Towards Sustainable Shrimp Culture in Thailand and the Region

Proceedings of a workshop held at Hat Yai, Songkhla, Thailand, 28 October–1 November 1996

Editor: **Paul T. Smith**

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Acronyms and Abbreviations

AAHRI	Aquatic Animal Health Research Institute (Thailand)
ACIAR	Australian Centre for International Agricultural Research
ASS	acid sulfate soils
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
DOF	Department of Fisheries
EU	European Union
FCR	feed conversion ratio
GIS	geographical information system
IHHNV	infectious hypodermal and hepatopoietic necrosis virus
MBV	*Penaeus monodon*-type baculovirus
NACA	Network of Aquaculture Centres in Asia–Pacific
ODA	Overseas Development Administration (UK)
OIE	Office International des Epizooties
PASS	potential acid sulfate soils
SEAFDEC	Southeast Asian Fisheries Development Center (Philippines)
SEMBV	systemic ectodermal and mesodermal baculovirus
UPV	University of the Philippines in the Visayas
WSBV	white spot baculovirus
WTO	World Trade Organization
YHV	yellow head virus

Glossary

Amphur	The word for district in Thailand.
Baht	The baht is the Thai unit of currency. There are around 35 baht to the Australian dollar (as of May 1998).
Changwat	The word for province in Thailand.
District	Each province in Thailand is sub-divided into districts. The number of districts in each province varies. Also called *amphoe*.
Province	Thailand is divided into 71 provinces. Also called *changwat*.
Rai	The rai is a measure of a unit of land in Thailand. One rai = 1,600 m^2. There are 6.25 rai per hectare.
Shrimp	In Australia and some other countries, marine and brackish-water species of shrimp are usually referred to as a prawns.

Preface

Toward the end of 1996, Thailand—the world's leading producer of farmed shrimp—and other countries in Asia began to feel the strain from a combination of major problems. The rapid expansion in productivity in Thailand that had occurred in the previous decade had reached a plateau and eventually declined. Outbreaks of new shrimp viral diseases were threatening the viability of farms in many parts of Thailand and elsewhere in Asia. Also, there was growing regional and international awareness about the need for more sustainable shrimp aquaculture practices, and concern about possible trade implications arising from the pressures and activities of international environmental organisations.

In light of such issues and their chronic impacts, it was timely that a workshop was held in Hat Yai, Thailand in October 1996, as part of the Australian Centre for International Agricultural Research (ACIAR) project 'Key Researchable Issues in Sustainable Coastal Shrimp Aquaculture in Thailand' (project number FIS/1993/843). Further details of the project are given in a complementary report (Smith, P. ed. 1999. Coastal shrimp aquaculture in Thailand: key issues for research. ACIAR Technical Report No. 49). The workshop brought together representatives from a broad cross-section of the shrimp farming industry in Thailand as well as participants from 12 countries in the Asia–Pacific region. These participants, with their experience and expertise, now had a forum in which to focus their attention on issues relevant to the sustainablity of coastal shrimp aquaculture in Thailand and the region.

The theme of the workshop was set by the address by Dr Plodprasop Suraswadi, Thailand's Director-General of the Department of Fisheries (DOF); he said the priority for research was to provide scientific guidelines for responsible management and sustainable development of the industry. Hassanai Kongkeo, the Coordinator of the Network of Aquaculture Centres in Asia–Pacific (NACA), supported this objective and stressed the importance of strengthening research links and collaboration within the region. Barney Smith, Manager of the Fisheries Research Program in ACIAR, acknowledged the complexity of the problems confronting the shrimp farming industry and encouraged the workshop to develop multi-disciplinary research responses that provide outcomes at the farm level.

The subsequent workshop deliberations covered a range of relevant topics. The principles of concern for sustainable development provided a framework for discussions; that is, development should be judged on the following criteria: maintenance of ecological systems; improvement in the social and economic wellbeing of people; and provision for both inter-generational and intra-generational equity. Those principles require consideration of the environment, use of the most appropriate technologies and understanding of socioeconomics, culture and politics. In the workshop that followed, the participants delivered concise and incisive papers, identifying: key issues for research relating to technical areas (production) and non-technical areas (society, environment, finance and trade); areas of research that are currently being undertaken in Thailand and the region; gaps in ongoing research and cost–benefits for research; constraints and possible solutions for implementing research; areas for regional collaborative research; and priorities for future research.

On behalf of the workshop participants and the research team, the editor gratefully acknowledges the valuable contributions to the planning and organisation of the workshop of numerous individuals and organisations, in Thailand, Australia and other countries, and the encouragement and financial support of ACIAR. The effectiveness of the workshop is due to the energy and enthusiasm of team members from NACA, DOF and Kasetsart University. As a result of the efforts of the participants, these Proceedings provide a contemporary insight into the key issues that are to be addressed by Thailand and the region as the shrimp farming industry moves towards sustainability.

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Shrimp Culture in Thailand—Present Status and Future Directions for Research

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AQUACULTURE in Thailand has been practised for a long time and marine shrimp culture has been practised for the last 70 years (Tookwinas 1993). However, the technology of intensive shrimp culture has expanded significantly along coastal provinces in recent years. Thailand has become the leading country in shrimp production since 1991 (Rosenberry 1995). The culture species is mainly *Penaeus monodon*. More than 90% of culture production has been exported frozen, headless and with shell on. The importing countries are Japan, United States, European countries, the People's Republic of China, Canada and others.

Farming Methods

Marine shrimp farming culture, as practised in Thailand, can be classified into three or four categories: extensive (traditional), semi-intensive, intensive and super-intensive. Each type is classified in terms of cultured area and stocking density.

Extensive shrimp farming, sometimes called traditional shrimp farming, is characterised by ponds of irregular shape and size varying from 5–10 ha. In semi-intensive shrimp farming, ponds are normally rectangular in shape with an area of about 1–6 ha. The stocking density is about 5–10 postlarvae/m^2.

Intensive shrimp farming requires high financial and technical inputs. Mechanical aeration is used to increase dissolved oxygen supply in ponds and paddlewheels are either powered by electric or diesel motors. Another common practice is injection of air by a propeller. Shrimp are fed with a nutritionally complete, artificial diet. Pond size varies from 0.16–1 ha and pond depth is around 1.5–2.0 m. The pond shape can be either rectangular or round. Stocking densities range from 20–50 postlarvae/m^2.

The number of crops possible with intensive farming is about 2–2.5 per year. Survival rates are usually around 60–90%. However, disease and environmental pollution are much greater problems than in extensive and semi–intensive farming systems. The average production is around 3,750 kg/ha/yr, but higher yields are common.

The super-intensive shrimp farming system is the most organised system in Thailand, and only a few farms can operate or convert the semi-intensive farm or intensive farm into a super-intensive farm. This is because of the very high financial and technical inputs required. Pond construction is the same as that of intensive farming but the seed stocking density is higher than 80 postlarvae/m^2. The average production is around 6,000–10,000 kg/ha/yr.

Production

Production from shrimp farming increased very rapidly after the expansion of intensive marine shrimp farming. The cultured area and number of farms increased from 40,769 ha and 4,939 farms in 1985, respectively, to 71,887 ha and 20,027 farms in 1993, respectively (Table 1).

As mentioned above, Thailand has been the leading country for cultured shrimp production since 1991. Exports increased from 153,000 t in 1991 to 250,000 t in 1994 (Table 2), valued at about US$2,000 million.

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Factors for Success of Shrimp Farming in Thailand

About 20 years ago, the Thai Department of Fisheries (DOF) succeeded in hatchery production of marine shrimp, especially of *P. monodon* (Tookwinas 1991), and farmers were encouraged to increase stocking densities of shrimp fry in traditional ponds (semi-intensive). Then, intensive marine shrimp farming developed about 10 years ago. Kongkeo (1994) stated that the key factors for the success of marine shrimp farming in Thailand are as follows.

Table 1. Marine shrimp farming in Thailand: area and number of farmers, 1985–1993.

Year	Number of farmers	Area (ha)
1985	4,939	40,769
1986	5,534	45,368
1987	5,899	44,770
1988	10,246	54,778
1989	12,545	71,165
1990	15,072	64,606
1991	18,998	75,332
1992	19,303	72,796
1993	20,027	71,887

Source: DOF 1994

Table 2. World cultured shrimp production, 1990–1994.

Country	Production (t × 1,000)			
	1991	1992	1993	1994
Thailand	153	163	168	250
Ecuador	100	95	90	100
Indonesia	140	130	80	100
India	35	45	60	70
China	145	140	50	35
Vietnam	30	35	40	50
Bangladesh	25	25	30	35
Taiwan	30	25	25	25
Philippines	30	25	25	30
Other	45	46	54	63
Total	733	729	622	758

Source: Rosenberry 1995

Suitable sites

Thailand is in the tropics with a climate suitable for the rapid growth of shrimp, and has abundant coastal areas suitable for shrimp farm construction.

Availability of wild broodstock

Tiger shrimp (*P. monodon*) is a local shrimp species in Southeast Asia, so wild broodstocks are available for hatchery production of shrimp fry. DOF has a program for restocking shrimp fry in coastal waters by releasing around 200–300 million fry every year. Some farmers, in cooperation with DOF, also release some portion of their shrimp production in order to maintain or supplement the natural population of tiger shrimp.

Long experience in aquaculture

The shrimp farmers have had a long experience in aquaculture and they are also enthusiastic to learn and practise advanced technologies. They always have new ideas for development or modification and they are eager to run these experiments by themselves. The present success of Thailand in this industry is testimony to the persistence and ingenuity of Thai people in utilising applied science to its utmost potential (C.P. Aquaculture 1994).

Well-developed infrastructure and supporting industries

Marine shrimp industries require adequate levels of infrastructure and supporting industries. Transportation, electricity and telephone communications are most important for rapid development and these are very well developed for industries in Thailand. Thailand also has supporting businesses in construction materials, heavy machinary, feed mills, shrimp fry hatcheries and food processing plants, which help in the development of shrimp industries.

Small-scale industry

Marine shrimp farms in Thailand are generally small-scale, with most culture areas being approximately 0.16–1.6 ha. This is quite convenient for pond construction and operation, and the cost of investment is much lower than with larger operations. Thailand originally developed techniques for backyard hatcheries, which are managed with simple but efficient technologies mainly by farmers with little education. They produce more than 80% of the national shrimp fry production.

Less environmental impact

Thailand has a coastline of about 2,600 km. Marine shrimp farming is now scattered in every coastal province of the country. The effluent from shrimp farms may be more easily dispersed than for other countries. Previously, mangroves were invaded for shrimp farm construction because of the convenient water supply, and large areas have been lost in the construction of extensive aquaculture ponds. It is now accepted that the destruction of mangroves destroys nursery grounds for fish and crustaceans as well as protection barriers from floods and storms (Sakthival 1985). The locations that are now considered the most suitable for shrimp farming are rice fields in coastal areas. These fields have very low rice production and contain a very high clay-silt content, which is suitable for pond construction and prevention of seepage.

DOF has a strong policy to move all shrimp farms out of mangroves to other suitable areas. The government also has regulations for shrimp farming registration and effluent regulations in order to reduce the effects of shrimp farming on coastal environments.

Government Regulations and Policies

Marine shrimp culture along the coast is one of the most important industries for the economy, providing employment and earnings for the national income. DOF has very strong policies to promote shrimp farming as a sustainable profession. The plans and policies can be summarised as follows.

- The area of marine shrimp farming should not exceed 76,000 ha.
- As announced by DOF on November 1991 under Fisheries Act 1947, the regulations for shrimp farming in Thailand are:
  1. Shrimp farmers must be registered with DOF through the Fisheries District Officer.
  2. Shrimp farms over 50 rai (8 ha) must be equipped with wastewater treatment or sedimentation ponds covering not less than 10% of the pond area.
  3. Water released from shrimp farms must contain a biochemical oxygen demand (BOD) not exceeding 10 mg/L.
  4. Salt water must not be drained into public freshwater resources or other agricultural areas.
  5. Sludge or bottom mud sediment should be kept in a suitable area and should not be pumped out to a public area or canal.
- Strengthening registration of hatcheries and farms. This is for the purpose of getting information about culture activities and allows effective law enforcement of effluent regulations.
- Monitoring program and antibiotic residue inspection. The coastal aquaculture centres and stations under DOF in every coastal province have environmental monitoring programs in marine shrimp farming areas. The purpose is to collect environmental data and to provide technical advice to farmers. The shrimp, water and sediment in culture ponds are also collected for antibiotic residue analysis. In addition, the finished frozen product is inspected for sanitary condition and antibiotic residue certification before export.
- Research program. Many research programs have been carried out in the last ten years. At the present time, the research plan has emphasis on:
  1. rearing spawners in earthen ponds and genetic improvement research;
  2. environmental management in culture ponds;
  3. biological treatment and water recycling systems;
  4. detection and prevention of disease; and
  5. culturing of alternative species of brackishwater organisms.

Environmental Impacts

As mentioned above, environmental impacts have occurred in Thailand and those impacts are summarised here.

Impact of mangrove removal

Shrimp culture was initiated in mangroves because seawater can be easily pumped into the farm at high tide and drained from the farm during low tide. However, the land in mangroves is not actually suitable for shrimp farm construction, since it usually contains pyrite which can be highly acidic when exposed to the air. Secondly, mangrove soil contains many plant roots and stumps which interfere with pond construction (Hidalgo 1989).

Satellite imaging (Landsat, TM5, 1:50000) in 1993 showed that only 17.25% of mangrove has been invaded for marine shrimp farming (Budget Bureau 1990; Kongsangchai 1993; Charuppat and Ongsomwang 1995; Research Council of Thailand 1995). The main loss of mangroves has been for other purposes.

Effects on fresh water

The use of underground fresh water for intensive shrimp farming in Thailand has resulted in saltwater intrusion and salination of fresh water (Primavera 1991; Liao 1992). The problems and conflicts which local farmers and residents in Songkhla and Nakorn Sri Thammarat experienced a few years ago occurred through salinity intrusion into water supplies for freshwater consumption and agriculture. At present, shrimp farmers in many areas prefer to use full strength seawater directly from the open sea. Therefore, many farmers have stopped using fresh water from aquifers for mixing with seawater. Now, the main effect now comes from the draining of salt water during water exchange and after harvesting of shrimp.

Effects on coastal water quality

Macintosh and Phillips (1992) compared the quality of shrimp farm effluent with wastes from other potential sources of pollution (Table 3) and found the pollution potential of shrimp farm effluent is considerably less than that of domestic or industrial waste water. However, the waste from intensive shrimp farms can still impact on local water quality through excess feeds, fertilisers, chemicals and antibiotics (Jair 1989; Satapornvanit 1993; Songsangjinda and Tunvilai 1993) as summarised in Table 4.

Chemicals and drugs

Chemicals and drugs are widely used in marine shrimp culture for prevention or treatment of diseases. They are used as feed additives, disinfectants, pesticides and for soil or water treatment. Several compounds in use pose a potential threat to shrimp health and product quality (Macintosh and Phillips 1992). Widespread use of oxytetracycline and oxolinic acid in Southeast Asian countries has resulted in the development of resistant strains of *Vibrio* spp. which has made treatment of vibrio infections extremely difficult (Nash 1990). Antibiotics and some other chemicals leave residues in shrimp flesh, which may lead to rejection of products in export markets.

Table 3. Shrimp farm effluent (mg/L) compared with other types of waste water (mg/L) (Macintosh and Phillips 1992).

Parameter	Shrimp farm effluent	Domestic waste water (untreated)	Domestic waste water (primary treatment)	Fish processing waste water (untreated)
BOD[a]	4.00–10.20	300	200	10,000–18,000
Total nitrogen	0.03–1.24	75	60	700–4,530
Total phosphorus	0.011–2.02	20	15	120–289
Solids	30.00–225.00	–	500	6,880–7,475

[a]BOD = biochemical oxygen demand

Table 4. Problems associated with effluent (Macintosh and Phillips 1992).

Waste material	Primary effect	Secondary effect
Uneaten food, faeces and dissolved excreta	Increased nutrient loads and reduced oxygen in ponds and water supplies; increased sedimentation	Environmental changes; reduced carrying capacity
Chemicals and drugs	Eco-toxicological impacts	Mortality and sublethal effects on organisms; water quality changes
Antibiotics	Increased antibiotic resistance among micro-organisms	Increased problems in treating bacterial diseases; residues in marketed shrimp

Current Key Constraints

There are clear key constraints to sustainable intensive marine shrimp culture in Thailand.

Poor water quality in coastal areas

Shrimp farmers have complained about poor water quality in coastal areas, saying that it causes stress and increased susceptibility to disease in shrimp. DOF monitored the water quality of every coastal province and found that, in some areas, water quality was poorer than in previous years, while in other areas it was still sufficient for coastal aquaculture. However, in some locations, the heavy organic loading of effluent has significantly deteriorated the water quality. Farmers should have sedimentation ponds to settle the organic matter and suspended solids before discharging waste water.

Exceeding the carrying capacity in culture areas

Intensive marine shrimp farms have a high demand for seawater exchange, however many areas do not have an adequate supply system to meet this demand. Since the discharge from shrimp farms deteriorates water quality in canals and coastal water areas, the number of intensive marine shrimp farms in some areas may be over the carrying capacity of the area. The maximum area allowance for shrimp farm construction should be studied so that laws and regulations can be implemented based on the technical results.

Overstocking of shrimp fry

When intensive marine farming first started, the stocking density of fry was about 30 postlarvae/m^2. After that, farmers tried to increase the stocking density of fry and at present it averages around 50–60 postlarvae/m^2. The survival rate has gradually decreased to about 30%. This is not surprising, as when the biomass in the pond is very high, farmers needs to provide more feed, and in turn more pollution is created in the pond.

Disease outbreaks

Disease outbreaks now frequently occur in shrimp culture areas. This has resulted in significant economic loss and it would appear to be the major constraint to sustainability of this industry.

Research Priorities

Research priorities for sustainable intensive marine shrimp culture cover many subjects. However, the most urgent need for long term research would be as follows.

Domesticated broodstock

At present, broodstock comes from the capture fisheries. Domesticated broodstock would be the first priority in increasing capabilities in genetic improvement in disease resistance and improved growth rates.

Recycle culture system

The development and application of recycle culture systems or closed culture systems could minimise the discharge loading. Effluent would be purified in the culture area and returned back to the culture pond. Research work has been done in this field, however more studies are needed.

Effluent treatment process

Effluent and sludge from shrimp ponds are major causes of negative environmental impacts in coastal areas. Scientists have conducted research to minimise the concentration of pollution in effluent by physical, chemical and biological treatment methods (Rubel and Hager 1979; Muir 1982; Darooncho 1991; Tunvilai and Tookwinas 1991; Chaiyakam and Tunvilai 1992; Tunvilai et al. 1993; Tookwinas and Neumhom 1995; Tunsutapanich et al. 1995). However, a compact method has not been developed yet. Therefore, research work in this field would be a priority.

Disease prevention

As mentioned previously, disease outbreaks have caused great economic losses for the shrimp farming industry in recent years. Research on disease prevention is needed.

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Key Issues Based on an Analysis of the Thai Shrimp Farm Survey

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Abstract

This paper reports on the statistical analysis of the 1995 survey of 451 shrimp farms in Thailand. The aim was to identify relationships which may indicate key issues for research into sustainability. Rigorous cleaning up of the data was carried out to eliminate cases where the data could not be validated or where a respondent consistently omitted data. In the subsequent analysis, nine key outcome variables were chosen as indices for sustainability and their relationships with 877 original variables and 214 derived variables were investigated, using one-way analysis of variance, Chi square or regression analysis. Significant relationships were found between the key indices for sustainability and 43 variables, with 11 significant variables for site description, 5 for farming system variables, 9 for problem analysis and 18 for economic analysis. For site description, the province to which a farm belonged was a highly significant factor for the key indices for sustainability. Also, the variables of previous use of the land, size of the storage reservoir, growing area, depth of pond, retention of mangrove buffer and use of effluent treatment pond had significant relationships with the key indices. For farming systems, variables which had significant relationships with key indices were: screening inflow water; applying lime before stocking ponds; applying inorganic fertiliser near harvest; use of local pellet feed; and sourcing information from extension officers. As for problem analysis, the significant variables were: costs relating to salinity problems; bloom problems; seed problems; lack of experience; water and sediment problems; and disease problems. Significant economic analysis variables were: average price of shrimp; production per hectare; cost of labour; cost of fertiliser; cost of feed; cost of seed; percentage of owner equity; percentage of equity of relatives; culture period; number of crops per year; fallow period; feed conversion ratio (FCR); total male workers; total female workers; and the previous year's profitability. In summary, if we could simply describe a sustainable farm as one which has high productivity, low problem costs, and reduced impact on the environment, then the results of the analysis would characterise a small, family farm with a storage pond for inlet water, grow-out ponds that are reasonably deep (i.e. 1.5–1.7 m) and an effluent treatment pond. The farmer would use a Thai commercial pellet feed, lime ponds prior to stocking, have a low FCR, use a fallowing period to dry ponds and would receive advice from an industry extension officer. Further, the farm would be located in an area where the mangrove buffer had been retained, and problems associated with blooms, salinity, sediment and water were relatively low. Key areas of research appear to be: the relationships between mangroves and farm productivity, and farm-based studies to improve pond management and pond ecology. It is suggested that the variables that have been identified in this analysis should be further investigated in multivariate analysis.

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Outline of the Thai Shrimp Farm Survey

In mid-1995, data were collected from 451 shrimp farms in Thailand as part of a regional survey. Funding for the Thai survey was from the Asian Development Bank, Thailand Department of Fisheries (DOF) and the Network of Aquaculture Centres in Asia–Pacific (NACA). A total of 877 variables were coded from the responses and a spreadsheet was produced in FOXPRO, a format that is compatible with EXCEL. This is arguably the most comprehensive survey of shrimp farms ever undertaken. Statistical analysis has already been carried out by DOF (Tavarutmaneekul and Tookwinas 1995) and further analysis is being carried out by the Thailand Development Research Institute and DOF.

The Australian Centre for International Agricultural Research (ACIAR) project aimed to further analyse the data in order to tease out and identify relationships between variables which may indicate key issues which need further investigation. At their initial meeting in November 1994, the members of the project decided that it would be interesting to analyse the data to determine whether factors in the survey could explain recent occurrences in various areas of Thailand. Particularly, we wanted to know whether the survey could shed light on (a) the decline in productivity of farms in older farming areas, such as Samut Sakhorn, (b) the impact of reported loss of mangroves on farm productivity, or (c) the success of newly developed areas in Surat Thani, Nakhon Sri Thammarat, Songkhla, and more recently, Krabi. Analysis of the survey was carried out with the objective of clarifying these issues as well as searching for other insights.

Method of Analysis

The data were received from NACA in May 1996 and every attempt was made to take a rigorous and methodical approach. An alternative approach of selective analysis may overlook key relationships. Analysis was carried out using SPSS (Statistical Package for Social Scientists) and the following process.

- Coding, validation and clean up of the data.
- Summary statistics.
- Presentation of summary statistics to ACIAR meeting at Darwin (Smith 1996).
- Further validation and clean up of data.
- Derivation of new variables.
- Summary statistics of derived variables.
- Further validation and clean up.
- Bivariate analysis.
- Application of the analysis to the geographical information system (GIS).

The statistical analysis reported in this paper is not complete, however it interprets the results obtained thus far. This is timely because an assessment at this stage will provide a focus for the final methods of analysis (see Pe and Smith 1999).

General Observations about the Survey

That initial analysis revealed that there are both strengths and weaknesses in the data.

Strengths

The survey has many strengths, which are summarised as follows.

- It is a comprehensive survey—877 variables covering a wide range of topics.
- It has a very large sample size (451 farms).
- Geographically, it is a broad survey, covering 48 *amphoes* (districts) in 10 *changwats* (provinces).
- The topics are well set out—with sections clearly and logically divided into site description, farming system, problem analysis, economics, social issues and future plans.
- The overall responses are generally within expectations—sometimes data can be validated internally and the ranges of data fall within those previously published.

Weaknesses

Unfortunately, there are weaknesses which had to be addressed before the analysis could be performed.

- The responses to questions on social conflicts were almost non-existent, even though 89.1% of farms reported moderately serious conflicts relating to the operation of their farm (Q.22). Thus, social issues could not be analysed.
- In some questions, 'no comment' was not distinctly separated from 'no', so both responses were usually coded as '0', distorting the data. The means of minimising this problem is outlined elsewhere (Pe and Smith 1999).
- Questions on farming system (Q.11—comprised of many sub-questions) have a complex format. Farmers were asked to list the order in which up to 45 management practices were carried out. This format is difficult to analyse.

- In Q.17, the economics of the farm were questioned for either 'last year' or 'last crop', and the answers were recorded as 'whole year or crop 1', or 'crop 2' or 'crop 3'. From the responses and internal verification from responses to other questions, it is clear that many respondents did not understand these options.

The Method of the Analysis

Cleaning up the data

In surveys that require self-assessment, there is always a risk that answers are not accurate. The reasons are numerous: unintentional mistakes made in recording the answers; misunderstandings by the respondent or the interviewer; defensive answers to prying questions; lack of attention (especially in large surveys); poor memory; and of course, deliberately misleading responses (particularly when the respondent is unsure of who will access the data). As a starting position, the analysis of any survey must assume that the data will include some distortions because of one or more of the above reasons.

Therefore, considerable effort was applied to cleaning up the data to minimise these problems. Analysis revealed that a significant proportion of respondents consistently answered 'no' to questions. To compensate for this distortion, the bivariate analysis was carried out by equating '0' to 'missing data'. Consequently, the bivariate analysis was based on the farms that gave positive responses. For example, economic analysis was carried out only on those farms which reported financial data. While this method of analysis of the data may not be optimal, it was the simplest and least intrusive method of accounting for the small but significant proportion of farms which consistently replied 'no'.

Developing an index for sustainability

A total of nine variables, seven of which were derived, were selected as key outcome variables. These variables were: total farm productivity (kg/ha/yr); ratio of sales to cost; 1994 productivity; 1993 productivity; total input cost (baht/kg), feed conversion ratio (FCR); cost of disease problems (baht/kg); cost of all problems (baht/kg); and confidence-planning index (from survey question Q.23). Relationships between these nine variables and the remaining variables in the survey were investigated by: (a) Crosstab with Chi square for category variable versus category variable; (b) one-way analysis of variance (ANOVA) for ordinal (continuous) variable versus category variable; and (c) correlation (bivariate) and regression analysis for ordinal variable versus ordinal variable.

From the bivariate analyses, the variables which had a significant correlation with the key outcome variables were tabulated. The significant variables were categorised as: site description variables (Table 1); farming system variables (Table 2); problem analysis variables (Table 3); and economic variables (Table 4). No social variables were found because of the lack of responses to those questions (i.e. Q.22 of the survey).

The most consistent result of the analysis was the impact of the site variable, province, on the key outcome variables. Figures 1 to 5 show examples of the key outcome variables versus province. These graphs indicate that multivariate analysis should be carried out with province and the significant variables in Tables 1 to 4 (see Pe and Smith 1999). Importantly for the aim of the project, the survey had supported the working hypothesis that the shrimp farming industry in each coastal province of Thailand had distinctly different characteristics. The task remaining was to draw out from the survey the possible reasons for these differences.

Results and Discussion

Limitations and overall results

The analysis had limitations because of a number of factors which have been minimised in the analysis (see Pe and Smith 1999). The bivariate analysis provided some very significant findings that have application to the topic of the project. Firstly, the analysis indicated that there were a total of 43 variables that had significant relationships with the key indices for sustainability. There were 11 significant variables for site description (Table 1), 5 for farming system variables (Table 2), 9 for problem analysis (Table 3) and 18 for economic analysis (Table 4).

For site description, the province to which the farm belonged was a highly significant factor in productivity, profitability and other indices for sustainability (Figures 1 to 5). The results show that farms in the provinces which began intensive shrimp farming more recently (i.e. southern and south-western Thailand), have higher productivity and lower costs from problems than the older areas.

Table 1. Variables for site description that are related to key outcome variables. The level of significance of the relationship is shown (– or >0.05 = not significant, ≤0.05 = significant association).

Independent variable	Productivity 1		Productivity 2		Input cost		Problem		Confidence planning index
	Total prod kg/ha/yr	Ratio of sales to cost	1994 profit index	1993 profit index	Total cost (baht/kg)	Feed conversion ratio	Disease costs (baht/kg)	Cost of all problems (baht/kg)	
Province	0.001	0.001	0.001	0.013	0.044	0.025	0.011	–	0.001
Recent major problem	0.037	–	0.074	–	0.038	–	–	–	0.043
Previous expanded crop area	0.013	–	–	0.019	–	–	–	–	0.001
Previous contracted crop area	–	–	0.039	–	–	0.001	–	–	0.039
Previous use of intertidal land	–	–	0.001	–	0.001	–	0.015	0.052	0.005
Previous use of supratidal land	0.010	0.001	–	–	0.019	–	–	0.038	0.070
Storage pond (% of farm)	–	–	0.012	–	0.076	0.023	0.063	0.035	–
Growing area (% of farm)	0.051	–	–	0.046	–	0.000	–	–	0.002
Depth of production ponds	0.055	–	–	0.013	0.001	–	0.001	0.001	–
Retention of mangrove buffer	–	0.042	–	–	0.051	0.001	–	–	0.039
Effluent treatment pond	–	0.039	–	0.001	–	0.025	0.086	–	0.019

Table 2. Variables for farming system that are related to key outcome variables. The level of significance of the relationship is shown (– or >0.05 = not significant, ≤0.05 = significant association).

Independent variable	Productivity 1		Productivity 2		Input cost		Problem		Confidence planning index
	Total production kg/ha/yr	Ratio of sales to cost	1994 profit index	1993 profit index	Total cost (baht/kg)	Feed conversion ratio	Disease costs (baht/kg)	Cost of all problems (baht/kg)	
Screen inflow water of storage pond	–	–	0.008	0.029	0.085	0.001	0.086	–	0.019
Apply lime to ponds before stocking	–	–	–	0.001	–	0.041	0.003	0.063	–
Apply inorganic fertiliser near harvest	0.047	–	–	–	0.054	0.015	–	–	–
Use local pelleted feed	0.039	–	0.017	–	–	–	–	–	0.054
Information from industry extension officer	0.082	–	–	–	0.019	–	0.027	0.024	–

Also, although farms in some provinces (e.g. Samut Sakhorn) have low productivity, they have low FCRs and other descriptions which suggest that low intensity farming is being carried out there. Perhaps the farmers in those provinces are resigned to low productivity and have reduced intensity and costs as a result.

Also, previous use of the land, size of the storage reservoir, growing area, depth of ponds, retention of mangrove buffer, and use of effluent treatment pond had significant relationships with the key indices. These factors show that smaller farms and farms which have taken steps to minimise environmental impacts were more productive.

For farming systems, variables which had significant relationships with key indices were: screening inflow water; applying lime before stocking ponds; applying inorganic fertiliser near harvest; using local pelleted feed; and sourcing information from extension officers. Importantly, many other management tools, such as application of chemicals (e.g. formalin, benzalkonium chloride etc.) were not found to have a significant relationship with the key indices.

For problem analysis, the significant variables were: costs relating to salinity problems; bloom problems; seed problems; lack of experiences; water and sediment problems; and disease problems.

Significant economic analysis variables were: average price of shrimp; production per hectarea; cost of labour; cost of fertiliser; cost of feed; cost of seed; percentage of owner equity; percentage of equity of relatives; culture period; number of crops per year; fallow period; FCR; total male workers; total female workers; and the profitability in the previous year.

Table 3. Variables for problem analysis that are related to key outcome variables. The level of significance of the relationship is shown (– or >0.05 = not significant, ≤0.05 = significant association, * = no analysis).

Independent variable	Productivity 1		Productivity 2		Input cost		Problem		Confidence planning index
	Total prod kg/ha/yr	Ratio of sales to cost	1994 profit index	1993 profit index	Total cost (baht/kg)	Feed conversion ratio	Disease costs (baht/kg)	Cost of all problems (baht/kg)	
Cost of salinity problems (baht/kg)	0.063	–	0.005	0.003	0.001	–	0.001	0.001	–
Cost of blooms and red tides (baht/kg)	0.061	–	0.013	0.002	–	–	0.031	0.058	–
Cost of first disease (baht/kg)	0.004	–	0.001	–	0.001	–	0.001	0.001	–
Cost of seed quantity problems (baht/kg)	–	–	0.020	–	–	–	0.024	0.001	–
Cost of lack of experience (baht/kg)	–	–	–	–	0.001	–	0.001	0.001	–
Total cost of water and sediment problems (baht/kg)	0.006	0.063	0.004	–	0.001	–	0.001	0.001	–
Total cost of disease problems (baht/kg)	0.001	0.022	0.001	–	0.001	–	*	0.001	–
Total cost of other problems (baht/kg)	0.024	–	0.027	–	0.001	–	0.001	0.001	–
Total cost of all problems (baht/kg)	0.005	0.050	0.001	–	0.001	–	0.001	0.001	–

Table 4. Economic variables that are related to key outcome variables. The level of significance of the relationship is shown (– or >0.05 = not significant; ≤0.05 = significant association; * = no analysis).

Independent variable	Productivity 1		Productivity 2		Input cost		Problem		Confidence planning index
	Total prod. (kg/ha/y)	Ratio of sales to cost	1994 profit index	1993 profit index	Total cost (baht/kg)	Feed conversion ratio	Disease csosts (baht/kg)	Cost of all problems (baht/kg)	
Average price of shrimp (baht/kg)	–	0.040	0.001	–	0.001	0.001	0.001	0.001	–
Total production (kg/ha/yr)	*	–	0.001	–	0.002	0.001	0.001	0.005	–
Sale value of production (baht/ha/yr)	0.001	–	0.003	–	0.002	0.001	0.001	0.005	0.046
Cost of labour (baht/kg)	0.011	0.001	0.001	0.001	0.001	0.001	0.001	0.001	–
Cost of fertiliser (baht/kg)	–	–	0.001	–	0.017	0.001	0.001	–	–
Cost of feed (baht/kg)	0.001	0.001	0.004	–	0.001	0.001	–	–	–
Cost of seed (baht/kg)	0.001	0.008	0.001	–	0.001	0.007	0.001	0.001	–
Cost of other inputs (baht/kg)	–	–	–	–	0.001	–	0.001	0.002	–
Percent owner equity (%)	–	0.023	0.085	0.001	0.035	–	–	0.048	–
Percent equity of relative (%)	–	0.054	0.079	–	0.001	–	0.003	0.001	–
Culture period (days)	0.091	–	0.050	–	0.039	–	0.001	0.001	0.048
Number of crops/yr	0.001	0.038	0.018	–	–	–	–	–	–
Fallow period (days)	–	–	–	–	–	0.012	0.001	0.001	0.002
Feed conversion ratio	0.001	0.001	0.049	–	0.004	*	–	–	–
Total female workers	–	–	0.040	0.059	–	0.053	–	–	0.001
Total male workers	0.031	–	–	0.006	–	0.057	–	–	0.033
Total workers	0.057	–	–	0.002	–	0.053	–	–	0.014
1994 profitability index	0.020	–	*	0.001	0.001	0.005	0.001	0.001	0.001

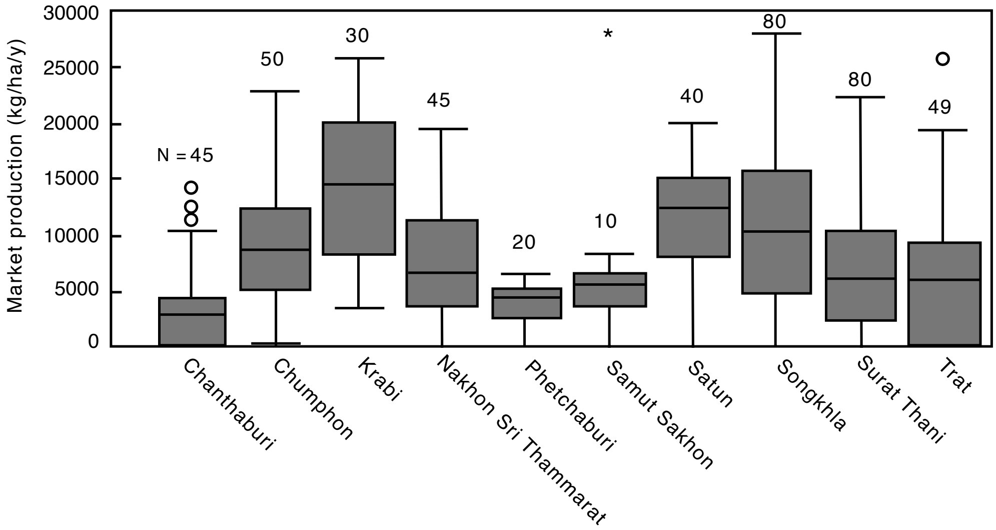

Figure 1. Market production for the provinces of Thailand. These boxplots were made using SPSS (Statistical Package for Social Scientists) where the bar refers to the median, and the box and vertical lines refer to four quartiles, i.e. 50% of cases are inside the box. Extremes (*) are more than 3 box-lengths from the 75th percentile and outliers (O) are more than 1.5 box-lengths from the 75th percentile (N = number of farms)

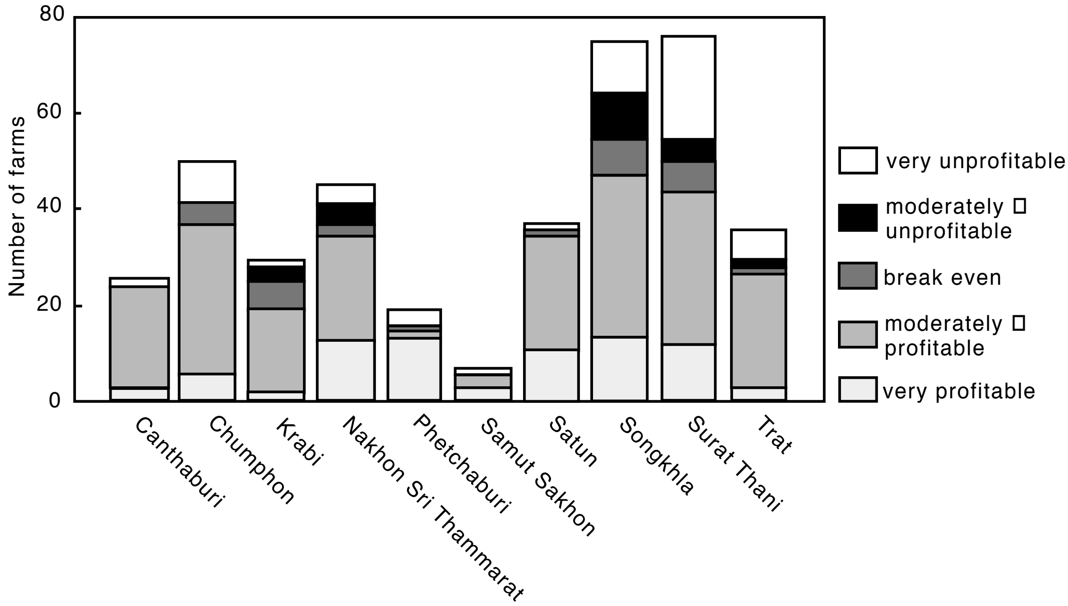

Figure 2. 1994 profitability of shrimp farming in the provinces of Thailand.

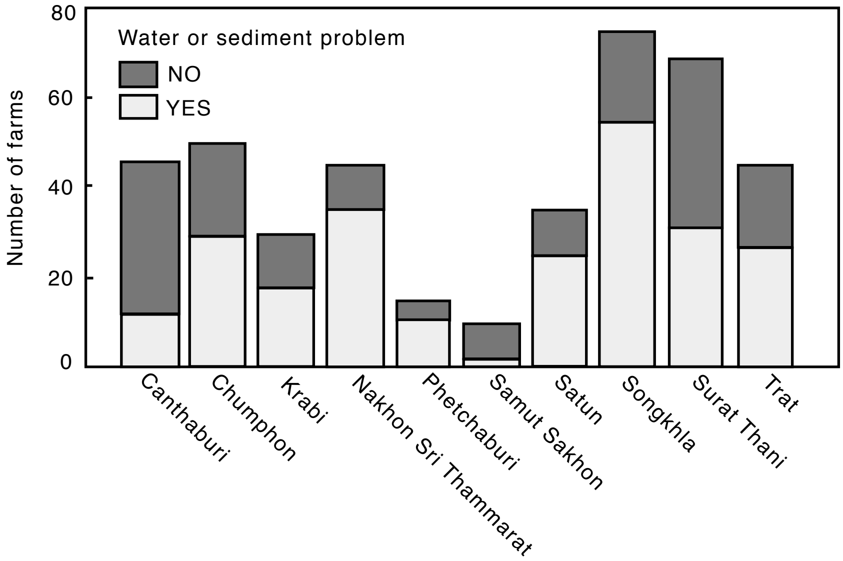

Figure 3. Occurrences of problems relating to sediment and water in the provinces of Thailand.

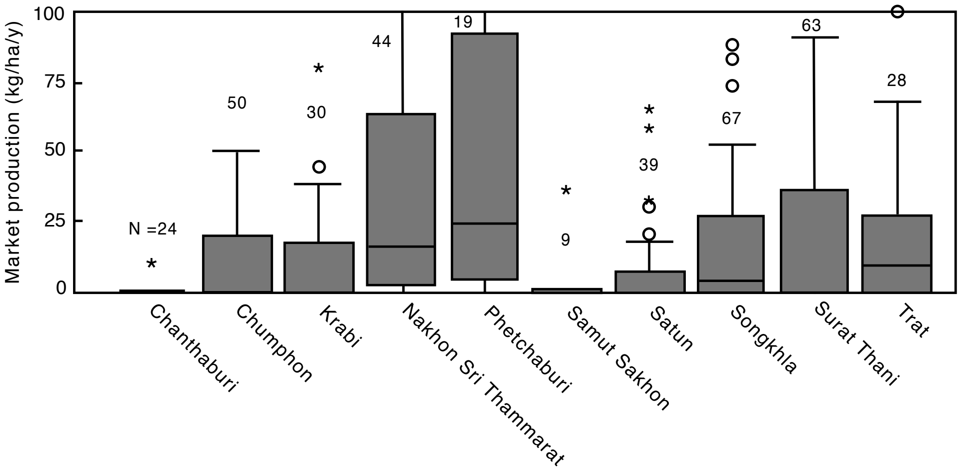

Figure 4. Total cost of diseases for the provinces of Thailand. These boxplots were made using SPSS (Statistical Package for Social Scientists)where the bar refers to the median, and the box and vertical lines refer to four quartiles, i.e. 50% of cases are inside the box. Extremes (*) are more than 3 box-lengths from the 75th percentile and outliers (O) are more than 1.5 box-lengths from the 75th percentile (N = number of farms).

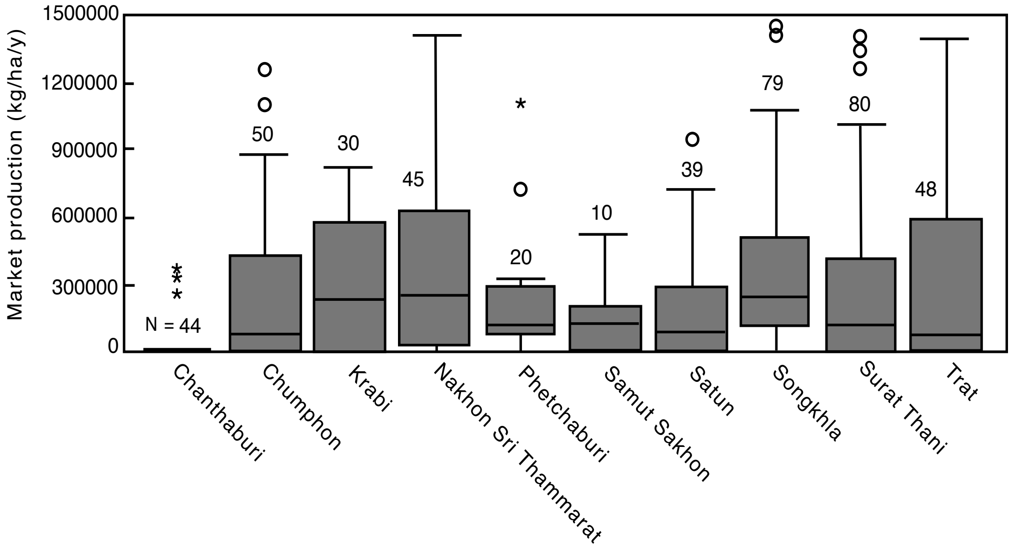

Figure 5. Total problem costs for the provinces of Thailand. These boxplots were made using SPSS (Statistical Package for Social Scientists)where the bar refers to the median, and the box and vertical lines refer to four quartiles, i.e. 50% of cases are inside the box. Extremes (*) are more than 3 box-lengths from the 75th percentile and outliers (O) are more than 1.5 box-lengths from the 75th percentile (N = number of farms).

In summary, if we describe a sustainable farm as one which has high productivity, low problem costs, and reduced impact on the environment, then the results of the analysis would characterise a small, family farm with a storage pond for inlet water, grow-out ponds that are reasonably deep (i.e. 1.5–1.7 m) and an effluent treatment pond. The farmer would use Thai commercial pellet feed, lime prior to stocking, have a low FCR, use a fallowing period to dry ponds and would receive advice from an industry extension officer. Further, the farm would be located in an area where the mangrove buffer had been retained, and problems associated with blooms, salinity, sediment and water were relatively low.

