PROJECT PN9412: MIXED SHRIMP FARMING-MANGROVE FORESTRY MODELS IN THE MEKONG DELTA

Termination Report

Part A – Main Report and Executive Summary

June 1999

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

RESEARCH INSTITUTE FOR AQUACULTURE NO. 2

NETWORK OF AQUACULTURE CENTRES IN ASIA-PACIFIC

PREFACE

This report consists of two parts, Part A, containing an executive summary and the main body of the report, and Part B, which consists of technical appendices with details of the research carried out.

Many people, too numerous to mention individually, have contributed to the work carried out in this project. For the most part, scientific and technical contributions are recognized by the authorships of the various appendices in Part B of the report. Here, however, we wish to acknowledge some special contributions to the project. Firstly, we acknowledge with gratitude the outstanding contribution of Dr. Danielle Johnston, the full-time Project Scientist, who had a key role in the design, implementation and analysis of the technical aspects of the project, and in the training component. Secondly, we wish to thank Mr. Barney Smith, the Coordinator of the ACIAR Fisheries Research Program, under the auspices of which this project was carried out. His wise counsel and constant support have contributed immeasurably to the outcomes of the project. Thirdly, we acknowledge the special interest and support of Dr. Nguyen Viet Thang, Director of the Research Institute for Aquaculture No. 2 at the time this project was carried out. Finally, we thank the farming families of Tam Giang III and SFFE 184 Enterprises for their hospitality and willing participation. We hope that they will benefit greatly from the results and recommendations of the project.

The Project Leaders

DISCLAIMER

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Executive Summary

PROJECT	PN 9412: Mixed shrimp farming mangrove forestry models in the Mekong Delta
COMMISSIONED ORGANISATION	Australian Institute of Marine Science
PROJECT LEADERS	Australia – Dr Barry Clough Thailand - Dr. Michael Phillips Vietnam – Mr Tran Thanh Xuan
DATE OF COMMENCEMENT	1 July 1995
DATE OF COMPLETION	31 August 1998

AIMS OF PROJECT

The overall goal of the project is to optimise the economic yield from mixed shrimp aquaculture-mangrove forestry farming systems in Ca Mau Province in a sustainable manner. Specific objectives for the project were to:

- Investigate factors controlling the yields of shrimp and wood from existing shrimp farming-mangrove forestry systems in Ca Mau Province
- Experiment with shrimp pond and mangrove forest management to evaluate different culture options
- Identify improved culture methodologies for these systems and to quantify where possible their expected yields and costs.
- Assist national and provincial authorities to transfer the results of the project to the wider coastal farming community in the Mekong Delta.

DESCRIPTION OF WORK

The project was carried out mainly in two State Fisheries-Forestry Enterprises (SFFEs) in Ca Mau Province, at the southern tip of Vietnam. Research was carried out on a number of topics; shrimp pond ecology and chemistry; water quality; shrimp seed supply and recruitment; shrimp harvest characteristics; pond design and farm management practices; factors limiting forest growth and yields; forest management practices and options for improving yields; infrastructural, social and economic constraints; the incidence of shrimp disease and disease risk management; and diversification of farm production (mainly with crab culture). Research activities were carried out using robust, widely used methods, adapted where necessary to suit local conditions.

RESULTS, CONCLUSIONS AND ASSESSMENTS

Most farmers rely on natural shrimp seed to stock their ponds. The supply of natural seed is poor and unreliable, both in the main rivers or canals, and more so in smaller secondary canals. To make matters worse, relatively low value *Metapenaeus* species make up more than 80% of the seed recruited into ponds. Possible reasons for the lack of seed of higher value *Penaeus* species include overfishing of broodstock and juveniles, both offshore and in the main rivers and canals, reduced migration of juveniles into waterways, and the lack of mangrove nursery areas. The latter is due partly to loss of mangroves, and partly to poor access to remaining mangrove areas, most of which are surrounded by ponds or levees.

Notwithstanding poor natural seed supply, shrimp yields and farm incomes of the most successful farmers were up to 4 times greater than the average for all farms, and up to 16 times greater than the least successful farms. This was due mainly to better pond design and water management practices that give a large pond volume, a more constant water level and more stable water quality. Simple, low-cost changes to pond design and farm management practices therefore offer a cost-effective way for less successful farmers to raise farm outputs and income to at least the present level of the more successful farmers.

