fishery modeling session. March 4-5, 2000.	20		✓			✓	✓						✓
London, UK	Chatham House session on Business and Biodiversity. Discussed BMPs and shrimp aquaculture. April 3, 2000.	140	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓
Mohonk, NY, USA	Social Venture Network Meeting on sustainability. Discussed BMPs using shrimp aquaculture as an example. April 13-16, 2000.	350	✓				✓	✓		✓	✓	✓	✓	✓
Monterey, CA, USA	SeaWeb/Packard Foundation Seafood Consumer Initiative Workshop. April 26-27, 2000.	55					✓	✓			✓	✓	✓	✓
Recife, Brazil	Meeting at Instituto Josue de Castro on shrimp aquaculture. May 22, 2000.	60	✓	✓			✓	✓	✓					✓
Recife, Brazil	Mangrove 2000 Conference. University of Pernambuco. Talk on the work of the consortium. May 23, 2000.	250	✓	✓			✓	✓	✓					✓
Recife, Brazil	Mangrove 2000 Conference. University of Pernambuco. Talk on BMPs and shrimp aquaculture development in Brazil. May 24, 2000.	200	✓	✓			✓	✓	✓					✓
Recife, Brazil	Mangrove 2000 Conference. University of Pernambuco. Talk on the Mexican case study of the consortium. May 24, 2000.	150	✓	✓			✓	✓	✓					✓
New London, NH, USA.	Second International Industrial Ecology Conference: Engineering Global Systems. Gordon Conference. Talk comparing the environmental impacts of aquaculture and fisheries. June 11-16, 2000.	130		✓			✓	✓						✓

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Washington DC, USA	World Wildlife Fund staff meeting. Presented the work of the consortium. July 14, 2000.	75					✓	✓						✓
Georgetown, Guyana	Addressed the President and Members of Parliament regarding natural resource management, BMPs and marketing. September 11, 2000.	150		✓		✓	✓	✓						✓
Zurich, Switzerland	Addressed WWF-Switzerland Conference on the identification and use of BMPs. October 18-19, 2000.	80					✓	✓						✓
Washington, DC, USA	Addressed ISANet Board on preliminary findings of the consortium's work. October 22-23, 2000.	12					✓	✓						✓
Panama City, Panama	Fourth Latin American Aquaculture Congress and Exhibition. October 25-28, 2000.	300	✓	✓	✓		✓	✓		✓	✓		x	✓
London, UK	Addressed Ford Foundation Environmental Staff about the use of BMPs to improve environmental performance, natural resource management and marketing. November 2, 2000.	25					✓	✓		✓				✓
Baja, Mexico	Pew Fellows' Fifth Anniversary Meeting of Marine Fellows. November 5, 2000.	75					✓	✓		✓				✓
Washington DC, USA	Met with Marine Aquarium Council to discuss differences between certifying aquaculture and wild caught products. November 20, 2000.	4					✓							
Washington DC, USA	Addressed the IFC's agriculture and sustainability divisions on BMPs with reference to shrimp aquaculture and agriculture. November 21, 2000.	35			✓		✓							
Washington DC, USA	Met with Inter-American Development Bank's Multi-Lateral Investment Fund to discuss shrimp aquaculture, the use of BMP screens for their investments, and the establishment of a trading company to handle third-party certified production. November 20, 2000.	3			✓		✓							
Washington DC, USA	Met with the International Finance Committee of the World Bank Group to discuss the use of BMPs for investment screens for shrimp aquaculture, January 2001	50			✓		✓							
Boston, MA, USA	Stakeholder meeting on aquaculture development in New England, USA, January 2001	150	✓	✓		✓	✓	✓	✓	✓	✓			✓
Vancouver, BC, Canada	Multi-stakeholder meeting on aquaculture development with particular emphasis on VC, Colombia, January 2001	120	✓	✓			✓	✓	✓	✓	✓		✓	✓