Application of results to research into sustainable shrimp farming in Thailand

Some of the main objectives of the project were to find out whether the survey could shed light on (a) the decline in productivity of farms in Samut Sakhorn, (b) the impact on farm productivity of reported losses of mangroves, or (c) the success of newly developed areas in Surat Thani, Nakhon Sri Thammarat, Songkhla, and more recently, Krabi. Results of the analysis, summarised in the previous section, have provided information which can help explain those three points.

Firstly, the farms in the older shrimp farming areas have reduced their farming intensity to reduce costs and risk. Conventional wisdom suggests that other industries and urban civilisation impact upon farms in these older areas. Also, farmers may not been able to alter production methods or their circumstances to take advantage of factors that appear to improve productivity (i.e. retention of a mangrove buffer, and use of an intake reservoir, an effluent treatment pond and deeper ponds). These factors which have been identified in the survey need to be researched in order to confirm their importance and provide reasons for their impacts on farming.

Secondly, retention of a mangrove buffer was identified as having a significant relationship to the indices of productivity (Table 1) and this issue is discussed elsewhere (Smith, Possible Applications of GIS, this proceedings). In areas where the mangrove buffers have been reduced, there is an increase in problem costs from disease and a lowering of productivity. Consequently, there is an urgent need for research to be carried out to determine the cause of these relationships.

Thirdly, the success of the newer farming areas is possibly due to the adoption of better practices, the setting up of farms on more appropriate sites and lower impacts from neighbouring farms (see Smith, Possible Applications of GIS, this proceedings). As discussed above, older farms may not be as flexible in adopting new practices, however when more recent farms were set up in provinces such as Krabi, they may have been in a good position to take advantage of improved farm designs and practices. This suggests that farm-based research into farm and pond management may be a useful way to investigate the reasons for improvements. Also, as indicated by the analysis, the extension of the research to the industry is an important process in the development of sustainable shrimp farming in Thailand.

Comments on further analysis of this information and future surveys

1. At this stage, bivariate analysis has provided important relationships that need to be further examined with multivariate analysis and modelling. This work is reported in Smith (Possible Applications of GIS, this proceedings) and elsewhere (Pe and Smith 1999).
2. A further survey of subsets of the farms could be carried out, allowing:
   - more powerful statistics to be performed based on cohorts and time sequences;
   - questions which focus on weaknesses in the 1995 survey; and
   - testing of the hypotheses developed from the 1995 survey.
3. Future surveys of farms should be set out with clear hypotheses and statistical methods clearly thought out beforehand. Some areas that could be added to a future survey are:
   - socioeconomic questions, i.e. questions on education level, previous occupation, main source of income, number of children, education level of children, membership of community groups etc.;
   - nursery, hatchery and larval supply;
   - post-harvest factors;
   - use of probiotics/beneficial bacteria;
   - use of global positioning system coordinates for exact location of farms; and
   - types of viral or bacterial problems that have been encountered.

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Key Technical and Farm Management Issues in Thailand

Pornlert Chanratchakool*

Recent Impacts of Diseases

Economic loss resulting from disease has been the major problem in shrimp production in Thailand. This has largely resulted from environmental pollution and poor management techniques. Shrimp exported from Thailand dropped by 8% from 190,650 t in 1994 to 174,974 t in 1995, and the expected export volume in 1996 was expected to be a further 15% lower (Anon. 1996). Among the diseases encountered in shrimp farms, bacterial and viral infections are the most common, usually associated with poor management or environmental conditions. In the past few years, viral infection has been the most significant cause of serious losses in Thai shrimp production relative to other diseases.

Of the viral diseases, yellow head virus (YHV) and white spot baculovirus (WSBV) have proved to be the most pathogenic to cultured shrimp. Outbreaks of these viral diseases appear to be triggered by environmental factors such as sub-optimal or unstable water conditions and deteriorated pond bottom conditions. This is especially the case for YHV. Careful farm management in association with modified culture techniques has now reduced the losses caused by YHV. Currently, this virus is now present in only some areas and is not as serious or as widespread as WSBV. Since 1993, WSBV has been the cause of the most severe production losses in Thailand. The virus appears to be able to enter ponds through avenues such as: incoming water; carriers (wild crustaceans); shrimp postlarvae; and possibly other vectors including bird and land animals as well as pond workers.

To reduce the risk of WSBV, reduction of viral contamination via the above routes has been recommended and has proved to be a successful preventative measure in some cases. Another approach has been to try to improve the health status of shrimp within the pond via diet, immunostimulants and the use of microbial remediation products. However, no method has proved to be totally effective. This probably results from a poor understanding of the interactions between the pathogen, host and the culture environment. In order to understand this and other viral diseases, there is a requirement for further research into the causes and amelioration of disease in the shrimp industry. This paper summarises the latest shrimp culture techniques developed in Thailand, together with the major problems facing the industry and its primary research requirements.

Updated Farm Management Techniques in Thailand

As mentioned above, there are at least three major routes by which viruses can enter the farm environment: incoming water, potential virus carriers and shrimp postlarvae. Previous culture techniques have been modified in order to reduce the possibility of viral contamination. Maintenance of optimal water quality in the culture pond by high rates of water exchange is no longer favoured due to the threat of introduction of disease via the influent water. Influent water to the farm is now treated chemically, biologically or physically to ensure good quality and freedom from virus and virus carriers. In order to achieve

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this, storage or settlement reservoirs are now increasingly used.

Since there are only a few occasions when water is exchanged during the culture cycle, pond construction has to be improved to minimise seepage and acid leaching. Ponds made with sandy soil and acid soil require a larger reservoir capacity (up to 40%) to store water and allow more frequent water exchanges than ponds made with clay or compacted soil.

Organic sediments, which accumulate within the pond during shrimp culture, should be removed before new stocking. This accumulated sludge has a high organic and phosphorus content, acting as a fertiliser and leading to over-blooming of plankton as well as producing toxic gases within the pond (ammonia and hydrogen sulphide).

Small ponds (<1 ha) with good water circulation to concentrate waste into the pond centre are necessary for providing a clean living and feeding area for the shrimp. Feeding must be closely managed to avoid overfeeding. Decomposition of waste feed leads to poor pond bottoms and poor water quality, as well as over-blooming of plankton.

In the limited water exchange culture system, the carrying capacity of ponds is reduced due to the accumulation of organic sludge within the pond. The stocking density must be modified accordingly and currently a density of not higher than 40 shrimp/m^2 is recommended.

Since frequent water exchange cannot be used to reduce the plankton density, organic waste products and other toxic substances within the pond, close monitoring of pond water quality is required. Now, the farm biologist is required to be experienced and capable of interpreting the wide range of information collected from the ponds.

Another potential route of viral infection is via the postlarvae. A virus-screening technique for postlarvae has been developed in Thailand utilising polymerase chain reaction (PCR) and gene probe techniques. It is now possible to check postlarvae for YHV and WSBV before stocking. Together with a low water exchange system, this technique appears to reduce the risk of WSBV and YHV infection in farms which were previously affected.

Whilst the low water exchange system and larval screening method appear to reduce the risk of viral disease, they are by no means perfect. The screening method is only effective for diseases that have already been identified and the low water exchange system places serious management constraints on farmers. It is important that more detailed information regarding the interactions of shrimp, pathogens and the environment is available for a better understanding of shrimp diseases.

Key Areas for Research

Pathogenicity and interactions between the virus, shrimp and the environment

Viral structures and pathogenesis have been described by Wongteerasupaya et al. (1995) and epizootical studies have been performed using co-habitation. They demonstrated that WSBV could be transmitted via water or by ingestion, however no dose titration (virion/ml or virion/g) studies were performed, thus there is no estimate of the number of virus particles which cause infection or mortality. Using the PCR technique, a dose titration study could be performed by making a serial dilution of the virus particles for infection trials. Once the infection dosage has been properly determined, further trials regarding the effect of environmental conditions on the pathogenicity of viruses, as well as the efficacy of drugs or chemicals on disease prevention or treatment, could then be performed.

Shrimp defence mechanisms and health management strategies

Basic information regarding the general defence mechanism in shrimp is still lacking. As yet, there are no standard values or protocols for measuring the status of shrimp health and the activity of immune defences. If these could be established, shrimp health research could be standardised. This would then allow the effects of environmental stress, immunostimulants and other factors on shrimp health or disease susceptibility to be determined and compared.

High health progeny from selected broodstock are required, particularly regarding virus-free sources. The occurrence of vertical transmission (as in *Penaeus monodon*-type baculovirus—MBV) is still uncertain in WSBV disease, though there appears to be some evidence that it is possible. Therefore, a domesticated broodstock program must be developed to select virus-free and high-health animals for seed production.

Pond environmental processes

Culture systems using limited water exchange have been adopted and widely practised in Thailand in order to reduce viral contamination via influent water. The build-up of waste organic materials within the pond during the culture process now presents a major constraint to maintaining a healthy rearing environment. The accumulated organic material in the sludge within the pond generates toxic products and encourages high bacterial loads in the pond. Reduction of this organic material by enhancing natural microbial breakdown processes is becoming more important. Research needs to be performed regarding the nutritional and environmental requirements of those micro-organisms which are either present in, or could be introduced to, the pond environment.

The potential side effects resulting from chemical use in water treatment need to be studied because many farmers still opt to use chemical compounds as part of their pond management strategy. The efficacy and level of residue for each chemical needs to be determined.

The carrying capacity of shrimp culture ponds varies according to the culture system, geography, soil type and season. Evaluation of the relative importance of these factors and how they vary between areas may lead to standardised culture techniques for each system, allowing specific regulations for different culture areas and systems.

In order to ensure that this research achieves meaningful results, there is a clear need for support from the private sector and individual farmers. Results from the laboratory trials must be tested under actual farm conditions to ensure that appropriate conclusions and recommendations are derived.

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Research Needs from the View of Surat Thani Shrimp Farmers Association

Suraphol Pratuangtum*

OUR Shrimp Farming Association was founded eight years ago at the beginning of intensive shrimp farming in Surat Thani Province. Since intensive shrimp farming is a very new business, we have to cooperate in exchanging ideas and experiences.

The main activity of the Association is to make shrimp farmers realise how important the environment is to their business. One of our successes has been to encourage farmers not to allow pond sediment to drain into the natural water resource. Instead of draining the sediment out of the ponds, we dry it, then excavate it and use it for landfill.

Our Association meets twice a month. At each meeting, we exchange ideas, brainstorm on some problems we are facing, and sometimes have guest speakers.

We have three full-time staff to run the Association and one technician to run polymerase chain reaction (PCR) amplification for detecting systemic ectodermal and mesodermal baculovirus (SEMBV—white spot virus disease). About 1,500 free copies of a monthly bulletin are distributed among shrimp farmers.

Our Association has concluded that we would like to have more research on the following aspects of shrimp farming.

Improving Broodstock

The production of larvae relies totally on wild broodstock. Recently, we have detected SEMBV in wild broodstocks from many major areas. Only at a few places was SEMBV not detected in broodstocks. What will happen to the whole industry if most of the wild broodstocks are infected with SEMBV or other diseases?

By developing techniques for domesticating broodstock, disease transmission can be reduced. We can also improve shrimp production by selecting for improved genetic characteristics, as happens in the salmon culture and agricultural industries.

Shrimp Nutrition

Feed is the highest single cost in shrimp production. Understanding more about shrimp nutrition will help us improve feed formulation. Compared to the improvements made to salmon feed which have led to better growth performance and reduced impact on the environment, there has been no significant recent improvement in shrimp feed.

Immunity and Vaccination

Knowing more about shrimp immunity and vaccination will help farmers reduce the risk of disease in their ponds. We hope that researchers will increase our understanding of shrimp immunity and that this understanding will lead to the development of effective vaccinations in the near future.

Environmental Impact

We would be much happier if more researchers were investigating the negative and positive impacts of the shrimp farming. We would like to make the public

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understand that different farming techniques cause different impacts on the environment. Furthermore, we need to assure the public that pond construction does not need to involve mangrove areas.

As shrimp farmers, we appreciate the work of all the devoted researchers. With continuous contributions from all researchers, we are sure that shrimp farming will be a successful and sustainable business.

The Australian Shrimp Industry—Research Issues for Sustainability

Elizabeth Evans* and Paul T. Smith†

Outline of the Australian Shrimp (Prawn) Farming Industry

The shrimp farming industry in Australia is comparatively small, producing about 0.2% of world production. There are 10 hatcheries and 36 farms—27 in Queensland, 6 in New South Wales (NSW) and 3 in the Northern Territory. A 1995 study of the industry reported 9 farms grew more than one crop per year and 11 farms were larger than 20 ha (Macarthur Consulting 1995). There was expected to be an expansion of 235 ha in 1996/7.

Two species are grown commercially—*Penaeus monodon* (250 ha) and *P. japonicus* (100 ha). Production of *P. monodon* has stabilised at 1,400–1,500 t since 1993–4, while production of *P. japonicus* increased steadily to 223 tonnes in 1995–6. A total of 160 million postlarvae were produced in the hatcheries in 1993/4 from the spawners which were collected by five licensed operators in Queensland (Macarthur Consulting 1995). One of the farms used pond-reared *P. monodon* broodstock for postlarvae when wild spawners were not available.

Research is provided by six institutions: the Commonwealth Scientific and Industrial Research Organisation, Queensland Department of Primary Industry, the Australian Institute for Marine Science, James Cook University, University of Queensland and University of Western Sydney. The report by Macarthur Consulting (1995) found that there had been 37 prawn farm projects with total funding of $9,245,210 of which the Fisheries Research and Development Corporation, the Aquaculture Cooperative Research Centre and the Australian Centre for International Agricultural Research (ACIAR) were the major providers.

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Government Regulations

Government regulations have a strong influence on the development of the industry. The emphasis is on environmental controls, and shrimp farm licences are regulated by:

- two Commonwealth Government Acts;
- a number of International Treaties and Conventions;
- eight Acts of the Queensland Parliament;
- ten Acts of the NSW Parliament; and
- seven Acts of the Northern Territory Parliament.

In NSW, a Green Paper was produced which considered the general level of red tape in setting up or carrying out business, with particular mention of the difficulties of aquaculture. The closing date for submissions on the Green Paper was 30/9/1996, and the outcomes were expected to improve the process for obtaining a licence.

Quality Assurance Program for Export—GATT

An important consequence of the General Agreement on Tariffs and Trade (GATT) has been that exports of shrimp will require ISO9002 accreditation. Export certification could be based on issues such as clean waters, disease status, harvesting procedures and post-harvest handling. In 1996, the largest Australian farm (Seafarm) was the first shrimp farm in the world to gain International Standards Organisation (ISO) accreditation for their processing operations. Currently, five other farms are taking part in a quality assurance project which is jointly funded by the Commonwealth Government and the industry with the aim of providing the participants with ISO accreditation for on-farm processing operations.

Exporters of live *P. japonicus* are required to meet Food Processing Standards of the Australian Quarantine Inspection Service to satisfy the Japanese market.

Pollution Reduction Program in NSW

In 1995 in NSW, the Environment Protection Authority (EPA) required all shrimp farmers to submit a report on a pollution reduction program. The main recommendations of the report were as follows (Smith 1995).

- Wastewater from the cooking of prawns should be discharged into suitably sized septic pits. (Reason: to prevent water which is high in biochemical oxygen demand and nutrients from entering effluent canals.)
- Effluent treatment areas should be constructed so that biofiltration and settlement of suspended material can occur. The treatment areas should consist of wide canals (>15 m wide, 50 m long and 1–2 m in depth) and wetland–mangrove habitats. (Reason: to slow the effluent and allow suspended solids to settle before it is discharged. Also, wetland habitats could reduce nutrients and provide a fish nursery habitat.)
- Discharge drains should allow for tidal flushing. (Reason: to enable wetlands and mangroves to develop, and to prevent the stagnation of effluent.)
- The discharge pipe from the drain of each pond should have an elbow added so that the discharge is directed into the effluent canal, rather than into the wall of the effluent canal. At these points, the canals should be deepened by 0.5 m and a gravel bed of rocks should be added. The rocks should be 150–300 mm in diameter. (Reason: to prevent erosion of the walls and the bottom of the effluent canal.)

In 1996, an existing farm developed a wetland to treat its effluent and was able to recycle its water because of the improvement in water quality. In 1997, the EPA required a new farm to implement most of the design features in the Pollution Reduction Program (Smith 1995).

Industry Code of Practice

A Draft Code of Practice has been written (Donovan 1996) and circulated for Australian prawn farmers. The Code of Practice was written to comply with the *Environmental Protection Act 1994* which requires industries to show a "general environmental duty of care". The document covers areas such as potential impacts, best practices for environmental management, environmental monitoring, record keeping, site rehabilitation and relevant legislation.

Table 1. Scoring of the research priorities of Australian prawn farmers, 1996. A total scoring of 30 points per member was allowed across the priorities listed, or additional priorities could be added by members.

Topic	Score
Total disease management	166
Quality postlarvae	115
Determining the real impacts of prawn farming	99
Spawner availability	73
Feeds	29
Pond management—water and soils	28
Control of bacteria in hatcheries	19
Effective marketing	12
Beneficial bacteria	6
Effective use of chemicals	5
Kuruma[a] grow-out	5
Aerators	4
Quality assurance	4
New species	3
Warm weather kuruma[a] harvest and transport	2

[a] 'Kuruma ebi' is the Japanese name for *Penaeus japonicus*—hence this species is often referred to as the kuruma prawn.

Table 2. Assessment of progress with shrimp research in Australia (codes relate to the listing of researchable issues in the text).

Code	Researchable issue	Past efforts	Result	Current effort	Progress	Planned research	Expectation	Identified gap
1a	disease diagnosis	✔	poor	✔	slow	✔	uncertain	no
1b	disease management	✔	poor	✔	poor	✔	uncertain	perhaps
1c	product treatment	nil		✔	work overseas (unpublished)	nil		perhaps
2a	quality postlarvae	nil		✔	slow	✔	low	yes
3a	environmental impacts	✔	not used by regulators	✔	regulators misunderstand	✔	will complete in 3 years	no
3b	indicators for monitoring	nil		✔	under way	✔	will complete in 3 years	no
3c	carrying capacity	nil		✔	under way	✔	will complete in 3 years	no
3d	water treatment	✔	not published	✔	may not be practical	✔	will complete in 3 years	no
4a	pond-reared broodstock	✔	poor	✔	slow	✔	unsure	yes
4b	re-stock fisheries	nil		nil		nil		local issue
5a	local feeds	✔	poor	✔	improving	✔	will complete in 3 years	no
6a	blue-green algal control	nil		nil		nil		perhaps
6b	pond management	✔	lab results not relevant	✔	mixed advice	✔	unsure	perhaps

Industry Research and Development Program, 1996–2005

In 1995, Fisheries Research and Development Corporation commissioned a research and development (R&D) plan for the Australian industry. The report was prepared by Macarthur Consulting (1995) in consultation with the industry, researchers and research providers. The research needs of farmers were generally being met by current research, although some of the earlier research demonstrated that, in the absence of an industry connection, it had lacked focus on end results that were useful to the industry.

At the annual meeting of the Australian Prawn Farmers Association in 1996, a survey of farmers was undertaken to update research priorities. The ranking of priorities had changed in the twelve months since the R&D plan had been written, but the basic topics were the same (Table 1).

The Australian Industry's Issues for Research

The researchable issues for the Australian shrimp farming industry are summarised below and, using the same numbering system, an assessment of progress in shrimp research is shown in Table 2.

1) Total disease management:
   a) development of accurate diagnostic tools for shrimp diseases in hatcheries and ponds;
   b) sound advice on the management of disease events; and
   c) development of effective treatments for inactivating shrimp viruses in imported products (pellet feed, frozen shrimp).
2) Quality postlarvae:
   a) development of a screening process and quality certification of postlarvae.
3) Environment:
   a) assessment of real environmental impacts of shrimp farming;
   b) identification of indicators which can be monitored cost effectively;
   c) determination of the carrying capacity of waterways; and
   d) assessment of cost effective means of water treatment.
4) Spawner availability:
   a) development of techniques for closing the life cycle of *P. monodon* with pond-reared broodstock; and
   b) build up of local wild populations by restocking fisheries with hatchery-reared postlarvae.
5) Feeds:
   a) development of locally produced, high quality feeds.
6) Pond management:
   a) development of methods to avoid blooms of blue-green algae; and
   b) identification of the optimum rates for fallow periods, liming, stocking densities, sediment removal, fertilisers, and biologically active chemicals.

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Research Issues in Sustainable Coastal Shrimp Farming: a Private Sector View

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Abstract

The research needs of the private sector are frequently overlooked in establishing research programs intended to improve the industry itself. The reasons for this vary. Often, the private sector fails to grasp the relevance of particular research areas and there is a dearth of people within the private sector who can communicate the needs of the sector or keep up with the research being carried out. It is also true, however, that a large communication gap exists between the research community and the private sector. Expectations from research often fail to be met, with the private sector looking for short-term, fast answers and researchers looking for longer-term projects which can maintain funding for their laboratories and staff. The level of application of existing research is disappointingly low, reflecting a lack of attention to the development phase of research work to include implementation on the farm. This does not reflect any fault so much as a lack of recognition of the importance of extension as a component of applied research. There also exists a great deal of competition in the supply of information to farmers so that the lack of extension from reliable or unbiased sources leads to the farmers obtaining the majority of their information from groups with a particular vested interest. These issues need to be tackled if any program designed to improve the sustainability of shrimp farming is to succeed. This paper highlights some of the factors governing the application of research work in Southeast Asia and those areas which, in the authors opinion, need to be addressed to improve the industry's ability to meet the demands of the future.

SHRIMP farming in Southeast Asia has been one of the success stories of modern aquaculture. The speed with which the industry developed from a cottage and backyard level, consisting of little more than tidal entrapment, to a large, multidisciplinary and highly sophisticated industry, has been truly remarkable. The profits to be made by shrimp farming attracted many entrepreneurs and increased investment in rural areas suitable for growing shrimp.

The growth of the shrimp industry has taken place in a largely undirected and unconstrained manner. In recent years, problems have continued to mount as outbreaks of disease and the consequences of over-expansion and pollution become more evident. The shrimp industry has reached a watershed in its development as the conditions and forces shaping the industry change. It is timely to look at the industry and assess the current status of its technological development and research needs, to allow it to continue to develop into a more consistent and predictable activity.

Before addressing the question of researchable issues in shrimp farming, it is useful to address three key questions:

- What is the 'shrimp industry'?
- How do we envisage the shrimp industry in 5–10 years time?
- How do we get it there?

The Shrimp Industry

The term 'shrimp industry' covers many different components which comprise the business environment of the industry. In Asia, the various components

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of the chain of production are mostly independent with little vertical integration. Broodstock fishermen catch wild broodstock and spawners and sell these on to hatcheries or nauplius producers. The nauplii are either stocked in the hatchery or sold on to other hatcheries for growing on to postlarvae. In some countries there is no dependence upon wild fry for stocking shrimp ponds other than the few extensive ponds operating on tidal entrapment. The on-growing of the shrimp to market size is undertaken by independent farmers who sell their shrimp, either directly or through brokers, to processors and exporters.

Outside of the production chain, there are several other groups who are also stakeholders in the business of growing shrimp. These are mostly suppliers, such as feed companies and companies selling other goods and services required by the farmers such as chemicals and fertilisers. These groups also comprise part of the industry although their dependence upon production levels and successes is less direct.

It is important to consider these various groups as their individual goals differ markedly depending upon how they view their involvement. These goals have a significant impact on the promotion, acceptance and adoption of new ideas and practices developed as part of a research strategy. They can also provide valuable insights into the best means of integrating these into the production system and the most effective intervention levels for their promotion.

The shrimp farming industry in Asia is dominated by small-scale farmers who have only a few ponds. Various estimates place the percentage at 70–80% of farms. This is extremely important to take into account in any planning for development of the industry. The planning and decision-making processes are much more complex than they would be for an industry dominated by a few key players. The idea of sustainable development has to be brought to these farmers and they need to be convinced, as the industry's development is nothing more than the sum total of the decisions, right and wrong, made by these farmers. It is essential that information is provided to these farmers in such a way that their decisions can be informed ones. The alternative approach is to enforce or impose regulations upon them. However, these regulatory approaches have so far failed to influence the development of the industry in any country.

To some extent, uncontrolled and unsustainable development is inevitable in any new venture that appears to give easy profits and high returns on investment. A 'gold rush' mentality leads to many investors rushing in to take advantage of the situation without being fully aware of the risks involved. This leads to an almost inevitable 'boom-and-bust' cycle as the shrimp farming activity exceeds the available resources, whether they be physical, technical, economic, human or infrastructure. As the risks become more apparent, many short-term investors pull out, leaving those who are genuinely interested in making a livelihood from shrimp farming. Then follows a period of consolidation and slower development from a more professional, knowledgeable base. The key to reducing the short-term impact and increasing the long-term sustainability lies in making the inevitable boom-and-bust as short and as small as possible, and promoting the development of a more professional and informed farming sector.

The Next Ten Years

In order to develop an effective strategy for research that will be adopted by the industry, it is necessary to have some idea of the ultimate goal. Visions of the future shape of the shrimp industry vary somewhat but generally tend to assume that it will develop into a similar 'commodity' producer as the chicken and salmon industries. If that vision is accepted, then comparisons will indicate some of the key areas in which knowledge is lacking. However, two caveats need to be considered. One, that the vision of the industry's future is shared by those who currently are involved, and two, that the current climate of public opinion and acceptance of industrial development is quite different to that which prevailed when both of the chicken and salmon industries went through their early development. It should also be considered that the development of the industry along these lines would have a great impact on the kind of people who will remain in and enter into the industry.

This medium to long-term view of the future should be developed in consultation with industry. This consultation can be difficult as many researchers, particularly government ones, tend to be caught between the need to regulate and the desire to assist. There is often a feeling of being outside the industry and a lack of appreciation of the role that economic and managerial considerations play in decision making, even at a small farm level. The fault is not entirely one-sided as, unfortunately, there also exists a lack of appreciation of the role of research and development in the industry's success even among technicians involved in the industry. However, there are scientists and industry managers who do appreciate the role and responsibility of both sectors in pushing the industry forward and it is important that the dialogue be not only continued but increased to allow a balanced development of the industry.

Problems with Research Implementation

For the purposes of this paper, the issues described will be those related to production rather than those related to the various service providers, except where service-oriented research has a direct bearing on production.

Before going into detail on the researchable issues, it may be useful to examine the differences in the way that research activities are viewed by the scientific and farming communities. Scientists are generally more involved in obtaining results rather than implementing them. There is a tendency to regard publication of results or papers as the end point and the implementation or adoption of new practices as a result of the work is the responsibility of someone else. The time taken to achieve results varies, but it is not uncommon for research activities to take several years to yield results.

Those involved in the private sector, on the other hand, tend to be less interested in how results are obtained than in how they can be applied. At the same time, they have little time to devote to scouring the technical literature and developing practical means of application. Time frames for results also tend to be far shorter, measured in weeks or months rather than years.

The differing attitudes to research and development (R&D) have been summarised as **R**&D versus R&**D**. In other words, most researchers place the emphasis on research with some development activities, whereas the industry demand is for more development and application of existing research information. Indeed, the word 'development' is frequently omitted by scientists when discussing their work. At the same time, many researchers become frustrated at the lack of application of their research findings while being unable or unwilling to effectively put them across to a non-technical audience. There is a need to address this issue by increasing the emphasis on communicating results and explaining the implications for industry. The effectiveness of this depends very much on finding people who can bridge the gap of understanding between the two groups.

From a commercial point of view, it is important that any research program or activity designed to be implemented by the industry should include a requirement and commitment by the project team to undertake activities to ensure that development activities towards successful implementation are carried out. This moves away from the traditional form of investigative research into applied research. Project plans and programs can be developed either jointly or in consultation with industry and the progress monitored together. In my experience, the greater the involvement of the eventual user in the project, the greater the rate of implementation.

The consequence of this gap can be seen in one key area of contention within the modern shrimp industry—the use of drugs and chemicals. A simple theoretical example can serve to demonstrate the difference between the points of view of scientists and farmers and the dynamic which leads to increased drug use despite a wealth of information demonstrating that it may not work.

In an outbreak of a disease, the ponds of 100 farms are affected. Of the 100, 50 farmers resort to a particular drug or chemical claimed as a cure and 50 carry on without any drug use. Of the group using the drug, 25 report an improvement and harvest, while 25 show no improvement and have a poor harvest. Of the group not using drugs, the same scenario develops—25 improve, 25 do not. Based on scientific analysis, there is no difference between the groups using or not using the drug and the conclusion would be that the drug did not work for the particular problem affecting the farms.

However, in reality, the 25 who used the drug and whose shrimp improved, would promote the use of the drug among their friends and among other farmers, sometimes at the request of a salesman. The 25 who did not use the drug and whose shrimp got worse, would be tempted to use the drug at the next outbreak. The 25 who used the drug and whose shrimp did not recover would be inclined to think that, since the drug did work on some farms, they either used it wrongly, too late or did not use enough. The final group, those whose shrimp recovered on their own, would generally not say much as the available evidence (the 25 who used it and got a good result) would tend to convince them that it may indeed help. They may even be tempted to use it in future to obtain an even better result.

Thus it can be seen that, even under conditions where scientific analysis of the available evidence demonstrates that a particular treatment does not work, its use in the farm could increase dramatically. This demonstrates the impact of marketing of information on farming practice. The vacuum created by the lack of reliable, unbiased information is taken up by providers of goods and services in the form of technical support. This support does not come free and, in the case of unscrupulous salesmen, is frequently biased in such a way as to promote the use of their product, often by dubious or tenuous associations. It should be mentioned that not all salesmen behave in such a cynical manner although, in my experience, the number of salesmen who do is significant. In general, this problem is most frequently encountered with salesmen who work independently or for smaller companies looking to make fast returns. More responsible or larger companies tend to take account of the effect on the entire market potential and avoid creating situations where short-term gain may cause long-lasting damage to their market prospects.

Researchers who wish to present information to farmers have to realise that they are in competition with alternative information sources and that the farmer often finds it difficult to judge between them. Viewed purely as a marketing exercise, the researcher may have a good product whose benefits can be justified but the battle for the farmer's mind is being lost in the marketplace. It is of vital importance that this gap is addressed as the consequence is that the credibility of scientists as a source of practical and useful information to farmers is under threat. As a result, scientists are frequently perceived as being out of touch and impractical compared to the purveyors of technical sales support, a perception bolstered by the lack of 'farmer-friendly' presenters of unbiased technical information.

Researchable Issues

The success of shrimp farming and some of the impressive rates of growth in production masks the primitive state of much of the technology involved. Despite the many grandiose claims made by various people concerning new advances and improvements, the majority of farmers still depend on a healthy dose of luck. The current level of sophistication of shrimp farming is still quite low. Broodstock are fished from the sea, there is a reliance upon wild spawners, hatchery methods lack standardisation, efficiencies are low, fry are stocked into ponds in which relatively few tools are available to control the production environment, and the yield and quality of the end product are largely uncontrolled. All of these factors combine to place the future sustainability of shrimp farming in considerable doubt and they need to be addressed so that the industry can develop in ways which will prove to be of long-term benefit.

It is also true to say that production efficiency has not so far been a major concern within the industry, with the possible exception of feed-use efficiency (feed costs represent around 50% of variable costs so there is a direct economic benefit in its efficient use). It may be trite but nonetheless should be kept in mind, that the producer's main aim is to maximise his profit for the lowest expenditure of time and energy. If profits are high without any great need to spend a lot of time and energy, the incentive to improve efficiency may be low. This is another reason behind the lack of application of research findings.

Hatchery issues

The current reliance on wild supplies of broodstock imposes a severe constraint on the future development of the industry. An animal production industry which depends on wild stocks alone cannot achieve long-term sustainability or begin to make any improvements in the genetic suitability of the stocks for cultivation. Closed-cycle rearing of broodstock from pond-reared shrimp has been achieved several times in several countries but has so far failed to develop into a commercially viable operation. The reasons behind the lack of interest in applying these methods demonstrate the differences in outlook between the scientific and commercial sectors. To date, the reported rates of nauplius production from pond-reared broodstock have been much lower than those from wild spawners. Although this is understandable given the current state of knowledge of shrimp reproduction, it reduces the attractiveness of the pond-reared stock as the cost of producing a fixed number of nauplii is perceived to be high due to the larger number of females needed. The resulting lack of commercial interest had stifled the development of closed-cycle breeding until relatively recently, when the appearance of several new virus diseases prompted renewed interest in it as a means of reducing the disease risks associated with wild stocks.

The development of closed-cycle breeding programs has demonstrated its worth in other areas of animal husbandry. The chicken, swine and cattle industries as we know them today would not exist in the absence of breeding programs to select for specific desirable attributes. Even the relatively young salmon farming industry has progressed at a tremendous rate since the development of controlled breeding programs.

The health status of broodstock sources has generally been neglected although there are a few recent reports that include estimates of prevalence of specific viral diseases in wild shrimp. However, the available information is often sketchy and no epidemiological study has been performed. There is a need for these kinds of study to be undertaken to identify the disease status of different stocks and to develop means of controlling the entry and movement of pathogens into the breeding and farmed populations. The information gained is also essential for the development of any certification program for disease control.

Hatchery production levels in Asian hatcheries are generally rather low. Various estimates are available but the average survival rates are generally accepted to be between 20–30% on an annual basis. This implies a great inefficiency in production, especially since survival rates in excess of 70% can be obtained on an occasional basis, suggesting a tragic waste of the resources available. Any consistent improvements in survival would help to remove the hatchery as a bottleneck in production and reduce the costs associated with postlarvae, which can represent 10–15% of the direct cost of production.

Overcoming restrictions in postlarvae supply would also allow a greater focus to be placed on the quality rather than the quantity of production. At present, many quality assessment programs for postlarvae fail due to a lack of postlarval supply. This forces farmers to accept lower quality postlarvae simply to ensure that their ponds are stocked. Removing the production bottleneck would allow hatcheries to differentiate their postlarvae based on quality. Farmers show great loyalty to hatcheries with a good record of supply and post-stocking performance and are willing to pay a premium for postlarvae that give better production performance.

Farming issues

The relative lack of sophistication and low efficiencies of production extend also to the farming sector. Relatively few major advances impacting positively on yields and efficiencies have occurred in the past ten years. It is to some extent true that this is due, at least in part, to the lack of sufficient research funding and expertise available in those countries in which shrimp are farmed. Even Thailand, with its large shrimp industry and well-organised government support, still suffers from a heavy reliance on a small group of people and a limited budget.

The situation can be clearly seen from an analysis of production data from Aquastar Ltd and contract farms in southern Thailand over the period 1989–1995. In the first crops, when farmers had little experience, stocking densities were kept low at around 18–20 shrimp/m^2. Yields averaged around 4 t and survival rates averaged around 65%. By 1995, stocking densities had increased to an average estimated at 60 shrimp/m^2 (having been as high as an estimated 75 shrimp/m^2), but yields had increased only slightly to 4.5 t due to a drop in average survival to around 35%. Although these figures include the effects on production of two serious viral diseases, it can be clearly seen that efficiencies, far from improving, actually declined. The example of Aquastar's contract farmers holds true for the industry in general, although it is difficult to obtain exact figures for the whole country due to the many shifts in production areas (previous shrimp farms closing down, new areas opening up).

It is widely stated and believed that shrimp farms have a limited lifetime for production although no good explanations exist for why this should be. Self-pollution as a factor is widely suspected but measurements of the organic content of pond soils generally fail to demonstrate any convincing relationship with productivity. Some ponds and farms have continued to produce consistently (allowing for disease impacts) over many years, proving that extended production in one area is possible. Obviously many factors are at work, including intensification, postlarval availability and quality, impacts of new diseases, impacts of feed quality and availability, development of new pond management techniques (which can have both positive and negative impacts) and economic factors, among others. However, there has been very little concerted effort to identify and assess the relative importance of these. Scientific research in particular tends not to consider the impact of economic factors on farmers' decision making and hence productivity. Explanations are therefore sought in purely technical terms.

Pond management has been frequently found to be by far the greatest determining factor in the success or failure of a shrimp farm operation. The levels of interest and skill have far more effect on the success of a farm than any other single factor. Even during problem periods, 'good' farmers tend to have better production than 'bad' farmers. Given this, it may be expected that an assessment of what makes a 'good' farmer would be quite useful. The information gained could be used to assist in the development of a 'best practice' for pond management.

The development of a range of best management practices would greatly improve the consistency of production. To do so would require a high level of cooperation between the scientific community and the production and business sectors. Even the adoption of uniform measures, targets and objectives would greatly assist in achieving such a goal. To give some examples, terms such as 'extensive', 'semi-intensive' and 'intensive' are widely applied, although there are no uniform definitions of these words. Even when they are defined, the definition depends upon the level of intensification that exists at that point in time or in one locality. Stocking densities are still frequently used by scientists and farmers despite the fact that the number of shrimp stocked has no real bearing on production due to differences in survival rate. Final yields are frequently used to measure success, although the final measure of a farmer's success is actually the profit from the crop. The development of clear definitions is, in my opinion, central to the success of any program intended to improve sustainability in shrimp farming at any level.

Good feed management is one of the most important factors in the success or failure of a shrimp farm operation. Feed costs represent between 40–60% of the direct cost of production in a farm. Good yields with poor feed conversion ratios (FCRs) can still result in a farm going out of business. A great deal of attention is paid by good farmers to keeping FCRs below 2:1 and a good farmer can consistently achieve an FCR of around 1.6:1. Having said that, the basis for feed management requires many assumptions to be made about the way in which shrimp feed. Many of these assumptions are anecdotal and untested. Research into these could assist in developing feeds and feeding strategies which will improve the average FCR, the profitability and the economic sustainability of farms.

Virtually all shrimp feeds sold are pelleted feeds. This imposes some severe restrictions on the formulator as the formulation must allow the production of a good, water-stable pellet. This limits the amount of fat which can be included in the diet, for example. The average FCR for salmon has decreased dramatically over the past ten years, partly due to the switch to extruded, rather than pelleted feeds. Extruded diets allow more fat to be included, which allows a reduction in the protein content. As protein is the most expensive ingredient, this can make the feeds cheaper to produce. The reduction in protein also reduces the pollution due to feed as the nitrogen content is reduced. The reason for a lack of acceptance of low pollution (low nitrogen, low protein) feeds is the common belief among farmers that high protein levels are necessary for good growth of the shrimp. This belief stems, in part, from feed companies competing on the basis of protein content. This has back-fired, as attempts to reduce protein content by feed companies are now perceived by the farmer as an excuse to cut their costs and increase profits at the expense of the farmer. More research into low pollution, cheaper feeds which achieve the same or better performance on the farm would benefit the farmer financially as well as reducing the pollution load on the environment.

The large impact of shrimp farming on the environment is due to the large volume of water discharged. The further development of systems which use lower rates of water will greatly alleviate the pressure on the environment as well as reduce the cost of pumping which, although often neglected, can be significant. A further area which is often neglected is the development and dissemination of techniques utilising full-strength seawater. It is still widely believed that fresh water is needed to mix with the seawater to achieve intermediate salinities in order for shrimp farms to succeed. However, large farms utilising ambient seawater do exist and production levels are comparable with farms situated in brackish-water or freshwater areas. The farmers in the Aquastar system in southern Thailand have been growing shrimp in ambient seawater conditions for the past eight years and production levels have been comparable to those of the industry in general. The benefit of such systems is that they can be situated in open coastal areas where the carrying capacity of the receiving water is much less of a problem than in estuarine or freshwater environments where user conflicts may be higher and where carrying capacities can be limited. The techniques required to successfully grow shrimp in ambient seawater are different from those for brackish water and still require a great deal of development. Additional research into the control of water quality and phytoplankton communities in seawater systems would further improve the performance and acceptability of such systems.

Health management

Health management (as opposed to disease control) is one of the key areas in which developments are needed both as a matter of short-term urgency and for long-term development of the industry. For many years the focus of terrestrial farming systems has been on health and productivity schemes, encompassing both prevention strategies and focusing on productivity of farmed stocks rather than the 'fire brigade' approach which still predominates in the shrimp industry. The absence of clinical or obvious disease problems does **not** indicate that there are no fundamental problems within the system. However, this still tends to be the dominant attitude among farmers.

Much can be done to improve the situation using currently available knowledge within the scientific and farming communities. For example, there is sufficient information and experience to allow for rudimentary risk assessment to be carried out for a number of diseases to determine the likelihood and severity of problems that may be encountered. This information will be paramount in developing strategies to deal with the specific diseases as well as suggesting generic strategies that can be implemented to deal with all diseases sharing common points in their epidemiology. The relative costs and benefits associated with diseases and prevention/treatment strategies can also be calculated. This will assist in deciding upon the most effective strategy from an economic and technical standpoint.

One of the most important factors in dealing with a disease outbreak is information. Knowledge is needed on the type of disease and the factors determining its occurrence. Also, knowledge is needed on the condition of the shrimp stocks and of the environment in the pond. These are key elements in deciding upon the best means of dealing with a disease. The relevant knowledge is not, generally speaking, easily available to farmers and is subject to the pressures of the 'information market' mentioned in the early part of this paper. Among the greatest aids to dealing with any disease outbreak is to ensure that the correct information is available to farmers as soon as possible. This may be as simple as providing them with the most up-to-date information on the spread, impact and diagnosis of the disease in terms that are easy to understand. If treatments are available, or just as importantly if they are not, this should be mentioned. When such information comes from a recognised, impartial body (such as the relevant government authority), farmers may be more inclined to accept it.

During the initial impact of the white spot epidemic in Thailand, for example, a working group was assembled to assess all available information on the disease. This working group comprised representatives from the private sector, including suppliers such as feed companies, as well as the academic and government sectors. Based on the discussions of the working group, the Department of Fisheries (DOF) undertook to produce a leaflet for farmers explaining what the disease was, how to diagnose it and what steps could (and could not) be taken to deal with an outbreak in a farm. The information contained in the leaflet was agreed upon and accepted by all members of the working group and all parties undertook to provide support for the dissemination of the information. This involved some companies funding the printing of additional copies of the DOF leaflet for distribution to their customers. In addition to the leaflet, a national task force was established to identify the key areas in which information necessary to develop a strategy to deal with the disease was lacking. Research proposals to carry out the necessary work were quickly developed and approved, the budget coming from a combination of government and private sector funding. As a result of the response by the working group and DOF, the impact of the white spot epidemic was significantly reduced. One single piece of information, that the disease was due to a virus and that there were no cures, probably saved most farmers from spending significant sums on bogus 'cures' and from additional losses by waiting too long before harvesting.

To date, almost all of the effort has concentrated on those diseases that cause direct losses through mortality. Relatively little attention has been paid to diseases which, although not fatal, can have a high economic cost. Diseases that affect productivity, by reducing growth rates or affecting the quality and value of the shrimp at harvest, can have a high economic cost. Any program dealing with shrimp health improvement must include non-lethal diseases and disease syndromes.

Present disease diagnostic capabilities depend largely upon the availability of sophisticated laboratories to conduct the tests necessary to establish a clear diagnosis of the problem. Techniques such as histology and polymerase chain reaction (PCR) testing, for example, require a fair degree of sophistication and qualified personnel to conduct. Very few countries or shrimp farming areas have easy access to the facilities and expertise required. Also, the majority of the tests do not give results quickly enough to allow them to be used as part of a decision-making process on the farm. There is a need to develop simple tests that can be used on the farm with a minimum of training to allow for real-time, pond-side diagnostic capabilities. This would allow farmers to make faster and better informed decisions to deal with problems when they arise. Further development and simplification of gene probes and rapid staining techniques show great promise in this respect but it is necessary to take the procedures out of the laboratory and explore ways in which they can be better applied under farm conditions.

The range of chemotherapeutic drugs approved for use in aquaculture is frustratingly small and has led to a widespread use of non-approved drugs. The non-approval is, in many cases, the result of a lack of sufficient data to support approval rather than the presence of data to support a ban. More work has to be done to demonstrate the efficacy or otherwise of the available drugs to obtain the appropriate conditions of use and approvals. A 'fast-track' or 'pending' approval procedure may be useful for those drugs approved for use in other food animals while the relevant data are being obtained for shrimp. The development of chemotherapeutic approvals should also include the dissemination of relevant guidelines on their proper use, control and application.

The establishment of safe residual levels of chemotherapeutics for shrimp is also necessary. The current situation is that, in many countries, no residuals of drugs commonly allowed in other food products such as beef and poultry are permitted in shrimp. This is frequently due simply to the lack of information on residuals. Acceptable residual levels of chemotherapeutics should be allowed for shrimp in the same way. Exporting and importing countries should work together to establish these standards.

Nutrition plays a large part in the management of shrimp health. Monitoring of the feeding behaviour and patterns of the shrimp is one of the main ways in which farmers can get early indications of pending problems. The role of nutrition in the shrimp's defence mechanisms is still very poorly understood. It is difficult to get good data on this in the field as feed companies do not (nor should they) publish details of their formulations. However, the effects of variations in raw material quality and the effect of the processing of the feed are poorly understood. A better understanding of these would allow feed companies to improve their formulations and processing to take account of these variations. At present, feed formulations tend to be compared on an 'as formulated' basis. However, the most important consideration at the farm level is what the formulation is at the point of ingestion by the shrimp. Feeds can change considerably once placed in the water as water-soluble components leach out and water stability affects the availability and palatability of the feed. Feed research should also include comparisons of formulations after one hour in water. This would better reflect the feed as eaten by the shrimp and may point the way to more far-reaching improvements in formulations.