Some farmers stock part of whole of their ponds successfully with hatchery reared postlarvae of *P. monodon*. Those that have been successful usually have better pond designs that minimise fluctuations in water quality, and are also usually better managers of their farms. Semi-intensive culture using hatchery reared postlarvae at low stocking densities is considered to be a viable option for farms with good pond design and good management practices. For many farms, however, attention would need to be given to improving pond design and management skills before they shift to semi-intensive culture of *P. monodon* or *P. indicus*. A sensible approach would be to start semi-intensive culture in a small, improved section of the pond and then for the farmer, after having gained success and experience, to gradually increase the area of pond given over to semi-intensive culture. However, caution should be exercised in shifting farms entirely to semi-intensive culture because of the ever present risk of losing a crop from disease or from uncontrollable changes in water quality, particularly given the highly variable and often poor quality of hatchery reared postlarvae. A sensible risk management strategy would be to maintain part of the pond area under extensive culture of wild shrimp with improved pond design and better management.

The risk of shrimp mortality from disease and poor water quality is a major factor affecting income security for farmers. The risk of mortality from disease and other causes can be reduced, and income security improved, by the adoption of better pond design and management practices. Income security would also be improved dramatically by diversification of the cultured species (including mud crabs), and by growing appropriate cash tree and vegetable crops on levee banks and other elevated areas.

By comparison with shrimp culture, there are fewer options for improving wood production from mangrove forests in Ca Mau Province. Since the prevailing climatic, tidal and soil conditions cannot be altered easily, the only realistic options for improving wood production are to change existing silvicultural practices or the species grown.

Modelling and direct measurement both suggest that changes to silvicultural management practices could increase the growth rates of *R. apiculata* in many parts of Ca Mau Province by 10-20%. The former planting density of 20,000 per hectare (pre 1992 policy) was too high, but the present policy of planting at 10,000 per hectare is consistent with the recommendations of this project. Heavier thinning (by about 50%) at about 9 years of age and again at about 14 years of age is predicted to improve production by 10-20%, but there is also an option to cut the forest completely at 14 years of age, thereby shortening the rotation. This would do much to reduce farmer concerns and low incentives related to poor short-term economic returns from mangrove forestry.

Only older mangrove stands (>=20y) produced significant numbers of seed (propagules). These older seed stands were the most seriously damaged by Typhoon Linda, suggesting a future shortage of seed for mangrove afforestation in Ca Mau province. This may impact on the afforestation component of the World Bank/DANIDA Coastal Wetlands Project. Furthermore, a reduction in the rotation from 20 to 14 years, would require that some areas of mangroves be set aside as seed stands.

The results of this project show clearly that good pond design and management are much more important in determining shrimp yields than the farming system employed. Overall, there was little to separate both separate and mixed farming systems, both presently being capable of producing better than average yields with appropriate farm designs and management. However, mixed shrimp-mangrove systems may not be sustainable in some parts of Ca Mau Province over the longer term. Already there is evidence that most mangrove forests grown on levees within ponds in mixed shrimp-mangrove farming systems are above the highest spring tides and hence are not flushed by tidal water. This is partly because soil excavated to make the pond is placed on the levees where mangroves are grown, and partly because the Ca Mau Peninsula is a net sink for fine sediment originating in the Mekong River catchment. Ponds and mangrove areas within ponds, in particular, act as sediment traps, ponds in some cases trapping up to 10 cm fine sediment annually. In consequence, land levels in both Tam Giang III and SFFE Enterprises appear to be rising at a rapid rate. This will decrease the growth rate and yields from mangrove forest, for which there is already circumstantial evidence. Another advantage of separating the pond from the forest (separate system) is that each can be managed optimally for maximum production without having to make a compromise in managing one to accommodate the other.

Opportunities for farmers to improve their farms and to invest in alternative cropping systems are presently limited by access to loans, which are short term and usually have high rates of interest. Farmers have difficulty obtaining institutional credit at more reasonable interest rates, partly because of they do not own their land and therefore have no collateral, and partly because shrimp farming is seen by institutional lenders as a high risk activity. Innovative approaches involving closer cooperation between lenders, farmers, provincial authorities and extension officers could offer opportunities for farmers to gain credit with a reasonable surety that loans will be repaid.

PUBLICATIONS

Six papers have been accepted or submitted for publication in refereed international scientific journals. Two papers have been presented at meetings of other related regional projects, and will shortly be published in the proceedings therefrom. A further six or so scientific publications suitable for submission to international scientific journals have been identified. Some of these are in preparation.