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San Francisco, CA, USA	Session on Aquaculture at the AAAS annual meeting. February 2001	125		✓			✓	✓						✓
Orlando, FL, USA	Session on the work of the consortium at the World Aquaculture Society annual meeting. January 2001	75	✓	✓	✓	✓	✓	✓			✓		✓	✓
Tana, Madagascar	Preliminary meeting with shrimp producers, consultants, NGOs and government officials regarding the potential of creating BMP-based regulations, permits and licenses for the shrimp industry. April 2001.	8	✓	✓	✓		✓							✓
Cartejena, Colombia	Meeting on certification potential of shrimp aquaculture with the Colombian Shrimp association. May 2001	30	✓	✓			✓	✓			✓			✓
Philadelphia, PA, USA	WWF sponsored meeting on the development of a certification program for shrimp aquaculture. July 2001	20	✓		✓		✓	✓		✓	✓	✓		✓
Rome, Italy	FAO meeting to develop indicators for sustainable shrimp aquaculture. September 2001	20	✓	✓	✓		✓	✓						✓
Shepardstown, WV, USA	Keynote address on shrimp aquaculture BMPs to the annual meeting of the Aquacultural Engineering Society. October 2001	125	✓	✓			✓	✓						✓
Madison, WI, USA	Meeting of Protected Harvest (third party certifier) to discuss certification principles, criteria, and standards with relevance to shrimp aquaculture	12					✓					✓		
Sevilla, Spain	Meeting with WWF's Mediterranean Program Office to discuss aquaculture and marketing strategies. November 2001	17					✓							
Kota Kintabala, Sabah, Malaysia	Meeting with WWF staff in Malaysia and Indonesia to discuss BMPs for shrimp aquaculture. November 2001	10					✓							
Brussels, Belgium	Meeting with WWF's agriculture and aquaculture staff to discuss strategies for identifying and adopting BMPs to reduce the impacts of production. December 2001	25					✓							
Bangkok, Thailand	Meeting in NACA to discuss potential follow-up work of the consortium on certification of shrimp aquaculture. December 2001	4			✓		✓							
Bangkok, Thailand	Meeting with GEF to discuss possible follow-up work on shrimp aquaculture and mangroves in SE Asia. December 2001	4			✓		✓							
Bangkok, Thailand	Meeting with private company possible roll-out of BMP work on shrimp aquaculture. December 2001	3			✓		✓							
Washington, DC, USA	Meeting of the Seafood Choices Alliance to discuss possible strategies to influence seafood consumption in the US. January 2002	50					✓					✓		✓

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Washington, DC, USA	Meeting with a certifier and industry analyst to discuss problems and opportunities for BMP-based shrimp aquaculture certification. January 2002	3					✓					✓		✓
Washington, DC, USA	Meeting with the IFC to discuss the development of a BMP-based investment screen and also a larger investor round table. January 2002	12			✓		✓							
Washington, DC, USA	Meeting with Island Press to discuss putting the consortium's shrimp aquaculture work into the Knowledge Environment. January 2002	3												
Monterey, CA, USA	Meeting with donors and researchers regarding trends in aquaculture and shrimp aquaculture in particular. January 2002	15		✓			✓	✓		✓				✓
San Diego, CA, USA	World Aquaculture Session on the Potential Uses of BMPs to improve aquaculture performance. January 2002	75	✓	✓	✓	✓	✓	✓		✓			✓	✓
San Diego, CA, USA	Meeting with the Global Aquaculture Alliance. January 2002	2					✓						✓	
San Diego, CA, USA	Meeting with seafood industry analyst to target those companies most likely to purchase certified shrimp. January 2002	2					✓							✓
San Diego, CA, USA	Meeting with Monterey Bay Aquarium and COMPASS to discuss seafood rankings, aquaculture experts, and strategic interventions needed to improve the performance of aquaculture. January 2002	5					✓							
Beijing, China	Committee on Fisheries, Sub-committee on aquaculture. First session. Beijing, China, 18th-22nd April 2002.	100		✓	✓		✓	✓						
Totals	Total of All Consortium Meetings	7925	35	36	18	14	58	54	20	13	10	11	12	49

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Anon. 1996g. Workshop focus on biotechnology research progress in aquaculture. *Fish Farming International* Dec.

Anon. 1996h. Immune system stimulant. *Fish Farming International* Sept.

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