Shrimp health enhancement programs are already being pursued in several countries. Development of *specific* pathogen-free (SPF) and *specific* pathogen-resistant (SPR) stocks has already taken place with some species of penaeid. (The use of the word *specific* should be noted here, as there has been much confusion over the terms. SPF/SPR shrimp are not 'disease free' or 'disease resistant' but have been specially bred and maintained to exclude particular disease organisms for which this approach is appropriate.) These programs are highly dependent upon the establishment of breeding programs using pond-reared stocks, emphasising the importance of closed-cycle breeding for the future of the industry.

The development and testing of immunoenhancers, immunostimulants and vaccines is still at a very early stage. Indeed, there is still a lot of controversy over the concept of vaccination as applied to shrimp because they have no specific immune system. Recent work has shown that disease 'tolerance' may also be a mechanism in the shrimp's arsenal of defences against infection. This work needs to be continued and refined to develop practical and applied measures that can be taken at the farm to reduce the risk of catastrophic losses to disease. The impact of vaccines and immunostimulants on the salmon industry in Europe has been substantial and demonstrates the benefits that may be gained from their application in shrimp culture.

One of the least investigated, yet potentially most significant, factors in the success or failure of shrimp farming may be the impact of pesticides or other harmful substances on the shrimp. Many shrimp farms are located in areas of high agricultural activity where the risk of contamination is high. Most farming activities nowadays involve the use of herbicides and insecticides. Some of these, particularly the insecticides, can be toxic to various life stages of the shrimp at extremely low levels. Bioassay experiments can be conducted on the farm to confirm the acute toxicity of the most common toxicants used in the vicinity of the farm, but the existence of chronic or sub-lethal effects requires more sophisticated facilities and equipment. Considering the potential synergistic/antagonistic effects of toxicants on shrimp in field conditions, it is surprising that so little work appears to have been done in this field.

Postscript

This paper has done little more than skim the surface of some of the major issues as perceived from the private sector. Obviously, such a brief presentation can do no more than highlight a few issues. Many more exist and the priorities may be regarded differently by other people. However, there remains one key issue which can and should be addressed in any program intended to enhance or influence the development of the industry, and that is communication. The better the dialogue between the private and public sector, the better the understanding will be. This will inevitably lead to an improvement and increase in the implementation of research findings. To do so will require some shifts in attitudes on both sides and the recognition that the communication of information and development of applied methods based on research results is a distinct skill and is essential to any applied research program.

Shrimp Culture in Sri Lanka: Key Issues in Sustainability and Research

J.M.P.K. Jayasinghe*

Present Status of the Industry

Shrimp farming in Sri Lanka is presently restricted to North Western Province and according to recent surveys the total number of farms is around 925 with an estimated area of about 3,500 ha. Total farm production during 1995 was around 3,250 t and foreign exchange earnings from the industry were rupees (Rs) 2,150 million.

The farms are concentrated over a distance of about 120 km around Chilaw Lagoon, Dutch Canal, Mundal Lagoon system and Puttalam Lagoon, with 70% of farms depending on Dutch Canal for their water resources. Ponds are operated at two different levels of semi-intensiveness with stocking densities ranging from 5–25 postlarvae/m^2.

This paper discusses the key constraints to shrimp culture development in Sri Lanka and examines the priorities for research.

Constraints Related to Water Quality

Farms take in water from and discharge their effluent into the same water source and no treatment procedure is practised. Due to unplanned development of inlet–outlet canals, the effluent water discharged from one shrimp farm is often pumped into the adjoining farm. Small-scale developers are generally more affected by self-pollution.

Discharge of pond effluent has led to deterioration in water quality in the main water sources. A study of Dutch Canal has revealed that several water quality parameters, particularly total suspended solids and toxic metabolic end products (nitrites, sulphides, ammonia), are at sub-optimal levels for shrimp culture for a considerable part of the year (Corea et al. 1995). A few farms now use effluent treatment systems, spurred on by the recent outbreak of systemic ectodermal and mesodermal baculovirus (SEMBV).

Salinity in the major sources of water falls below an acceptable range for shrimp culture (less than 5 ppt) during the wet periods of the year. The high evaporation rates and relatively low rainfall in dry and arid zones result in unfavourable salinity ranges (50–65 ppt) during dry weather periods of the year. Some farms tap into groundwater resources to dilute high salinity water, which is not an environmentally sound practice.

Considering the high rates of water exchange, unplanned extraction of water will have considerable impact on groundwater resources. Also, during wet weather, when salinity of water sources falls, farmers stop or minimise water exchange. This results in a build-up of toxic metabolites (sulphides and nitrites) in culture ponds, resulting in slow growth and low survival. Shrimp are more vulnerable to pathogens during this period.

Constraints Related to Accumulated Sediment and Problem Soils

The accumulated sediments in pond culture have high pollutant potential. Although practices of some large-scale and medium-scale farms remove dried sediment from pond bottoms following each harvest, this is not practised by most of the small-scale developers.

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Currently, farms are mainly on inter-tidal areas which are marginal for shrimp culture development. The land belongs to the Crown and was obtained on lease. However, new Crown land is now not available and farmers are developing supra-tidal areas for shrimp culture. Trends in recent land use show that conversion of land from coconut and rice paddies to shrimp culture is occurring. A recent estimate indicates that about 70% of farms are on inter-tidal areas while 30% are on supra-tidal land.

Most of the inter-tidal areas in Sri Lanka have a pyritic zone which is acidic or potentially acidic. The main adverse impacts for shrimp culture are acidification of the water and soil, poor farm productivity, poor fertiliser response, clogging of gills by hydrated iron oxides, iron deposits on the ventral side of shrimp, and release of iron, aluminium and manganese ions into the culture environment (Jayasinghe 1991).

Although farmers suffer from problems related to accumulated sediments and acid sulphate soils, they do not realise the actual cause. Farmers relate most of the problems only to water quality.

User Conflicts and Sociological Considerations

Shrimp farming provides direct employment to about 40,000 people and has improved infrastructure facilities in villages and living standards of communities. However, the majority of investors in shrimp farming in Sri Lanka are entrepreneurs rather than farmers, outsiders rather than people from the community. This has resulted in conflicts between shrimp farmers and other users of coastal resources.

The main conflicts are in the areas of utilisation of common property resources, and occur with traditional agriculture, traditional animal husbandry, artisan fishing activities and traditional small-scale industries.

Conflicts and other social problems which have been recorded in North Western Province are summarised as follows:

- Conflicts over utilisation of mangrove resources and salt marsh areas.
- Conflicts with traditional agriculture practices over:
  - salinisation of agricultural waters; and
  - conversion of agricultural land to shrimp farms.
- Conflicts with non-traditional export crops over reduction in available land.
- Conflicts with paddy cultivation over:
  - conversion of paddy land to shrimp farms;
  - salinisation of water;
  - deposition of salt on leaves; and
  - lowering of the watertable.
- Conflicts with traditional animal husbandry over:
  - pollution and depletion of drinking water for animals; and
  - reduction in grazing land.
- Conflicts with traditional and artisanal fishing industry over:
  - depletion of natural fish/crustacean resources;
  - reduction in nursery grounds;
  - reduction in feeding grounds;
  - reduction in spawning grounds;
  - obstruction to landing sites;
  - obstruction to navigational paths;
  - obstruction to natural water movements; and
  - reduction in temporary fishing grounds.
- Adverse impact on village expansion activities.
- Obstruction to traditional roads and paths.
- Retention of flood water and more frequent floods in the area.
- Salinisation of drinking water.
- Conflicts with traditional, small-scale salt production.
- Reduction in small mammal populations.
- Reduction in migratory bird populations.
- Depletion of groundwater resources.

Disease Outbreaks

Sri Lanka experienced two major disease outbreaks: in 1988–1990 (Jayasinghe and MacIntosh 1993) and in 1996. The first outbreak resulted in losses in production of 35–72% because of *Penaeus monodon*-type baculovirus (MBV) infection. Poor farming practices, bad water quality, poor soil conditions and larval imports were identified as the main contributory factors for the outbreak. Then in May/June 1996, a SEMBV epidemic was recorded and around 85% of total farm areas became non-functional due to this outbreak. The total loss in foreign exchange earnings is estimated at Rs 1,000 million.

There are also frequent, localised outbreaks of disease in farms and the symptoms are mainly related to bacterial infections and fouling of gills by *Zoothamnium* spp. The problems are related to poor sediment condition and/or acid sulphate soils. Such problems are rarely understood by farmers.

Hatcheries frequently suffer from luminous bacterial problems.

Sustainability of the Industry

The total annual production of cultured shrimp in Sri Lanka has not increased proportionately to the increase in culture area. It appears that the coastal area developed for shrimp farming is approaching the carrying capacity of the environment, although this needs confirmation through further scientific evidence (Jayasinghe 1995). It is important to fund research efforts to determine the carrying capacity of the various areas and to improve the environment.

Economic Constraints

Shrimp farming has developed into one of Sri Lanka's most valuable non-traditional industry, earning foreign exchange of over of Rs 5.5 billion from 1990 to 1995. However, the industry has been affected by a variety of production problems including an acute shortage of postlarvae, floods, continuous curtailment of power, and disease outbreaks. Consequently, many shrimp farmers are now burdened with financial problems.

Existing term loans obtained by shrimp farmers are Rs 650 million. An interest rate of 18% is payable to banks and this amounts to interest payments of Rs 117 million. Farmers need to rehabilitate and restructure their farms with cooperative treatment systems. The cost of restructuring has been estimated at Rs 250 million. Another Rs 250 million is required by farmers to cover the working capital to recommence operations. Farmers expect this money from banks on a concession.

Current Research in Sri Lanka

The National Aquatic Resources Agency (NARA) is the institution responsible for national research activities in shrimp culture and it acts as the research wing of the Ministry of Fisheries and Aquatic Resources Development. There are proposals by the private sector to develop research facilities in the area of health management and all national universities are willing to participate in shrimp culture research. Several universities have developed research programs jointly with NARA. The University of Peradeniya, University of Colombo and the Postgraduate Institute of Agriculture are presently carrying out collaborative programs.

Most of the research activities are designed to tackle immediate problems faced by the industry and research is carried out with the participation of farmers. The main mechanisms of disseminating research are production of leaflets, seminars, workshops and group discussions at farm sites. Constraints include a lack of facilities, trained personnel and funds. Some research components recently included the:

- effects of chlorine treatment on water quality and growth of *P. monodon* in semi-intensive culture ponds;
- influence of source of water on disease symptoms and quality of cultured shrimp;
- effects (some) of chlorine treatment on bacterial quality in the culture environment and in cultured shrimp;
- influence of soil acidity and stocking density on farm performance and quality of cultured shrimp;
- influence of farm management procedures on farm performance in semi-intensive culture systems; and
- environmental impact of shrimp farming on the Dutch Canal.

Priorities for Future Research in Sri Lanka

Research issue: health management in shrimp culture systems

Objective: to improve the health management aspects in shrimp culture systems in Sri Lanka.

- Identification of pathogens.
- Measures to minimise the risks of disease outbreaks.
- Quarantine procedures to prevent disease transmission.
- Rapid diagnostic methods.
- Identification of carriers of different virus species and methods of disease transmission.
- Studies on recent viral outbreaks.

Research issue: development of treatment systems for small, medium and large-scale culture systems

Objective: to minimise the risks of disease outbreaks and to improve the sustainability of the industry.

Physical treatment

- Processes to improve the efficiency of physical treatments.
- Effective storage times and mesh sizes for filtering water.
- Improved engineering designs for sedimentation tanks and treatment tanks.

Chemical treatment

- Determination of effective doses/effective chemicals for different pathogens.
- Measures to minimise impacts of chemical treatment (plankton collapses, lab-lab formation).
- Measures to improve primary productivity in ponds after chemical treatment.

Biological treatment

- Identification and assessment of organisms for biological treatment under different physico-chemical conditions.
- Investigation of effective densities and appropriate ratios of treatment area to culture areas.

Research issue: management of sediment condition and problem soils for shrimp culture

Objective: to improve the sediment condition in grow-out systems by better management practices and to ameliorate problems related to conversation of acid soils for shrimp culture.

- Identification, mapping and assessment of problem soils for shrimp culture, adverse impacts and amelioration measures.
- Measurement of sedimentation rates, sediment quality, and identification of measures to improve sediment condition.

Research issue: determination of the carrying capacity of the environment

Objective: to determine the carrying capacity of the environment and develop policy and legal frameworks to maintain this capacity.

- Determination of the carrying capacity of the water resources to receive effluent.
- Determination of the carrying capacity of the environment to support shrimp farming (with respect to farm density, stock density, culture cycle, stocking size and water quality).
- Pollutant loadings and trends in water quality changes.
- Improvement of on-farm management procedures.
- Development of policy and legal frameworks to control and maintain activities that affect the carrying capacity of the environment.
- Coastal zone management planning.
- Development of standards for effluent.
- Environmental protection licence procedures.
- Improvements to environmental impact assessment procedures and legal framework.
- Restrictions in using chemicals/harmful substances.

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Shrimp Culture in India: Key Issues in Sustainability and Research

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In India over the past five years, there have been major developments in shrimp farming. On the east coast in 1994–5, there were 100,000 ha of shrimp farms and they produced 83,000 t. However, shrimp diseases and environmental problems occurred, so that in 1995–6, production dropped to 70,000 t. There have also been incidents of social problems in many areas where shrimp farming occurs.

Over 90% of the farms are small scale (<2 ha) and, while a range of stocking densities are used, most farms are extensive. The farms are found near creeks, canals, estuaries and the sea. Although the Indian Government has encouraged investment in shrimp farming, there have been recent restrictions on the location of shrimp farms in an effort to prevent some of the problems that have occurred in the past.

Constraints on the industry can be summarised as follows:

- the concentration of farms in some areas is too high for the infrastructure facilities as well as the carrying capacity for the waterways;
- the reliance is on only one species of shrimp;
- there is limited seed and broodstock; and
- there are substantial irrigation problems in some areas.

Research activities are attempting to address some of the difficulties. Some ongoing research is investigating diversification of species and the use of captive broodstock. Other work involves examining the environmental impacts of shrimp farming and considering ecologically sustainable methods for the rational use of water (i.e. carrying capacity of waterways). This work is also assessing methods for effluent treatment.

The priority areas for research in India are:

- shrimp broodstock development:
- pathogen-free seed;
- production system management;
- immunostimulants and health monitoring;
- feed quality and probiotics;
- physiology of shrimp;
- effluent treatment systems for hatchery and farm discharges;
- monitoring impacts of shrimp farming;
- developing ways of determining carrying capacities;
- pond microbiology;
- genetic characterisation of shrimp and breeding programs;
- developing appropriate quarantine procedures;
- transfer of technology; and
- investigating the role of women and other groups in socioeconomic studies.

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Shrimp Culture in Bangladesh with Emphasis on Social and Economic Aspects

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Abstract

Over the last two decades, shrimp farming has emerged as a major industry in Bangladesh. The impact of the process has economic, social and environmental dimensions. All of these may have serious implications for sustainability, not only of shrimp farming itself, but of the rural community in the coastal areas of Bangladesh. This paper provides a broad overview of issues and sets the research agenda for in-depth analysis. Analytical and methodological issues include a critical appraisal of ecological, economic, institutional, social and cultural factors that significantly influence the growth and development of shrimp aquaculture. It is argued that sustainable development of the shrimp industry could be achieved by explicitly taking into account the long-term and cumulative effects of the factors embedded in the integrated shrimp–rice farming system. This paper suggests two research strategies: (1) a robust approach to the complicated and interlocking issues of integrated shrimp–rice farming, which develops indicators for measuring the sustainability of shrimp farming and could be used by shrimp producers at the farm level; and (2) an approach that offers policy guidelines to respond effectively to changes in different variables that determine and affect shrimp farming.

SHRIMP culture is of central importance to the fisheries sector in Bangladesh. It grew from next to nothing in the early 1970s to contribute about 11% of total exports in the mid-1990s (DOF 1995). No other primary commodity enjoyed such spectacular growth in post-independence Bangladesh. Although shrimp farming has had a significant impact on the economy of Bangladesh, it has had high environmental costs, including destruction of mangrove forests, and reduction in crop production (especially rice) and green vegetation. It has also set in motion socioeconomic changes. All these changes may have serious implications for the sustainability of shrimp farming.

The overall research question of relevance is:

> Is shrimp farming in Bangladesh sustainable, given the existing social and institutional arrangements, the ecological characteristics of the shrimp–rice farming regions and the economic factors that influence and determine the short-term and long-term profitability of integrated shrimp–rice farming systems?

To address such a complex research issue, it is critical to have detailed data on social and institutional arrangements, ecological processes that affect and determine the productivity of shrimp farms, economic parameters (i.e. input and output prices, export and domestic prices) and the market structure of production. This paper begins with a background of the shrimp sector, highlighting trends in the size of the industry and production statistics. It discusses existing farming systems and technology, then identifies different components of sub-sectors with reference to their growth and linkages. Finally, relevant research issues for the sustainability of shrimp farming and the shrimp industry in Bangladesh are raised.

Industry Background

Traditional *bheri/gher* aquaculture had been practised in the coastal areas of Bangladesh to grow

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shrimp and fish long before the introduction of current shrimp culture practices (DDP 1985). In the early 1960s, the government constructed a large number of coastal embankments to protect agricultural land in the coastal areas from tidal waves and saline water intrusion. This process brought an end to traditional shrimp aquaculture in these areas. However, since the 1970s, strong international market demand and high prices for product have encouraged farmers to resume shrimp farming in polders within the embanked areas. Equally important was the fact that it was no longer financially viable to cultivate rice because the polders had become waterlogged due to poor drainage. These two factors together provided a catalyst to the process of accelerated shrimp farming (Karim 1986). The government of Bangladesh recognised shrimp farming as an industry under the Second Five-Year Plan (1980–85) and adopted measures necessary for increased shrimp production (Haque 1994). In 1979–80, slightly more than 20,000 ha were under shrimp cultivation (Ahmed 1988). According to an estimate by the Master Plan Organisation (MPO 1986), the total area under shrimp culture was expected to rise from 96,048 ha in 1990 to 135,000 ha in 2005. As of 1994, there were already about 130,000–138,000 ha of shrimp farms (DOF 1994; Rosenberry 1995), exceeding the projection for 2005. An estimate showed that production would be 89,000 t in 2005 (Marr Associates 1985) as opposed to production of 30,000 t in 1995 (Rosenberry 1995).

The leading shrimp farming areas of Bangladesh are the Bagerhat, Khulna and Satkhira Districts in the south-western region, Cox's Bazaar District in the south-eastern region and, to some extent, Pirojpur District in the south-central region. Experts and fisheries resource planners predict that all leading shrimp areas are unlikely to experience similar expansions. Satkhira District has the greatest potential for expansion of shrimp farming in the south-western region while potential for expansion in Cox's Bazaar District of the south-east seems also very high (MPO 1987).

Among several species available in the coastal regions, *Penaeus monodon* (locally known as *bagda chingri*) is the preferred species for brackish-water shrimp farming and attracts a very high price in international markets. In Bangladesh, *P. monodon* comprises 60% of farmed shrimp production, followed by the giant freshwater prawn, *Macrobrachium rosenbergii* (*galda chingri*) which accounts for 25% of production (Rosenberry 1995; Ahmed 1996).

Existing Shrimp Farming Systems and Technology

In the south-western coastal areas (i.e. greater Khulna region) the cropping pattern is for brackish-water shrimp culture in dry months (December–July), followed by transplanted aman rice during July through to December. In some areas, shrimp farming is characterised by monoculture. In the south-eastern coastal areas (i.e. Cox's Bazaar region) shrimp are grown from May to November and for the rest of the year, the land is used for salt production. In some parts of the south-eastern tidal area, rice alternates with shrimp and fish production (ESCAP 1988). The shrimp farmers mostly rely on wild shrimp stock because there are only nine hatcheries in Bangladesh, all with limited capacity for shrimp fry production. Furthermore, only one of these hatcheries, located in the south-eastern zone, produces *bagda* (*P. monodon*) fry—the preferred shrimp species (Karim 1995). The existing shrimp seed production capacity of commercial hatcheries is nowhere near the total requirement for Bangladesh's increasing shrimp culture industry (Hussain 1994; Karim 1995). Consequently, shrimp farmers are forced to rely on wild stocks or the importation of fry, which lead to an increased cost of shrimp farming (Kashem 1996).

An improved extensive method is a slight modification of the traditional extensive method, whereby farmers apply a few components of shrimp farming technologies. This method is, perhaps, specific to shrimp aquaculture in Bangladesh and Vietnam. An annual yield of 250–1,000 kg of shrimp can be obtained (Mazid 1994; Ahmed 1996).

The semi-intensive method requires the incorporation of a nursery phase in the shrimp farming process. Shrimp fry obtained either from wild catch or commercial hatcheries are stocked in the nursery ponds at high density before transferring to shrimp fields (*ghers*). The annual yield is 500–5,000 kg/ha (head on) with an average of 2,000 kg/ha (Rosenberry 1995). In 1995, only 1% of the shrimp farms in the country used this method (Begum and Banik 1995; Rosenberry 1995).

Intensive farming is practised in small shrimp ponds with high stocking densities. This farming method entails heavy feeding, removal of farm waste, water exchange and installation of an aeration system. This method of production is very uncommon in Bangladesh.

Shrimp in Bangladesh's Export Trade

Shrimp are grown primarily for the international market and, although Bangladesh is a small player in terms of its share of the international market (i.e. 4.2% of world production of farmed shrimp), it is the seventh largest cultured shrimp producer in the world. The United States of America (USA), Japan and the European Union (EU) are the major destinations of exports. Foreign exchange earnings from Bangladesh's fisheries sector depend, in the main, on shrimp (Kashem 1996). In 1993–94, shrimp accounted for 57% of exports in the primary goods category (EPBB 1995) and had overtaken raw jute, which was previously the dominant primary export commodity.

Shrimp shipments to USA are subject to automatic examination by the United States Food and Drug Administration because of the previous export of unhygienic shrimp (Market Asia 1995). EU also expressed their concern over Bangladesh's shrimp crop and a visit by an EU team to Bangladesh in February 1995 found that the hygiene level of the processing plants was not up to standard and the water used therein was not chlorine-free (Economics News 1995). It is important to note here that the Bangladesh Frozen Foods Exporters Association immediately took measures to address these problems (Economics News 1995).

The Shrimp Industry: Linking the Components

The shrimp industry comprises four sub-sectors: shrimp farms (*ghers*), shrimp hatcheries, feed mills and shrimp processing plants (Haque 1994). Figure 1 represents sectoral linkages in the shrimp industry. The success of the industry depends on the concurrent development of all these sub-sectors. It is important to note that development, on the other hand, depends on the availability of modern technology, management concepts and finance. The shrimp marketing system is also crucial and comprises a complex chain of agents who are involved in the process from the farm gate to the processing plants. While providing the details of shrimp marketing is beyond the scope of this paper, it is important to mention that the processing plant sub-sector has ultimate command of the marketing system. In other words, this sector has a vertical line of command, which in turn acts on international market signals. Most of the people engaged in shrimp marketing are either directly or indirectly employed by this sub-sector. Often 'buying houses' act as negotiators between the exporting and importing companies.

Shrimp hatcheries

About 95% of farm stock come from wild fry catch (Ahmed 1996) and this has implications for biodiversity. Since black tiger shrimp (*bagda chingri—P. monodon*) is the most targeted species, wild shrimp collectors discard other shrimp and fish species onshore. For every single *bagda* fry collected from the natural habitat, up to 99 other species of shrimp and finfish could be destroyed (Selim 1994). Realising this, DOF provided plans for construction of about 30 private-sector hatcheries (Selim 1994) 12 of which were under construction in 1995 (Haque 1995). In 1995, there was only one *bagda* hatchery (out of 10 shrimp hatcheries; DOF 1995) in Bangladesh producing between 20–30 million postlarvae. The estimated requirement for the 130,000 h of shrimp farms is 2.6–3.0 billion postlarvae and the difference is made up from wild fry (Karim 1995; Rahman and Pal 1995). Mazid (1995) suggested the establishment of a shrimp hatchery village for *galda* (*M. rosenbergii*) shrimp which would be specially designed for small farmers with a production capacity of 150,000–200,000 postlarvae/unit/season.

The greatest obstacle to shrimp hatchery technology is the collection of unstressed broodstock from the sea. Unfortunately, there are no definite data on the distribution and abundance of such stock, the state of standing stock (stock assessment by various research teams revealed different results), or the timing of their availability. Khan (1994) quoted a standing stock of 7,000–8,000 t of shrimp, but there is a wide variation in standing stocks reported by several authors (for details see Khan 1994). In addition, there is no provision for broodstock collection on a commercial basis (Hossain 1995). In 1995, hatcheries relied on the government research vessel, *Anusandhani*, which catches broodstock from the sea. Largely under-utilised public-sector hatcheries suffer from various management problems that limit their production (Khan 1995).

Shrimp feed mills

There is a shortage of artificial shrimp feed in Bangladesh (Hussain 1994; Hossain 1995; Karim 1995; Khan 1995). Only 6,000 t of shrimp and fish feed are produced locally as opposed to a total

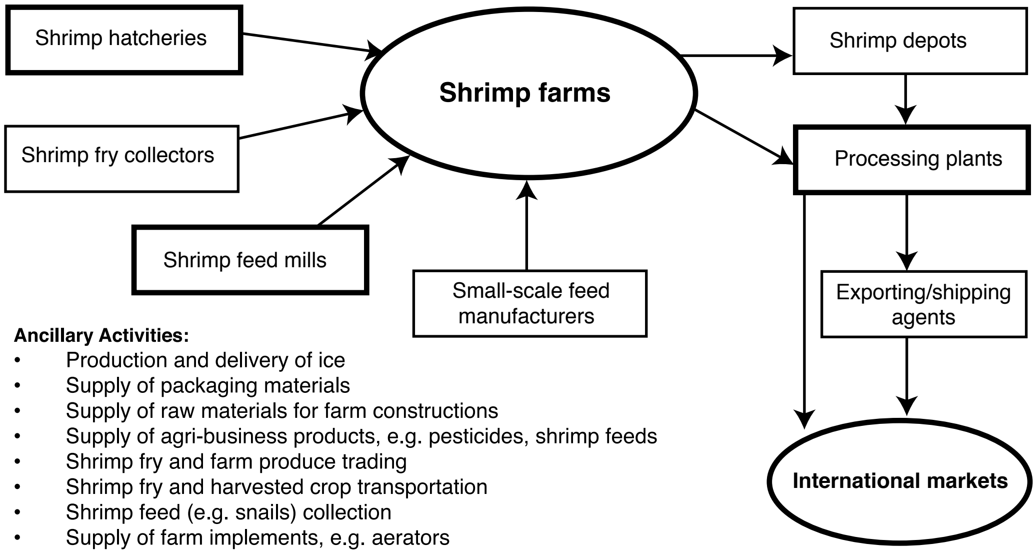

Figure 1. Schematic diagram of Bangladesh's shrimp industry, showing sectoral linkages.

requirement of more than 100,000 t (Hussain 1994). Apart from the Bangladesh Fisheries Development Corporation's fishmeal plant, there is only one other feed mill operating in Mymensingh and a few small-scale local manufacturers of fish feed (Karim and Aftabuzzaman 1995). Shrimp feeds, usually with a shelf-life of about three months, are imported from Thailand and Taiwan. It has been reported that stale feeds are supplied at the farm level, leading to adverse effects on shrimp farming (Karim and Aftabuzzaman 1995). Consequently, most farmers rely on natural feed and their farms suffer from lower productivity.

Processing plants

There is a big mismatch between the raw material requirements of shrimp processing plants and the supply of farmed shrimp. As of 1994, while there was a requirement of 156,000 t of shrimp to utilise the maximum production capacity of 93 plants, the supply was only about 20,000 t, resulting in only 13% utilisation of plant capacity (Haque 1994).

Further, Hussain (1994) pointed out that the processing industry had a 500% overgrowth in capacity as compared to raw material production. He added that in 1992–93, only 32 plants were under production. In 1994, most of the plants were out of operation, mainly due to the lack of raw material supply. He argued that factors such as an unplanned credit system, liberal attitudes of financial institutions towards this industry, expectations of some stakeholders to make quick fortunes, and easy availability of loans to build plants, were the main reasons for this unpleasant situation.

Land Use and Property Rights Issues

Attracted by prospects of high incomes, farmers are bringing more land under shrimp culture. As a result, the land that was previously used for other crops (especially rice) or remained fallow (grazing land) has been brought under shrimp farming.

Patterns in land tenure

There is an uneven distribution of land ownership in the coastal regions of Bangladesh, with a significant proportion of land in the hands of large landowners. Over the past decade, the land holdings of marginal and small farmers have declined, while large and very large farmers have acquired more land (DDP 1985). In 1996, 50% of the rural population was functionally landless (Khan 1996) and landlessness was on the rise. A study conducted by the Delta Development Project (DDP 1985; see also Alauddin and Tisdell 1996) identified the following shrimp farm ownership and control pattern in south-western Bangladesh (Figure 2).

Type 1. Single or household operations on their own land using their own or domestic labour.

Type 2. Single control on owned or rented land using hired labour.

Type 3. Multiple owners, all or most of whom participate in, and hence control, the farming operations. (There are three sub-categories under this category on the basis of contribution of inputs and sharing of profits.)

Type 4. Small number of owners and local people who farm shrimp on land which is partly owned and partly rented. (This type of farming can be sub-grouped on the basis of labour source.)

Type 5. Outsiders who control shrimp farming, using rented land and hired labour. (Some local people may join in this type of farming.)

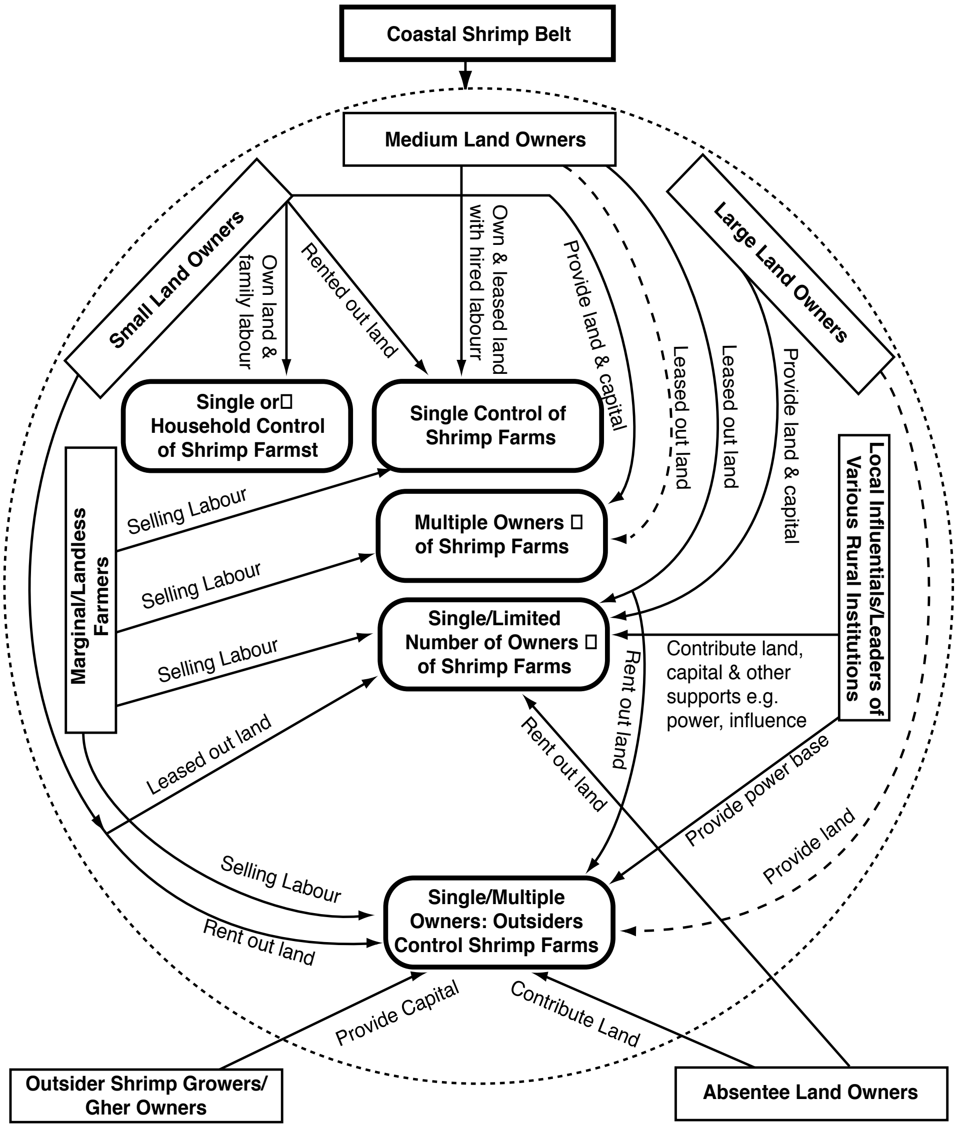

Figure 2. Identification of ownership and control in the shrimp farm industry in Bangladesh.

This grouping is not exhaustive and is sometimes overlapping. Therefore, it is rather a continuum of possible arrangements.

Lease arrangements and rural power

Among the types of land ownership and control discussed above, type 3 is the most common and constitutes nearly 50% of the total number of farms. Although outsiders (type 5) control 20% of all farms, they occupy 43% of the total shrimp area (DDP 1985). Because the inherent characteristics of shrimp cultivation require the cooperation and collaboration of all land holders in the *gher*, and given the uneven distribution of wealth and power in rural areas, small farmers are often forced to cooperate with large landowners, surrendering their modest share from the return (ESCAP 1988). This process is accelerating the landlessness in rural areas. Outsiders, who do not have any shrimp ponds, in many cases take control of land by providing capital and forming alliances with local big farmers (ESCAP 1988).

Centre–periphery issues

The dominance of outsiders (type 5) in shrimp farming is a sensitive issue. Shrimp culture was turned into a commercial proposition by outsiders in response to international demands (Rahman et al. 1995). Outsiders, who are based in urban centres (towns/cities), entered into this industry because of its profit potential. Basically, they are very powerful individuals who have direct links with government bureaucracy and political parties and are insensitive to local problems. This has led the local people to be very critical of shrimp culture (Rahman et al. 1995). Although the number of outsiders engaged in shrimp production has declined over time, the area under their control has created social tension in shrimp areas. Rahman et al. (1995) identified three types of conflicts between locals and outiders:

- conflicts between local and outsider shrimp producers;
- conflicts between local self-employed and outsiders; and
- conflicts between local and outsider labourers.

Contradictions between local and outsider shrimp producers have some implications for local marginal/small and medium farmers. Rahman et al. (1995) described the implications. Firstly, the presence of outsiders helps to increase the rent, to the benefit of local landowners. Secondly, the social status of elites of local power declines. Given their urban origin, economic strength and linkage with administration, the outsiders seem to dominate the local power structure by replacing local elites. This turns local shrimp producers against outsiders. In order to maintain an exclusive management style, the outsiders prefer to keep a smaller number of operators in the shrimp industry. As a result, they endeavour to bring the neighbouring smaller farms under their larger operations. Unlike locals, they are only profit-oriented and do not care about the societal and environmental impact of shrimp culture on the local areas. Also, there is conflict between local and outsider shrimp growers over the control of nearby channels. These channels provide saline water for shrimp farming and the outsiders, in most cases, try to have total control of them.

Finally, the outsiders generally lease shrimp *ghers* from absentee landowners and those locals who have land around such *ghers* can not always grow shrimp because of opposition from outsiders. As a result, the locals are compelled to leave their land in return for very low rent. Sometimes outsiders do not even pay any rent for these lands. As J. Guimaraes (unpublished report) pointed out, shrimp culture in Bangladesh supports the argument that "when a new and profitable productive activity (e.g. cash crop) is introduced in a rural context, the distribution of the income it generates is biased in favour of the people or groups who control the scarcest among the resources necessary for the new activity". If this is the case, then the economic benefits for the community of the shrimp farming regions seem to be minimal or even negative due to the outflow of profits from the periphery to the centre.

Employment Implications

Shrimp culture, through a network of backward linkages, created a substantial volume of employment in shrimp farms as well as in ancillary activities (i.e. trade/commerce, processing, marketing and exporting). In 1983, 4.1 million person days of on-farm employment were created from 51,000 ha of shrimp farms in the coastal areas of Bangladesh. Off-farm employment was 5.9 million person days (MPO 1986). Based on the projected expansion of shrimp farming areas, on-farm and off-farm labour requirements for 1990 were 22.6 million person days. The corresponding figure for 2005 is expected to be 59.4 million person days (MPO 1986).

Shrimp farming on a large scale in the coastal regions of Bangladesh has created a new employment structure. Although shrimp farming itself is less labour-intensive than rice cultivation, the overall labour requirement of the shrimp industry (including employment opportunities in ancillary activities) is higher than that of rice production. To this end, it is logical to assume that the shrimp industry would play a pivotal role in absorbing the surplus rural labour force in coastal areas. In reality the situation does not exactly follow this assumption, since outsider shrimp producers prefer hiring labourers from outside the areas.

Environmental and Sustainability Implications

While the gains in employment and export are highly impressive, they have been achieved at considerable cost. Rahman et al. (1995) identified the following problems that resulted from 'unplanned' shrimp cultivation:

- lower production from paddies;
- destruction of trees and vegetation due to salinity;
- decline in household incomes from non-farm sources, especially those from ecological reserves;
- decline in the production of poultry and livestock; and
- various forms of social conflicts.

The findings of these studies seem to be supported by Alauddin and Tisdell (1996). Using farm-level data on shrimp *gher* owners, landowners and landless labourers in the coastal districts of Khulna, Bagerhat and Satkhira of south-western Bangladesh, Alauddin and Tisdell (1996) report the following broad findings:

- uneven gains between *gher* owners and landowners, especially the small land-owning households;
- adverse environmental spill-overs in the form of loss of green vegetation (e.g. vegetables, coconut trees, bamboo plantations) and other crops, loss of genetic diversity (e.g. loss or extinction of indigenous species of fish), and declining rice yields;
- increased employment opportunities off the shrimp farms—i.e. an overall increase in employment; and
- depending on the contractual arrangements with the financiers, some *gher* owners also stand to lose from environmental degradation.

Even though shrimp cultivation and ancillary activities have provided employment and income gains, they may have been achieved at the cost of the future. Thus it is at odds with the concept of sustainable development as defined by the World Commission on Environment and Development (WCED 1987, p 43).

Shrimp Culture: Some Further Ramifications

Rural–urban interactions

The most unexpected consequence of the transformation of traditional agriculture in developing economies is rural–urban migration. The shrimp industry has reduced the on-farm work opportunities considerably, with marginal and landless farmers being the most affected rural classes. A section of rural people has lost employment, and these rural unemployed labourers usually migrate to cities seeking work.

Law and order and shrimp production

The shrimp belt of Bangladesh is always the subject of debates on law and order. There have been a few incidents of violence in connection with shrimp farming, with the most common incidents involving leased lands. In most cases, outsiders impose force to acquire land and this process also results in increased corruption among the members of law enforcement agencies. Control of large shrimp *ghers* by outsiders is the prime cause for social imbalance and deteriorating law and order in rural coastal areas.

Research Agenda

Research questions and goals

Let us now come back to the overall research question of investigating sustainability of shrimp farming in Bangladesh, given: the existing social and institutional arrangements; the ecological characteristics of shrimp–rice farming regions; and the economic factors that influence the short-term and long-term profitability of shrimp–rice farming systems. Thus the broad research goal is one of assessing long-term viability and sustainability of shrimp–rice farming systems in Bangladesh.

This broad goal can be achieved by identifying several sub-objectives:

- to analyse factors which underlie domestic and foreign demand and supply of rice and shrimp;
- to identify and define ecological, economic and social factors influencing sustainability of shrimp and shrimp–rice farming systems;

- to determine allocation and technical efficiencies of shrimp farming;
- to estimate ecological and environmental damage that may result from alternative farming systems and alternative technologies, and to identify externalities of the shrimp culture process; and
- to suggest policy measures to minimise and alleviate unfavourable impacts of shrimp aquaculture.

Research methodological issues

I suggest the appropriate direction for research is to develop an overall framework for an integrated social, ecological and economic analysis using a farming systems research methodology as applied by Be (1994) with some modifications, together with the extended benefit–cost framework employed by Primavera (1991) and Pearce et al (1989). Issues relating to allocation and technical efficiencies can be addressed using the frontier production function technique as developed and applied by Kalirajan and Shand (1994) and Alauddin et al. (1993). Samples from all stakeholders, as illustrated in Figure 3, should be included.

In summary, this paper suggests two research strategies: (i) a robust approach to the complicated and

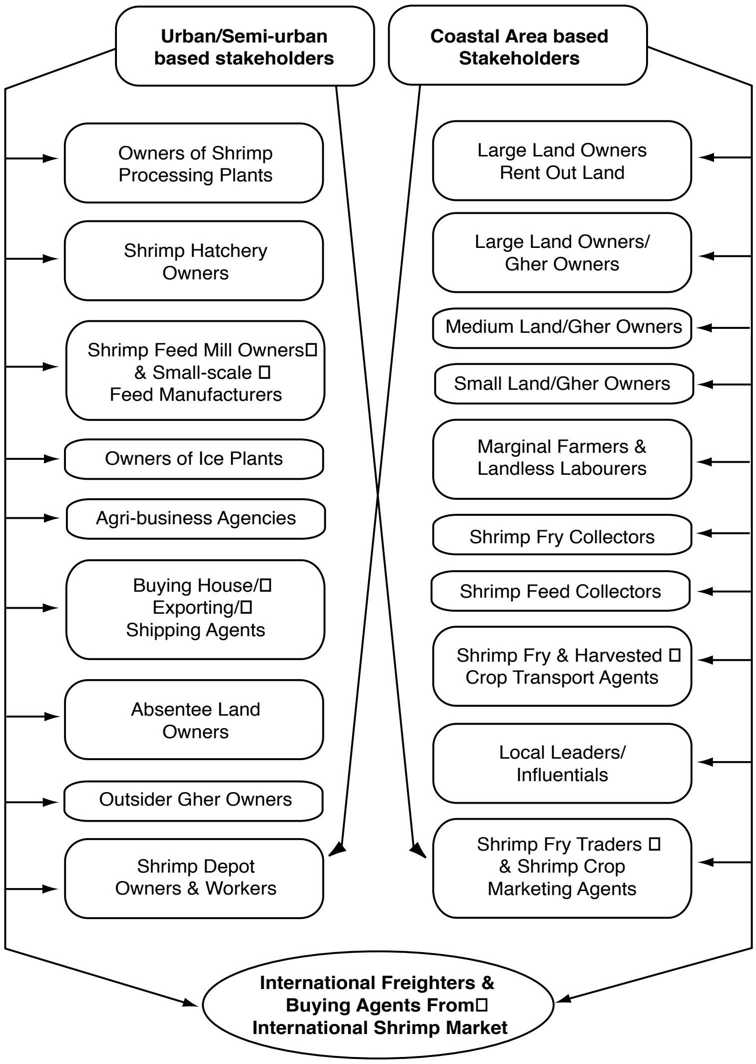

Figure 3. A schematic diagram of stakeholders in the shrimp industry in Bangladesh.

interlocking issues of integrated shrimp–rice farming, which develops indicators for measuring the sustainability of shrimp farming and could be used by shrimp producers at the farm level; and (ii) a research approach that offers policy guidelines to respond effectively to changes in different variables that determine and affect shrimp farming.

Acknowledgment

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Shrimp Acquaculture: the Philippine Experience

Rolando R. Platon*

SHRIMP aquaculture has a long history in the Philippines. It can be said to have its beginning at the same time as brackish-water aquaculture which, according to some accounts, predates even the arrival of Magellan in 1521 (Yap et al. 1995). However, it was in the early 1950s that culture in earthen ponds of the jumbo tiger shrimp, *Penaeus monodon*, was first documented by Villadolid and Villaluz (1951). This was followed by the first account on its phenomenal growth rate by Delmendo and Rabanal (1953). After only 16 years, the first successful attempt in breeding the species was reported (Villaluz et al. 1969). The industry took off in the 1970s, bloomed in the eighties, only to stagnate and even decline in the nineties.

Brief Status of the Shrimp Aquaculture Industry

Farm production and exports

In 1995, the shrimp farming industry in the Philippines had 54,912 ha of shrimp ponds, a production of 88,815 t and contributed about peso (Ps) 19.0 billion to the economy (Ps 26.20 to US$1.00). This production figure is based on estimates by the Philippine Government (BAS 1996). Rosenberry (1995) reported a much lower production figure of less than 20,000 t for 1995, but it appears that those figures were based on export volumes rather than on total production. While Rosenberry's figures appear to be too low, those of the government appear to be too high.

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In the Western Visayas Region, where most of the intensive shrimp farms are found, shrimp farming activity is down because of massive disease problems. In the province of Negros Occidental alone, it was estimated that only 10% of the shrimp farms were still operating in 1996. However, even as the industry suffers, Region VI (Western Visayas), Region IX (Western Mindanao) and Region XII (Southern Mindanao) appear to be enjoying an upsurge. Region III (Central Luzon) doubled its production from a maximum of only 13,510 t between 1986 and 1993 to 27,749 t in 1994, although it dipped slightly to 25,591 t in 1995. It should be noted that in all the regions where the industry remains strong, the growers practice either extensive culture, semi-intensive culture, or even polyculture with milkfish.

Hatcheries, processors and feed mills

In 1992 there were 461 hatcheries of which 342 were operating. However, in 1995 only 298 hatcheries remained, of which 164 were in operation. The number of processors also declined—in 1990 there were 53 companies listed and in 1995 this dropped to only 18 companies.

Due to a greater degree of awareness of shrimp fry quality standards, it was the very small, backyard hatcheries that were not able to survive. The Philippines probably has the strictest industry standard for shrimp fry quality in the region. The quality criteria include: presence and degree of infection in the hepatopancreas, gut, gills and appendages; and body length as related to number of rostral spines and muscle development. These criteria are used in addition to the traditional practice of visual examination of size, distribution, activity, colour and environmental stress resistance. Figure 1 shows a scoring system

Fry Analysis Summary Report

Client:____

Source:______________________ Tank no:__________ Pop:________

PL age:______________________ Date received:________________

SAMPLES	Hepatopancreas		BODY LENGTH (rostrum to telson)	GUT			MUSCLES			GILL			ROSTRUM		APPENDAGES						
	MBV														N	RN+N		FBI		PI	
	D-INF	Rating		SHG	GN	Rating	MN	GMR	Rating	FBI /PI	N	Rating	RS	RN		RN+ N/A	Rating	Degree	Rating	Degree	Rating
TOTAL	= _____		Ave.: ___ A/N= ___	= _____			= _____			= _____					= ____ = ____ = ____ Ave.: _______						
%	X 30% =		X 20% =	X 15% =			X 10% =			X 15% =											

Legend: D-INF, degree of MBV infection; SHG, swollen hind gut;GN, gut necrosis; MN, muscle necrosis; GMR, gut-to-muscle ratio; FBI, filamentous bacterial infestation; PI, protozoan infestation; N, necrosis; RS, rostal spine; RN, rostral necrosis; N/A, necrosis per animal.

Total body length (tip of rostrum to tip of telson) = (actual body length - 6)/ (theoretical body length - 6) x 100

TOTAL SCORE:____________________

Remarks:________________________

Analyzed:__________ Noted:__________

Figure 1. An example of a scoring sheet used to judge the quality of fry from hatcheries.

used to quantify fry quality. It is not uncommon for a grower to have fry from a hatchery examined by more than one laboratory to ascertain their quality before making a commitment to purchase. Thus, the actual drop in the fry production may not be as severe as the drop in the number of operational hatcheries.

Current Key Constraints

Technical constraints to fry production

Shrimp hatchery technology in the Philippines appears to have matured. Consistent and predictable results are now the norm. Erratic production due to perceived water quality problems, disease outbreaks and a host of other unexplainable reasons appear to be a thing of the past. The main concern of Philippine hatcheries has shifted from merely attaining a target number to producing high health fry and marketing.

The present concern of hatcheries to produce high health shrimp fry has pointed to the need to have a captive broodstock and with it the capability of selective breeding. Thus the lack of a truly domesticated breeding stock can be considered the major constraint to shrimp fry production. The present production crisis in intensive grow-out operations has generated an increased demand for specific pathogen-resistant strains of shrimp.

Technical constraints to the grow-out operation

The production problems which used to plague the hatcheries have shifted to the grow-out operation. This includes the luminescent bacterial disease which is caused mainly by *Vibrio harveyii*. This is especially acute in the province of Negros Occidental which has the highest concentration of intensive farms. Since this problem is mainly due to poor sanitation, the approaches that are now being tried follow what has been found successful in hatcheries. These include the use of chemotherapeutics such as chlorine, benzylkonium chloride, formaline and even antibiotics. However, such approaches have been found to be impractical and costly for grow-out ponds due to the wider areas and much larger volume of water involved.

Shrimp growers in the Philippines are now also trying bio-remediation or bio-augmentation. This approach includes use of the so-called ‘green water’ system wherein finfish are also stocked in the growing pond to induce chlorella to bloom. Commercial probiotics, which were actually developed for sewage treatment, are now also finding their way to shrimp farms as growers become desperate. The results have not always been consistent.

Use is also being made of immunoenhancers. These are typically applied to the feed as dressing immediately before feeding. The theory is that such substances will intensify the capacity of the shrimp to resist diseases.

Another approach, which has been talked about but has had only limited trials so far, is the use of a reservoir pond to store incoming water for a certain time before using it in the rearing ponds. In addition, with the growing understanding of the role of intensive shrimp farms in polluting nearshore waters, the concepts of aquaculture wastewater treatment and recirculating or low-discharge systems have been introduced.

While the tools to rehabilitate the industry seem within reach, these are not immediately useable until the production protocols for their use have been established. The present constraints therefore now lie in coming up with answers to the following questions.

- Which of the commercially available probiotics are effective for shrimp pond use and how should they be applied?
- If the use of finfish improves the condition of pond water for shrimp culture, what is the optimum biomass per unit area and when should the fish be stocked?
- What is the ideal ratio of rearing pond to reservoir pond for incoming and outgoing water?
- Can the reservoirs be used to grow other crops instead of merely holding water? If so, what species can be stocked in such ponds?
- How does one deal with pond discharge during harvests?

Environmental constraints

The problems now facing the intensive shrimp farming areas in the Philippines are partly due to shrimp farm discharges which exceed the natural carrying capacity of the surrounding waters. Part of the problem, however, lies also with exogenous factors not related to shrimp aquaculture.

There is a need to determine the hydrography of water bodies which serve both as supply and discharge points for shrimp farms. This will assist in determining residence times of specific indicators of organic and nutrient load (i.e. total nitrogen and total phosphorus). By knowing these, it might be possible to regulate shrimp farm density to a level which the environment can support and sustain. This will require the setting up of water quality standards, not only for discharge from shrimp farms but for other industries as well.

Social constraints

The general perception of shrimp aquaculture is that it is the domain of the rich and has not benefited the poor, even in terms of employment. The perception is that shrimp aquaculture has, at best, no effect and, at worst, negative effects on employment, living standards and health (Amante et al. 1989).

When the Comprehensive Agrarian Reform Program was passed as a law, fishponds were also included. The implementation of such a law should have led towards a more equitable distribution of aquaculture resources. This was welcomed by most of the farmers and fisherfolk groups. However, with a very strong lobby from the fishpond sector, and to the consternation of the grassroots sector, fishponds were recently granted exemption from land reform.

It appears that the Department of Agrarian Reform was never able to come up with a model for subdividing a large fishpond into several independent units for distribution to farmers and fisherfolk. There are problems of supply and discharge canals as well as access to the waterways. Also, there is the problem of defining what is an economically viable unit, which of course will depend on the species to be cultured and the intensity of culture.

The concept of a fishpond estate consisting of independent small growers with a company, or even a cooperative of farmers, operating the common centralised facilities (i.e. hatchery and or nursery, processing shed, pumping station) has been floated for a long time, but a working model has never been established. If such a system could be demonstrated to be feasible and profitable, much of the objection over the inequitable features of the shrimp culture industry could be greatly minimised if not totally eliminated. This remains the dream for fisheries development planners in the Philippines.

Economic constraints

In the Philippine Prawn Industry Policy Study made by Auburn University (1992), the economic constraints were as follows.

- The cost of feed was identified as the most serious constraint, being significantly higher than in Thailand and Indonesia.
- Receipt of tax credit is often delayed for 6–12 months.
- The cost of electric power varies greatly within the country, but is substantially higher than in many other shrimp producing countries.
- All loans have to be secured with real estate and carry very high interest rates.

Further, the effect on shrimp aquaculture of two new developments will need to be studied. These are (i) the present import liberalisation and change in tariff structure on all commodities under the General Agreement on Tariffs and Trade (GATT), and (ii) the partial deregulation and eventual total deregulation of petroleum products.

Political and administrative constraints

Many in the shrimp industry complain about government laws, requirements and regulations. Bureaucratic obstacles to getting permits and tax credits are common complaints. Lack of communication and coordination has been reported for various agencies, particularly the Department of Agriculture and the Department of Environment and Natural Resources. There is also a perceived lack of political will to enforce environmental laws whenever the rich and politically connected are involved.

Research Activities and Priorities for Future Research

The task force for shrimp farm research

The present problems in the shrimp culture industry are caused by over–intensification of culture operations wherein the effluents produced by the shrimp farms themselves exceed the capacity of the natural environment to degrade and render them harmless. This causes deterioration of soil and water quality within the shrimp farms as well their surrounds.

It is for this reason that the Director of the Bureau of Fisheries and Aquatic Resources (BFAR) conceived of a ‘task force’ which consists of technical people from various agencies working on the shrimp disease and production problem, in order to have a unified and concerted effort to rehabilitate the country’s shrimp farms. The task force is named OPLAN SAGIP SUGPO.

In the process of devising the strategies and detailed action plans, the task force has considered the recommendations for shrimp research which were raised at various meetings and conferences undertaken by the Southeast Asian Fisheries Development Center (SEAFDEC) Aquaculture Division.

The general objective of the task force is to rehabilitate the shrimp culture industry and make it sustainable through a focused effort to develop sound shrimp health management techniques.

The specific objectives are:

- to 'tailor-make' culture techniques for each specific culture system;
- to determine the carrying capacity of each given area for shrimp production and develop practical guidelines on regulating the development and operation of shrimp farms;
- to set in place a monitoring system to ensure compliance of whatever regulation the task force may recommend for implementation; and
- to train shrimp farm operators and technicians on sustainable shrimp culture techniques.

Research activities

The detailed activities to be undertaken under each strategy are as follows:

Identification of expertise

To make an inventory of technical persons with BFAR, SEAFDEC, University of the Philippines in the Visayas (UPV) and other agencies who are directly involved in the study of shrimp diseases, culture, genetics etc.

Short-term studies (1–2 years)

A. Field evaluation of biological interventions (probiotics, integration of finfish, molluscs, and/or seaweeds with shrimp).

- Validation of commercially available probiotics on growth and survival of shrimp (to be undertaken by SEAFDEC/Negros Prawn Producers Marketing Cooperative, Inc.—NPPMCI).
- Documentation of 'lumbac'-free (i.e. no luminous bacteria) shrimp pond areas (SEAFDEC/BFAR).
- Evaluation of the use of 'green water' on growth and survival of shrimp (BFAR/NPPMCI).
- Effectiveness of integrating finfish and other aquatic organisms with shrimp to prevent or minimise incidence of luminous vibriosis (BFAR/NPPMCI).
- Pond dynamics and nutrient budgets (UPV).
- Use of molluscs and *Gracilaria* as biofiltering agents (BFAR).
- Screening and identification of beneficial bacteria with potentials as probiotics (BFAR).
- Establishment of the bacterial profile of healthy, normal shrimp (SEAFDEC).

B. Field evaluation of physical interventions (recirculating systems, reservoirs, semi-closed systems).

- Development of a prototype recirculating system using existing shrimp ponds (Society of Aquaculture Engineers of the Philippines—SAEP/BFAR).
- Evaluation of the use of reservoirs in shrimp farms (NPPMCI).
- Documentation on the effectiveness of backfilled shrimp ponds. (UPV/Department of Agriculture Regional Fisheries Unit—DA–RFU).

C. Field evaluation of chemical interventions (residue studies, alternatives to antibiotics).

- Study of the fate of antibiotics (SEAFDEC).
- Study of the residual effects of chlorine, formalin, and other chemicals in brackish-water ponds (SEAFDEC).
- Screening of environmentally friendly chemicals for pond conditioning and disinfection (SEAFDEC).
- Promotion of the use of tobacco dust as a pond pesticide (BFAR).

D. Development of an aquaculture effluent treatment system (BFAR/Department of Environment and Natural Resources—DENR).

E. Field evaluation of crop rotation/fallowing (data already available at Philippine Council for Aquatic and Marine Research—PCAMRD).

Medium-term studies (3–5 years)

A. Immune enhancement in shrimp (basic and applied) (BFAR/SEAFDEC/UPV).

B. Determination of water quality standards for discharges from shrimp farms (NPPMCI/Bureau of Agricultural Research/Environmental Management Bureau—EMB-DENR).

C. Development of an aqua-silviculture prototype (SEAFDEC/DENR/DA-RFU).

D. Development of systems for monitoring impacts of shrimp farming on coastal ecosystems (DENR/BFAR/Local Government Unit —LGU/RFU).

E. Mass production of beneficial bacteria which have potential as probiotics (BFAR).

F. Development of rapid sero-diagnostic kits for detection of *Vibrio* (SEAFDEC/BFAR).

Long-term studies (6–10 years)

A. Development of captive shrimp broodstock (SEAFDEC/BFAR).

B. Development of disease-resistant shrimp stock (SEAFDEC/BFAR).

C. Determination of the effluent absorbing capacity of mangroves (SEAFDEC/DENR/Ecosystems Research and Development Bureau—ERDB).

D. Upgrading of field diagnostic facilities (BFAR/SEAFDEC).

E. Development of human resources in shrimp health diagnostics and management through both short-term and formal training (BFAR/SEAFDEC/UPV/PCAMRD).

F. Development of formal academic programs in aquatic veterinary science (UPV).

Constraints and dissemination of results

The research action plans call for some studies that require innovative, biotechnological expertise and facilities. Although we may have the biotechnical expertise, lack of laboratory equipment and facilities will be a major constraint in the conduct of important studies.

The effective translation of research findings into workable techniques for individual farmers is sometimes under question. The language gap may be a constraint in the process of writing for publication of research findings and also in attendance at training courses and seminars. The problem of site specificity may also be a constraint in the repeatability of results. The conduct of verification tests in different areas may iron out problems related to site specificity. These trials may eventually serve as demonstrations or pilot projects where farmers and technicians can obtain first hand experience on technical, economic and environmental aspects.

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Shrimp Culture in Indonesia: Key Sustainability and Research Issues

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Abstract

Indonesia is a vast country of 8.7 million km^2 with a coastline of 81,000 km. It consists of more than 17,000 islands, spreading along the equator, between the continents of Asia and Australia. Indonesia has 800,000 ha of potential area for brackish-water ponds of which 360,000 ha have been developed for aquaculture. More than 30% of ponds are used for shrimp culture.

The current key constraints to sustainable shrimp culture are: environmental degradation due to both internal and external pollutants, ineffective coastal land-use planning, technically poor design and layout of brackish-water ponds, and improper culture management. The main threats are magnified due to rapid industrial development. Efforts are being made to minimise some of these problems.

Future research activities should be established to study the following issues:

1. impacts of large-scale intensive shrimp farms and industrial and agricultural activities on coastal waters, reservoir water treatment on large-scale shrimp farms and industries, the use of gigantic plastic sheets in shrimp farms, and absorption capacity of different species of aquatic flora to treat pollutants;
2. development of high quality broodstock and fry through genetic engineering;
3. development of immunostimulants to combat shrimp diseases and development of early warning systems for shrimp diseases; and
4. an integrated approach to proper coastal land use and coastal zone management, with government and non-governmental organisations playing an important role in providing better environmental conditions for sustainable shrimp culture.

INDONESIA consists of more than 17,000 islands with a total coastline of 81,000 km, and a total land area of approximately 192 million ha (Ritung and Widjaja-Adhi 1994). The coastal area covered by mangrove vegetation was 4.25 million ha, however some mangrove areas have been converted to fishponds or other uses, bringing about the reduction of mangrove area to 3.5 million ha.

Aged brackish-water ponds constructed before 1985 were mainly designed for milkfish culture (Poernomo 1996) but, following the success experienced by some shrimp farmers, many farmers converted extensive milkfish ponds into semi-intensive and intensive shrimp ponds. Further uncontrolled development of brackish-water ponds has caused serious environment degradation and the recent failure of shrimp culture in many areas.

Efforts to overcome the problems of environmental degradation have been made by farmers, the Government of Indonesia and research institutions, but so far in many areas the farmers are still facing difficult problems. Some farmers have quit shrimp culture activities and others have converted their ponds to milkfish culture. In this paper, the efforts to solve the problems for sustainable shrimp culture are discussed.

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The Present Status of Shrimp Culture

The estimated potential area for brackish-water ponds is 800,000 ha and existing pond area is more than 360,000 ha. However, detailed data on the suitability and capability of the potential area for development of shrimp culture are very limited (Anon. 1994). Out of the total existing brackish-water ponds, more than 30% are practising shrimp culture. The sizes of ponds used by more than 100,000 farmers are classified into <2 ha (46.58%), 2–5 ha (31.37%), 5–10 ha (14.70%) and > 10 ha (7.35%). In 1993, shrimp exports amounted to 98,569 t, worth US$876 million.

The Directorate General of Fisheries recommended five levels of technology for shrimp culture (Table 1). The relatively low stocking density aims to avoid harvest failure for farmers having aged ponds with minimum improvement.

The characteristics of coastal areas vary from location to location and from one island to another. Typically, Java, Sulawesi, Bali-Nusa Tenggara, Timor and Maluku Islands are dominated by mineral soils, while outside Java, particularly Sumatera and Kalimantan, more than 50% is peat soil or affected by peat soil.

Constraints on Sustainable Shrimp Culture

Shrimp culture management

The management of shrimp culture varies from location to location, depending on the level of technology applied. However, in semi-intensive and intensive shrimp culture the constraints being faced by many farmers at present are much the same. The important factors to be considered for successful shrimp culture are water quality (pollution problems) and production inputs, such as feed, fry and culture management.

The quality of shrimp feed is determined by its nutrient composition, method of processing and storage. There are at least five different imported and locally-made artificial feeds available to farmers. There is no monitoring of shrimp feed quality at present, thus the farmers select by trial-and-error. However, Hamid (1992) tested two different artificial feeds and found that feed conversion ratio (FCR) fluctuated, ranging from 1.7 to 2.6 in one case, and 1.7 to 3.3 in others. Excessive feeding caused a drastic drop in water quality, particularly dissolved oxygen content. A. Hanafi (unpublished data) observed that under laboratory conditions, excessive feeding caused dissolved oxygen to drop to <1.0 ppm within two days, and all shrimp tested were dead. The uneaten feed and shrimp excreta settled on the pond bottom, causing an increase in the organic content, which in turn resulted in an anaerobic zone. These observations indicated that feed and feeding techniques have an important role in shrimp culture.

The success of shrimp culture also depends on fry quality. Certification to guarantee high quality fry from hatcheries seems to be impossible at the present time.

There are many different chemicals involved in culture management but they are not understood by farmers. The chemicals which are used include probiotics, fertilisers and pesticides (tobacco dust, saponin and thiodan) (Hanafi 1989). The probiotic chemicals are expensive and their effectiveness is questionable. Thiodan has a toxic effect and residues may be dangerous for shrimp. Under laboratory conditions it was observed that low concentrations significantly affected the growth of shrimp (Hanafi and Pantjara

Table 1. Shrimp culture stocking densities and the expected yields recommended by the Directorate General of Fisheries.

Technology	Size of pond (ha)	Stocking density (fry/ha/crop)	Expected yield (kg/ha/crop)
Traditional	1–4	7,500–12,000	150–240
Semi-intensive	1–2	30,000–60,000	600–1,200
Intensive	0.2–0.1	100,000–150,000	2,000–3,000
Shrimp–milkfish	1–4	1,500–9,000[a] 1,500–2,000[b]	110–180[a] 250–300[b]

[a] Shrimp [b] Milkfish

1995), hence residues affected shrimp quality and in turn the consumers. For the proper use of fertiliser, both the dosage and nutrient requirements should be studied to minimise negative effects and cost of production. The total use of fertilisers for brackish-water ponds is 8,217,000 kg of organic fertilisers and 11,090,000 kg of inorganic fertilisers, such as urea and triple superphosphate (Anon. 1994).

Environmental problems

Poernomo (1989) identified reasons for failures of shrimp culture as: improper site selection, poor design and layout of ponds, inadequate pond preparation and extremely high stocking densities. Since then, vast areas have opened up for intensive culture, e.g. in Lampung, shrimp pond area was only 1,500 ha in 1986 and increased to 13,500 ha in 1995 (Anon. 1996a). Improper planning resulted in a poor irrigation system, and many shrimp farmers faced problems in obtaining the right quantity and quality of seawater and fresh water. This situation induced the outbreak of shrimp diseases in many areas, hence the failure of shrimp culture could not be avoided. From this bad experience many farmers changed their pond management from shrimp culture to milkfish culture, or from intensive culture into semi-intensive culture, and some farmers completely stopped their activities for a period of time, e.g. in Central Java, out of 45 private shrimp farms, 40% were no longer operational (Anon. 1996b). Shrimp disease outbreaks started in 1990, with 264 ha of shrimp ponds affected, and peaked in 1995 with a total area of 4,749 ha affected.

Other factors that may reduce the quality of the environment for shrimp culture include changes in the biophysical features of the river catchment areas. Some examples are forestry activities in the upper catchment of coastal rivers, pesticide use for agricultural activities, and land disturbance by industry and mining.

Social conflicts and benefits

Many coastal zones are becoming areas of intense economic, social and biological activity, including over-exploitation of fisheries and other marine resources. Urban uses, recreation, industrial development and pollution are the major threat to the coastal zone and to shrimp culture. Local issues such as conflict between development and preservation of mangroves or conversion of paddy fields, serve to emphasise the complexity of the problems faced in planning, administrative and legislative aspects of coastal zone management. Shrimp culture has also caused conflicts with people in surrounding areas through seawater intrusion, consequent failure of certain agricultural crops and reduced quality of fresh water for daily needs.

Economic constraints

Placement of permanent fishing traps near shrimp culture areas has significantly affected the success of shrimp culture. For example, in Bone Regency, organic material from outlets of shrimp farms, crowded residential areas and agricultural activities all flush into the sea and are trapped by the relatively small mesh size of fish traps. Thus, rapid sedimentation occurs and the water becomes very turbid, causing reduced water quality for shrimp culture. However, the removal of fishing traps would create conflict with their operators.

Mining of mineral sands for metals like chromium, nickel and other heavy metals is an activity which has had a major impact on many coastal waters. Mining could alter the coastal landscape and lead to degradation of coastal ecosystems, and residues of heavy metals in fishery products (including shrimp) may be a danger for human consumption.

Legal aspects

Effective enforcement of laws for fishing in coastal waters and laws for coastal land use will help in the effective management of coastal areas and provide a better environment for brackish-water shrimp culture. The approach to sustainable shrimp culture should be integrated, rather than in a piecemeal fashion. Plans for use of the coastal environment should be carefully integrated with all institutions concerned with forestry, agriculture, plantations, mining and industry. The Indonesian Government should take action on coastal land use and develop policies for regulating coastal management. It should take strong action to strengthen the size and capability of Bapedal (Agency for Evaluation of Environmental Impacts).

Research Activities Related to Constraints

Ongoing research activities

Research is under way to characterise existing brackish-water ponds in the Pangkajene district, southern Sulawesi, to evaluate the suitability of using different levels of technology for environmentally sound shrimp culture. The factors being studied include climatic conditions, physical, chemical and biological characteristics, and management aspects (Mustafa and Hanafi 1996).

A preliminary study on genetic variation of shrimp broodstock from different locations in waters of western and eastern Indonesia (i.e. Aceh, Madura, Bali, Sumbawa and Sulawesi) has been carried out in Gondol Research Station, Bali. The results showed that broodstock collected from Aceh is the best. In addition, a study on enzyme polymorphism in the giant tiger shrimp from Indonesia and Taiwan has been done and the results showed no differences in allele frequency between these two samples (Sugama 1993).

A study on breeding of broodstock reared in brackish-water ponds concluded that the minimum size was 60 g after 8–12 months rearing and it spawned with a hatching rate of 10% and survival rate of 0%. The hatching and survival rate increased for broodstock of two years rearing, i.e. 98% hatched and 80% survived after 1–2 months. The size of broodstock was >150 g (K. Sugama 1996, pers. comm.). Performance of tiger prawn larvae produced from wild and pond spawners was also studied by Khalik et al. (1993).

A study on the effect of external waste, mainly industrial waste, has been conducted in West Java in the Ciujung and Cisedane Rivers, in Central Java in the Tapah, Bango and Suwatu Rivers, and Porong, Surabaya, Candi, Rejoso and Curah Rivers in East Java by Poernomo (1996). The various industrial wastes caused environmental degradation, and the shrimp were stressed, stunted and their eating desire dropped drastically. This was followed by a disease outbreak. Rachmansyah and Ahmad (1996) have been studying residues of heavy metals and pesticides on different biological samples taken from coastal waters in Sulawesi.

The study on shrimp diseases has focused on identification, characterisation and prevention through improvements in the culture environment (A. Rukyani, 1995, unpublished report). Dominant shrimp diseases were caused by bacteria (*Vibrio*, *Aeromonas* and Enterobacteriaceae), viruses (yellow head disease and MBV—*Penaeus monodon*-type baculovirus) and ectoparasites (*Zoothamnium*, *Epistylis* sp.).

Research target

Brackish-water farms of Indonesia are dominated by small-scale farmers, almost 50% have less than 2 ha, and 30% have 2–5 ha. Thus, Government policy focuses on the elevation of income of small-scale farmers by introducing lower risk technology. One of the Indonesian Government projects, INTAM (Intensifikasi Tambak or Pond Intensification), recommends low stocking densities (Table 1). There are only a few private businesses operating large-scale shrimp farms, like those in Lampung Province, with an area of more than 10,000 ha (Poernomo 1996). One of these large shrimp farms is using gigantic plastic liners to cover the sediment in the ponds.

In general, Indonesian research aims to deal with the needs of aged brackish-water ponds as well as those of newly established ponds (i.e. outside Java and in eastern Indonesia). The Research Institute for Coastal Fisheries is also doing basic research.

Research dissemination

The Assessment Institute for Agricultural Technology (AIAT) is an apex body responsible for promoting and assessing technologies for the National Research Institute for Agriculture, which includes fisheries. There are 16 AIAT offices under the Agency for Agricultural Research and Development (AARD) representing the different provinces. AIAT conducts first line demonstrations for the transfer of improved technology at the farm level at selected sites. All the provinces facilitate direct linkage of research from scientists to extension workers and farmers.

The Institute of Brackish-water Aquaculture in Jepara, Central Java, is involved in education and primary extension of technology in brackish-water aquaculture, particularly shrimp culture.

Research constraints

Due to high variability in characteristics of coastal environments, the technology produced should be location specific. This condition implies that the resources of the coastal zone must be carefully evaluated for their suitability for the development of shrimp culture. At present, detailed data on coastal areas are limited. Many farmers applied technologies which were successful for other farmers, but found it could not be directly transferred to their location due to their specific problems. This is one of the reasons the Government, through AARD, established AIAT to conduct research and assess results conducted under specific conditions to establish the most appropriate technology for farmers at different sites.

Priorities for Future Research

A. Research priorities for dealing with environmental issues.

- The impact of large-scale intensive shrimp farms on coastal environments. The objectives are to characterise the causes and changes in water quality which result from high loadings of organic matter and other chemicals.
- The impact of mining, industry and agricultural activities on coastal environments. The objectives are to determine the toxicity of different pollutants, the effect on survival rates and growth rates, the levels of residues in shrimp and their distribution in the environment.
- The impact of 'wetland treatment' on discharges from large-scale shrimp farms and industries.
- The impact on the environment of the gigantic plastic liners which are used in shrimp farms in Lampung. The objectives are to determine impacts of plastic on bottom soil quality and loading of organic matter on aquatic plants and water quality.
- Absorption capacity of different species of aquatic plants to various pollutants. This study will be able to find the most effective aquatic plants for environment improvement.

B. Development of high quality broodstock through genetic engineering to produce improved seed (i.e. resistant to disease, healthy, fast growing and adaptable to environmental change).

C. Development of immunostimulants to combat shrimp diseases. Effective immunostimulants will increase survival rates and growth rates. Low cost shrimp feed will reduce production costs.

D. Identification and characterisation of coastal land in newly established brackish-water shrimp ponds, particularly those outside Java and in eastern Indonesia. The objectives are to classify the suitability and capability of the area according to the level of technology needed for sustainable shrimp culture. In this study, the physical, chemical, biological, economic and social aspects must be considered. Characterisation and evaluation of aged brackish-water ponds also need to be studied in order to restore and improve shrimp culture.

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Some Aspects of the Shrimp Farming Industry in China: Constraints and Priorities

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Abstract

Shrimp farming is one of the most important industries in coastal China. During the period from 1988 to 1992, more than one million people were employed in the field and about 200,000 t of shrimp was produced each year. But since 1993, the industry has been frustrated by problems. This paper briefly introduces the developmental history and the current status of shrimp farming in China. Some key constraints to sustainable shrimp culture include disease, impacts on the environment, and seedstock quality. Achievements in scientific research which have been gained in recent years are epizootic pathogen research, diagnostic techniques, comprehensive culture techniques, polyculture and methods of culture in lower salinities. The priority issues for future research are high health seedstock, healthy culture systems, fast diagnosis of shrimp diseases, development of vaccines and immunostimulants, high quality formulated feed and techniques for ecosystem optimisation.

Brief Review

There are about 100 penaeid shrimp species in China's coastal waters, of which a dozen *Penaeus* spp. and *Metapenaeus* spp. have commercial value (Liu 1989a). The main species cultured in China are *Penaeus chinensis*, *P. monodon*, *P. japonicus*, *P. merguinsis* and *P. penicillatus*.

Chinese shrimp farms are distributed along almost 18,000 km of coastline from Hainan Province in the tropics to Liaoning Province in the temperate zone. Farmers usually culture two crops of shrimp per year in southern China, while to the north of Yangzi River farmers can harvest only one crop. More than 80% of shrimp farms use low intensity culture technology. Air blowers or paddlewheel aerators are rare.

The modern shrimp farming industry in China has a history of only about two decades but it has gone through an extraordinary experience which can be roughly divided into four stages: steady increase (1978–1984), rapid increase (1984–1988), prosperity (1988–1992), and recession (1993–1995). There were only 1,300 ha of shrimp ponds in China in 1978, however the area of ponds reached 160,000 ha in 1991. Total shrimp output increased by more than 400 times, from 450 t in 1978 to 200,000 t in 1991, and the average yield increased from 350 kg/ha to 1,500 kg/ha. Since 1988, more than 100 billion shrimp larvae were produced each year (Wang and Cai 1995). About 100,000 t of cultured shrimp were exported annually, earning more than US$500 million (Cen 1993). The development of shrimp culture also promoted related businesses, such as feed manufacture, processing, transportation and marketing. It was estimated that more than one million people were employed in shrimp culture or related businesses in China (Wang and Cai 1995).

China's shrimp farming, however, has suffered from serious disease epidemics since 1993. The total output decreased from 200,000 t in 1992 to 80,000 t in 1993, then to 60,000 t in 1994. Many shrimp farmers have been frustrated and some have changed to new culture species. The recession in shrimp farming

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has generated large socioeconomic impacts in China's coastal areas.

Constraints

Many people, including some researchers, consider viral diseases to be the chief cause of the industry's collapse. Thus, what they eagerly long for are techniques which can control diseases effectively and quickly. However, there are many other factors which contributed to the shrimp culture recession in the past and constrain the sustainable development of the industry in the future.

Disease

In early times, bacteria were the main shrimp pathogens and malnutrition also played an important role in shrimp disease. People were often able to control these diseases relatively easily by applying antibiotics or taking technical measures. However, those measures were not able to control recent epizootics and diseases spread so quickly that, if a few shrimp were found dead or diseased, then a few days later the whole pond would be dead or dying (Cai and Wang 1995). We now know that infectious hypodermal and hematopoietic necrosis virus (IHHNV) was responsible for the disaster.

Environment

The environment around shrimp farming areas was partly responsible for the shrimp farming recession in China. One reason is the pollution from industrial waste water and sewage. According to Jiang (1994a) about 6 billion t of waste water drains into Chinese coastal waters from 43 coastal cities each year, of which 4 billion t is industrial waste water and 2 billion t is domestic sewage. Unfortunately, many shrimp ponds are concentrated near estuaries where polluted water drains directly, and many shrimp farms suffer heavy losses from this pollution. For example, at the estuary of Dagu River near Qingdao, juvenile shrimp cannot survive in summer if water is directly pumped from the estuary. Farmers have to reserve culture water for an appropriate time to avoid or eliminate the pollution. Although the government has been strengthening the protection of the environment, the pollution from industry waste water and sewage is still a big problem for shrimp farming.

Another cause of environmental problems is pollution from the shrimp farming industry itself. A large amount of shrimp faeces and waste feed are drained into coastal waters with the effluent and this results in eutrophication. Also, the composition of phytoplankton in many culture areas has changed dramatically and some microalgae seldom bloom. There are big fluctuations in the micro-environment, especially in indicators such as pH, dissolved oxygen, transparency and some factors which are closely related to algal propagation.

In addition, the abuse or overuse of disinfectants, chemicals and antibiotics disturbs or destroys the natural microbiology, affecting its ability to degrade or convert organic compounds.

Seedstock quality

Unfortunately, little research has been conducted to improve the seedstock of cultured shrimp until now. We should clearly recognise that shrimp culture is still based on the genetics of wild populations. Culturing larvae in hatcheries where good rearing conditions and antibiotics prevent diseases but, at the same time, reduce the ability of the larvae to resist unfavourable environmental conditions.

Current Status

In response to the epizootic in 1993, the China State Science and Technology Commission and the Ministry of Agriculture organised an emergent research program to deal with the difficulties confronting the shrimp culture industry. Demonstration shrimp farms in each shrimp producing province (e.g. Shandong, Liaoning, Hebei, Guangdong and Fujian Provinces), were established to research and teach successful ways of shrimp culturing. Desirable results have been achieved after concerted efforts in the last few years.

Pathogen Studies

The major pathogen of shrimp in China is IHHNV. The size of the virus is 120×360 nm, without inclusion. Its main targets are hypodermal tissue, hematopoietic tissue, connective tissue, the antennal gland and blood cells. The virus reproduces slowly when the temperature is below 20°C, however it propagates very quickly as temperature rises above 25°C (Huang and Song 1995). The virus was also found in other crustaceans, e.g. copepods and *Artemia*, which are abundant in natural sea waters or shrimp farming ponds.

After years of research, the Yellow Sea Fisheries Research Institute (YSFRI) and other fisheries-related institutes and universities have developed a series of diagnostic techniques for viral diseases such as gene probes, polymerase chain reaction (PCR), and monoclonal antibody techniques which have been successfully applied in farms.

Culture Techniques

Concerted efforts have been made to explore optimal culture modes for shrimp. Shrimp farmers also actively participated in different experiments to prevent epidemics according to their local ecological conditions. The following are some examples.

Comprehensive culture techniques

The maricultural scientists at YSFRI and other related fisheries institutes and universities have summarised some comprehensive technical measures which have proven to be effective in preventing epizootics in shrimp farming:

- thoroughly disinfecting the farming ponds and removing the sediment from last year's farming before stocking;
- propagating natural feed organisms in ponds and enriching juvenile shrimp' nutrition;
- installing aeration equipment and improving the ecological conditions in ponds;
- improving water quality and treating the water in sedimentation ponds before use in farming;
- supplying high quality formulated feeds;
- controlling water quality in optimum conditions and keeping the micro-ecosystem in balance during grow-out; and
- preventing high temperature larval rearing and overuse of antibiotics in hatcheries.

Polyculture

The main polyculture modes are shrimp–fish (e.g. mullet, tilapia, *Fugu* spp., perch, sea bream etc.), shrimp–algae, and shrimp–crab (Liu 1989b; Wang 1993; Jiang 1994b). The shrimp–fish system is the most successful, according to recent reports. Some experts inferred that there are two factors which keep shrimp growing healthily in the shrimp–fish system. One is that predatory fish eat sick or morbid shrimps, thereby eliminating the spread of disease in shrimp ponds. The other is that there is an improved balance in the mini-ecology of shrimp ponds. The chief drawback is that shrimp survival may be low if the proportion of fish to shrimp is not ideal.

Culture in lower salinity

P. chinensis and *P. monodon* can grow well in a salinity of about 5 ppt. Investigation showed that some shrimp farms located at estuaries or where fresh water was available, cultured their shrimps normally, while their neighbouring farms with higher salinities had suffered severely from disease. In recent years, some farms tried to lower the salinity of the culture water with fresh water (river or well water) and to grow their shrimp in low-salinity waters—most had desirable results.

Priorities for Future Research

The Chinese shrimp farming industry has many problems and the following priorities are suggested for future research.

Establishment of high-health seedstock

Domestication and systematic selection are needed for establishing a high-health seedstock for the industry, just as in agriculture and animal husbandry.

Establishment of healthy culture systems

It is important to develop healthy culture systems for preventing cultured shrimp from being infected by various pathogens and which are harmonious to the local environment. In the long run, different culture systems should be modelled for different locations from south to north along the country's coastline.

Fast diagnosis and checking techniques for shrimp disease

Fast and convenient test-kits are urgently needed for shrimp farmers to diagnose or check for shrimp diseases occurring in their farms, so that the disease may be quickly diagnosed on site and the necessary measures can be taken.

Development of vaccines and immunostimulants

Emphasis should be placed on the development of vaccines for vibrios and immunostimulants for enhancing the health of cultured shrimp.

Development of high quality formulated feeds and additives

Studies are needed to investigate the metabolic physiology of shrimp, with the aim of developing nutritionally-complete feed formulae and special-function additives for feeds.

Ecosystem optimisation in shrimp ponds

Identify appropriate methods to develop a harmonious microbial population in shrimp ponds by micro-organism propagation, water quality control and feeding strategy.

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Viral Diseases of Farmed Shrimp—Present Status and Future Research

Siddhi Booyaratpalin*

Types of Viruses

The viruses that infect shrimp can be subdivided into two groups: those that infect the ectoderm and mesoderm; and those that infect the endoderm and hepatopancreas. The viruses of the ectoderm and mesoderm include:

- IHHNV (infectious hypodermal and hematopoietic necrosis virus) which has caused severe problems in the United States of America;
- YHV (yellow head virus) which has caused high mortalities in Thailand since 1992;
- SEMBV (systemic ectodermal and mesodermal baculovirus), also known as WSBV (white spot baculovirus), which is the most serious pathogen in Asia since 1994; and
- TSV (Taura syndrome virus) which has caused high mortalities in Central America (Ecuador).

The viruses of the endoderm and hepatopancreas include:

- BP (*Baculovirus penaei* type);
- BMNV (baculoviral midgut gland necrosis type virus);
- HPV (hepatopancreatic parvovirus);
- MBV (*Penaeus monodon*-type baculovirus); and
- TCBV (type C baculovirus of *P. monodon*).

In Thailand, YHV and SEMBV cause the most serious problems, while some viruses, such as HPV, cause no significant losses to farmers. Traditional techniques for detecting viruses in diseased animals have been by light microscopy (i.e. stained, squashed cells of gills etc.) or by transmission electron microscopy (TEM). Some viruses are associated with occlusion bodies.

SEMBV, or white spot virus, is more common in 15–90 day old postlarvae. Affected shrimp often have a red body and haematoxylin and eosin (H&E) staining usually shows swollen nuclei. Viruses that appear to be very similar to, and possibly the same as SEMBV, are present in China, Japan, India, Malaysia and Vietnam. This virus also can infect many other species of crustaceans.

Research Strategies

Strategies for carrying out research into these viruses is based on five approaches: diagnosis; transmission; carriers and reservoirs; prevention and control; and treatment.

Diagnosis

As mentioned above, light microscopy, TEM, histopathology and bioassays are the main tools for diagnosis. However, genetic methods (i.e. DNA probes and PCR—polymerase chain reaction) are recent innovations that have been applied to some viruses. These appear to be successful approaches for SEMBV but the methods are in the developmental stages for YHV.

Transmission

Horizontal transmission occurs with YHV and SEMBV, but the evidence for vertical transmission is not conclusive.

Carriers and reservoirs

The carriers and reservoirs are mostly crustaceans, but there is uncertainty regarding shellfish, insects and plankton.

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Prevention and control

The protocol for minimising and reducing the occurrence of diseases at farms are as follows:

- select healthy postlarvae;
- use a low stocking density;
- ensure the farm is located where it can obtain good quality water;
- treat the water for 3–4 days before it is used;
- prevent entry of carriers and eliminate carriers;
- disinfect water before it is discharged; and
- use a closed, semi-closed or recycle system.

Treatment

Unfortunately there is no treatment that has been found which is effective at curing infected animals. This is an area that contrasts with other forms of agriculture and animal husbandry.

The main areas which should be priorities for research are: improved tools for diagnosis; determining possible modes of vertical transmission; development of vaccines and immunostimulants; investigating forms of viral treatments; and developing viable methods for domesticating broodstock.

A Summary of Key Issues in Shrimp Health Research in Thailand

Timothy W. Flegel*

THIS paper comments on the progress that has been made with respect to diseases affecting the shrimp farming industry in Thailand.

The Shrimp

- There are no routine measures of shrimp health (e.g. 'blood' cell assays, stress molecule assays).
- The defence mechanisms of shrimp are poorly understood (e.g. do immunostimulants and probiotics really work?).
- We do not understand the 'tolerance' of shrimp to new diseases (possible development of 'vaccines' or 'tolerines').
- The relationship between nutrition and health is poorly understood.
- No domesticated stocks of *Penaeus monodon* are available for reliable harvests and uniform research.
- The current understanding of shrimp genetics is limited.

The Environment

- The relationship between disease and the environment is poorly understood (e.g. what are the predisposing factors and stress factors for disease?).
- There are no biochemical engineering models for ponds to provide precise definitions and control of the pond environment.
- No rapid, sensitive and simple methods to detect toxicants are available (e.g. for insecticides and heavy metals).
- We need to define and enforce best operating practices.

Contingent Needs of the Industry

- Training and extension services;
- facilities and infrastructure;
- standards and codes for best practices; and
- regulations for the sale and use of drugs and chemicals.

Recent Developments in Thailand

- A shrimp industry consortium has been formed (Shrimp Culture Research and Development Co. Ltd.).
- The shrimp supply companies have formed a self-regulatory group.

The Detection of Pathogens

- Good capability has developed to respond to new disease syndromes.
- Good cooperation amongst disease research scientists has developed (e.g. National Standing Committee on Shrimp Disease).
- Good progress has been made on research for rapid diagnostic probes to detect systemic ectodermal and mesodermal baculovirus (SEMBV), yellow head virus (YHV), hepatopancreatic parvovirus (HPV), infectious hypodermal and hematopoietic

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necrosis virus (IHHNV), *Penaeus monodon*-type baculovirus (MBV) and *Agmanoma*.

- The use of probes is poor, except for SEMBV.
- We do not yet understand the linkage between bacteria, phage and virulence.
- We have a poor basic understanding of pathogen virulence.
- There is a low level of cooperation amongst farmers.

The Spread of Infectious Diseases in Farmed Shrimp: a Population-based Perspective

Chris Baldock*

AS animal production systems have intensified, the interaction of disease agents with other factors such as the physical environment, nutrition and genetics has become more complex. This complex interplay among a variety of factors sits in delicate balance while the goal of increasingly efficient production is sought. In such a system, even small changes in some factors can provide enough stress to cause the expression of disease. Resultant morbidity and mortality translate to lost production and reduced profitability.

Aquaculture in general and shrimp farming in particular are classic examples of where extreme intensification and simplification of a complex natural system towards a farmed monoculture have led to substantial infectious disease problems. The rapid global spread of 'new' diseases, particularly viral diseases, of shrimp has emerged as one of the most important issues in aquaculture today. If not effectively addressed, it is likely that similar events will continue to occur, causing quite dramatic cyclic production shifts. The problem is that the search for solutions has difficulty keeping pace with the emergence and spread of new diseases and this is likely to continue. When a new disease occurs, it causes marked production loss and urgency for quick solutions which are usually not forthcoming. By the time scientists can complete the research necessary to gain some insight into its aetiology, pathogenesis, modes of transmission etc., its impact has diminished from the original epidemic and stabilised to a level which is tolerated by farmers and the impetus for a specific solution is gone. In the meantime, another new disease emerges. And so on. This cycle poses a major problem for scientists investigating aquatic animal diseases.

In this paper, I associate some of the important technical principles of the behaviour of diseases in populations with recent developments in the regulation of international trade. I then argue that we may need to rethink how we view research with respect to the importance of an excessively specific focus. I conclude with some of my views on the general researchable issues relevant to this area as a nucleus for further development through workshops such as this.

The Research Method

In any discussion of researchable issues, it is important that we have a clear understanding of the interactive processes involved in systematically examining the 'knowns', developing hypotheses, and then attempting to unravel the 'unknowns'.

Our knowledge of disease causation and methods of spread is gradually modified and expanded by successive executions of several related processes in a continuous cycle, each of which is a transition between two 'adjacent' content categories of empirical research. Given a certain understanding of a disease, each researcher may formulate one or more conceptual hypotheses based on his or her insight and 'hunches'. The hypotheses are then tested by carefully defining the methods of research and collecting data according to a set protocol. The raw data are put into a useable format, summarised appropriately, and analysed by testing the operational hypothesis. Using our results we make causal inferences that allow us to

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modify existing theories and generate new hypotheses. Thus, the cycle continues—the new findings generating new hypotheses, which in turn generate new empirical studies. Naturally, research does not always follow this exact order. Nevertheless, the concept of a generalised approach to research is important for recognising the roles of the various research disciplines in solving complex problems.

The Downwards–Upwards Challenge

The traditional approach to the emergence of new disease entities is through seeking interventions which will prevent or cure disease at the individual animal level. This traditional paradigm requires developing an understanding of disease processes, starting at the individual animal then progressing to the organ, cellular and genetic levels. Such a 'downward approach' largely ignores the complex interplay that occurs among individuals when they are aggregated in populations existing in environments not always ideal for good health and optimal production. A population of animals has attributes that go beyond the mere summation of its constituent animal units in the same way that the individual animal is more than just the sum of its individual organ systems.

For the epidemiologist, the population is the patient. Quantitative epidemiological approaches to the investigation of production loss can help unravel the complex interplay among factors causing disease. Quantitative epidemiology has been described as the formal study of the distribution and determinants of disease in populations using a collection of specific research methods. Epidemiological studies provide insight not only into those factors which are unique to the population per se, but can also raise hypotheses worth exploring further at the individual animal, organ, cellular and genetic level.

Thus, the understanding of disease processes operating at the population level requires both a 'downward' and an 'upward' approach to investigation. By using such a bidirectional approach, fresh insights into the mechanisms and control of disease can be obtained.

The Unit of Interest

Understanding how disease processes work using a population-based approach requires the measurement of levels of disease and associated factors in different sub-groups of the population of interest and then making comparisons. Hopefully, this then leads to the identification and application of measures to reduce both the risk of disease and its impact.

In studying disease, population-based methods begin with the individual animal and work 'upwards'. Thus, the lowest level in terms of unit of interest is the individual animal. Methods that involve studying factors affecting the individual are quite feasible for some terrestrial animals such as humans, cattle or horses, but are clearly difficult with shrimp.

The next level of aggregation where specific factors affecting health occur is the pond level. Thus, for diseases affecting shrimp, the 'lowest' feasible unit of interest in our hierarchical model is the pond. Where this is the unit of interest, it is assumed that factors operating at the pond level impact equally on all shrimp in the pond. Examples are depth of water, level of salinity and oxygenation, rate of water interchange etc. Although these factors do not operate equally on all shrimp in the pond, they do impact on the pond population as a whole and may be amenable to the development of interventions which either reduce the risk of contracting disease or at least reduce the impact of disease.

Moving up the ladder, factors operating at the farm level include a wide range of husbandry, management and environmental influences. The designs of studies to investigate these factors are quite specialised and require careful methods of data collection, analysis and interpretation in order to draw valid conclusions.

Disease Transmission and Spread

We normally think of 'transmission' as the movement of disease from an infected to a susceptible individual animal within an infected population. 'Spread', however, is the movement of disease from an infected population to a susceptible one. For infectious diseases, it is important to know how the disease is transmitted between different members of the population. This has led to the notion of the 'chain of infection' which is summarised below:

> infected host → portal of exit → mode of transmission → portal of entry → susceptible host.

In epidemiology, the interest in the mode of transmission will focus on different mechanisms depending on the unit of interest of the study. For example, the most fundamental level of interest is transmission from animal to animal. However, within a particular farm there may be interest in methods of spread from pond to pond. At higher levels again, the interest will be in methods of spread from farm to farm, and district to district within a country. Finally, quarantine authorities are interested in mechanisms of spread from country to country and world region to world region.

A number of ways of looking at different modes of transmission have been devised. These are summarised in Table 1.

Table 1. Methods of transmission of disease within populations.

Direct transmission		Indirect transmission	
Contact		Airborne	– droplet nuclei (<5 microns)
Droplet			
Vertical	– in utero		– droplet nuclei (>5 microns)
	– via milk		
		Vehicle	(fomites)
		Vector	
			– mechanical
			– biological

The most effective method of long distance spread for relatively fragile agents such as viruses is through the movement of live animals and animal products. These are likely to be important in the spread of infectious diseases of shrimp and are justifiable areas of well coordinated and intensive research attention.

'Cause' from an Epidemiological Perspective

Not all shrimp in a pond die during an outbreak of, for example, white spot disease. Likewise, not all ponds in a farm are necessarily affected nor all farms in the local area. The questions therefore arise: what causes some shrimp to become infected and die?; what causes some ponds to be affected and not others?; what causes some farms to be affected and not others? These are questions which can be extremely difficult to answer, but that should not prevent us from attempting to find answers with the view to both reducing the risk of disease occurrence and its impact on production in the future.

We all view problems differently, according to our prior experience and knowledge. Epidemiologists are interested in diseases and their production impacts, but take a different approach to the pathologist or microbiologist. The epidemiologist interprets causality in quite a wide sense. This is somewhat different to the more traditional view that the role of 'cause' is restricted to aetiological agents, while all other contributions are relegated to 'contributing' or 'predisposing' factors. An epidemiological definition of a cause of a disease is *an event, condition or characteristic that plays an essential role in producing an occurrence of a disease*. Under such a definition, the presence of the fungus *Aphanomyces* sp. in a pond of fish may not of itself be sufficient to 'cause' an outbreak of epizootic ulcerative syndrome (EUS). It may require the contribution of a stress trigger leading to skin damage to 'cause' an outbreak of disease in the group. Under this concept, the fungus is a **necessary** (no disease would occur if the fungus was not present) but not a **sufficient** cause of the particular syndrome, whereas the stress is neither necessary nor sufficient but can be a **component** of a sufficient cause. In fact, for any particular expression of a particular disease, there may be a range of possible sufficient cause complexes.

The challenge for the epidemiologist is to identify some of the more important components of sufficient causes for a particular disease with the view to devising cost-effective intervention strategies at critical points to either prevent disease expression or reduce production impacts. Thus, in the case of EUS, reducing the risk of outbreaks may not necessarily require interventions directly targeted at the aetiological fungus. By altering factors that cause skin damage, we may be able to greatly reduce the risk of outbreaks as well as their overall impact on production when they do occur.

Disease Patterns

It is sometimes not appreciated that, although there are many chance elements in the spread of infectious diseases in populations, the resultant patterns are not distributed randomly. Rather, these patterns have characteristics which can be observed and analysed to give a great deal of insight into the underlying processes. If this were not so, then epidemiology as a scientific discipline would not exist!

However, identifying the patterns and understanding the principal driving processes is usually very difficult. The problem is that records of disease occurrence are frequently very sparse and lack the level of detail required to be able to detect the underlying pattern. For infectious diseases particularly, this situation is frequently exacerbated by the sensitivity of the information, leading to lack of disclosure because of potential financial implications through loss of trade. This sensitivity to information disclosure occurs from the farm level upwards and is influenced by the direction of spread. For example, if I am a grower of shrimp and have a disease outbreak which I think I have acquired from elsewhere, then I am likely to divulge my problem. However, if I have a hatchery and I know I have an infectious disease agent circulating, I may be reluctant to divulge the information because of the likelihood of personal loss of business.

This dichotomy in attitude to disclosure of information continues through the various upward levels of aggregation to the country level. Measures being implemented by the World Trade Organization (WTO) through the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) and the Agreement on Technical Barriers to Trade (TBT Agreement) are aimed at reducing the impact of these types of issues on international trade. The SPS Agreement probably has greater relevance to agricultural trade than the TBT Agreement.

WTO uses the codes of the Office International des Epizooties (OIE) to guide standards and to settle disputes between country trading partners. These codes have only recently been developed for aquaculture and their continued improvement with the view to increasing effectiveness will depend on the results of ongoing research. OIE tries to develop codes which have a factual, technical basis. Hence, their quality with regard to the international spread of disease largely depends on the level of the existing understanding of the biological processes by the relevant scientific community.

It is therefore worth considering both the SPS Agreement and OIE codes further as this will lead to the identification of useful research areas pertinent to the reduction in the international spread of disease.

WTO and the SPS Agreement

The international trading environment is rapidly changing. Perhaps the single biggest factor influencing outcome requirements for national animal health authorities over the next decade is the change in trading arrangements being effected through WTO. WTO not only impacts on international trade, but also on domestic trade legislation and regulations.

WTO is the embodiment of the results of the Uruguay Round trade negotiations and is the successor to the General Agreement on Tariffs and Trade (GATT). It was established on 1st January 1995 and is the legal and institutional foundation of the multilateral trading system. WTO provides the principal contractual obligations determining how governments frame and implement domestic trade legislation and regulations. In addition, it is the platform on which trade relations among countries evolve through collective debate, negotiation and adjudication.

The underpinning principle of WTO is that members are bound to grant to the products of other members no less favourable treatment than that accorded to the products of any other country. The provision on 'national treatment' requires that once products have entered a market, they must be treated no less favourably than the equivalent domestically-produced goods.

The three prime objectives of WTO are:

1. *Ensuring predictable and growing access to markets.*

   While quotas are generally outlawed, tariffs or customs duties are legal in WTO. Tariff reductions, for the most part, are being phased in over five years.

2. *Promoting fair competition.*

   WTO extends and clarifies previous GATT rules that laid down the basis on which governments could impose compensating duties on two forms of 'unfair' competition: dumping and subsidies. WTO Agreement on Agriculture is designed to provide increased fairness in farm trade.

3. *Encouraging development and economic reform.*

   GATT provisions intended to favour developing countries are maintained in WTO, in particular those encouraging industrial countries to assist trade of developing nations. Developing countries are given transition periods to adjust to the more difficult WTO provisions. Least developed countries are given even more flexibility and benefit from accelerated implementation of market access concessions for their goods.

The SPS Agreement concerns the application of sanitary and phytosanitary measures; in other words, food safety and animal and plant health regulations. The Agreement recognises that governments have the right to take sanitary and phytosanitary measures but that they should be applied only to the extent necessary to protect human, animal or plant life or health, and should not arbitrarily or unjustifiably discriminate between members where identical or similar conditions prevail.

In order to harmonise sanitary and phytosanitary measures on as wide a basis as possible, members are encouraged to base their measures on international standards, guidelines and recommendations where they exist. However, members may maintain or introduce measures that result in higher standards if there is scientific justification or, as a consequence of consistent risk, make decisions based on appropriate risk assessment. The Agreement spells out procedures and criteria for the assessment of risk and the determination of appropriate levels of sanitary or phytosanitary protection.

It is expected that members would accept the sanitary and phytosanitary measures of others as equivalent if the exporting country demonstrates to the importing country that its measures achieve the importing country's appropriate level of health protection. The Agreement includes provisions on control, inspection and approval procedures.

In summary, key technical elements of the SPS Agreement are:

- harmonisation;
- equivalence;
- risk assessment;
- regionalisation;
- transparency;
- technical assistance; and
- special and differential treatment.

Of these, the first four carry implications for developing priorities for researchable issues relevant to shrimp farming and are briefly described further.

'Harmonisation' implies that, to achieve uniform acceptance of sanitary and phytosanitary measures, WTO members should base those measures on existing international standards, guidelines or recommendations wherever possible.

'Equivalence' means that an importing member country should accept the measures of its exporting partner if the partner can demonstrate its measures achieve the importing country's appropriate levels of protection.

WTO members are meant to apply measures on the assessment of the risks relevant to human, animal and plant health. Because of its growing importance in international trade, risk assessment is discussed in more detail in the next section of this paper.

'Regionalisation' has a specific meaning both within OIE and WTO. It is the consideration of a group of countries as a single unit with regard to disease status. This is in contrast to 'zoning' which is the division of an individual country into a number of distinct areas with regard to disease status.

Of course, not all countries which trade in shrimp are members of WTO. Whether or not such countries can be encouraged to apply some of the principles mentioned above is a matter for negotiation as specific issues arise. However, such an approach would appear to be in everyone's interest.

OIE International Aquatic Animal Health Code

OIE is an inter-governmental organisation created by international agreement in 1924. OIE has its headquarters in Paris and in March 1996 comprised 143 member countries.

The codes of OIE form the basis for international agreements and dispute settlement with regard to quarantine issues in agriculture between countries of WTO. This includes aquaculture. The aim of many of OIE codes is to provide internationally agreed guidelines on measures which reduce the risk of international spread of infectious disease agents.

For animal health and zoonoses including aquaculture, the relevant international organisation in terms of the SPS Agreement is OIE. OIE's "International Aquatic Animal Health Code" (the Code) was adopted in May 1995 and is the basis for undertaking quarantine risk analyses by member countries. The Code underwent revision during 1996.

The Code aims to facilitate trade in aquatic animals and products by providing detailed definitions of minimum health guarantees that should be required of trading partners in order to reduce the risk of the international spread of aquatic animal diseases. In its initial form, the Code was directed mainly towards aquaculture rather than the wild-caught fishing industry.

The Code has two lists of diseases:

1. Diseases notifiable to OIE. This list comprises those transmissible diseases considered to be of socioeconomic and/or public health importance within countries and which are significant in the international trade of aquatic animals and products.
2. Other significant diseases. These are diseases which are of current or potential international significance in aquaculture but have not been included in the list of diseases notifiable to OIE. This is because: they are less important than the notifiable diseases; their geographical distribution is either limited, too wide for notification to be

meaningful, or not yet sufficiently defined; or because the aetiology of the disease is not well enough understood.

The Code provides guidelines on notification of disease occurrences, ethics in certification, methodology for import risk analysis, evaluation of government services, implementation of zoning, import and export procedures, and hygiene and health controls. There is an accompanying volume, "The Diagnostic Manual for Aquatic Animal Diseases" which gives detailed diagnostic methods for the listed diseases, details of fish health surveillance programs and international reference laboratories.

Preventing International Spread

With the emerging appreciation of the impact of infectious diseases of shrimp, many countries are in the process of undertaking risk analyses to prevent the entry and spread of unwanted pathogens. For example, in Australia, a ban on the importation of uncooked shrimp not for human consumption was imposed in November 1996. This was a direct result of the recent waves of infectious diseases and will be maintained until the results of a full import risk analysis are available. The ban is directed towards products such as bait for fishing as these come into direct contact with populations of both wild and cultured shrimp. This is regarded as posing a high risk of introduction of disease until the risks can be more carefully evaluated.

The International Aquatic Animal Health Code says:

> The principle of import risk analysis is to provide importing countries with an objective, defensible method of assessing the risk associated with the importation of aquatic animals, aquatic animal products, aquatic animal genetic material, feedstuffs, biological material and pathological material. The analysis should be transparent in order that the exporting country may be provided with a clear and documented decision on the conditions imposed for importation or refusal for importation.
>
> The use of these principles is preferable to a zero-risk approach because it should lead to a more objective decision and enable competent authorities to discuss any differences in conclusion which may arise concerning potential risks.

The components of import risk analysis identified by OIE include:

- **risk assessment** (identification and estimation of the risks, and evaluation of the consequences), **risk management** (identification, documentation and implementation of measures that can be used to reduce the risks and their consequences) and **risk communication** (means of communicating the results of the risk assessment to decision-makers, regulators, industry and the public);
- **evaluation** of Competent Authorities; and
- **zoning** within countries.

A standardised risk assessment method is prescribed in the Code. The importing country should elaborate scenarios by which the introduction of a disease agent in an imported commodity and its subsequent exposure and transmission to aquatic animals is possible. Each scenario will comprise a set of factors that require identification (and quantification, if possible) to allow estimation of risk. Four categories of factors are identified:

Country factors: principally, the prevalence of the disease agent in the aquatic population from which the commodity was drawn. Country factors which could be considered for a particular pathogen are:

Situation in importing country

- Occurrence of relevant pathogen
- Available diagnostic tests and their reliability
- Available control measures and their effectiveness

Situation in exporting country

- Population(s) susceptible to infection by agent
- Prevalence of infection
- Available diagnostic tests and their reliability
- Disease control policies and their effectiveness
- Disease zoning measures in place

Commodity factors: parameters specific to a particular commodity that affect the probability of disease agent presence and survival in a commodity at the time of import. Commodity factors which could be considered for a particular pathogen are:

The commodity

- Commodity species and stage being imported
- Susceptibility of particular species and stage
- Variation in prevalence with factors such as time of year
- Water source from which commodity was derived
- Water conditions at the time of harvest

The pathogen

- Host predilection sites
- Numbers of pathogen expected in different tissues of host
- Transmissibility
- pH lability
- Temperature lability
- Survival outside host
- Effect of processing

- Survival in stored host
- Effects of additives and treatments

Exposure factors: factors specific to the use and distribution of the commodity in the importing country which will affect the probability that a susceptible host species will be exposed and infected. Exposure factors in importing country which could be considered for a particular pathogen are:

- Range of potentially susceptible hosts
- Range of hosts experimentally infected
- Distribution of primary, secondary and intermediate hosts
- Required infectious dose and possible modes of transmission
- Nature of the commodity and its market distribution channels
- Different ways in which commodity is likely to be used
- Calendar period of importation
- Disposal practices for unused commodity and contaminated materials

Risk reduction factors: measures that can be applied to reduce the risk that a disease agent will be introduced into the importing country, exposed and/or transmitted to an aquatic animal. Risk reduction procedures for pre-entry and post-entry that could be considered to lessen the risk of introduction of a disease through an imported product are:

- Restricting zone of origin, species, life cycle stage
- Treatment of commodity host (e.g. vaccination for relevant pathogen)
- Product testing with tests of high sensitivity
- Prevention of cross-contamination (e.g. batch processing, cleansing, pre-shipping quarantine)
- Processing (e.g. evisceration, head removal, trimming, filleting, skin removal)
- Inspection and grading
- Maturation and storage under conditions known to destroy pathogens
- Treatments such as heating and disinfection
- Limiting size and frequency of imports
- Restriction of destinations in importing country
- Packaging into retail-ready packs
- Certification of various measures

For each of the above categories, a number of options are identified in the Code. In practice, information on each of the factors is obtained from available sources including precedents, scientific information, experience and expert opinion. Where possible, quantitative data are obtained for a factor. Where quantitative data are sparse or unreliable, a qualitative risk assessment may be made.

The Researchable Issues

This section borrows heavily from the outcomes of an Australian Centre for International Agricultural Research (ACIAR) workshop on epidemiology in tropical aquaculture held at the Aquatic Animal Health Research Institute, Bangkok, in July 1996. I am greatly indebted to my Australian colleague, Dr Dick Callinan, who led the workshop and to the participants from many countries of the Asian region. Collectively, that group identified a number of key researchable issues, several of which I will repeat and reinforce here.

From a population-based perspective, the key issues where research is likely to be both fruitful and provide distinct benefits to shrimp aquaculture in Thailand relate mainly to identifying those factors affecting the spread of infectious agents and the technical measures required to reduce both the spread and impact. Although the issues have been grouped under a number of headings there is considerable overlap.

Issues relevant to farm-to-farm spread

- Development and evaluation of the sensitivity and specificity of techniques for the rapid and accurate diagnosis of infectious agents of shrimp.
- Design and evaluation of statistically-sound sampling designs for the detection of disease in shrimp populations using rapid screening tests.
- Development and evaluation of methods to inexpensively monitor important environmental factors at the pond level and to assess morbidity and possibly mortality rates in ponds.
- Identification of pond and farm level risk factors affecting the spread of infectious disease agents using a true multidisciplinary approach.
- Development and evaluation of on-farm quality assurance measures, including hazard analysis and critical control points (HACCP) techniques, and monitoring systems to reduce the risk of entry of infectious agents and to enable early detection of disease.
- Development and evaluation of response strategies aimed at reducing the spread and impact of infectious disease.

Issues relevant at the country level

- Development and evaluation of reliable surveillance methods for the early recognition of emerging disease problems and for producing

information relevant to risk analyses and risk management.
- Evaluation of the potential role of modern information management techniques such as the geographical information system (GIS) in disease reporting, decision making and risk analyses.
- Development and evaluation of suitable methods for the economic analysis of the impact of disease and benefits of control.

Issues relevant at the regional level

- Development and evaluation of appropriate certification measures based on sound technical principles and that result in a demonstrable reduction in the international spread of disease.
- Development and evaluation of regional standards for disease diagnosis and reporting.
- Development and evaluation of regional information systems to manage aquatic animal health data which are harmonised across countries in the region. Again, the feasibility of including such techniques as GIS should be explored.

Conclusions

Infectious diseases have had major impacts on shrimp farming in Thailand and many other countries of the world. A feature of these diseases has been their relatively rapid international and sub-national spread. Identifying the important factors affecting this spread will take time and a considerable, collaborative research effort. Solutions will need to be found within the framework of new and emerging international trading arrangements.

I would like to pose an idea for consideration. There is a saying, which is becoming more and more relevant in this rapidly changing world—"think global, act local". Perhaps our research equivalent should be—"think general, research specific". That is, as we undertake research on specific infectious diseases, we should take care not to focus excessively on the specific issues of interest for the particular disease in question. Rather, we should be looking for factors in the spread of this disease which act more generally and are likely to give insight into the behaviour of new diseases when they occur and thus lead to some general principals on which to base solutions. Hopefully, population-based approaches can contribute along with other methods in finding these solutions.

The Role of AAHRI in Sustainable Shrimp Aquaculture

Kamonporn Tonguthai*

THE Aquatic Animal Health Research Institute (AAHRI), Thailand, is dedicated to the study of diseases in aquatic animals and has responsibilities in:

- research;
- issuing of health certificates for the export of live aquatic animals;
- diagnostic services for aquatic animal disease;
- training at various levels;
- disease resource services; and
- information services.

AAHRI is funded with support from the Overseas Development Administration (ODA) as part of the South East Asia Aquatic Disease Control Project of the Royal Thai Government and the Department of Fisheries. The activities of AAHRI have now been expanded to involve the following countries in the region: Lao People's Democratic Republic, Vietnam, Cambodia, Philippines, Malaysia, Myanmar, Thailand, Indonesia, Bangladesh and Nepal.

As a result of its activities, AAHRI has now become a regional centre of excellence in aquatic animal disease. Typically, workshop training organised by AAHRI and ODA will involve all the nine countries and other interested parties from the private sector.

AAHRI is currently actively working towards sustainable shrimp culture by taking a direct role through research and an indirect role through workshop and training programs.

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Research Conducted at AAHRI

There are a number of areas of research in which AAHRI is involved. The main three are as follow.

Antibiotics

Some of the research projects which are being conducted on antibiotics are:

- retention of oxytetracycline in tiger shrimp (*Penaeus monodon* Fabricius);
- diseases in tiger shrimp culture in Thailand;
- efficacy of oxolinic acid against *Vibrio alginolyticus* infection in black tiger shrimp;
- leaching of oxytetracycline from surface-coated shrimp feed;
- study of oxytetracycline pre-treatment and injection of *Vibrio parahaemolyticus* into *P. monodon*; and
- study of residues of oxolinic acid in *P. monodon*.

White spot disease

The National Science and Technology Development Agency is funding studies on pathogenesis, transmission and treatment of white spot baculovirus (WSBV) using formalin. The studies investigate the prevention of disease transmission via water and ingestion. The mechanism of formalin treatment are being determined as well as the effective dose and duration of treatment for different stages of culture.

The shrimp defence system and immunity

A study on the basic shrimp defence mechanism and the effect of some environmental stressors on the defence system is funded by ODA. The aims of the project are to produce baseline information on the different parameters relating to health status. It is intended to develop a standard procedure for determining the sensitivity of the defence mechanism. Results from this study will be used for evaluation trials on chemotherapeutic agents and potential immunostimulants.

A deeper understanding of the shrimp defence mechanism will enable improvements to be made in management techniques to minimise environmental stress and disease susceptibility. Also, demonstration of efficacy of immunostimulants should reduce the requirement for antibiotic use in the treatment of bacterial infections.

Future Projects

1. Pathogenicity of WSBV via different infection routes. Different stages of shrimp development will be used to study the standard lethal dose and protocols for infection. The results could be used to study the efficacy of different disease therapies.
2. Vertical transmission of the WSBV needs to be studied urgently.
3. A domesticated broodstock program may be required to ensure the supply of high health seed. This project may need collaboration among institutions within the country.

Training and Workshops

Workshops on health management in shrimp ponds have been organised at AAHRI since 1990. Due to the continued demand for training in this subject, AAHRI organises two workshops per year. With support from ODA under the Aquatic Disease Control Project, and the demand from member countries, AAHRI will continue to provide training workshops until 1999, when the second phase of this project will conclude.

Regional Cooperation and Networking

Our knowledge of shrimp diseases has advanced considerably since the beginning of the shrimp industry. Fast detection techniques for known viruses have been developed and assistance via Government and private disease services now exists. However, these services are unable to cover the regional industry due to the wide geographical range of the farms and their diverse requirements. The investment required to establish new laboratories is considerable, not only in terms of the capital cost of equipment, but also the human resources required for training. Taking this into account, it would be more effective to upgrade existing laboratories and develop the human resources. AAHRI, can cooperate with any country or institution to train their staff and develop their laboratories.

The ODA project also has a smaller sub-project where the expertise of AAHRI is utilised to provide research training at AAHRI for a period of one to three months. This is intended to develop the capacity of researchers in their particular field, relating to their existing research projects. ODA provides funding to those researchers while they are attached to AAHRI. In the future, when project member countries or institutions are able to do research at their own laboratories, it will be possible to have joint research projects between AAHRI and other project member countries.

The issues in aquatic animal disease within the Southeast Asian region are common to all member countries. In this way, research performed by member countries has broad applicability to the region. Additional benefits from research collaboration include the strengthening of institutional ties and networking between the various research organisations within the member countries. AAHRI has excellent contacts within the broader aquatic disease community and this further strengthens its capacity to function as a regional focus for aquatic animal health.

Shrimp Health Research in Vietnam, Including Current and Planned Activities

Nguyen Van Hao*

Brief Profile of Shrimp Aquaculture in Vietnam

In 1994 the total area for shrimp culture was 204,950 ha. The area for extensive farming was 161,603 ha (79% of the total area), improved extensive was 37,202 ha (18%), semi-intensive was 6,117 ha (3%) and intensive was 26.3 ha.

In general, the design of ponds, the irrigation systems, the technology and the methods of farm management are not appropriate for eliminating pathogens and pollution.

Farm location

Table 1 shows the results of a survey by Can Tho University in two provinces, Tra Vinh and Minh Hai. It reveals that former mangrove forests were used for 100% of extensive farms, 77% of improved extensive and 61% of semi-intensive. Less than 10% of shrimp farms were located in former rice paddies, supra-tidal areas or swamps without forest. The soil of former mangrove forests contains high levels of organic matter and acid sulfate soils.

Water management

Almost all farmers exchanged water daily using a tidal regime. In extensive farms, 59.1% of households used a mesh screen in the sluice when exchanging water. In the improved extensive and semi-intensive farms, this percentage grew to 67–70%. Very few farmers used lime, inorganic or organic fertiliser in shrimp ponds, while 57–80% of farmers discharged waste water to the supply water canal.

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Table 1.The results of a survey of former land use and soil types of shrimp farms in Vietnam.

Location	Percentage of farms		
	Extensive	Improved extensive	Semi-intensive
Soil origin			
Former mangrove forest	100	77	61
Swamp without forest		1	3
Former salt farm		18	24
Former rice paddy		2	5
Supra-tidal		2	7
Soil characteristics			
High organic matter	68.2	41.1	16.9
Acid sulfate soil	31.8	8.9	20.3
Other	0	50	62.8

Feed and feeding

In the improved extensive and semi-intensive farms, the farmers used trash fish (81–82%). Improved extensive farms used wet feed mixed (34–93%) and domestically produced pellet (53%).

Semi-intensive farms feed shrimp with imported pellet (39%), homemade feed (20%) and domestically produced pellet (27%).

Loss of production in 1994

The loss of cultured shrimp production in 1994 was valued at US$30 million and affected an area of 90,000 ha. Shrimp production fell by 5,000 t. Among ten provinces in southern Vietnam, Minh Hai Province suffered the biggest damage, where the loss was estimated at about US$20 million.

Current Key Constraints to Sustainable Shrimp Culture and Action Being Taken

Current key constraints

The preparation and treatment of the pond bottoms before stocking and after harvesting are not carried out with appropriate technology. The mud on the bottom is not taken out, dried or limed. Also, the irrigation systems are usually not appropriate. Only one canal is used for supplying and discharging waste water. This method does not eliminate contamination by pathogens or pollution.

The density of shrimp ponds has not been controlled. The area of shrimp farms is greater than the total area of mangrove forests. In Minh Hai Province, the area of culture shrimp is two times greater than that of mangrove forests (199,000 ha versus 74,400 ha). In Ben Tre, the area is three times greater (20,693.5 ha versus 6,126 ha), in Tien Giang two times greater (2,606 ha versus 1,352 ha) and in Soc Trang three times greater (16,229.7 ha versus 5,000 ha).

The government does not have enough facilities, equipment and human resources to examine the quality of seed and control the health status of postlarvae.

Feed and feeding methods in shrimp farms are not appropriate. Most feeds are homemade and do not supply the nutritional requirements of shrimp. Also, feeding practices may have increased the contamination of ponds by introducing pathogens and pollution.

The survey indicated that farmers generally did not have enough experience in shrimp farming. They could not determine the appropriate season for stocking and could not manage the pond environment or shrimp health. The government did not have an appropriate policy for developing shrimp farming.

Action being taken to deal with constraints

Seed problem

- Strengthen and upgrade capacity to assess quality control, health status and presence of pathogens in seed before release.
- Announce regulations on necessary standards for shrimp hatcheries.
- Plan and reorganise the current hatcheries in an appropriate and flexible way.

Management problems

- Develop aquaculture extension activities.
- Promulgate central and local regulations for developing shrimp areas and protecting mangrove forests.
- Undertake mangrove reforestation.

Technology problems

- Build appropriate demonstrations in each ecological area.
- Establish other agricultural activities in areas not sustainable for shrimp farming (i.e. fish, molluscs).
- Apply rotation to farms in inland areas.
- Diversify the cultured species in brackish-water areas.
- Provide guidelines for managing pond environment and shrimp health.

The long-term solution

- Central and local policy of planning and developing aquaculture.
  - Plan and establish appropriate irrigation systems in shrimp culture areas.
  - Plan area for shrimp seed production and establish a national shrimp hatchery.
  - Identify appropriate areas for different farming models. Encourage the development of the semi-intensive model and be careful with the development of the intensive model in order to reduce pollution of the environment.
  - Establish an effective system for examination, control and diagnosis of shrimp health and pathogens.
- Establish close cooperation between different government agencies (i.e. Forestry, Water Management, Agriculture and Fisheries).
- Establish a national program of research for developing shrimp farming in Vietnam. This will be fundamental for its sustainable development.

- Establish a national system for monitoring the aquaculture environment in all southern coastal provinces.
- Re-establish the ecological balance in the coastal area by mangrove reforestation.
- Develop appropriate government tax and credit policies.

Shrimp Health Research Activities in Vietnam

There are many problems that have to be resolved in order to have sustainable shrimp development in Vietnam. Shrimp health research has been one of the priorities. The cooperation of many institutions, government offices and some universities is considered to be the most effective way to carry out this research (Figure 1). In the north, the research institutions include the Research Institute for Aquaculture No. 1 (i.e. RIA No. 1), the National Veterinary Research Institute for Marine Products and some central and provincial government departments for fisheries resource protection.

The RIA No. 3 and Nha Trang Fisheries University are in the central region. Some research relating to shrimp health has been carried out in the Faculty of Aquaculture on:

- diseases of tiger shrimp larvae in Nha Trang Province;
- initial studies on *Penaeus monodon*-type baculovirus (MBV) in cultured shrimp of Khanh Hoa Province; and
- resistance to drugs of luminescence bacteria in tiger shrimp larvae in Nha Trang.

In the south, the RIA No. 2 has carried out studies on shrimp diseases in the region on:

- bacterial pathogens in the pond environment and in shrimp of the southern coastal area of Vietnam;
- pathogens in cultured tiger shrimp in different shrimp farming systems;
- environmental aspects of shrimp disease of the southern area; and
- the main causal agents of shrimp disease in the Mekong Delta and some proposed integrated technologies for prophylaxis and treatment.

As an example of one of these projects—from 1996 to 1999, RIA No. 2, with the cooperation of the different regional organisations, has been conducting a project on entitled "Methods of diagnosis and appropriate technologies of prophylaxis and treatment of shrimp disease in the Mekong Delta". The main components of this research project are:

- investigating the health status of larval and grow-out stages of tiger shrimp cultured in the different areas of the Mekong Delta (i.e. pathogenic agents, timing of disease outbreaks, clinical signs, necessary conditions for outbreak of disease, the damage to shrimp);
- establishing specific tests for rapid diagnosis of the presence of some of the main pathogens which cause dangerous diseases in areas of concentrated production (i.e. hatcheries in Nha Trang and Vung Tau, shrimp farms in Minh Hai Province);
- collecting statistical data and establishing appropriate farming models;

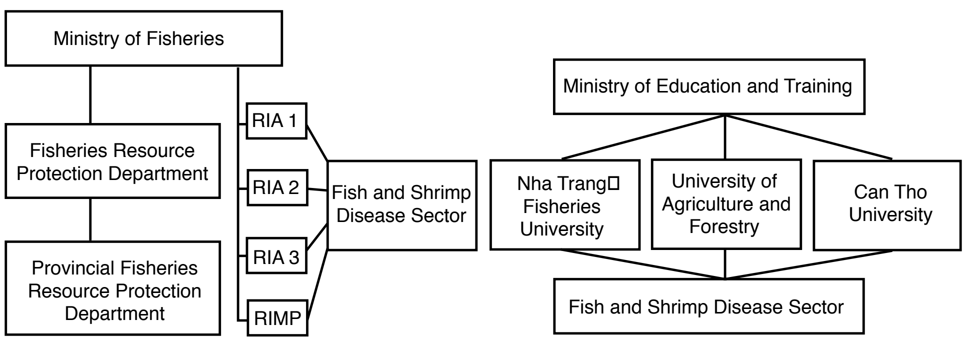

Figure 1. Linkages between institutions, universities and government agencies that are involved in shrimp and fish disease research and control in Vietnam (RIA = Research Institute for Aquaculture; RIMP = Research Institute of Marine Products).

- establishing demonstration systems in different ecological areas; and
- establishing technical procedures for sustainable development of shrimp farming in the Mekong Delta.

Research Constraints and Priorities

The main constraints are:

- financial support;
- facilities and equipment for carrying out viral disease research;
- experts in shrimp disease, especially in the field of viral disease;
- regional and international cooperation; and
- infrastructure for shrimp farming in Vietnam.

The priorities for future research topics are:

- shrimp pond dynamics;
- viral disease;
- rapid diagnosis of infectious disease;
- model hatchery systems; and
- appropriate technologies for different systems of shrimp farming (i.e. extensive, improved extensive, semi-intensive, intensive and integrated).

Review of Recommendations from Recent SEAFDEC Workshops: SICCPPS and AQUACHEM

Celia R. Lavilla-Pitogo*

THE Second International Conference on the Culture of Penaeid Prawns and Shrimps (SICCPPS) was convened in Iloilo City by the Southeast Asian Fisheries Development Center (SEAFDEC) on May 14–17 1996 to bring together scientists, researchers and industry practitioners to discuss developments and constraints in shrimp culture. Two simultaneous workshops were held after the presentation of scientific papers: the Workshop on Seed Production and the Workshop on Pond Grow-out Culture of Shrimp.

Research Issues for Seed Production

The participants of the Workshop on Seed Production set the following objectives:
- to obtain a reliable supply of spawners;
- to develop captive broodstock;
- to improve the reproductive performance and survival of captive broodstock;
- to develop disease-resistant stocks; and
- to develop cost-effective methods for production of good quality postlarvae in the hatchery.

Having agreed upon the objectives, the participants then discussed the following areas for research.

Genetic selection

- Determine the genetic diversity of wild shrimp populations and establish genetic databases.
- Establish a breeding program for future development of strains or maintenance of diversity in the populations. The outputs of this program will be specific pathogen-free or disease-resistant stocks.

Nutrition

- Formulate broodstock diets that match the nutrient composition of their food in the wild.
- Compare the reproductive performance of pond-reared and wild-caught broodstock using different diets.
- For larval rearing, find practical substitutes for *Artemia salina*.

Endocrine control

- Develop assays for vitellogenin and neuro-hormonal substances.
- Find alternatives to eyestalk ablation as a method for inducing maturation.
- Conduct more basic studies on the reproductive biology and physiology of shrimp.

Environmental manipulation and maturation systems

- Determine the activity patterns of adult shrimp (e.g. the effects of tidal fluctuation, time of feeding etc.).
- Determine stress indicators in the maturation system.
- Develop methods to determine viability of sperm in the thelycum.

Health management

- Evaluate and improve disinfection practices for spawners.
- Study the effects of immunostimulants on shrimp broodstock and larvae.

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- Evaluate the use of probiotics.
- Evaluate methods for maintaining microbial balance in the culture system.

Research Issues for the Grow-out of Shrimp

The participants in the Workshop on Pond Grow-out Culture of Shrimp agreed that the main objective should be to improve pond production through the use of environmentally friendly methods. The following are the recommended research areas.

Culture systems (including monoculture, polyculture and integrated farming systems)

- Test the efficacy of probiotics.
- Test ways to minimise nutrient load or devise means to prevent its accumulation.
- Evaluate or devise effluent treatment techniques through various mechanical, biological, or chemical methods.
- Evaluate other culture techniques (i.e. fallowing, crop rotation and polyculture with molluscs, seaweeds, or fish).
- Develop plankton manipulation techniques.
- Conduct studies on the effects of various culture systems on the environment.
- Study aquasilviculture to augment or diversify the source of income for fishermen.

Pond management

- Evaluate pond design and its engineering aspects.
- Evaluate water quality in coastal areas including the effects of effluent on receiving waters.
- Evaluate different soil profiles and determine techniques for pond preparation.

Nutrition

- Formulate cost effective and 'least polluting' feeds.
- Develop or refine feeding strategies.

Health management

- Investigate the residual effects of therapeutics and other chemicals.
- Study the epidemiology of white spot baculovirus and other shrimp viral diseases in the region.
- Evaluate the use of probiotics as a means of disease prevention and control.
- Adapt a multidisciplinary approach to address problems with vibriosis.

Socioeconomics

- Conduct studies on coastal zone management.
- Determine the impacts of closed shrimp farming systems.
- Determine the economic viability of closed systems and crop rotation.
- Establish closer networks and linkages between research institutions and the private sector.

The Use of Chemicals in the Shrimp Industry

Following SICCPPS, the meeting on the Use of Chemicals in Aquaculture in Asia (AQUACHEM) was held at SEAFDEC Aquaculture Department (AQD) from 20–22 May 1996. This meeting was organised by SEAFDEC AQD and the Food and Agriculture Organization of the United Nations (FAO) Fishery Resources Division, with support from SEAFDEC, FAO and Canadian International Development Agency's Association of South-East Asian Nations (ASEAN) Canada Fund. After the presentation of review and country papers, the participants and observers met in two workshop groups. They discussed the roles and responsibilities of both the private sector (manufacturers, suppliers, retailers and users of chemicals) and the public sector (government, line agencies and academics) in relation to the use of chemicals in aquaculture.

The general findings from the expert meeting, as reported by Barg and Lavilla-Pitogo (1996), were as follows.

1. Many types of chemicals are being utilised in aquaculture for numerous purposes and in different aquaculture systems.
2. Many chemicals are essential for successful and efficient farm and hatchery management.
3. If applied appropriately, most chemicals do not appear to have significantly adverse effects on human health or the environment.
4. Significant difficulties were encountered in the compilation of data on chemical usage in Asian aquaculture. An information database for management to advise on safe and effective use of chemicals is urgently needed.
5. There is a need to facilitate exchange of information and collaboration among manufacturers, sup-

pliers, traders, importers and users (i.e. aquafarmers) of chemicals.

6. The roles and responsibilities of the public sector are significant with regard to management and regulation of chemical usage in aquaculture.
7. There are major constraints on the promotion of safe and effective use of chemicals in aquaculture, and these are summarised here.
   – Lack of: trained human resources (i.e. experienced fish health management specialists); schemes for building capacity; and support services to disseminate information on fish health management.
   – The misapplication of some chemicals (e.g. prophylactic use of antibacterials) is often due to a lack of: access for aquafarmers to information on appropriate use; effective and economically viable alternative management measures; or suitable alternative chemicals to help reduce the use of some potentially hazardous chemicals. Promotion of certain chemicals by traders or drug companies may also play a significant role in the overuse of chemicals.
   – Insufficient understanding of the mode of action and efficacy of certain chemicals, especially under tropical aquaculture conditions.
   – Uncertainties with regard to legal and institutional frameworks to govern chemical usage in aquaculture. Some examples are: specific provisions are insufficient or lacking; mandate and responsibilities of various line agencies in charge of public health and food safety, agriculture, animal health services and environment are not always well defined; and there are enforcement problems.
8. The use of chemicals in aquaculture may have significant implications for international trade of aquaculture products. Countries exporting aquaculture products, especially shrimp, are facing food safety requirements (e.g. maximum residue levels, banning of chemicals) which have been or are being formulated by importing countries. Controversy on these issues may increase due to activities by certain pressure groups.

The findings of the Meeting on the Use of Chemicals in Aquaculture in Asia were discussed by an ad hoc meeting of the Group of Experts on Scientific Aspects of Marine Environmental Pollution (GESAMP) Working Group on Environmental Impacts of Coastal Aquaculture held in SEAFDEC from 24–28 May 1996. GESAMP includes experts from International Maritime Organisation (IMO)/ FAO/the United Nations Educational, Scientific and Cultural Organization (UNESCO)-Intergovernmental Oceanographic Commission (IOC)/World Meteorological Organization (WMO)/ World Health Organization (WHO)/International Atomic Energy Agency (IAEA)/United Nations Environment Programme (UNEP). The Working Group discussed major environmental and human health issues related to the use of chemicals in coastal aquaculture as practiced worldwide. The proceedings of this Working Group meeting will be published by GESAMP.

Reference

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Amelioration and Management of Shrimp Ponds in Acid Sulfate Soils: Key Researchable Issues

Jesmond Sammut*

THE rapid expansion of shrimp farming has resulted in extensive excavation of coastal sediments that contain pyrite (FeS_2). When oxidised, pyritic sediments develop into acid sulfate soils (ASS), which are characterised by high acidity and elevated concentrations of sulfate and toxic metals (Golez 1995). ASS reduce water quality in shrimp ponds, groundwater and nearby creeks and estuaries. Consequently, ASS adversely affect shrimp production (Simpson and Pedini 1985; Singh 1985) and reduce the conservation, recreational and commercial value of estuaries (Sammut et al. 1995). Acidified shrimp ponds are often abandoned, leading to 'shifting aquaculture' and increasing pressure on land and water resources. Under current practices, the production of shrimp in ponds which are impacted by ASS cannot be sustainable. Unless ameliorated and managed, acidified shrimp ponds also become a long-term source of pollution to off-site areas. The role of ASS in shrimp production is often overlooked and the associated socioeconomic and environmental impacts are not widely recognised. This paper briefly discusses the impacts of ASS, some of the methods that have been used to ameliorate and manage affected ponds, and identifies key researchable areas.

Acid Sulfate Soils

Genesis of potential ASS

Pyrite forms when bacteria reduce sulfate (from seawater) to sulfide in the presence of iron and decomposing vegetation. These conditions are common in salt marshes, mangroves and other estuarine wetlands. Pyrite is formed in several stages and the overall process can be summarised asshown in equation (1).

Potential acid sulfate soils (PASS) are pyrite-bearing sediments that have the potential to oxidise and generate sulfuric acid when exposed to oxygen. Although PASS are usually associated with mangroves and other intertidal settings, they may also occur in supra-tidal landscapes because of burial by alluvium and the infilling of estuarine embayments following the Holocene Stillstand about 6,500 years ago. In some instances, PASS layers may be present in landscapes where ground surface elevations are up to 5 m above mean sea level (White et al. 1995).

Pyrite concentrations vary between sediment types and tend to be highest in clays (up to 15% w/w). In sandy soils, even very low pyrite concentrations (<0.1% w/w) can cause severe and rapid acidification because of the low acid neutralising capacity of the sediments (White et al. 1995).

Formation of actual ASS

PASS may oxidise under natural conditions when watertables fall below the surface of the pyritic zone. In Asia, this could occur during prolonged dry seasons. However, excavation and drainage of PASS greatly increase the exposure of pyrite and generates more acid than under natural conditions (Sammut et al. 1996). When oxidised, pyritic sediments are characterised by pHs less than 3.5, an increased concentration of sulfate, and the presence of jarosite [$KFe_3(SO_4)(OH)_6$], goethite [α-FeOOH] and haematite [α-Fe_2O_3]. The acid mobilises iron, aluminium, manganese and other metals to concentrations that are generally phytotoxic (White et al. 1995). Pyrite

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Equations

$$Fe_2O_3 + 4SO_4^{2-} + 8CH_2O + 1/2O_2 \text{ R } FeS_2 + 8HCO_3^{-} + 4H_2O \quad (1)$$

$$FeS_2 + 15/4O_2 + 7/2H_2O \text{ R } Fe(OH)_3 + 2SO_4^{2-} + 4H^{+} \quad (2)$$

oxidation occurs in several stages but the overall process can be expressed as shown in equation (2).

Once oxidised, an actual acid sulfate soil (AASS) layer is formed and it usually overlies a PASS layer. Pyritic sediments are generically referred to as ASS whether oxidised or not (White et al. 1995).

On-site Impacts of Acid Sulfate Soils

Pond conditions

Acid generated by the oxidation of PASS can enter shrimp ponds in several ways. Dykes constructed from PASS will oxidise and supply acid by direct contact with pond water and run-off from the dyke. When the pond water level is lower than the adjacent watertable, acidic water from an adjacent groundwater reserve will enter the pond. During drying phases, the pond bottom will oxidise and supply acid to the pond during filling. To a lesser degree, acid can enter ponds from acidified run-off from nearby ASS, especially in heavily disturbed and drained landscapes as found in the estuarine floodplains of Australia (Sammut et al. 1996). Acidified ponds are usually clear (<3 NTU—nephelometric turbidity units) because of aluminium-induced flocculation of suspended sediments. This may lead to increased water temperature (Sammut et al. 1994). Iron mobilised by the acid may precipitate as the pH rises above 4 (Simpson and Pedini 1985), blanketing the pond (Sammut and Mohan 1996).

During oxidation, pyritic sediments are chemically and physically altered. Oxidised sediments can shrink when dried but do not swell back to their original volume when resubmerged (White et al. 1995). Shrinkage causes land subsidence, cracking of dyke walls and pond bottoms, leakage of pond water, salination through sub-surface intrusion of seawater, and increased erosion (Poernomo 1992; Sammut and Mohan 1996).

Shrimp health

Shrimp production in ASS can be affected by lethal and sub-lethal impacts on shrimp health. Sudden changes in pH may cause mass mortalities because of damage to gills from aluminium, iron and the direct effects of acid (Simpson and Pedini 1985). In aquatic organisms, the products of pyrite oxidation cause fusion and clogging of gill lamellae as well as excess mucus production which impair osmoregulation and oxygen uptake (Singh and Poernomo 1984; Sammut et al. 1995).

Under sub-lethal conditions, acidified water can cause ‘soft shell syndrome’ or ‘no-moult disease’. The probable causes of these conditions are the loss of calcium from shrimp shells and the loss of alkalinity during the neutralisation of acids (Simpson and Pedini 1985). Poor growth rates have also been reported from shrimp ponds in ASS (Neue and Singh 1984; Simpson and Pedini 1985; Lin 1986).

Off-site Impacts of Acid Sulfate Soils

During wet weather and when water is discharged from acidified ponds, acid can be exported into estuarine waters. In many cases, acidic discharges from individual shrimp farms are only likely to affect tidal creeks. However, where groundwater is also acidified, many kilometres of estuarine waters can be impacted (Sammut et al. 1996). In areas where shrimp farming is the dominant land use, groundwater acidification and salination are potential problems (Jayasinghe 1994) which have not been adequately monitored in many environmental impact studies.

The off-site impacts of acidification include mass mortalities of gilled organisms, loss of seagrasses, degraded habitat, altered plankton communities, and loss of spawning and nursery areas (Sammut et al. 1995). Soil eroded from acidified dykes can cause silt problems, smother habitat and alter estuarine hydraulics and hydrology. Other potential impacts of acidified water include higher water temperatures, increased penetration of ultraviolet B light, infestations of waterways with acid-tolerant water plants, and chemical barriers to fish migration (Sammut et al. 1994, 1995).

Current Management Methods

There have been country-specific studies on the amelioration and management of ASS over the last decade (e.g. Singh 1982, 1985; Tan 1983; Simpson and Pedini 1985; Singh et al. 1988; Poernomo 1992). Current management methods can be broadly grouped into the following areas.

Chemical neutralisation

The most common method is the application of lime, dolomite, calcite or magnesite (Tan 1983; Simpson and Pedini 1985; Golez 1995). Chemical neutralisation has limited benefits because acid is regularly transported into the pond, thereby depleting the neutralising agent. Up to 90 t/ha of lime may be required to treat severely acidified soils (Tan 1983). Liming is used on pond bottoms, dykes and canals feeding the pond (Neue and Singh 1984). Some success has been achieved in neutralising and detoxifying acidified waters using filter press mud, fertilisers, rice hull ash and organic wastes (Tan 1983; Neue and Singh 1984).

Site selection criteria

Identification of PASS enables decisions to be made on whether land should be developed and if so, what acid management methods are required (Poernomo 1992).

Water management

Seawater is often used to neutralise, dilute and remove acid and iron flocs. However, the amount of acid generated by ASS can overwhelm the acid neutralising capacity of seawater. For example, 150 exchanges of seawater would be required to neutralise each 10 cm of acidic soil in a 1 ha by 1 m deep shrimp pond (Simpson and Pedini 1985). Such a high number of exchanges may not be practical and could increase the risk of importing pathogens and lead to the loss of nutrients. Water level management is also used to maintain a hydraulic gradient towards the dyke thereby restricting the movement of acid into the pond (Kungvankij et al. 1990).

Forced oxidation and leaching

This method works on the principle that the oxidisable component of the pond environment can be forced to oxidise during the drying phase and then acid is neutralised and removed with flushing. The method is impractical for sediments with high pyrite concentrations and may lead to soil structure decline.

Capping, compaction and lining

Compressed laterite is sometimes used to create a barrier between ASS and the pond water and also to reduce contact of run-off with ASS. Compaction of dykes is usually unsuccessful because it is not performed properly (Kungvankij et al. 1990). Plastic liners have also been used but can be costly.

Despite these previous studies, problems with ASS still occur and PASS are still naively excavated and developed with an expectation of high shrimp yields. In Australia, some shrimp farms are threatened by ASS from nearby developments and existing areas of drained estuarine floodplains (Sammut and Mohan 1996).

Researchable Areas

Revised site selection criteria

Although site selection criteria do exist, they tend to be country-specific and do not recognise all possible sediment types and landscapes that contain pyrite. Effective site selection criteria should incorporate field indicators of pyrite such as soil characteristics, vegetation communities, elevation data and hydrology, as well as soil survey methods, geomorphic principles, simple but effective field and laboratory analysis of soil samples, and a clear and accurate estimate of the net acid-generating capabilities of the sediments. Site selection criteria should be systematic and iterative. Accurate site selection criteria enable: avoidance of potentially problematic areas; the selection of methods for managing ASS if pyrite concentrations are low and treatable; and a more accurate environmental impact assessment to be made. Of national and regional importance is the accurate mapping of pyritic sediments as has taken place in Australia (Naylor et al. 1995) and Sri Lanka (Jayasinghe 1994).

Pyrite removal

The mining industry has minimised the impacts of pyrite oxidation by either reducing or removing pyrite from sediments. Hydraulic separation of pyrite from coastal sediments intended for development has had some success using hydrocycloning (Bowman 1993). Pyrite may also be separated by sluicing of sediments. In addition, there is some potential for using bactericides to eliminate or reduce oxidising bacteria. In some soil types, forced oxidation and leaching of pyrite may eliminate or reduce it to concentrations that are manageable (White et al. 1995). The practicability of these and similar methods of pyrite removal and reduction have not been rigorously evaluated for shrimp farming. They are, however, unlikely to be cost-effective for most operations.

Acid neutralisation

Methods that augment the use of lime and seawater flushing need to be evaluated. Research is needed to identify which methods or combination of methods are best suited to different soil types and the intended use of the ponds. Bio-remediation of acidified soils using algae and the effects of reflooding extensively acidified areas are also important researchable areas. There are little data on the effects of long-term flooding of ASS, especially on changes in soil chemistry and structure.

Improved water management

Water management strategies can be improved to limit the oxidation of pyrite, the movement of oxidation products, the neutralisation and dilution of acid, and the reduction of iron and aluminium flocs. Water management is complementary to other methods of preventing or ameliorating acidification but must consider disease control issues, nutrient supply and cost.

Alternative land use

Where ponds cannot be ameliorated for sustainable shrimp aquaculture, their use for finfish or rehabilitation for other land use should be considered (Neue and Singh 1984). Methods of reshaping degraded lands to minimise erosion and the export of oxidation products are required to protect off-site areas and to improve the quality of former shrimp farms. Alternative land uses include *Melaleuca* plantations, mangroves, acid-tolerant crops and artificial wetlands. The success of alternative land use relies on the acid tolerance of the plants selected, the effect of land use on the export of residual acids, the potential for pyrite to keep oxidising even when reflooded and the cost of earthworks and replanting.

Capping and lining

Further studies are required on the effectiveness and feasibility of capping or lining ASS. These methods may reduce the movement of oxidation products but may present other pond management problems.

Conclusions

The demand for land and water resources will increase with the expansion of the shrimp industry in Asia. The social, economic and environmental costs associated with the development of ASS will be high and persist unless ASS are ameliorated and managed effectively. Underpinning the management is the need for more applied research and long-term monitoring of managed sites. New technology for the management of ASS needs to be trialled for shrimp ponds, and standard procedures for decommissioning unproductive ponds are urgently required. Without appropriate principles of land stewardship, education, awareness and tighter control on development, ‘shifting aquaculture’ will continue to be a problem.

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GIS and Coastal Aquaculture Planning in Thailand

Phutchapol Suvanachai*

GIS and Planning

The advantage of the geographical information system (GIS) is that spatial and descriptive data can be integrated, analysed and viewed. Geographical data can include soil types, physio-chemical data, coastline information and socioeconomic data. The users of this type of technology are generally planners, researchers and developers.

The hardware that is required consists of a computer, plotter and printer. Software packages are available for use at various levels of complexity, e.g. ARCVIEW and MAPINFO. Spatial data require a geographical reference, such as coordinates or map location. Remote sensing techniques are one method of providing spatial data.

Examples of Geographical Data Analysis and Requirements

Aerial photographs and satellite images can be used to show land use in coastal areas. In such applications, mangroves appear red and the maps can be overlaid with features such as streams, urban development, agricultural land etc.

GIS technology can enable spatial analysis of data by interpolation from points to continuous data. For example, this occurs when data on temperature and water depth are received from spectral data from satellite images. Spatial analysis can also be useful in overlaying possible zoning schemes onto current land use.

Ideal data sets have parameters for physio-chemical, biological, political or administrative, and socioeconomic data. The data should have, as a minimum, accompanying information on the time the data were collected, who collected the data, the method that was used, the units of measurement and a geographical reference point.

Projects in Thailand

In Thailand there are four main projects which use GIS technology in fisheries:

- GIS and human resources;
- inland aquatic resource mapping;
- coastal aquaculture zoning; and
- restoration of marine fisheries.

Recently GIS has also been applied to shrimp farming in inland freshwater systems.

Management Goals

The use of GIS for shrimp culture in Thailand will enable managers and planners to determine the extent of shrimp farming activities, the loss of land cover and vegetation, and ecological impacts. GIS provides managers with a tool for recording and viewing environmental data over space and time (i.e. spatial and temporal information and trends).

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Coastal Planning of Shrimp Farming: Carrying Capacity, Zoning and Integrated Planning in Thailand

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THAILAND has huge flood plains and long riverine systems which include natural lagoons, estuarines and brackish-water areas. The total coastline of both the Gulf of Thailand and Andaman Sea is approximately 2,600 km. The Thai fishery industry has developed dramatically both for capture and aquaculture fisheries, with production increasing from 200,000 t in 1960 to 3,239,800 t in 1996.

Marine Shrimp Farming

Shrimp farming has been in practice on traditional or extensive farms in coastal areas for nearly three-quarters of a century. Shrimp fry were trapped in the salt beds and paddy fields around estuarine areas after they entered during tidal water exchange or were intentionally gathered from the wild and stocked directly into ponds. Production was dependent on the seasonal abundance of wild fry which fluctuates widely from year to year.

In 1973, Thailand successfully spawned and partially reared penaids such as *Penaeus monodon* and *P. merguiensis* (Tookwinas 1993). The Department of Fisheries (DOF) encouraged the addition of seedstock from hatcheries into traditional ponds and the application of supplementary feed; thus developing the semi-intensive marine shrimp farming system. In the past decade, the technology for intensive farming of *P. monodon* has been developed and practiced in Thailand. Thus, marine shrimp farming has expanded tremendously to cover an area of 71,887 ha and can be classified into three categories: intensive, semi-intensive, and traditional or extensive. The shrimp production is quite remarkable as it reached 225,514 t in 1993 and Thailand has been the leading country for exporting culture marine shrimp since 1991 (Kongkeo 1994).

According to the survey of the Network of Aquaculture Centres in Asia–Pacific/Asian Development Bank (NACA/ADB) (Tookwinas 1995), most marine shrimp farms in Thailand are intensive or extensive. Most of the extensive farms are located in the Inner Gulf of Thailand, Chanthaburi, eastern Thailand, Nakorn Sri Thammarat and southern Thailand.

Culture Area and Production

The suitability of coastal areas for intensive marine shrimp farming depends on many factors or criteria. The main ones are source of saline water, soil quality and socio-political factors. Suitable water should range during the year from 10 to 30 ppt of salt. The texture of the soil should be mud or muddy sand, in order to reduce water seepage and prevent water losses from ponds. The soil pH should be around 7–8 (Tookwinas 1993).

The culture area of 4,939 farms was only 40,769 ha in 1985, increasing two-fold by 1993 to 71,887 ha in 20,027 farms (see Table 1, Tookwinas, Shrimp Culture in Thailand, this proceedings).

The farming areas are mostly located along the coastal provinces of the country. The area has shifted from the Inner Gulf and east to the south due to the pollution problems in the Inner Gulf area. Most of shrimp farmers are small operators with farming areas typically categorised: 0.16–1.6 ha (78.7%), 1.6–8.0 ha (18.8%), 8.0–32.0 ha (2.20%) and more than 32.0 ha (0.3%). (C.P. Aquaculture 1994).

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The Royal Thai Government through DOF has a very strong policy to develop marine shrimp farming as a sustainable industry. The Seawater Pump System Project and shrimp quality certification are two examples of many policies to assist in developing an environmentally friendly industry with premium grade product for export to world markets.

Coastal Zone Situation in Thailand

Thailand has 2,614 km of coastline, with the west coast bordered by the Andaman Sea and the east coast facing the Gulf of Thailand (South China Sea). Almost one-third of Thailand's 76 provinces border the sea. About 70% of the population live within a few kilometres of the sea. The coastal lands are richly endowed with natural resources such as fertile soil, minerals, beautiful scenery, mangroves and hardwood forests. The coastal seas support coral reefs, seagrass beds and diverse fish stocks. The coast is thus the focus of much socioeconomic activity.

Intensive marine shrimp farming is the major form of coastal aquaculture in Thailand and it has been quoted as causing a deterioration in coastal natural resources and the environment. The impact of shrimp culture on mangroves has received considerable attention, both in the scientific and popular press (Macintosh and Phillips 1992; Satapornvanit 1993). Also shrimp culture has had some conflicts with the tourism industry.

It is very difficult to enforce laws and regulations in many coastal areas. For example, mollusc culture is sometimes destroyed by push nets or seashell dredging, although these activities are prohibited within 3 km of the shore. Integrated coastal zone management (ICZM) can be applied to resolve the conflicts. The local people should be informed about the possible impacts of coastal developments on natural resources, and the problems that they face should be considered. Local people should be allowed to participate in the process of development planning and decision making should recognise their needs. Using this process of ICZM, the local people will have the chance to be responsible for their natural resources.

Planning for Shrimp Farming

The Royal Thai Government through DOF has tried to develop coastal zone planning for aquaculture. The provincial committees have been encouraged to take responsibility for this duty through the support of the Ministry of the Interior and the Ministry of Agriculture and Cooperatives, however progress has been slow. This may be because of the many conflicts which occur over coastal land use, as well as insufficient laws and regulations.

DOF carried out a large study on carrying capacity and zoning of coastal areas for aquaculture activities. Also, technical studies have been performed in some pilot areas, such as Kung Krabaen Bay (Tookwinas 1996) and Pattani Bay, southern Thailand. Studies for other coastal areas have been planned. The technical results would provide support information for decision-makers. It is hoped that coastal zone planning for aquaculture, especially for intensive marine shrimp farming, will be carried out in the near future.

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Coastal Mangrove Habitats and Shrimp Farming

Barry Clough*

COASTAL aquaculture and mangroves have an uneasy relationship. It is uneasy because mangroves are still being cleared in some countries to provide land for aquaculture, even though it is now recognised that mangrove land is generally not suitable for intensively managed aquaculture ponds.

Issues

Coastal mangroves are being lost or degraded due to:

- destruction for aquaculture and agriculture;
- mining;
- urban, port, industrial and tourist development; and
- uncontrolled cutting for firewood and timber.

Coastal water quality is deteriorating due to:

- aquaculture;
- industrial effluent;
- agricultural chemicals (herbicides, pesticides);
- sewage and domestic effluent;
- urban run-off;
- seepage from industrial and mining containment ponds and from refuse dumps; and
- shipping wastes (solid refuse, bunker oil and ballast water).

Why do mangroves matter?

- Coastal protection;
- fish nurseries;
- food chains;
- habitats and coastal ecosystems;
- forest products;
- fisheries; and
- subsistence coastal dwellers.

Constraints

Issues which place constraints on the mangrove–shrimp farm system are:

- international, national and regional standards/guidelines;
- cost of compliance; and
- other sources of contamination.

Research for Mangrove–Shrimp Farming Systems

The general question becomes: "How much can we discharge and comply with the constraints?" The specific questions are as follows.

- What is the carrying capability of a mangrove habitat?
- What criteria should be used to evaluate the impacts?
- What is the fate of the effluent from shrimp farms in mangrove habitats?
- How do we measure the assimilative capacity of mangrove habitats with respect to:
  - time,
  - scale,
  - inputs, and
  - decay or removal?
- What bio-indicators should we use in our studies?

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Research Approach

When designing a research project on mangrove habitats and shrimp farms, we need to pay attention to the approach which will be most productive. Researchers need to consider:

- modelling versus monitoring;
- time frames; and
- milestones.

Coastal Management Research Issues

Somsak Boramthanarat*

Background

Some of the negative impacts of shrimp farming in Thailand have been mangrove destruction, saltwater intrusion, water quality impairments, and discharge and disposal of pond sediments. The clearing of mangrove and coconut habitats may have amplified the effects of the discharge of sludge into the coastal zone. Also, the depletion of the coastal resources has led to the 'boom–bust' cycles that have occurred in areas of Thailand as well as elsewhere. Consequently, it is critical that we evaluate shrimp farming practices.

Coastal Zone Management and Research

Coastal zone management (CZM) is really common property management. That is, shrimp farmers need to be protected from harmful environmental changes, and likewise, other coastal users need to be protected from impacts of shrimp farming.

CZM requires the integration of disciplines and cooperation of many government and non-government agencies. In some cases, this may require that local institutions assist local people in a participatory approach. For example, in order to meet the water needs and expectations of local communities, an integrated participatory approach could be used to treat wastewater management—a single, small-scale farm may be unable to treat its waste water, but with the support of the community and the resolve of all nearby farmers, an effective plan for treating the collected waste waters from these farms could be developed.

We should start research projects with the question: "Do we know enough?" If the answer is "no", then research needs to be carried out. The results should flow to technology and then to management. For example, sludge and water quality issues need to be tackled by researchers. Some questions could be: Can sludge be treated? Can a value-added product be manufactured? What types of models should be applied to the investigation of effluent (i.e. loading models, plume models etc)? What do bio-assays reveal about the toxicity of discharges?

Importantly, the goals of the research must be set and the objectives determined (e.g. enhanced capacity of the local community to manage waste water). Then linkages between the local communities and the formal institutions need to be established. The steps in the implementation of technology are: (1) training; (2) local participation; (3) integration into provincial planning; and (4) implementation and monitoring.

Tasks to assist in coastal zone management include the mapping of shrimp farming areas and natural habitats. Geographical information systems are important tools for finding spatial relationships between causes and effects.

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Application of GIS to the Thai Shrimp Farm Survey

Paul T. Smith*

THE geographical information system (GIS) is a digitalised mapping process in which data from topographical maps, remote sensing satellite imagery, high-altitude photographs and other maps can be layered and analysed. GIS has been applied to a number of research disciplines because it is an effective means of relating data to geography. An important advantage of using GIS is that layers of unrelated data can be added to maps for analysis, as long as the geographical coordinates are available.

In shrimp farming, Tookwinas and Leeruksakiat (1993) used GIS and remote sensing to study mangrove and shrimp farms in Chanthaburi Province in Thailand. Others have also applied these techniques to shrimp farming (Loubersac 1985; Quader 1986; Shahid and Pramanik 1986; Populus et al. 1995; Anon. 1996; Wibowo et al. 1996), but this paper reports for the first time on the analysis of the 1995 shrimp farm survey with GIS. The aim of the study was to determine whether (a) GIS could assist researchers, coastal planners and epidemiologists in their study of the shrimp farm industry in Thailand and the region, and (b) new insights into the farm survey could be gained.

Method Used in Applying GIS to the Thai Farm Survey

GIS software consisted of an interface from MAPINFO and digitalised maps from VIEWSIAM. An alternative software system is produced by ARCINFO, and MAPINFO is compatible with that system. The GIS software was used to view the statistical results (described in Smith, Key Issues, this proceedings) of the 1995 Thai shrimp farm survey.

Results

GIS analysis of the data is divided into three parts: (1) general scope of the study; (2) production trends, location, costs and treatments; and (3) trends in disease. This paper provides examples for each type of data analysis. (Note: *changwat* and *amphoe* translate into province and district, respectively.)

General scope of the application of GIS to the shrimp farm survey

Figures 1 and 2 show how GIS was used to illustrate the levels of average total production for the *amphoes* of Thailand. Lowest production was generally in central, eastern and south-eastern areas, while highest production was mainly in the south and south-west. The areas with highest production were also the most recently developed for shrimp farming.

Although not shown here, geographical features such as rivers, railways, contours and towns could be added as extra layers to GIS maps. Also, at higher levels of magnification, it would be possible to plot the location of shrimp farms and geographical features. For example, global positioning systems could be used during a future survey to accurately plot features such as sheds, ponds and canals. Statistics from this or other surveys could then be added to the map. This process would eliminate confusion in locating target farms for follow-up studies.

Another advantage of GIS is that once coordinates have been determined for the sites where data were

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collected, it is feasible to join databases, e.g. it was possible to merge data from the 1995 Thailand population census with data from the Thai shrimp farm survey. In that case, populations for the southern *amphoes* were plotted on a map which indicated the average cost of disease problems for shrimp farms. Although no significance could be attached to the map which was produced, it illustrates the ability of GIS to assist in studies of trends, time-series and epidemiology (i.e. the study of patterns of spread of disease).

Looking at production trends, location, costs and treatments

The economic data from the Thai shrimp farm survey were viewed using GIS and some of the findings are reported here. Figures 1 and 2 illustrate that the levels of average total production were generally proportional to the production costs in each *amphoe*. This may suggest that returns to farmers were determined by the intensity of the production methods employed in the various *amphoes*. Farmers may have made decisions with respect to the production level or carrying capacity of their ponds and farmed at an intensity they believed was sustainable.

A comparison was also made between the average cost of disease problems (as reported by farmers) and the salinity levels in the wet and dry seasons (map not shown). Many *amphoes* in the south-east had large differences between salinity levels in wet and dry seasons, while in the south-west, farms had lower differences. The cost of disease problems was generally lower in the south-west.

The relationship between drying out of ponds and average total production was interesting for *amphoes* in central and eastern Thailand. The highest production levels were in *amphoes* where a high percentage of farms dried their ponds between crops.

Figures 3 and 4 illustrate the costs of production and average total production for farms in southern, and central and eastern Thailand, respectively. While feed was the most significant cost for most *amphoes*, seed and labour costs were also important. Significantly, costs of production were highest in Surat Thani (Figure 3), where average total production was lowest.

Figures 5 and 6 compare the average costs of problems and average total production for *amphoes* in Thailand. They show that the magnitude of the costs varied considerably between *amphoes* as did the breakdown of the costs. However, the west coast and southern areas had the highest average total production and lowest problem costs. In those areas, the costs for disease problems were also generally the lowest.

Positive intentions of farmers can reveal the areas which have been experiencing favourable results and, importantly, the areas which are likely to come under greater farming effort in the future. Figures 7 and 8 show the positive intentions of farmers in southern, central and eastern Thailand, respectively. Generally, *amphoes* which are likely to see expansions are on the south and west coasts. A high percentage of farms in these areas are intending to add extra ponds, while others are planning to expand by other means—presumably by increasing the number of farms. It was difficult to interpret the meaning of responses to questions about changing intensity, species or density, because the survey did not indicate in which direction the change would occur. Nevertheless, *amphoes* with farms having low levels of production tended to have less positive intentions and were often intending to change shrimp density.

Looking at disease trends and impacts of environmental aspects

The environmental aspects of the survey indicated this was an important parameter for shrimp farm productivity. The study revealed that there was great variablity between *amphoes* with regard to aspects of environmental design. Figures 9 and 10 illustrate two aspects of experimental design and their possible associations with costs of disease problems. The use of separate intake and discharge canals is less common on the south-west coast and central region of Thailand, but it is not easy to see a relationship with disease costs. Regarding the percentage of farms which kept mangroves, there does appear to be an association with costs of disease problems. *Amphoes* in the east and south-west had higher percentages of farms which reported keeping mangrove buffers and these areas generally had lower disease problems. Other *amphoes*, particularly in the south-east, from Chumphon to Nakhon Si Thammarat, had fewer mangrove buffers and higher disease costs.

Figures 11 and 12 compare the methods of effluent treatment in Thailand. Settlement ponds were more common in *amphoes* in the south-west and east, and these were the areas with generally high production. Discharging effluent into drainage canals was the preferred method in most areas and this did not appear to be associated with levels of productivity. Biological treatment was uncommon but was found in some *amphoes* with high levels of production. Those areas may also be more recently farmed sites.

In data not shown, *amphoes* with farms which did not dry out their ponds before restocking had higher average costs of disease problems. This finding supports the statistical result (Smith, Key Issues, this proceedings) that production was generally lower in farms which did not dry out their ponds.

Figures 13 and 14 illustrate the association between data on neighbouring farms and costs of disease problems. Surat Thani and Nakhon Si Thammarat had the highest costs from disease problems and this correlated with large numbers of farms within 3 km of each other. Interestingly, the farms on the south-west coast had significantly lower impacts from neighbouring shrimp farms and the levels of disease costs were also lower in these farming areas. These *amphoes* reported fewer farms within 3 km, less sharing of the water supply, and rarely was effluent discharged into the water supply. By comparison, in the south-eastern *amphoes*, higher disease costs and impacts from neighbouring farms were more common.

Conclusions and Possible Issues for Further Research

1. Application of GIS to the Thai farm survey enabled multivariate analysis to be plotted and possible trends to be visualised. Variables that had significant associations with production indices were analysed geographically.
2. The layering of data from the 1995 Thailand population census and the 1995 Thai shrimp farm survey showed that more than one unrelated database could be used with GIS to analyse relationships in data.
3. Resolution of the maps was restricted to the *amphoe* level, although further analysis to the village/town level is possible.
4. Only one type of digitalised map was used in this study. The analysis of databases could be improved by adding extra layers from other maps (i.e. soil type, vegetation maps, hydrology etc.).
5. Any future surveys should consider the use of global positioning systems to gain coordinates of the farms or natural features. This would allow more detailed and precise analyses of data to be undertaken.
6. Data from future surveys as well as from previous studies could be layered for statistical analysis with GIS. For example, data on water quality for river systems could be layered onto data from shrimp farms.
7. The analysis provided significant evidence that some pond management practices and aspects of environmental management were impacting on farm productivity and disease costs. The general comments are as follows.
   – The most recent farming areas had higher productivity and lower disease costs.
   – Disease costs may be higher in farming areas that have greater variations between the salinity of the intake water in the wet and dry seasons.
   – Farms that do not dry out their ponds have higher disease problems and lower production levels.
   – Farms that treat their discharge, particularly using settlement ponds, are in the *amphoes* that commenced farming more recently and these farms have higher productivity and lower disease costs.
   – The main costs faced by farms varied widely between *amphoes*, though 'other' problems (i.e. seed, feed etc.) are substantial.
   – The main cost of production is feed for farms in most *amphoes*, though seed and labour costs are also significant.
   – *Amphoes* that have kept the mangrove buffer are more common in the south-west and these farms have lower disease costs.
   – The impacts of neighbouring farms on disease are very significant. Farming areas that have lower disease costs are those which have fewer farms: within 3 km; sharing the water supply; and discharging effluent into the water supply.

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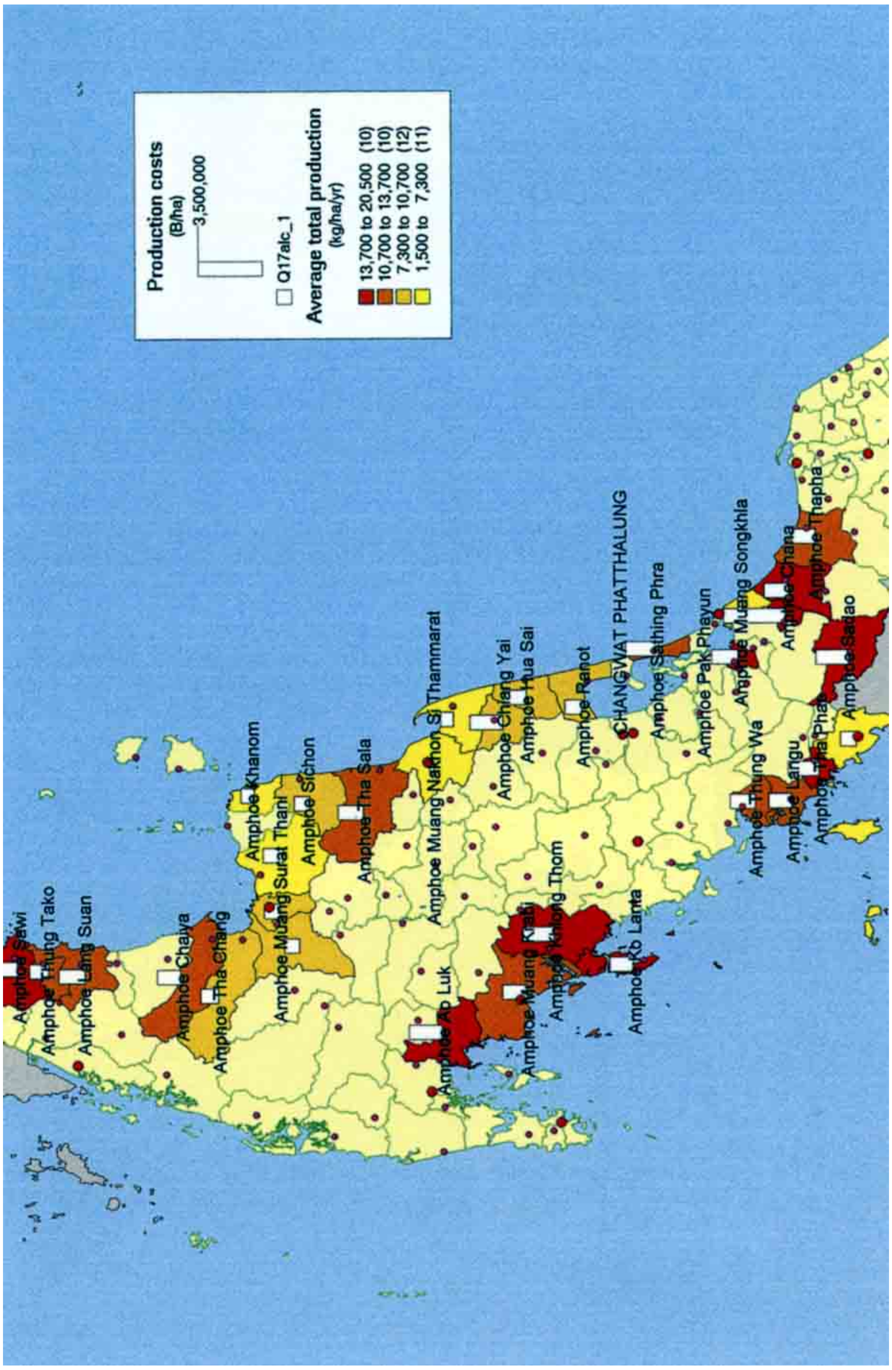

Figure 1. Average total production costs and average total production of farms in *amphoes* of southern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category]. (Note: Q17alc_1 is the code used in the survey for the derived variable for all production costs.)

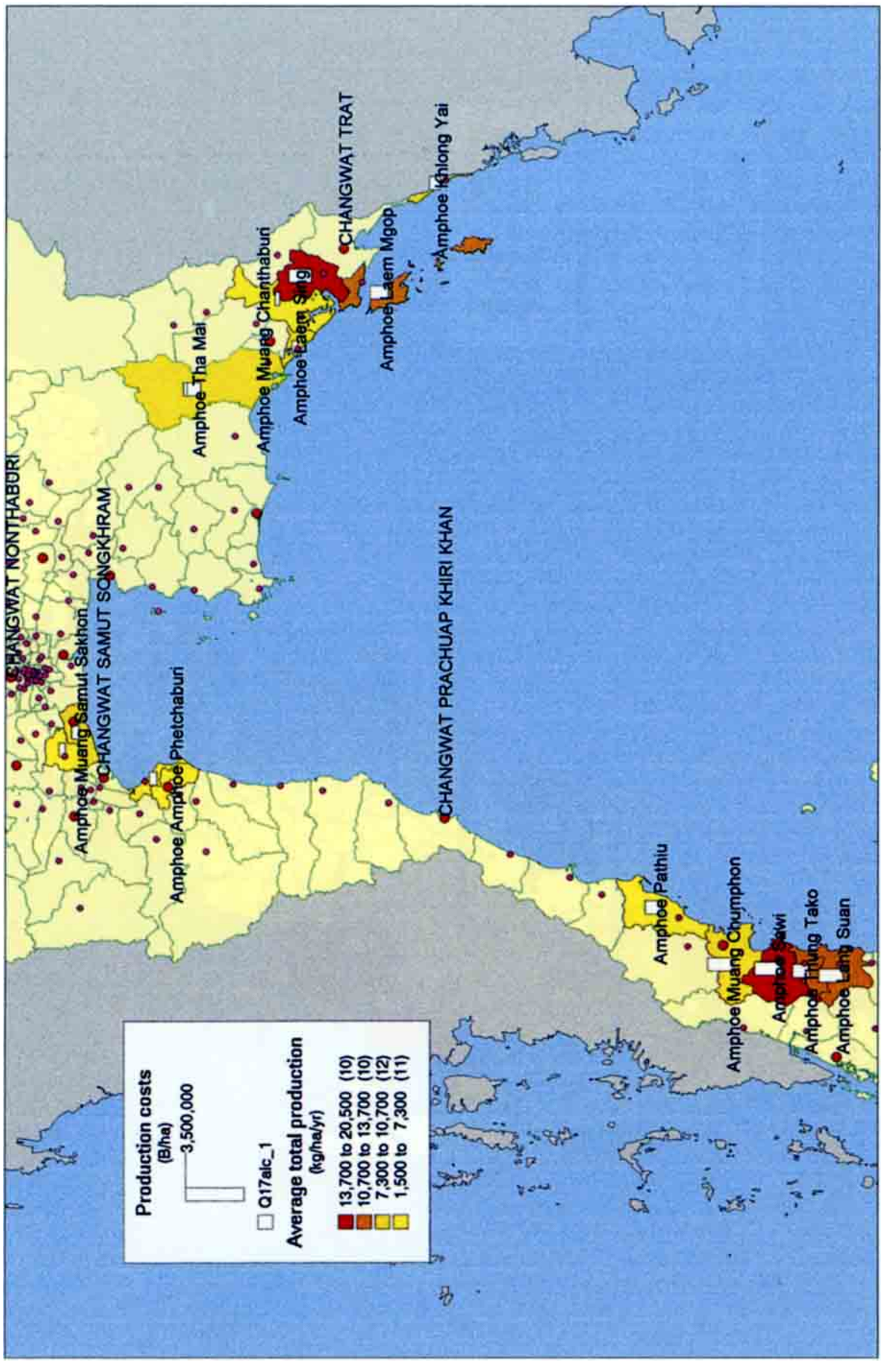

Figure 2. Average total production costs and average total production of farms in *amphoes* of central and eastern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category]. (Note: Q17alc_1 is the code used in the survey for the derived variable for all production costs.)

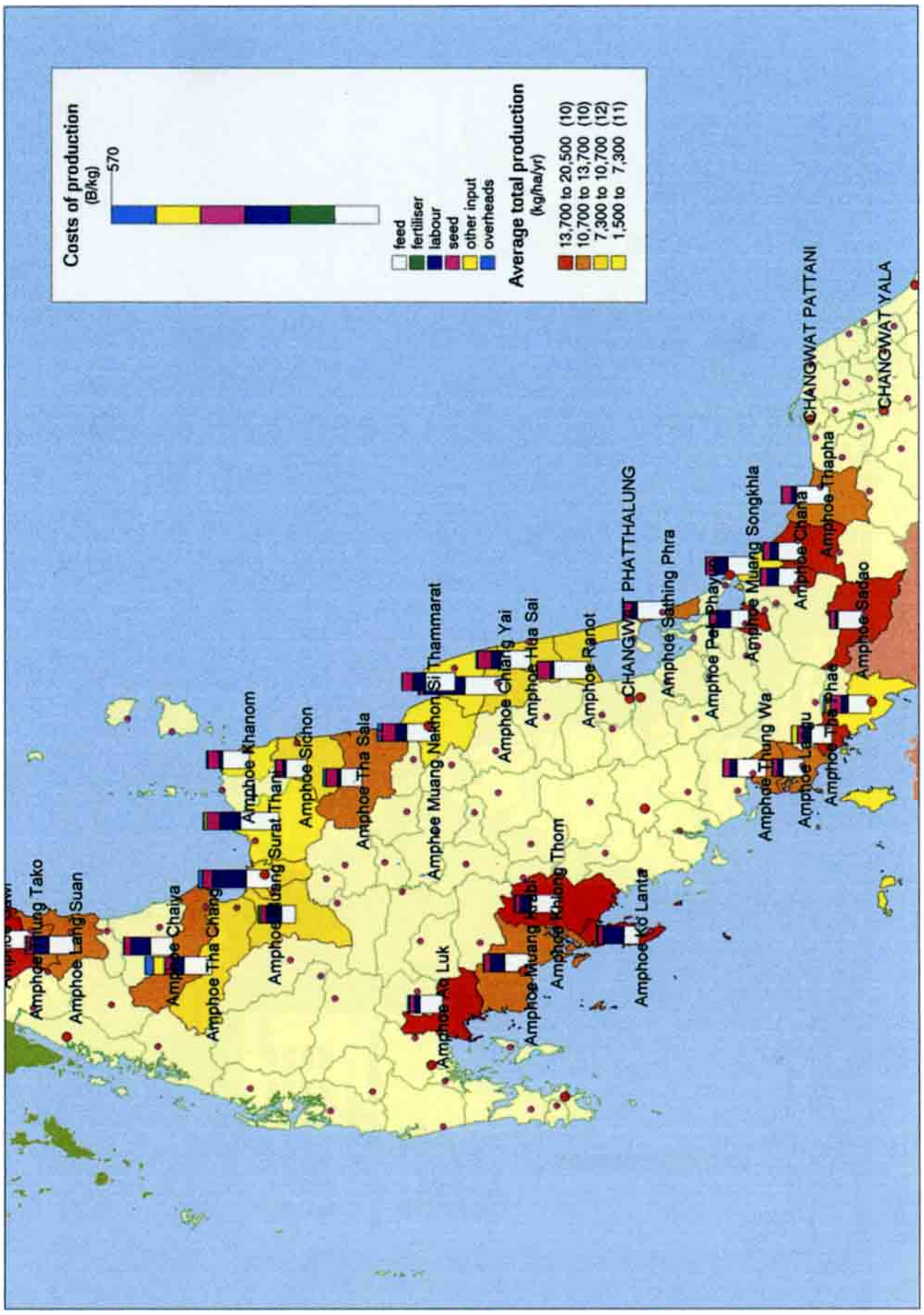

Figure 3. Average itemised costs of production and average total production of farms in *amphoes* in southern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

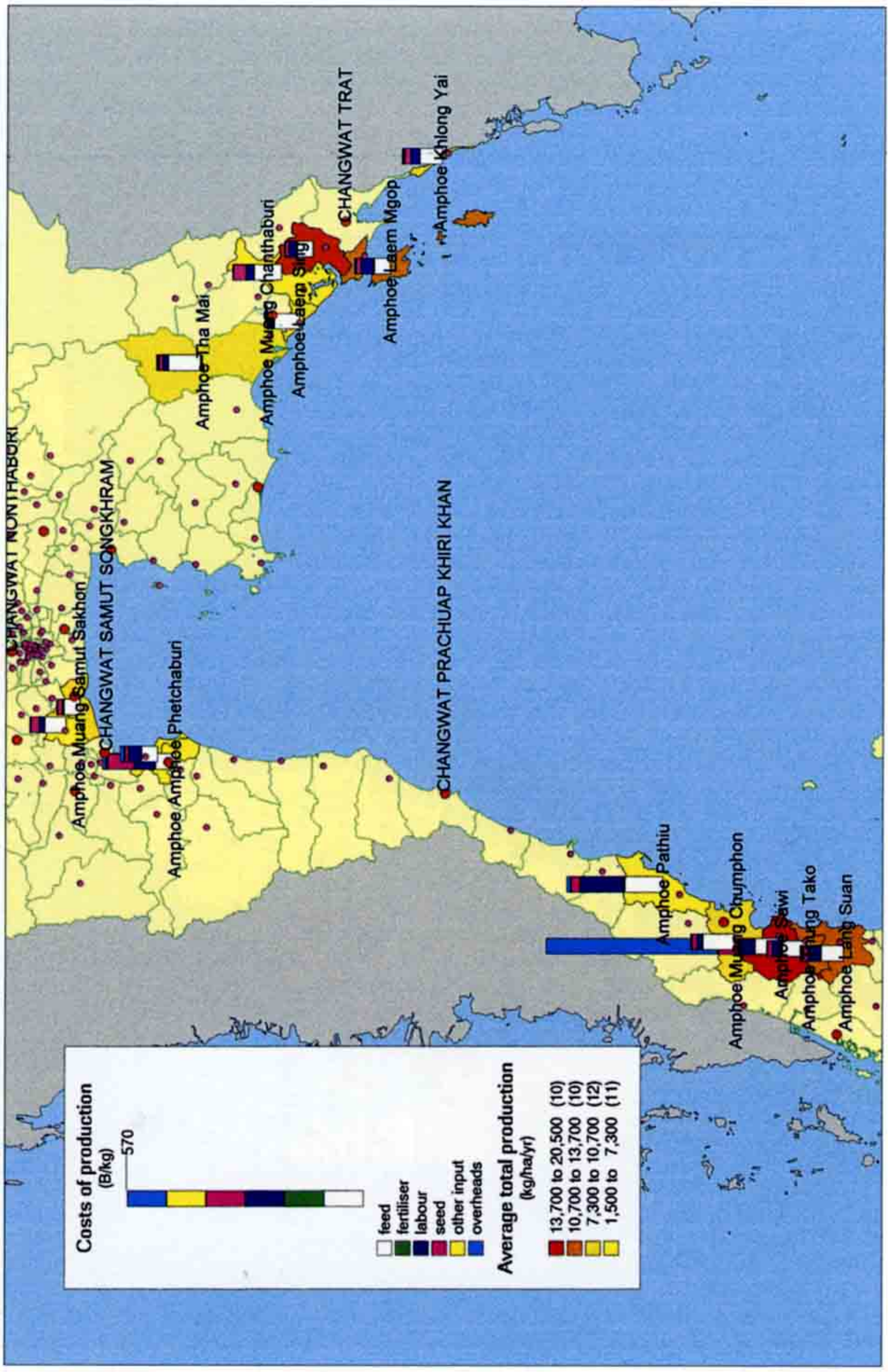

Figure 4. Average itemised costs of production and average total production of farms in *amphoes* in central and eastern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

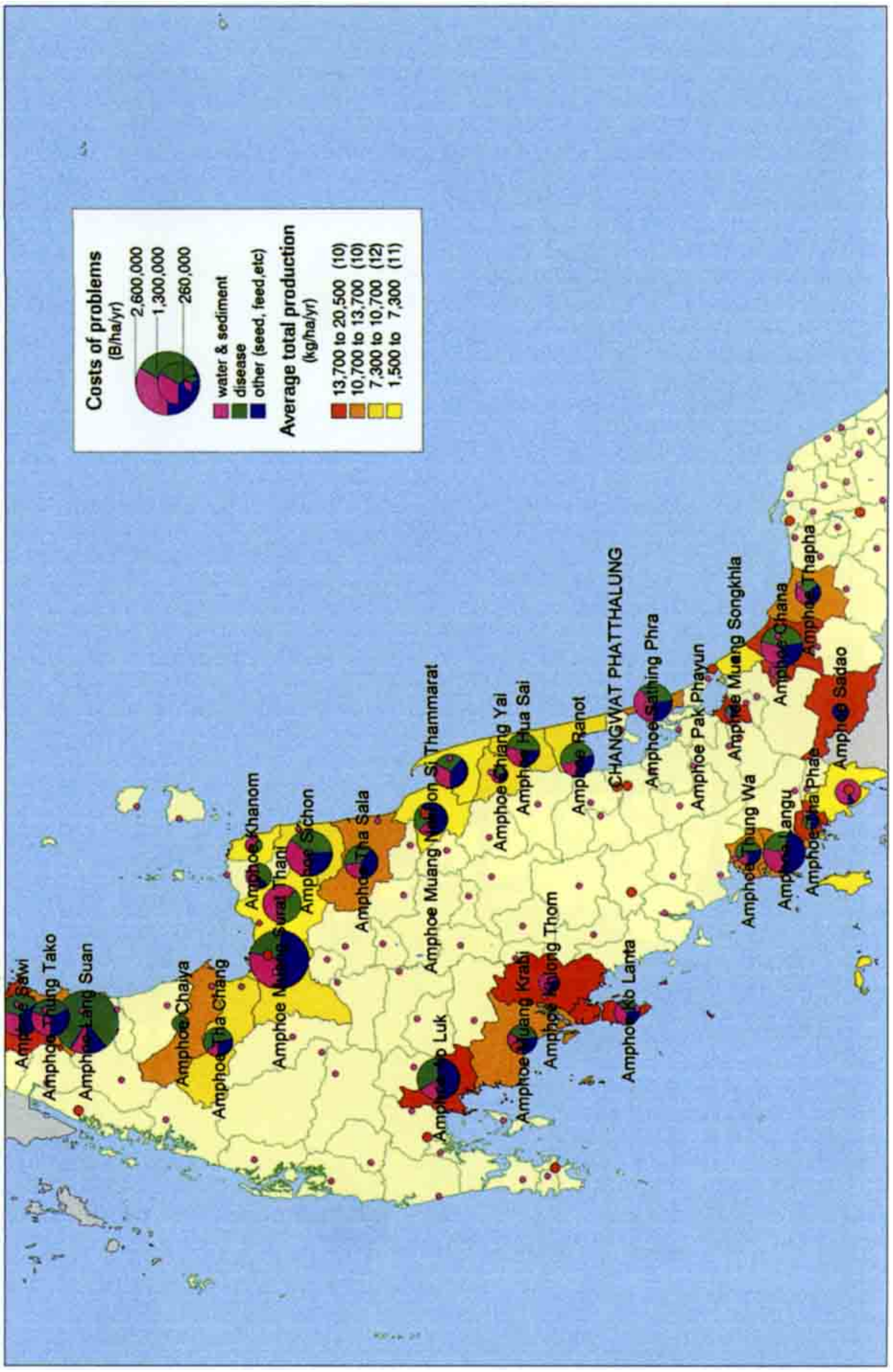

Figure 5. Average costs of problems and average total production for farms in *amphoes* of southern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

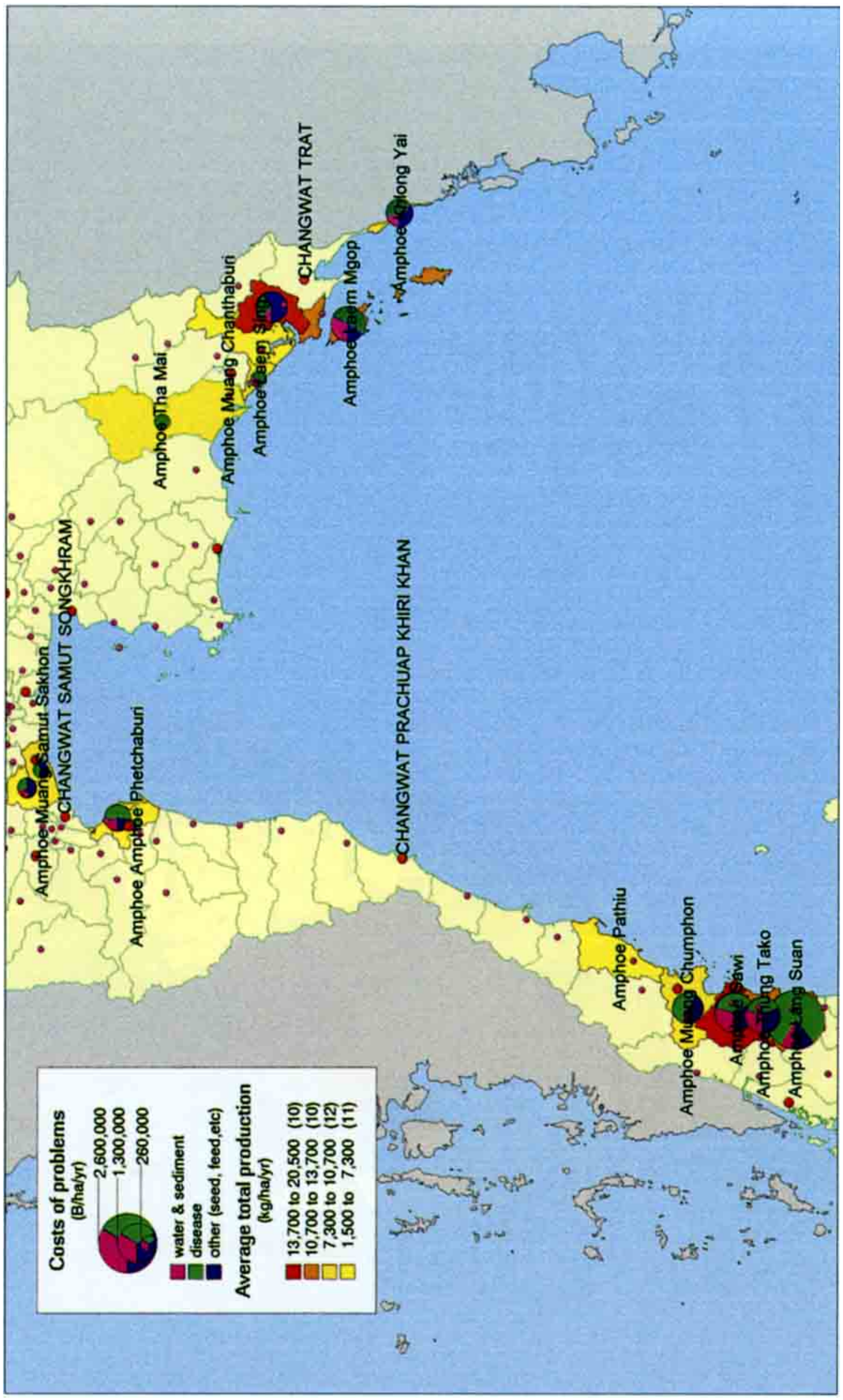

Figure 6. Average costs of problems and average total production for farms in *amphoes* of central and eastern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

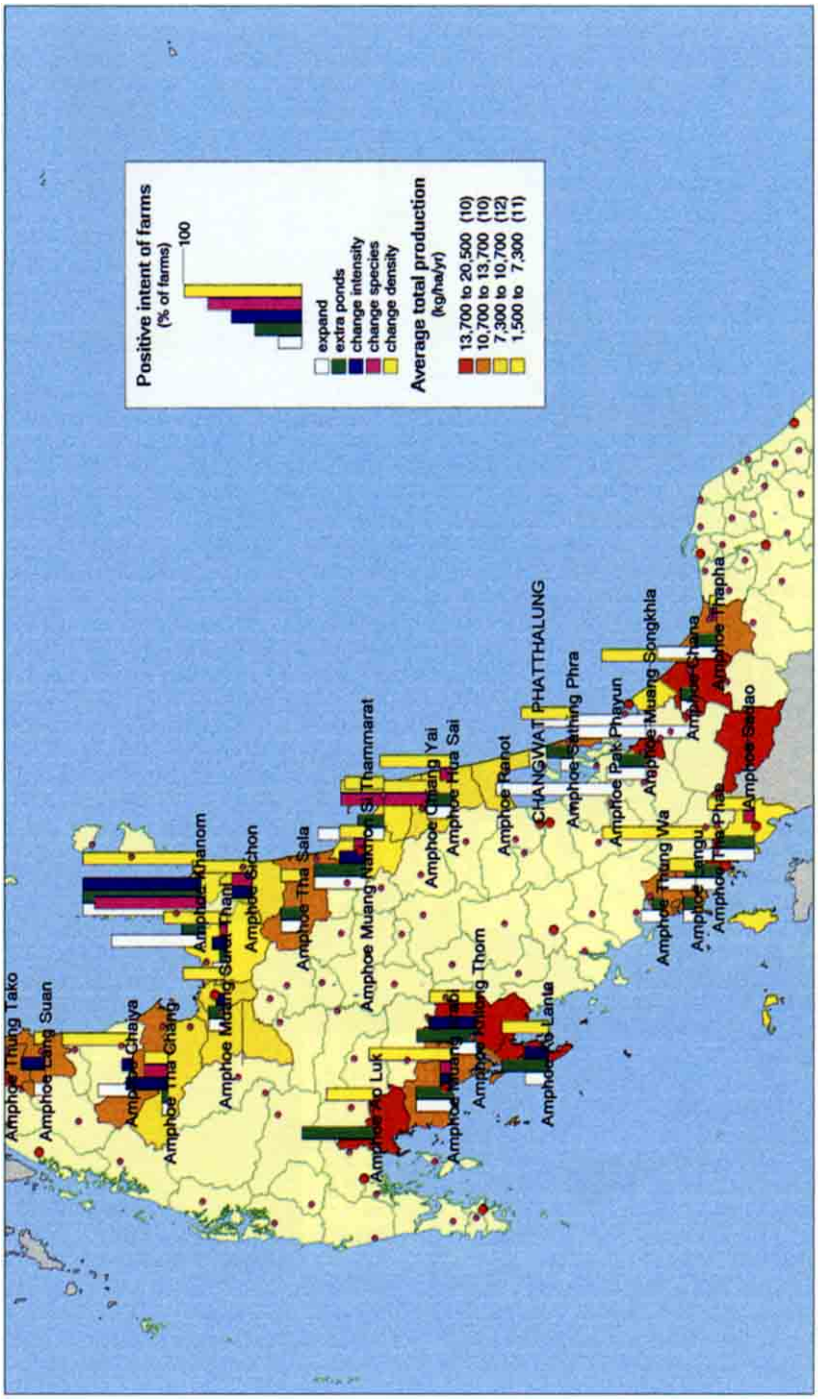

Figure 7. Average percentage of farms in which the farmers had positive intentions and average total production for farms in *amphoes* of southern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

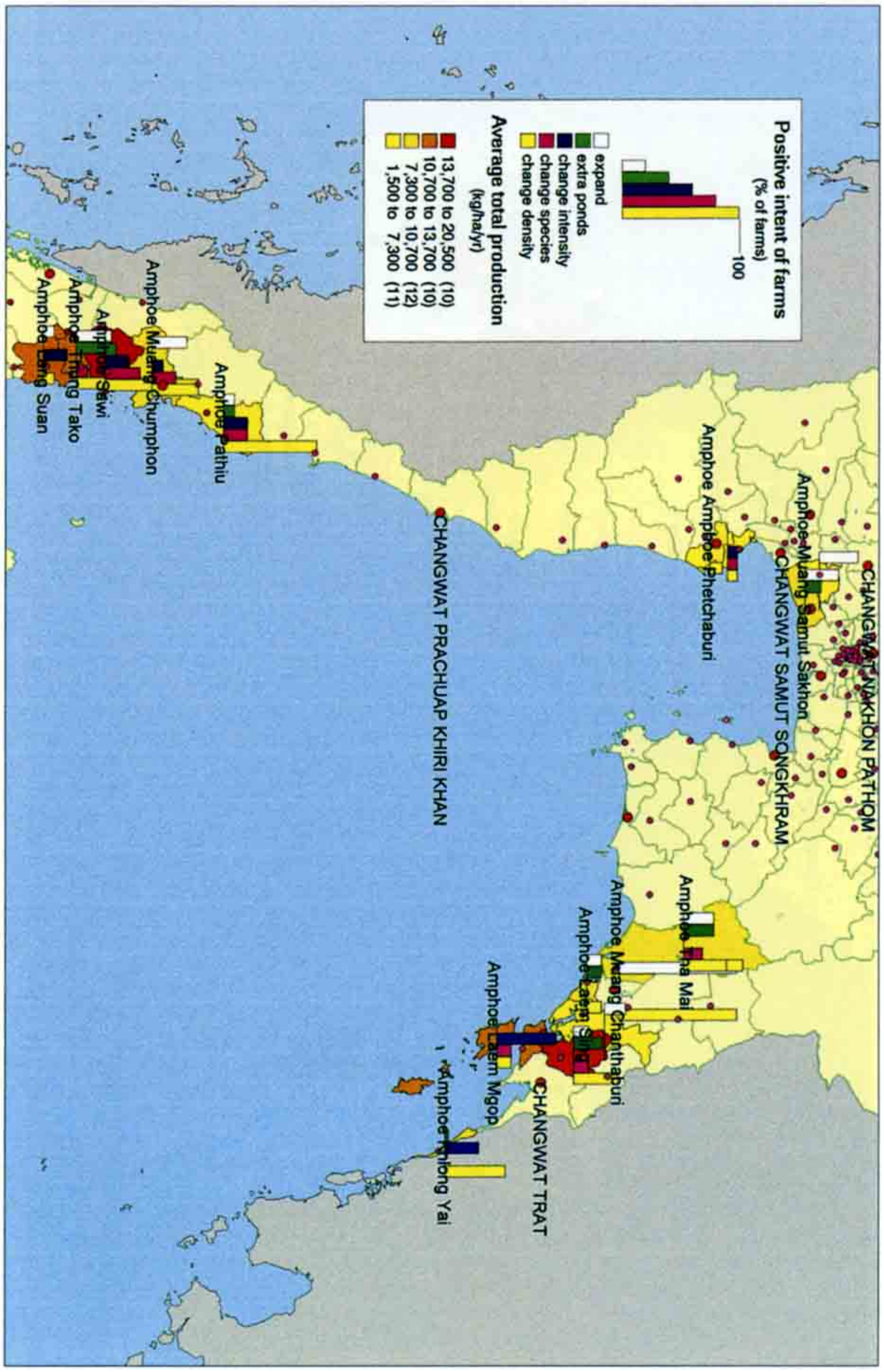

Figure 8. Average percentage of farms in which the farmers had positive intentions and average total production for farms in *amphoes* of central and eastern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

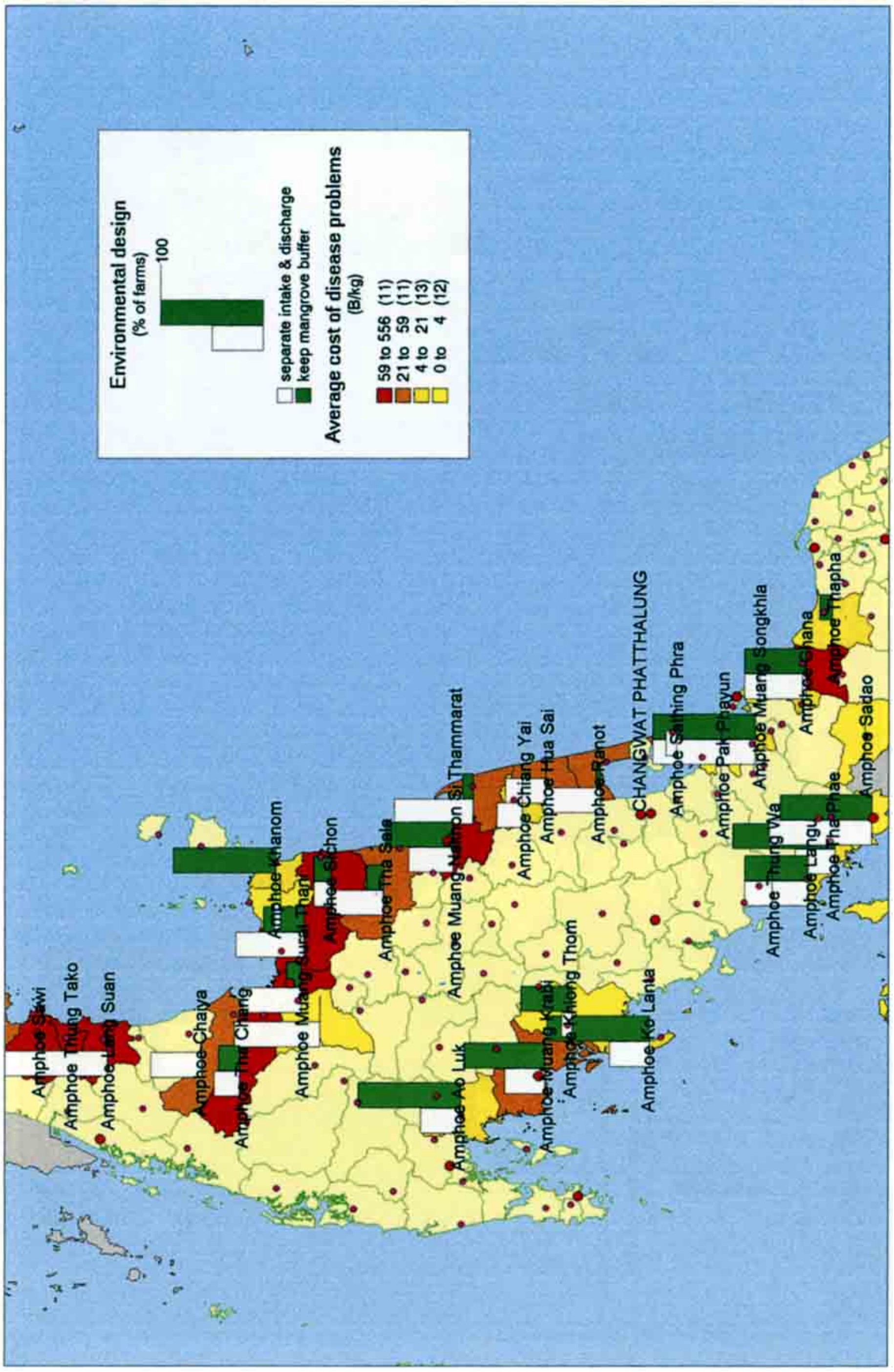

Figure 9. Average cost of disease problems and aspects of environmental design of farms in *amphoes* of southern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

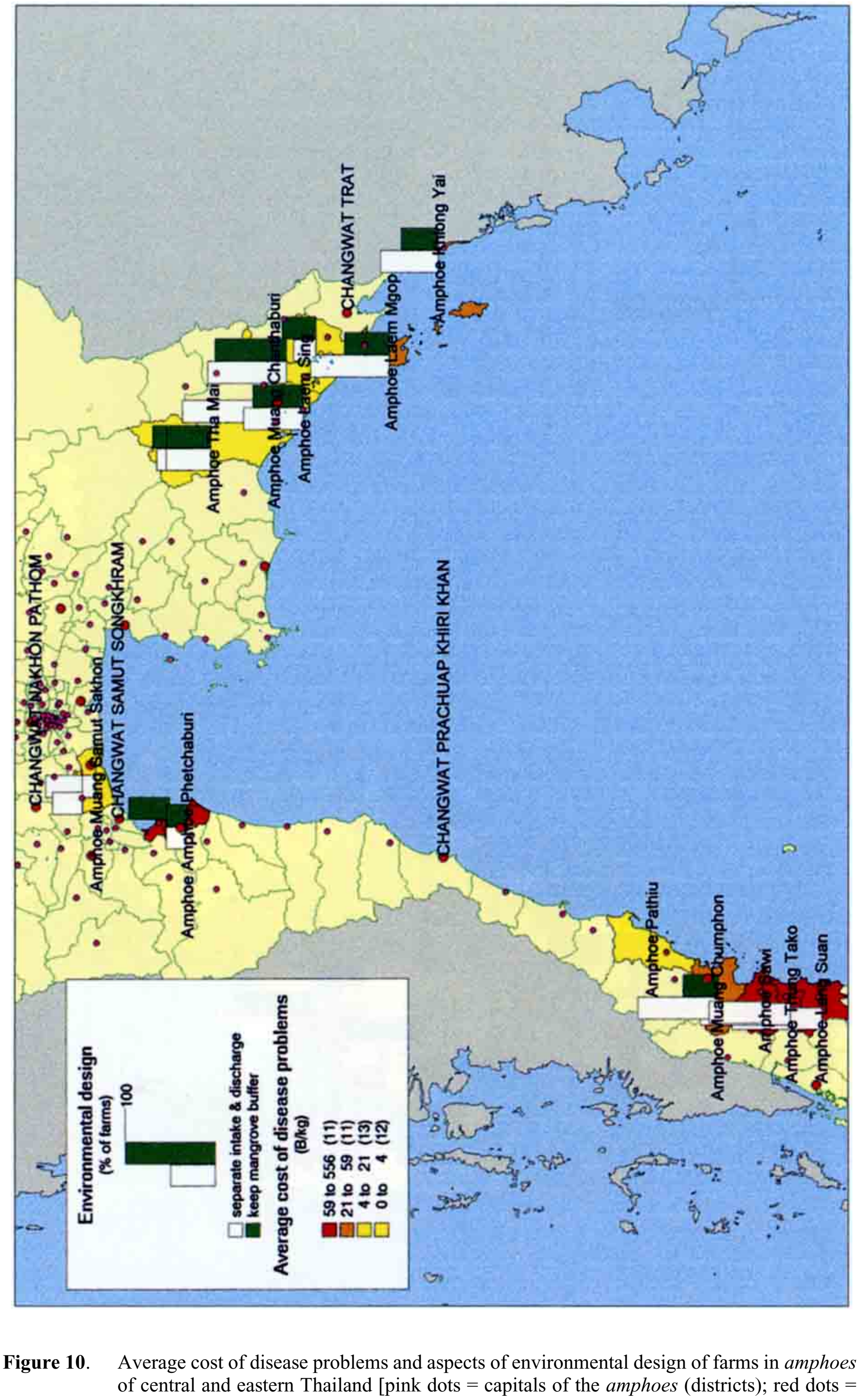

Figure 10. Average cost of disease problems and aspects of environmental design of farms in *amphoes* of central and eastern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

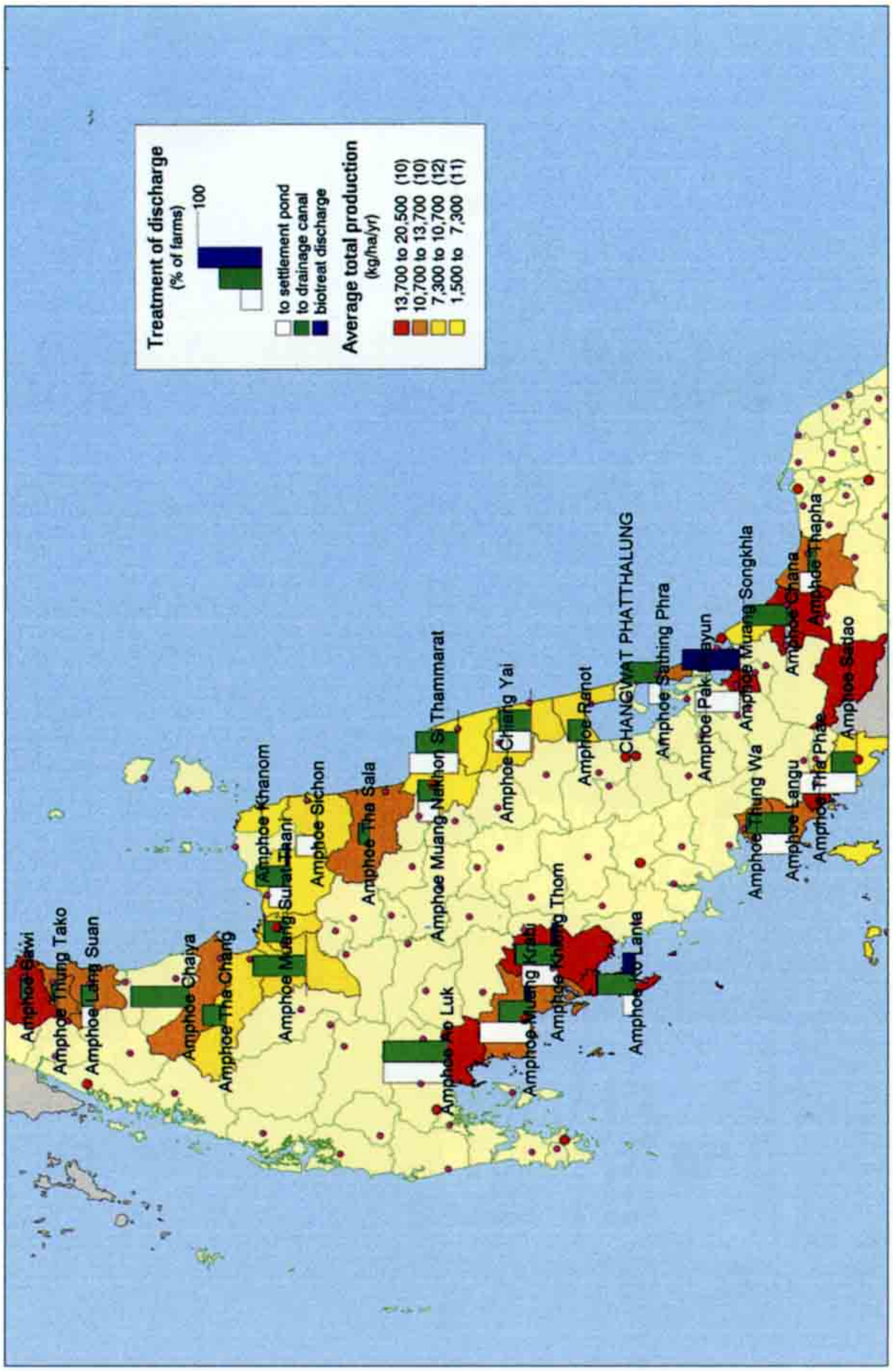

Figure 11. Comparison between average total production and treatment of discharge of farms in *amphoes*of southern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

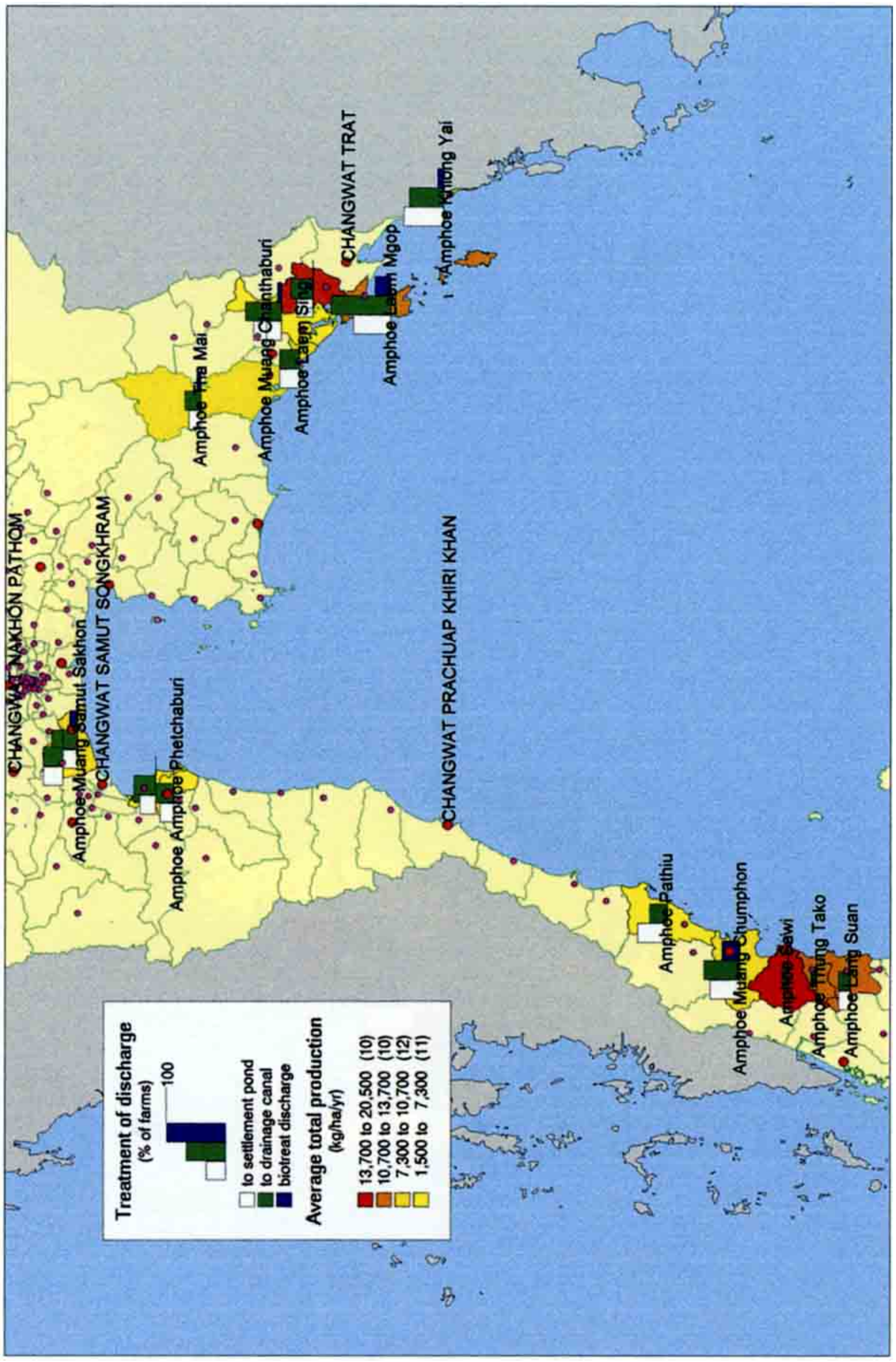

Figure 12. Comparison between average total production and treatment of discharge of farms in *amphoes* of central and eastern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

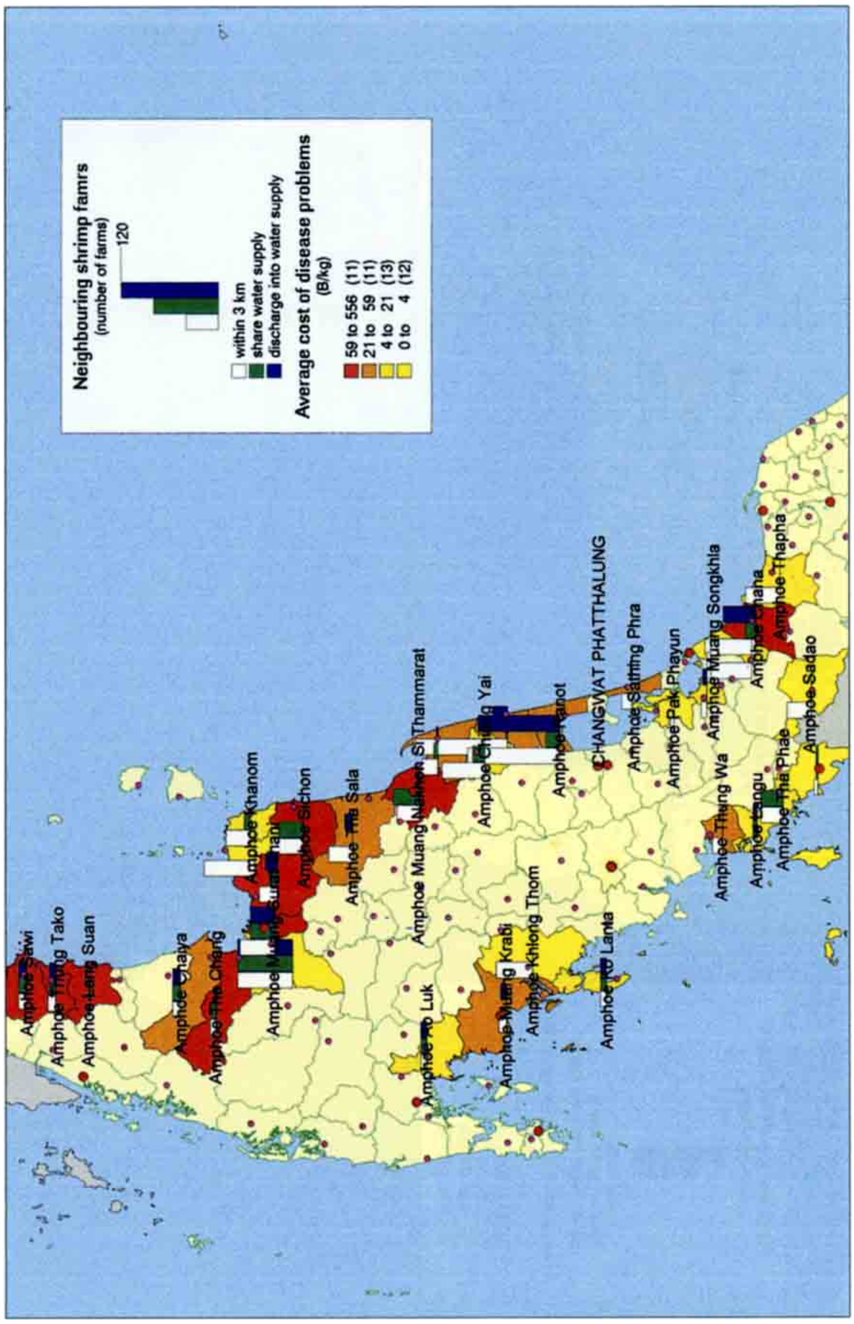

Figure 13. Average costs of disease problems and data on neighbouring farms in *amphoes* of southern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

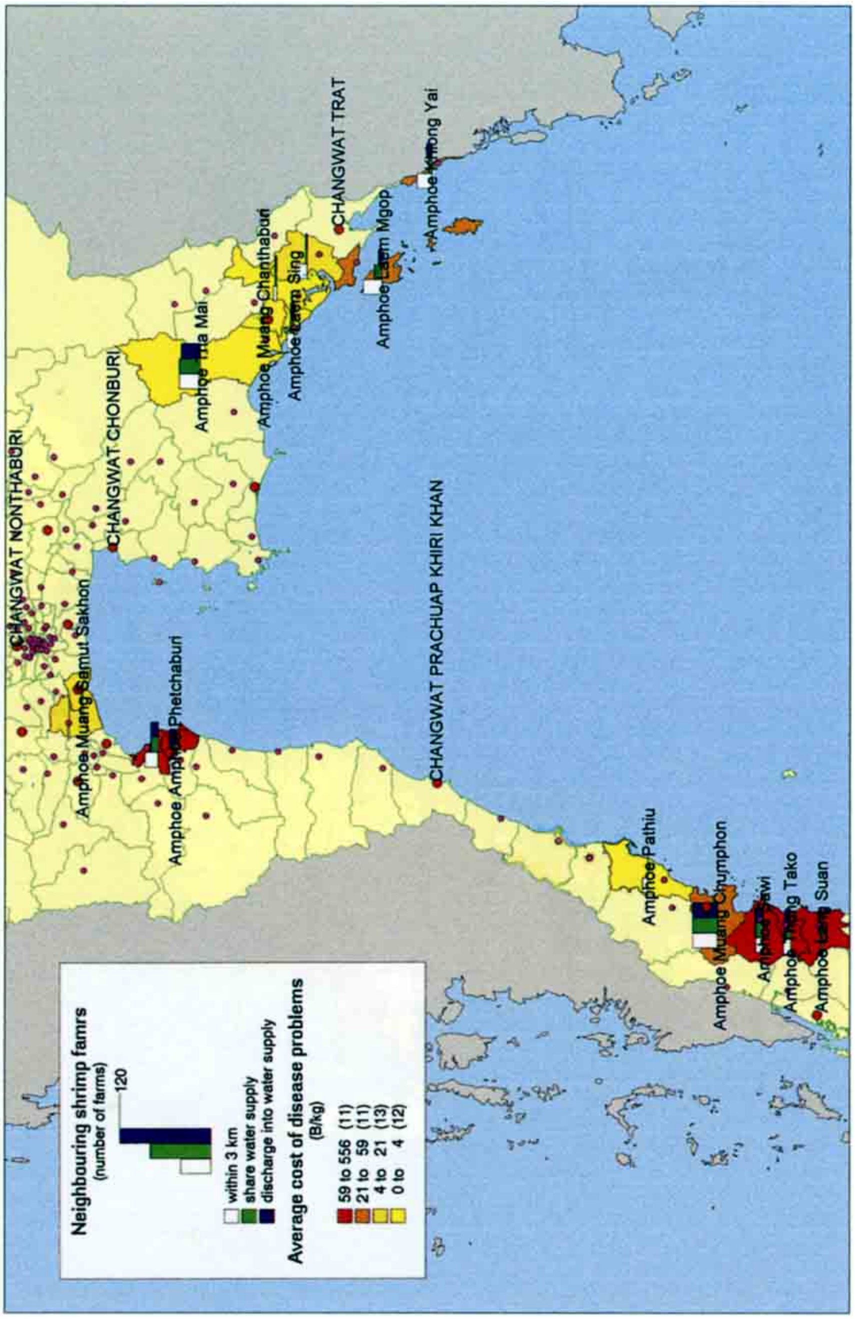

Figure 14. Average costs of disease problems and data on neighbouring farms in *amphoes* of central and eastern Thailand [pink dots = capitals of the *amphoes* (districts); red dots = capitals of the *changwats* (provinces); numbers in brackets = the number of *amphoes* in that category].

International Trade, Environmental Issues and the Impact on Sustainability of Shrimp Culture in Thailand

Direk Patmasiriwat, Martijn Bennis and Sunil Pednekar*

THE rapid expansion of shrimp farming, induced by new technologies such as formulated feed and hatchery production of shrimp seed, has led to dramatic changes in coastal resource utilisation. These can be categorised by changes such as the conversion of rice fields, salt farms and other coastal land uses to shrimp farms, decline in mangrove forest, coastal water pollution and a rise in new businesses associated with shrimp farming (e.g. feed, chemicals, cold storage, shrimp export industry networks etc). There has been an increase in contract farming involving large private enterprises in association with a large number of small-scale shrimp farmers.

Shrimp farming is now viewed by many developing countries as a tool for export earning (Goss et al. 1996). For example, in Thailand, marine farmed shrimp has become a very important export commodity and to a smaller extent, a contributor to domestic food supply. The Thai shrimp sector earned the country over US$2 billion in foreign exchange in 1995. Thailand has become the world's leading exporter of giant tiger prawns (*Penaeus monodon*) since 1993, and currently supplies 20% of the world trade.

On the environmental side, new developments in shrimp farming have stirred up controversies among different groups of people over what the true consequences of the farmed shrimp industry to the health of the environment are. Are economic returns from shrimp farming worth the environmental costs? Can the farmed shrimp industry be made sustainable from an economic/business perspective as well as biological and social perspectives? In international trade, environmental issues are increasingly being brought into trade negotiations.

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Historical Background

Marine shrimp farming has been practised in Thailand for over 70 years in the Inner Gulf of Thailand. According to one study, a depression in salt prices in 1947 motivated salt farmers in the Inner Gulf of Thailand to convert their lands to shrimp farms (Supee 1991). Farms were sited near the coast because juvenile shrimp and nutrients were easily available and high spring tides provided water exchange without the need for a pump. Most of the incoming shrimp seed were white or banana shrimp (*Penaeus marguiensis)*. This first crop was usually harvested during November to February, the time of the weaker north-east monsoon, when high salinities yielded higher outputs. The second crop during the rainy season (south-west monsoon) when salinities would be low, usually generated low output, mainly of *Metapenaeus* spp.

In 1967, the Department of Fisheries (DOF) began promoting freshwater prawns (*Macrobrachium* spp.). DOF invited Japanese experts to teach shrimp culturing techniques. In the early 1970s, DOF set up three experimental stations in Rayong, Songkhla and Phuket to produce 1 million shrimp seeds per year at each station. The seeds were then supplied to farmers (Supee 1991).

Earlier statistics recorded by DOF in 1971 indicated that there were 1,137 shrimp farming families occupying a total farm area of 8,712 ha (TDRI 1986). Most farmers adopted an extensive polyculture method (less than 10 shrimp/m^2) using finfish as feed. In the 1970s the area of brackish-water ponds steadily increased.

When the freshwater prawn industry reached a point where supply exceeded demand and the market price was pushed down, the government changed its policy by supporting the conversion of *Macrobrachium* hatcheries to panaeid hatcheries. These hatcheries concentrated on producing *P. monodon* due to its large size and rapid growth rate for subsequent intensive pond culture (Briggs 1994).

In the early 1980s Taiwan was the first country in Asia to transform traditional extensive shrimp cultivation into intensive farming. High stocking densities, artificial feeding, chemical treatment of water and the use of antibiotics drastically increased production. After 1986 there was rapid expansion of shrimp farming in Thailand, with the help of Taiwanese technicians and government support through tax incentives. Intensive *P. monodon* farming spread along the northern edge of the Gulf of Thailand from Samut Songkhram to Chonburi. At the end of the 1980s when Taiwan's shrimp industry crashed, Thailand's production of cultured shrimp sharply rose, from 18,000 t in 1986 to 93,000 t in 1989 and to 163,000 t in 1992 (Briggs 1994). The rapid increase in shrimp farming was motivated by high profit margins. Despite the high initial investment cost, farmers could earn revenue from the first harvest within four months; and 2–3 crops could be obtained in one year.

DOF statistics show that since 1983, captured shrimp production has declined from 139,000 t to 119,000 t. Conversely, since 1990, cultured shrimp production has exceeded captured shrimp production, and in 1993 reached 227,000 t.

As in Taiwan and elsewhere, the farmed shrimp industry in Thailand has gone through boom and bust cycles. During 1989/90 farm gate prices of shrimp fell drastically as the result of a number of factors, including (a) a rapid production expansion throughout Southeast Asia, (b) a slow market in Japan following the death of Emperor Hirohito, and (c) a high dry-season production in Thailand (Briggs 1994). In response, the Thai Government intervened by supporting measures such as (i) temporary tax-free importation of high quality fishmeal for the feed industry in order to push down the production cost of shrimp farming; and (ii) construction of new cold-storage and processing facilities promoted by the Board of Investment (Briggs 1994). In 1990, shrimp farming in the Inner Gulf suffered from the production crash which forced about 90% of shrimp farmers in this region out of business and led to farm migration from the Inner Gulf to eastern and southern provinces. The migration left behind 45,000 ha of disused shrimp farms.

The production crash in the central region was followed by a boom of shrimp farming in the eastern and southern provinces. Nevertheless, many farms are probably operating in an 'unsustainable' manner in the sense that self-induced degradation of the local environment will eventually force farmers to stop operating. It does not necessarily mean that the farmers do not make rational or optimal choices, nor that the farmers' behaviour is socially undesirable. It is possible that farmers are suitably mobile to move to other areas. Another possibility is that the farm households are able to accumulate sufficient profits in a short period of time to enable them to acquire other sources of income, once the shrimp farms have been abandoned.

Thailand exports its shrimp in the forms of fresh, frozen and canned shrimp. Fresh and frozen shrimp account for 70% of all fishery exports, followed by frozen fish, and frozen cuttlefish, respectively. The growth rates of frozen shrimp exports between 1986 and 1994 averaged 27.4% per annum (Table 1). Thailand has been the leading exporter of canned shrimp since 1981. A study by Suporn (1983) with a focus on the marine shrimp industry reported that there were 39 export-oriented cold storage firms with high horizontal and vertical integration. The cold storage industry in Thailand was started in the 1960s and received government support through investment promotion privileges.

Table 1. Thailand's exports of fresh and frozen shrimp, 1986–1995.

Year	Quantity (t)	Value (million baht)
1986	28,717	4,391
1987	33,910	5,749
1988	43,624	9,049
1989	79,601	16,652
1990	84,723	20,454
1991	121,002	26,230
1992	139,884	32,232
1993	148,862	37,839
1994	199,119	49,062
1995	108,855	32,224[a]
Growth rate (1986–94) 27.4% per year		

Source: Thai Frozen Foods Association
[a] Jan–Aug

Shrimp Farming and Changes in Land Use

At present there are about 20,000 shrimp farms in Thailand located along the country's 2,600 km coastline, in the central, eastern and southern provinces. About 80% of farms are small in size, with farm areas no larger than 1.6 ha (Tookwinas 1996). The total land area under shrimp farming in Thailand is estimated to range from 70,000–80,000 ha. The giant tiger prawn (*P. monodon*) is the major species farmed (219,901 t, or 97%) and about 85% of production is exported.

Statistics on different coastal land-use types converted to marine shrimp farms in Thailand are imprecise. In 1961 the area of mangrove forest in Thailand was estimated to be 2.3 million *rai* (about 3,700 km^2). The 50% decrease in mangrove forest over the past three decades was due to a number of factors, such as urban and rural settlement expansion, port construction, salt farming, extensive shrimp farming, and expansion of agriculture. Many studies have evaluated the causes of reduction in mangrove forest and there seems to be a large discrepancy in the estimated percentage of mangrove area converted to shrimp farming. According to Ruangrai (1994) and Kanittha (1994), 64% of the reduction in mangrove forest was due to land conversion to shrimp farming. On the other hand, Briggs (1995, p.14) assessed that of the 80,000 ha of land currently used for shrimp culturing, only 10,000 ha (12.5%) was formerly mangrove forests and 40,000 ha (50%) was formerly paddy field. Recent statistics, based on the interpretation of remote sensing data (Landsat TM5, 1:50,000), now indicate that marine shrimp farming has invaded only 17% of the mangrove area of 372,448 ha that existed before 1961 (e.g. Tookwinas 1996; Piamsak 1996).

Associated Industries

Rapid growth of shrimp farming in Thailand has led to an economic boom in coastal provinces of the eastern and southern regions and stimulated related industries/businesses. The industries associated with shrimp farming include: shrimp feed production; capture and supply of wild broodstock by fishermen; hatchery production of nauplii and shrimp seed; nursery operations; manufacture and sale of shrimp farming equipment (e.g. paddlewheels); live and pelleted feed processing; cold storage plants; and shrimp processing and exporting companies.

Most feed manufacturers provide technical services to their customers. CP Group alone has 14 technical extension centres. Each centre has well equipped laboratories for chemical and microbiological analysis and the services of experienced biologists. The farmer can bring water or shrimp samples to the centre for free water quality analysis or disease diagnosis and advice. The extension centres also arrange seminars and offer training free of charge. In highly developed shrimp culture areas, the CP Group provides mobile laboratories to visit shrimp ponds in emergency situations.

There are about 30 large hatcheries; at least 1,000 backyard hatcheries and nurseries; and about 70 shrimp processing plants and cold-storage facilities, with a total processing capacity of 40,000 t/yr of black frozen shrimp.

Costs and Benefits at the Farm Level

Several studies on financial/economic aspects of shrimp farming have been done, largely based on data at farm level from different regions. The findings from those studies are highlighted below. Firstly, a report by Funge-Smith and Aeron-Thomas (1995), based on survey data from about 103 farms in five southern provinces in 1994/95, concluded that:

- Shrimp farming in southern Thailand is characterised by intensively stocked small ponds (0.32–0.64 ha). Most farms adopt a low or zero water exchange method.
- Production yields are in the range of 5.0–9.4 t/ha/crop with the typical feed conversion ratio (FCR) range of 1.7 to 2.4.
- Labor usage ranges from 1–2 workers per pond. The average monthly wage was 3,000 baht/month.
- Land cost is difficult to estimate because actual land transactions are rare. The rental cost of land was assumed to be 5% of land prices (187,500–387,500 baht/ha).
- 37% of farmers used their own money to finance their investment costs and operating costs; and 24% of farmers used their own money and partly borrowed.
- Major investment costs are pond digging and concrete work (93,750 and 43,750 baht/ha respectively). Water pumps are required in all farms (181,250–218,750 baht/ha).

- The variable cost may be of greater importance (712,500–762,500 baht/ha). Of the variable costs: 51% went to feed, (379,400 baht/ha/crop); 14% went to stocking (about 108,406 baht/ha/crop); and 11% to fuel (79,600 baht/ha/crop).
- The total cost of shrimp farm averaged 961,344 baht/ha/crop.
- Harvest weight on average amounted to 7.05 t/ha; the average shrimp price at farm gate was 158 baht/kg; and FCR averaged 1.95. The total revenue from shrimp farming was estimated at 1,230,000 baht/ha/crop. Net profit from shrimp farming was 251,963 baht/rai/crop, giving a fairly high rate of return of 30%.
- A sensitivity exercise found (a) a 10% increase in shrimp prices led to a 73% increase in profits; (b) a 10% increase in production weight led to 47% increase in profits; and (c) a 10% increase in feed price reduced the profit by 26%.

Another study by Nataya Srijantuk and Siri Tookwinas (1993) based on the survey data of 20 small shrimp farmers in Chanthaburi Province (all farms located within the Royal Project at the Khung Krabaen Bay) reported the cost of farm investment and the financial rate of return. Their findings indicated that:

- On the average, farms were small in scale, i.e. each farmer was allocated 0.96 ha of land for shrimp culture in which three shrimp ponds were developed. Shrimp culture required an average of 4.4 months per crop. Survival rate was found to be low (only 37.5%).
- The production yield was 4,119 kg/ha/crop (live weight).
- The cost per crop averaged 82,730 baht, which could be broken into variable costs of 53,697 baht/crop and fixed costs of 29,033 baht/crop.
- This study concluded that shrimp farming was a profitable activity. On the average, a small farm earned a net income of 133,212 baht per year, which was higher than that from rice farming in the same region.
- About 20% of farmers in this case study did not own their land. Farmers had to rent land at an average cost of 10,000 baht/pond/crop.

Pollution and Environmental Impacts

Environmental impacts from shrimp farming have been discussed by many authors (e.g. Macintosh and Phillips 1992; Primavera 1993; MIDAS 1995; Tookwinas 1996). The intensive nature of shrimp farming stresses the pond ecosystem causing water pollution, disease outbreaks and production crashes. Pollution in the ponds is transported to the coastal environment via water and sediment. Thus, pollution created by shrimp farming may re-enter the pond at some point in time, threatening the long-term sustainability of the sector (Macintosh and Phillips 1992).

Many previous studies concluded that many small-scale shrimp farmers do not have the knowledge to manage their farms sustainably (Briggs 1994; MIDAS 1995). The majority of small-scale farmers have limited education, usually less than 4th-year primary education (NACA 1996) and no previous training in shrimp farming.

Of the pelleted feed applied, only 14% is incorporated in shrimp biomass, while the remaining 86% is either metabolised or lost to the pond as uneaten waste. Feeds have been shown to supply 92% of nitrogen, 51% of phosphorus and 5% of solids entering the intensive shrimp ponds. Calculations of feed wastage show that for each 0.1 reduction in wet weight FCR, nitrogen wastage is reduced by 1.5–2.0% and phosphorus by 1.8–2.3% (Funge-Smith and Briggs 1994).

In brief, shrimp farming is currently a high-profit and a high-risk industry, with negative environmental impacts both on-site and off-site.

Sustainability of the Shrimp Farming Industry

Decreasing productivity is often cited as an early sign of unsustainability of shrimp farming. The major reason is that the amount of waste from an intensive shrimp farm exceeds the carrying capacity of the environment. The ability to produce shrimp at high densities cannot be sustained in the long run, particularly for the small-scale farms. According to Briggs (1995), shrimp production yield in general is currently decreasing at a rate of 3–8% per crop. This declining productivity results from poor growth rates, increased incidence of disease, and poor FCRs.

According to Briggs (1995), sustainability of the Thai shrimp culture industry is in doubt for the following reasons: (i) there is a tendency for an oversupply of shrimp in the world market; and (ii) production costs of shrimp are rising as the Thai shrimp feed industry is running out of high quality fish meal. Briggs (1995, p.6) warned that the shrimp farm industry in the southern Gulf of Thailand will surely collapse and that the government should avoid further expansion of shrimp farming in the mangrove-covered areas in western Thailand on the Andaman Sea. According to him, disease and a production crash similar to Taiwan's experience in 1988 and the Inner Gulf of Thailand in 1990 is inevitable. "The repeated use of the techniques that destroyed the industry of Taiwan and central Thailand is beginning to shake the industry in southern Thailand, Indonesia and the Philippines, and still further expansion is imminent both within Thailand and in other countries…" (Briggs 1995, p.7) Similarly, MIDAS (1995) concludes that shrimp farming is likely to be unsustainable, unless there is tighter control and appropriate coastal management strategies are implemented. In the Philippines, Primavera (1993) recommends that shrimp farmers should be encouraged to shift to semi-intensive systems for ecological and economic reasons.

Government Policies and Regulations on Shrimp Farming

The shrimp farming industry in Thailand is in the hands of private companies and a large number of small shrimp farmers. The industry receives mild support from the Government in forms such as (i) the DOF promotion of shrimp farming during the 1970s, (ii) the Board of Investment promotion of investment in supporting industries and (iii) the temporary measures by Government to support the shrimp farming industry when shrimp prices have fallen, or energy prices sharply increased.

Government regulations in the area of shrimp farming are related to concerns over the environment. In response to the depletion of mangrove forest, the DOF has set a limit on the production area to no larger than 80,000 ha (500,000 rai, Siri Tookwinas, July 1996, pers. comm.). In 1991 DOF announced that shrimp farms greater than 8 ha must be registered with DOF (Ministerial Announcement, 18 November 1991) under The Fishery Act, B.E. 2490 (1947). Violations are subject to fines (not over 100 baht each time) and/or imprisonment. DOF made the rules that: the fishery enterprises over 8 ha must allocate at least 10% of the total area to treatment ponds; biochemical oxygen demand from water discharge cannot exceed 10 mg/L; and that sediments cannot be disposed of in public areas. According to a Network of Aquaculture Centres in Asia–Pacific (NACA) study, 48% of shrimp farms (10,542 farms) complied by registration with DOF in 1995 (NACA 1996, p.145). The NACA study recommends that law enforcement be strengthened by:

- adding to the list of poisoning materials, all the chemicals that are used in shrimp culturing;
- announcing that DOF's officials can act as government officials responsible for fishery feed quality (Fishery Feed Quality Control Act, B.E. 2525);
- broadening the definition of government officials responsible for pollution control (Environmental Quality Promotion Act B.E. 2535) to include DOF's officials;
- widening shrimp farming registration with DOF to cover all shrimp farms with an area over 0.8 ha; and
- limiting access of shrimp farming in targeted zones and not allowing location near conservation areas, tourist attractions or marine national parks.

To be fair, the Government's awareness of the environment is certainly on the rise and it has tried to tackle environmental problems on many fronts. The Government's budget allocation for environment correction has sharply increased; the bureaucratic agencies related to environment protection have been strengthened. But environmental degradation still continues, suggesting that environmental problems may be too complex to be solved under the existing government policy tools. New policies and regulatory measures may be necessary. But policy implementation is rather slow due to many obstacles (i.e. the legislation process in Thailand is notoriously slow and enactment of new laws in most cases take many years). Separation of power among bureaucratic agencies makes it difficult to reach consensus, thus delaying the implementation process. Despite all these weaknesses, the Thai Government has been quick in responding to some issues. For example, after the Japanese ban of shrimp in 1991 due to chemical residues, DOF immediately strengthened an inspection process by establishing 20 centres for material investigation prior to export, and established 4 centres to certify fisheries product quality. NACA (1996) reported that about 3,000 farms have already cooperated by participating in DOF's program.

Also, the Thai government has tried to stop further destruction of mangrove forests. In 1987, a Cabinet Resolution declared three type of mangrove zones: (1) Conservation Zone, which would be strictly protected; (2) Economic A Zone, which can be used for exploitation of forest products on a sustainable yield basis (including charcoal production and local uses); and (3) Economic B Zone, which can be used for other developments with due consideration to environmental impacts (MIDAS 1995). In 1991, the Cabinet Directive approved a mangrove replanting program (to be implemented between 1991 and 1996) aimed at planting 50,000 rai (8,000 ha) of mangroves in each year of the project. The budget allocation gave 3,000 baht per rai as the cost of planting.

In addition, in 1993 the Royal Forestry Department launched a new division, called the Marine Park Division, to manage coastal resources and to protect them against degradation. Recently the Department of Pollution Control under the Ministry of Science, Technology, and Environment commissioned NACA to undertake a study for water pollution from coastal fisheries. Similarly, the Office of Agricultural Economics, Ministry of Agriculture and Agricultural Cooperatives commissioned a consulting firm named Mekong International Development Associates (MIDAS) to study and to propose coastal resource management strategies. MIDAS examined six subject areas:

- sustainability of shrimp aquaculture;
- rehabilitation of abandoned shrimp ponds;
- sustainability of small-scale fisheries;
- mangrove forest management and protection;
- management of coastal/marine protected areas; and
- conservation of marine biodiversity.

This study reported that there was mismanagement of coastal resources in many areas and proposed that government regulatory agencies (notably DOF, the Royal Forestry Department and the Department of Livestock Development) be strengthened to monitor coastal resource management effectively. The report specifically proposed a new program called "A Coastal Resource Management Program" which will cost US$174 million (4.35 billion baht) to be financed from the blend of loan, grant, and Government funds. Recommendations of the MIDAS strategy included:

- promoting research and development in water treatment techniques;
- defining coastal protected areas;
- designating a shrimp aquaculture area in order to limit shrimp farming outside the zone by imposing an environment tax for shrimp farming outside this zone;
- imposing an export surcharge on processed shrimp and processed shrimp products, to be varied according to the world price of frozen shrimp, with revenue allocated to the fund; and
- establishing a coastal management company in which the Government may share in the venture. This would be similar to precedent cases of the East Water Resources Management Company, Waste Water Management Company and Electricity Generating PCL.

International Trade Issues

Recent trade problems

Thailand's shrimp exports into markets in developed countries are becoming increasingly more difficult, largely because of the concerns of importing countries about environmental degradation and health problems. In 1991 the Japanese government discovered antibiotic residues in imported cultured shrimp from Thailand and Indonesia, and threatened to ban shrimp imports. In response, the Thai Government stepped up shrimp quality inspection before export, and published a manual on how to deal with chemical residues in shrimp which was widely distributed to farmers. Later on, the use of antibiotics in shrimp ponds decreased significantly. In 1992 the Asian Shrimp Culture Council called for the setting up of drug residue standards.

Shrimp farming in developing countries has also come under pressure from international environmental non-government organisations. In Germany, the Greenpeace group requested consumers not to buy shrimp products from Asia and Latin America on the grounds that shrimp farming is the major cause of mangrove forest destruction and water pollution as well as a cause of undesirable social changes among coastal communities. Recently a Marine Stewardship Council was established with support from World Wildlife Fund and Unilever to issue a certificate and logo to sustainable fishery enterprises as a consumer information service (CP Group Newsletter, June 1996).

The most important blow to the Thai shrimp sector was the United States (US) shrimp import ban (effective May 1 1996) on the grounds of a lack of law enforcement to protect sea turtles. Specifically, the US wants all boats that capture marine shrimp to be installed with turtle excluder devices. In response, the Thai Government has teamed up with the Association of South-East Asian Nations (ASEAN) and Japan to protest to the World Trade Organization (WTO) on the grounds of unfair trade protection (CP Group Shrimp Culture Newsletter, May 1996). The US Foreign Ministry announced that in order for shrimp to be eligible for import, the supplier must prove that the shrimp are cultured, not captured.

From 1 January 1997, the European Union (EU) excluded Thailand from the list of Generalised System of Preferences (GSP) recipient countries. This makes Thailand's shrimp exports to EU more difficult because shrimp products from Thailand are subject to a higher import tariff than other competing countries. Under the new GSP (1996–1998), fishery products are listed under the semi-sensitive sector—the countries under the GSP system are entitled to a 35% reduction in tariff rates. According to the CP Group Newsletter (June 1996), shrimp exports from Thailand entering EU are taxed at a 9.72% import tariff rate, which is higher than the 5.04% tariff rate applied to other shrimp exporting countries, such as Indonesia.

Technical barriers to trade

The Agreement on Technical Barriers to Trade (TBT Agreement) requires governments to apply their technical product regulations and standards[1] in a non-discriminatory way. The agreed disciplines in this Agreement also apply to environmental product regulations and standards. The TBT Agreement encourages the use of international standards, but it does not require their use. Standards and regulations may specify product characteristics and related processes and production methods (PPMs). The TBT Agreement specifies that countries shall not be prevented from taking measures necessary to protect human, animal and plant life or health or the environment. Such measures must be no more trade restrictive than necessary to fulfil their objectives, taking account of the risks that non-fulfilment would create. In assessing such risks, relevant considerations are, inter alia, available scientific and technical information.

The TBT Agreement covers the range of conformity assessment procedures (e.g. registration, inspection, laboratory accreditation) used to determine conformance to a technical regulation or standard. It also encourages mutual recognition of these procedures among countries. The Agreement improves the transparency of product standards policies and related procedures by requiring advance notice and opportunity for comment. The Agreement establishes a Committee on Technical Barriers to Trade that provides a framework for avoiding and resolving disputes.

Sanitary and phytosanitary measures

The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) establishes rules and disciplines for the development and application of measures taken to protect human, animal or plant life or health in areas of food safety and agriculture.

The SPS Agreement measures include a wide range of health protection measures, e.g. quarantine procedures, food processing and production measures, meat slaughter and inspection rules, and procedures for approval of food additives or for the establishment of pesticide tolerances. The SPS Agreement clearly recognises and acknowledges the sovereign right of each country to establish laws, regulations and requirements necessary to protect life and health, but specifies rules and disciplines intended to prevent a contracting party from using SPS measures as disguised barriers to trade.

The SPS Agreement generally requires the use of international standards as a basis for SPS measures. But each government remains free to adopt an SPS measure more stringent than the relevant international standard, where the more stringent measure is based on available scientific evidence and risk assessment as provided in the Agreement or where it is the consequence of the level of protection that the Government has determined is appropriate.

The SPS Agreement also aims to ensure increased transparency in the process of establishing SPS measures by requiring advance notice and opportunity for comment and national inquiry points.

1. The TBT Agreement defines a technical regulation as a document which lays down product characteristics or their related processes and production methods, including the applicable administrative provisions with which compliance is mandatory. It may also include or deal exclusively with terminology, symbols, packaging, marking or labelling requirements as they apply to a product, process or production method. A Standard is a document approved by a recognised body, that provides, for common and repeated use, rules, guidelines or characteristics of products or related processes and production methods, with which compliance is not mandatory. It may also include or deal exclusively with terminology, symbols, packaging, marking or labelling requirements as they apply to a product, process or production method.

European Union regulatory measures on shrimp and prawns

For fishery products, the European regulation is laid down in Council Directive[2] 1291/493/EEC with the title: "The production and the placing on the market of fishery products" (Commission of the European Communities 1991 OJ L 268). In the directive, it explicitly stated that third countries exporting into the EU must fulfill all standards applied to producers within the community. An 'establishment' (producer) being eligible for exporting to the European markets will need a health certificate issued by the competent authority in the exporting country, stating that all standards laid down in this directive have been met. EU experts may carry out inspections in the third country in order to verify the conditions of production, storage and dispatch of fishery products for consignment to the EU are met.

The import conditions of aquaculture products from Thailand have been further specified in Commission Regulation 94/325/EC entitled "Special conditions governing importance of fishery and aquaculture products originating in Thailand". This regulation contains a list of establishments that are certified by the Thai competent body.

The health certificate accompanying all shipments of cultivated prawns and shrimp stipulates the products:

- were handled and packaged, prepared, processed, frozen, thawed and stored hygienically in compliance with the requirements laid down in Chapter III of the Annex to Directive 91/493/EEC;
- have undergone health control checks in accordance with Chapter V of the Annex to Directive 91/493/EEC;
- are packaged, marked, stored and transported in accordance with Chapters VI, VII and VIII of the Annex to Directive 91/493/EEC;
- do not come from toxic species or species containing biotoxins; and
- have satisfactorily undergone the organoleptic, parasitological, chemical and microbiological checks laid down for the certain categories of fishery products by Directive 91/493/EEC and in the implementing decisions thereto.

2. Directives are binding as to the result to be achieved, but leave to Member States the choice of the form and method of implementation. That means that they need to be incorporated into national legislation within a certain period fixed by the directive itself.

Process-related issues

Apart from the product-specific environmental policies, there are new initiatives relating to voluntary systems to help improve the environmental management of firms. These systems generally include process-related issues. Governments and WTO may encourage such developments, e.g. by establishing legal provisions and providing infrastructure. While essentially aimed at environmental purposes and despite being voluntary, environmental management systems (EMS) and related labelling programs may have both positive and negative effects on trade and competitiveness. A certificate or label may give the firm greater credibility with clients, financial institutions, insurance companies, regulators and consumers. On the other hand, the existence of labelling schemes may have adverse effects on a firm's competitiveness. This may be the case, for example, for firms in developing countries, which may find it difficult (or expensive) to adapt the production process towards the required standards. Moreover, the growing use of EMS in developed country markets may intensify a trend to impose environment-related requirements on their suppliers, including supplies from developing countries.

Canada presented a paper on the relationship between WTO rules and eco-labelling (WTO 1996). It said that eco-labelling could be an important tool for encouraging industries to adopt higher standards of environmental protection. Granting eco-labels to environmentally preferable products and services was designed to influence consumer purchasing behaviour and provide opportunities for increased market share. Eco-labelling programs were valid environmental policy instruments that must be developed and implemented in a manner consistent with fundamental WTO disciplines of non-discrimination and national treatment. Canada therefore suggested that the following four basic principles should be accepted:

- Mandatory and voluntary eco-labelling schemes and eco-labelling compliance procedures are within the scope of the TBT Agreement and its Code of Good Practice;
- The coverage applies to all eco-labelling programs, whether voluntary or mandatory, governmental (central or sub-central) or non-governmental;
- Eco-labelling programs are established by standardising bodies, and such bodies should accept the TBT Code of Good Practice; and

- The scope of the TBT Agreement should be interpreted to cover the use of certain standards based on unincorporated (non-product related) process and production methods (PPMs) in voluntary eco-labelling programs, provided the standards adhered strictly to multilaterally-agreed guidelines.

Acknowledging that many Members had expressed concern, Canada said the best way forward was to limit the possible coverage of unincorporated PPMs to voluntary eco-labelling programs (i.e. standards, not technical regulations). However, life cycle analysis was an integral part of eco-labelling programs and when the life cycle analysis indicated that a significant environmental impact was at the production stage, the resulting eco-labelling criteria could have a strong component of unincorporated PPMs. From a trade perspective, Canada felt it important that eco-labelling schemes be subject to disciplines to reduce the potential for protectionist abuse. Guidelines such as those under development in the International Standards Organisation and the Global Eco-labeling Network and complementary work carried out by United Nations Environment Programme would reduce the possibility of protectionist abuse and trade discrimination. These guidelines were expected to be more on the level of procedures and methodologies rather than specific benchmarks, reflecting the fact that specific environmental standards might vary as a function of local environmental absorptive capacities.

Issue labelling

Besides the full environmental impact assessment of a production process, private initiatives may focus on a particular environmental issue related to the production process. For shrimp, a recent example is the turtle excluder devices required by the US to avoid the killing of turtles while fishing for shrimp[3]. Although most shrimp exported by Thailand are cultivated in ponds and therefore not affecting turtles, this measure may harm Thai exports if the producers have to provide proof of the origin of the shrimp or if the consumer imagines a problem with Thai shrimp.

Other future, single-issue consumer actions may be related to mangrove destruction associated with shrimp farming.

3. This case shows strong similarities with the Tuna–Dolphin case brought to WTO by Mexico, which successfully fought the US ban on imports of tuna caught in a manner disadvantageous to dolphins.

Summary

EU legislation (directive 91/492/EEC) does have a strong component of unembodied PPMs. To obtain a certificate to export to the EU, producers need to comply with process standards of which the relation to the final product is questionable.

The WTO standpoint is moving towards measures based on life cycle analysis, although exists between eco-labelling approved by national governments and the autonomy of countries with regard to the choice of production methods. An eco-labelling program may include unembodied PPMs and should therefore be left to private initiatives, as suggested by Canada.

In summary, eco-labelling, issue labelling, product measures and related PPMs are potentially powerful instruments for influencing the production methods chosen in shrimp producing nations.

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Socioeconomic Aspects of Shrimp Farming in Thailand

Penporn Janekarnkij*

LINKAGES in the shrimp farming industry in Thailand occur between the micro and macro levels. At the micro level, the main groups are the shrimp farms and the local community. At the macro level, the groups are the shrimp industry, national bodies and international bodies. A study of the linkages between groups at these levels indicates that there are three central socioeconomic issues in shrimp farming in Thailand.

Firstly, socioeconomic problems are caused by 'shifting aquaculture', a term that describes the movement of farming operations to new areas as old areas become unproductive. The obvious direct outcome is abandonment of farms. The main problems caused by shifting aquaculture are environmental degradation and the perpetuation of economic 'boom–bust' cycles. Possible solutions may be the encouragement of contract farming, cooperatives, co-management and community-based management. The researchable issues are (a) the study of factors affecting success and failure of each structure and (b) comparative studies of each structure.

The second socioeconomic issue is the conflict between shrimp farming activities and other activities. The problems are resource use conflicts, resource allocation problems, externality effects and social conflicts. Possible solutions may be internalisation of environmental costs and reductions in government subsidies for shrimp farming. The researchable issues are (a) economic valuation of natural resources and environment and (b) 'green' benefit–cost analysis.

The third socioeconomic issue relates to Government involvement, including laws and regulations which affect shrimp farming. Problems occur because many agencies are involved, there are enforcement problems, and there are unintended impacts of multiplicity of agencies governing resource uses. The solutions would require a holistic approach to the planning process, and a review of laws and regulations. The researchable issues are (a) institutional analysis and (b) policy analysis.

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Communicating Research Results to Farmers—a Key Issue for Sustainability

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In Asia, aquaculture has been primarily oriented towards meeting local food requirements, creating gainful employment opportunities and supplementing family income. As a result, the majority of the sectoral contributors are small farmers. Inputs from research institutions and intra-regional exchange of information have accelerated the pace of development of Asian aquaculture. Large-scale commercialisation of aquaculture activities is a recent development in Asia that has been influenced by the price structure and increasing demand for high-value aquaculture products, especially shrimp. Governments in the region have also given high priority to the development of aquaculture because this sector is a major source of foreign exchange earnings through export of high-value products like shrimp.

Aquaculture extension services are recognised as the vital link between researchers and primary producers. The governments of countries within the region have worked diligently to expand and improve the network of field staff available to assist the aquaculture industries. In almost every instance, federal governments provide the framework for extension services. The main objective of these is to transfer appropriate technology packages to farmers to help them raise farming efficiency, production and profit. However, aquaculture extension services did not get parity with the growth of the sector and as a result the system functions under a limiting environment. Unlike agriculture, hardly any research was undertaken to develop effective and appropriate extension methodologies, approaches, training materials and tools. Sustainability issues are yet to be incorporated in the extension delivery system.

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Highly Diversified Groups of Primary Producers

Aquaculture helps to intensify lowland development and fits within the framework of rural development. Aquaculture is both a primary source of livelihood as well as a secondary or supplementary activity. Again, aquaculture may be an income-generating activity or contributor to local and national food security. Whether it is small-scale or large-scale, the principle activities are cultivation, harvesting, processing and trading. At one end, there are small-scale shrimp farmers, fry collectors and workers and, at the other, large-scale farmers, corporate groups, manufacturers, processors and marketing agents, national and international investors, and agencies.

As culture technologies became more economically viable, the sector attracted a lot of 'outsiders'. However, such developments created several social problems and the uncontrolled development resulted in negative environmental impacts. This phase of the development was quite quick and without much input or advice from extension services. Most of the recent entrants are either multi-national business houses or large local companies. They have the ability to hire technical consultants and experts and their main objective is income generation.

Large-scale farmers, the corporate sectors and large companies are highly organised, having access to information and innovations, and enough resources to benefit from new technologies. These groups also have better access to policy-making institutions and they are well organised and powerful enough to influence decisions.

On the other hand, the small-scale or subsistence-level farmers have relatively limited resources and little access to technical innovations. Small-scale farmers make up a relatively enormous sector, are highly unorganised, have a poor level of education, and little awareness about environmental implications and regulations. To ensure that the small-scale sector get the benefit of modern technology, it is desirable that information from research is channelled to them through an efficient extension services system. The task becomes more difficult when the technologies to be introduced are developed with the objective of long-term benefit and sustainability. It is easier to convince them of the benefit of modern technology through demonstrating an increase in production and profit than to show the long-term benefits from sustainability and reduced impacts on the environment. Alternatives, incentives, education and a lot of persuasion are needed to re-orient their attitudes and actions.

Sustainability—Issues and Considerations

As with other farming systems, the issue of sustainability is the focus of the shrimp industry's attention. Sustainability of shrimp aquaculture became an issue after the collapse of shrimp culture in Taiwan, provinces of mainland China and subsequently in several other countries in Asia. Negative impacts, like mangrove destruction and the consequent depletion of local fisheries, pollution, and other forms of land and water degradation are often highlighted. The social impacts on local communities that live in the tropical coastal regions where shrimp acquaculture is an increasing source of income include disrupting traditional systems of production, distribution and social relations. As defined by the Food and Agriculture Organization of the United Nations, "sustainable development is the management and conservation of the natural resource base and 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 fishery sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (FAO 1988). This definition clearly implies environmental, economic and social components of sustainability. However, the parameters of sustainability are yet to be made clear to all stakeholders. Again, this reflects the poor communication between the policy-makers and the primary producers.

The issue of sustainability in aquaculture is invariably discussed at different forums. For farmers, investors and government agencies, sustainability of shrimp aquaculture relates to maintenance of at least the current level of production and profit. For environmentalists, sustainable aquaculture refers to sustained production at a level that creates minimal negative impact on the environment and ensures no further environmental degradation. To social activists, it is a program of development that is sensitive to the question of social equity. Until all stakeholders in shrimp acquaculture come to a generally acceptable definition, it is wise to get hold of all three focal points—economic efficiency, ecological security and social equity.

Dr M.S. Swaminathan made the proposition in 1990 (see Jian 1994) that "development which is not equitable will not be sustainable, and a better common present is essential for a better common future". According to Jian Song (1994), the variables of economic efficiency and ecological security deserve heaviest weight and are the decisive factors for the elimination of poverty and achievement of a dignified life for the rural poor. 'Consumer awareness' and trade barriers have also been placed on the agenda, especially in the West, as a tool which could be used against the potential negative consequences of inappropriate growth of shrimp aquaculture. In any case, bi- or tri-faceted models of sustainable shrimp aquaculture demand greater participation of the local community.

Extension and its Potential Role in Bringing Sustainability to Shrimp Aquaculture

Before research findings can be made effective, there needs to be a radical change in the role of government departments involved in controlling and coordinating industry activity (Jenkins et al. 1995). Barraclough and Finger-Stich (1996) concluded that effective policy and institutional reforms are required at all levels with close cooperation at the grassroots. Stability and sustainability, however, will come only through long-term planning and participatory implementation programs. This will be difficult because the majority of primary stakeholders do not possess an adequate understanding of the concept of sustainability in shrimp aquaculture. The problem is acute in countries where the majority of primary producers are small-scale farmers with a low level of literacy. This deficiency leads them to follow blindly anyone offering a potential short-term solution to their problem.

A Difficult Task Ahead

The task of educating and involving local communities in the management of resources, so that they can be exploited on a sustainable basis, is a matter of discussion at conferences and symposia but is yet to be widely introduced. The majority of local communities are poor and believe that "something of today is better than much of tomorrow". Tomorrow is always masked by uncertainties. According to Sir Shridath Ramphal (1994), "poor people often destroy their environment—not because they are ignorant, but to survive". They over-exploit the soils, overgraze fragile grasslands, and cut down dwindling forest stocks for firewood. In the context of the short-term need for survival, each decision is rational; in the long-term and wider context, the effects are disastrous. Poverty is both a cause and an effect of environmental degradation. However, it is not only the small-scale and poor farmers who are less concerned with environmental issues. Environmental aspects are also ignored by certain groups of self-centred and short-sighted, large-scale farmers. This is in spite of the fact that they have access to information and the capacity to buy it, and employ well-trained staff and technicians who are capable of developing and implementing sustainable farming practices.

When the support from extension services is not adequate, the small-scale operator has to depend upon external sources for information. Aquaculture extension will have to widen its scope to include the entire ecosystem and the issue of social equity as well. Naturally, the extension services will have to bear additional responsibilities. For performing such a role, they need major institutional reorganisation, increased operating capacity, innovative methods and adequate support.

Ineffective and Irrational Communication

The task of educating farmers and investors in the industry about the negative consequences of environmental degradation, social inequity and the benefit of sustainability, has been ignored. These issues are discussed at many national and international forums, which are dominated by environmentalists, scientists, administrators and policy-makers. However, the national governments have not addressed these issues with the farmers and with the industry. Fegan (1996) reported that this lack of communication is compounded by the sense of unfairness felt in the aquaculture industry at being repeatedly branded as environmental terrorists and the consequent reluctance to communicate for fear of inviting more troubles for themselves.

It is also true that there are instances where the certain factors have been clearly singled out to highlight the negative impacts of shrimp culture. An organised and well-tuned aquaculture extension system is needed to counteract such unbalanced reports.

Sustainable shrimp aquaculture requires adequate blending of new technologies with indigenous practices and traditional knowledge. Without such considerations we may end up with simplistic and inept models which will be quickly rejected. Extension will have to play a role in this area.

In the absence of effective extension services systems, most information is volunteered by groups associated with manufacturers and dealers of chemicals, feed, appliances and equipment. Aggressive marketing efforts by these interest groups often push the farmers to over-intensify their operations, by luring them to short-term profitability.

During the early stages of the development of shrimp culture, mangrove areas were frequently proposed for siting extensive shrimp farms. Subsequently, it was found that mangrove areas are generally unsuitable for shrimp ponds due to acidic soils. Unfortunately this information was poorly disseminated among existing and prospective farmers. Farmers in many countries still look at mangroves as potential sites for shrimp farms. In Thailand, where the shrimp farming system is more intensive, it has been found that of the total mangrove area that has been cleared, only 17% is used for aquaculture.

Policy Issues for Sustainable Aquaculture

The possibilities for bringing about reform will largely depend upon the active participation of the key social actors at the grassroots level and alliances of concerned parties in both producing and consuming countries.

Some Asian nations have formulated regulatory measures for coastal resource management, such as issuance of permits for fishing, logging, mangrove harvesting and construction of shrimp farms. However, most of these measures have not proven effective, due partly to enforcement failure and largely to lack of support and active involvement of the communities concerned. A well-organised system of extension services with appropriate approaches and strategies is required for educating, convincing, persuading and mobilising the active participation of primary producers and other stakeholders for effective implementation of regulations.

Subsidies, in the form of cash and kind ranging from 10–50% of project cost, are available to fish farmers and shrimp seed hatcheries in some countries (Pathak 1989). Promotion of aquaculture without the provision of grants, credit or subsidies, but with extensive extension support is slow and difficult but takes place in a healthy, long-term environment and is a relatively more sustainable approach. The provision of material/credit assistance to small-scale farmers usually attracts a bigger crowd than the genuine farmers. As soon as the delivery of inputs are withdrawn, many tend to lose interest. They remain active in the 'credit/free material input' phase but avoid meeting the extension agent during the 'credit recovery' phase (Kumar et al. 1996). However, there are instances where small credit systems have worked well and complemented the extension program of small-scale aquaculture development.

Research—Extension Linkage

To facilitate the transfer of information and appropriate technologies, and mobilise mass participation for the promotion of sustainable shrimp aquaculture in the region, there is a need to improve the institutional capacities of the extension services system. Closer links and cooperation among administrators, scientific communities, development workers and primary producers need to be fostered. As appropriate, the private sector should be encouraged to provide support, not only for research but also extension which is highly relevant to their needs. The various components of extension services, such as research, participatory management, training and information dissemination, should be integrated under a well organised extension services system. Capacity building and efficiency increase are simultaneously required at all levels (i.e. extension managers, field extension workers, primary producers and other stakeholders).

Areas needing attention are as follows.

- Developing appropriate organisations to tune the respective Departments of Fisheries with respect to their extension and training functions.
- Developing practical and cost-effective training tools and programs.
- Harnessing the potential of folk media for more effective communication. These range from individual skills in talks, running meetings, writing articles and leaflets, to techniques such as the use of drama groups, songs and the broadcasting media.
- Developing appropriate extension approaches and methodologies.

Appropriate Strategies for Extension Services

Popularisation of responsible, sustainable aquaculture needs an appropriate approach to be taken. The following are some of the strategies which need consideration.

Privatisation of extension services

Extension services could be supported by the organisation of the farms/local communities themselves. Perhaps participatory extension services would be a more appropriate term. In China in very recent years, efforts have been made to privatise extension services at the country level. The farmers pay fees for the extension services rendered and the amount usually depends upon the additional production achieved. Such a system adds efficiency to the system but how effective it would be in promoting sustainable aquaculture is a matter of experimentation and observation.

Recognising extension as an integral part of the research and development process

Incorporation of aquaculture extension into tertiary curricula and refresher courses is highly desired. Strategies which enable scientists and researchers to have closer and frequent interactions with farmers/farms/extension workers need to be seriously considered. Likewise, involving extension workers in research planning exercises is equally important in fostering stronger links between research and extension.

Community organisations for managing aquaculture

The biggest problem in many developing countries limited critical resources and funds to carry out extension activities. Most of the extension staff are unable to fulfil their missions because of inadequate means of transport and shrinking budgets. They are not able to reach and effectively serve the farmers. However, this could be achieved through developing appropriate extension strategies and approaches. In addition to this, there is a need to design and test various tools for participatory and interactive training, as well as developing appropriate and cost-effective training materials, manuals and field programs. As an example, the results of an experiment in the forestry sector of Nepal are quite encouraging. The forestry department has now assumed the role of forestry extension service, giving forest dwellers the right to manage the forest themselves for sustainable exploitation. Dramatic improvement has been noticed since then. However, it needs substantial institutional reorganisation as well as adequate understanding of personnel of the elements of human resource management, as well as technical, environmental and social aspects.

Credit program and extension

Extension programs can also be integrated into credit programs. Credit programs are facing a number of constraints, such as widely dispersed communities that are difficult to reach, weak linkage between financial institutions and extension services, complex and time consuming lending procedures, and difficulties in arranging collateral. Certain experiences in promoting aquaculture through participation of women have been encouraging. It has been found that women follow the routine activities more diligently, are more sensitive towards family welfare and more concerned for the future of their children and family. In Lai Chau Province of Vietnam, the Women Union has successfully implemented a small-scale credit program ensuring quick delivery and timely recovery of credit.

Cooperative approach

Constraints on inter-departmental conflicts affecting aquaculture extension need to be studied to develop appropriate approaches to foster greater collaboration.

Conclusions

There is a clear need for more field-based studies in order to better understand the social and environmental implications of shrimp aquaculture in specific social and ecological contexts. Inputs from such studies will help develop strategies to demonstrate how shrimp acquaculture can bring more benefits to local groups and how such activities can be made more participatory and sustainable. Self-sustainable development is difficult to introduce in one step. It has to be achieved gradually and through several progressive steps. Well organised and professional extension assistance could remove many constraints.

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Priorities for Regional Research on Sustainable Shrimp Aquaculture

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THIS paper attempts to identify priorities in some of the sustainable shrimp aquaculture problem areas that could be effectively tackled by joint research between two or more countries. It is based on three sources of information, namely, two recent studies (FAO/NACA 1995; ADB/NACA 1995) and preliminary information from a regional survey of aquaculture research priorities and capacities, with the collaboration of the Food and Agriculture Organization of the United Nations (FAO). The countries/territories considered are Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Pakistan, the Philippines, Taiwan, Thailand and Vietnam.

Overview: What Makes Shrimp Culture Unsustainable?

That the shrimp industry (and for that matter, aquaculture) should be sustainable is the fundamentally expressed objective of every country represented in this workshop. From this common point everyone thereafter proceeds to define the issues with varying degrees of divergence but also with some common areas of agreement. Notable among the agreements on basic issues are that:

- the shrimp culture industry can pollute itself out of sustainability;
- its sustainability is threatened by normal impacts from other activities; and
- it has both positive and negative impacts on society and the environment. If the negative impacts are not mitigated, they will ultimately impair its sustainability (Phillips 1995).

It is remarkable that none of the above threatens short-term profitability of individual farms. This observation suggests that research should simply focus on maintaining the biological productivity and economic efficiency of farms over a series of short-term horizons, while insulating the industry from external threats and eliminating emissions from farms that cause adverse ecological impacts. At first glance, this seems to move attention away from a longer term and holistic research outlook. On the contrary, it directs attention to assessing the immediate priorities of a production unit so that it does not collapse in the future. In so doing, it eliminates the temptation to get as much as one could today and never mind tomorrow, the basic motivation for the ‘rip-and-run’ behaviour that has largely been blamed for unsustainable management practices.

Framework for Identifying Priorities for Collaborative Research

Farm-based approach

A strategy based on a ‘farming systems’ approach seems to be an appropriate framework for identifying research activities. In essence, research oriented to farming systems seeks to ensure that the system is biologically feasible (the crop can grow and/or reproduce under a given agro-climatic condition), technically feasible (the farmer can grow the crop and market it) and economically viable (it pays to grow

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the crop). If what is not sustainable cannot continue to be profitable in the long term, there is support for the proposition that research should focus on ensuring farm profitability over a series of short-term horizons.

Regional approach

I tried to identify the opportunities for collaborative research simply by identifying the expressed areas of common concern. These are further classified into research areas that would apply to all systems (non system-specific) and those that are system-specific. For instance, research responsibilities that apply to extensive and improved extensive shrimp culturing systems could be shared by Bangladesh, Vietnam, and perhaps Sri Lanka, India and to a certain extent the Philippines. Those that apply to the intensive system could be shared by Thailand and others that look at the Thai system as a model which they may want their industry to emulate. I then attempted to identify examples of problem areas for collaborative research in disciplines of competence in the participating countries.

Common Concerns

Every country reported that better farm management techniques were a high priority, but it might help to focus on the components of this issue rather than treat it as a single research concern. The major concerns reported for each country/territory are listed in the Appendix. The most commonly expressed priority problems were as follows.

Seed

12 of 12 countries/territories. Issues ranged from concern for reliable supply (hatchery technology), risks of importing diseased seed, depletion of wild seed sources, destruction of other species during wild seed collection, and production of vigorous and healthy seed. Surprisingly, despite all the concern for broodstock development in previous sessions, only Thailand, Malaysia, the Philippines and Indonesia mentioned it as a priority problem.

Disease

10 of 12 (except Myanmar and Pakistan). The priorities included: capabilities for diagnosis; methods for treatment and control; studies on causes and predisposing factors; and development of immunostimulants.

Water and sediment management

9 of 12 (except Cambodia, Myanmar and Pakistan). The concerns in this area varied among countries. Thailand's concerns were for recirculating systems, biofiltration, bio-enhancers for effluent, sediment management and salination of crop lands. India and Malaysia focused on bio-enhancers, while the Philippines was concerned with adequacy of freshwater supply, land subsidence, salination of aquifers and adjoining crop lands, and the use of bio-enhancers (probiotics). All reporting countries listed proper water intake and drainage system as priorities.

Mangroves

10 of 12 (except China and Pakistan). Concerns were mostly on the allocation of mangrove areas for aquaculture, although priority has shifted towards rehabilitation and conservation. This shift should impact favourably on ecology and public image.

Site suitability

7 of 12 (namely Bangladesh, India, Indonesia, Malaysia, Pakistan, the Phillippines and Thailand. Zoning was the main concern, with emphasis on carrying capacity. Sri Lanka did not express concern, perhaps because more attention was focused on ameliorating problem soils in present sites. Malaysia was concerned with having additional areas.

Pollution from outside, including red tides

5 of 12 (namely China, India, Malaysia, the Philippines and Thailand).

Low-pollution feed and feed quality

Very few countries reported this as a high priority. India, Sri Lanka and Indonesia were concerned with feed quality, and Thailand with both quality and less-polluting effects.

Other concerns

There are also concerns about the use of bio-fertilisers, rotational and polyculture systems, rehabilitation of non-active ponds, crop insurance schemes, optimum farm size (economies of scale) and social research to avoid conflicts. Taiwan is studying captive broodstock improvement, disease prevention, viral identification technology, and predator and plankton control. It is also investigating the relationships between water quality, nutrition, automatic monitoring and feeding systems.

From the above list of priorities, the research concerns that would be system-neutral are broodstock development, improved and healthy seed, site suitability, carrying capacity, water intake and drainage systems, research on avoidance or resolution of social conflicts, and economic studies. Those that apply more to the extensive and improved extensive systems are crop rotation, polyculture (including alternative species) and bio-fertilisers. Studies that apply to semi-intensive and intensive systems are water recirculation systems, low-polluting and high-quality feed, nutrition and feeding regimes, viral disease diagnostics and control, immunostimulation, vaccine development, bio-enhancers or probiotics, effluent treatment, and sediment management.

Sharing Research Responsibilities

The following exercise is only illustrative. It attempts to show how the competencies of the participating governments could be brought together to work on common problems for cost-effective collaborative research.

By research area

- Viral disease studies—Thailand, Australia
- Broodstock development (genetics)—Thailand, Malaysia, the Philippines, Australia
- Healthy seed and hatcheries—Philippines, Thailand, Malaysia, Australia
- Problem soils amelioration—Australia, Sri Lanka, India, Indonesia
- Integrated and rotational culture systems—China, Vietnam, Bangladesh, India, Indonesia, the Philippines
- Feed and nutrition—Thailand, Australia
- Low water-use systems—Thailand, Malaysia, Australia
- Bio-enhancers/probiotics—Thailand, Malaysia, Australia, Philippines, China
- Integration of aquaculture and mangroves—Vietnam, Bangladesh, Indonesia, Thailand, Malaysia

By research tool

- Biotechnology for disease studies—Thailand, Australia
- Biotechnology for studies on bio-enhancers/probiotics—Malaysia, India, China, the Philippines, Thailand, Australia
- Geographical information systems—Thailand, Australia, India, Malaysia (Sabah)

Researchable Issues and Research Needs

The following research issues were summarised from the recommendations made in recent country survey reports (FAO/NACA 1995; ADB/NACA 1995).

On-farm management issues

- Assistance with diseases of unknown origin
- Prevention of diseases
- Pond bottom soil and water analysis
- Effluent management
- Use of probiotics
- Feed from locally available material, cheaper pelleted feed
- Feeding regime
- Environmentally sensitive intensification
- Stocking densities that give maximum profitability
- Economies of scale—size of production area (pond and farm)
- Water circulation systems
- Quantity and quality of seed

Environmental issues

- Design of farming estates—separate intake and discharge canals
- Carrying capacity of watershed areas
- Problem soil management and amelioration
- Site selection
- Reservoir and sedimentation ponds
- Larger sized farms tend to be more involved in social conflicts
- Water quality and sediment management
- Less flushing, less water exchange
- Biological treatment, reduction in use of chemicals and drugs
- Buffer-zone areas
- Assessment of land use
- Zoning: identification and assessment of suitable shrimp zones

Policy issues

- Monitoring of external threats to aquaculture
- Insurance system to cover environmental changes
- Effluent discharge standards, optimum practical limits of effluent
- Mangrove management guidelines
- Integrated approaches to use of inland and coastal resources

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Appendix

Research Needs by Country/Territory

India

- Use of bio-fertilisers and bio-filters
- Improved feed and seed quality, bio-genetic capacity
- Definition of optimum levels of physico-chemical parameters, including optimisation of feeding rates

Malaysia

- On-farm water management
- Reduction in water exchange requirements
- Improvement of performance in acid sulphate soils
- Disease diagnosis and monitoring
- Water quality monitoring systems
- Biological filters/integrated systems

Philippines

- Broodstock development in ponds
- Water quality monitoring systems
- Integrated management system using biological filter organisms
- Reduction of pond water exchange
- Disease diagnosis, control and treatment
- Water pollution control
- Genetic improvement

Sri Lanka

- Effluent treatment
- Disease diagnosis, prevention and control
- Amelioration of acid sulphate soils and potential acid sulphate conditions
- On-farm water quality management and improvement in quality of water supply
- Management of pond sediment
- Social research to minimise conflicts

Taiwan

- Disease prevention
- Virus identification technology
- Relationship between nutrition and water quality
- Captive maturation technology to improve broodstock quality and fecundity
- Genetic improvement of captive matured stock
- Development of specific pathogen-free broodstock
- Improve productivity and feed for shrimp polyculture systems
- Optimum teaseed cake application for effective predator control
- Automatic monitoring and feeding systems

Thailand

- Feed, feed quality, feeding
- Use of chemicals and antibiotics
- Integrated coastal farming
- Shrimp broodstock development
- Environmental impacts of drugs and chemicals
- Impacts of effluent on ecosystems
- Environmental impacts of seawater irrigation systems
- Development of low water-use systems

Vietnam

- Disease prevention and cure
- Integrated shrimp/mangrove systems
- Survey of coastal ecological systems and effects of environmental change
- Conservation and rehabilitation of reservoirs, mangroves and brackish waters
- Improved extensive and semi-intensive systems