FOLLOW UP

This project has largely achieved its objectives of assessing the main factors limiting shrimp and wood production, and identifying simple and cost-effective options for improving farm production and income security. In addition, a number of workshops for farmers and provincial extension officers have been held to extend project findings to end users. However, the project has not yet fully achieved its objective of assisting national and provincial authorities to transfer project results and recommendations to coastal farming communities in the lower Mekong Delta. In the longer term the success of the project will be judged by its impact on the ultimate beneficiaries, the coastal farming communities of Ca Mau and nearby provinces.

An extension of the project for a period of 12-18 months, as recommended in the project review, would enable it to assist national and provincial authorities to develop the materials and a strategy to ensure the transfer of project results to farmers, both in the shorter and longer terms. Drawing on the combined experience and resources of present project staff and collaborating agencies, together with additional inputs from other institutions with appropriate expertise and experience, an extension of the project for 1 year would focus on:

- The preparation of appropriate extension materials for provincial extension officers and for farmers, based on the findings and recommendations of the project.
- Training a core group of provincial extension officers to a high level of competence.
- Developing linkages with other existing and planned new projects in the lower delta provinces, so than other projects can build on the results and experience of the present ACIAR project, thereby maximising spillover benefits. This is seen as a key activity in ensuring long term benefits to farming communities from the present project. The more developmental orientation of planned new projects in lower Mekong Delta would provide an appropriate channel to maximise spillover benefits.

Background

All coastal provinces in Vietnam have identified shrimp culture as a priority area for development and research (Ministry of Fisheries, Vietnam, 1992). Rapid and unregulated expansion of shrimp farming in sensitive coastal environments of Vietnam could result in a repetition of the widespread loss of mangrove habitat, environmental pollution and deterioration in shrimp farm productivity experienced in Thailand, the Philippines and elsewhere. Mangrove forests serve a large number of functions for the human population in tropical coastal regions, including the provision of housing materials, support of coastal fisheries, buffering against storms and trapping of sediments (Saenger *et al*., 1983). The biggest losers in the uncontrolled expansion of coastal shrimp industries and their boom and bust cycle are the fishing families and coastal poor who depend on mangrove forests and their associated fish and forest products (Pullin, 1993).

Severe landuse conflicts occur in the large areas of the intertidal, mangrove dominated habitat that makes up much of Ca Mau province in southern Vietnam. In addition to supporting coastal capture fisheries and providing protection from storms, mangrove forests currently supply most of the firewood needs for domestic heating in the Province, but are unlikely to meet the projected requirements for the year 2000. Recent, rapid expansion of coastal shrimp aquaculture has resulted in destruction of more than half the forest that existed in 1982. Provincial managers have reacted to this situation by establishing 22 State Fisheries Forestry Enterprises (SFFEs), where both shrimp and mangrove wood are produced by individual farmers on small holdings. These enterprises offer a potential solution to the problem of conflicting land use. However, farm production and income has declined in recent years.

Project Objectives

The overall goal of the project is to optimise the economic yield from mixed shrimp aquaculture-mangrove forestry farming systems in Ca Mau Province in a sustainable manner. Specific objectives for the project are to:

- Investigate factors controlling the yields of shrimp and wood from existing shrimp farming-mangrove forestry systems in Ca Mau Province
- Experiment with shrimp pond and mangrove forest management to evaluate different culture options
- Identify improved culture methodologies for these systems and to quantify where possible their expected yields and costs.
- Assist national and provincial authorities to transfer the results of the project to the wider coastal farming community in the Mekong Delta.

Research Activities

STUDY AREA AND SITES

The project was carried out in the Ca Mau Peninsula, southern Vietnam (Fig. 1). When the project commenced in July 1995, the entire Ca Mau Peninsula fell within the boundary of single province, Minh Hai Province. However, early in 1996 Minh Hai Province was split into two provinces, Bac Lieu and Ca Mau. Two enterprises, Tam Giang III and SFFE 184, in the Ngoc Hien District of what is now Ca Mau Province were selected as the main foci for research activities, in consultation with national, provincial and enterprise officials (Fig. 2). Both enterprises are designated by provincial authorities as State Fisheries-Forestry Enterprises (SFFEs). Some forestry plots were also established in Kien Vang Enterprise, in order to include forest ages not represented in Tam Giang III or SFFE 184 Enterprises.

FARMING SYSTEMS

Two main fisheries-forestry farming systems presently operate in Ngoc Hien District (Cuong, 1995).

Traditional capture fisheries-mangrove forestry farming system. In this system, being carried out in **Kien Vang Enterprise**, mangrove forest occupies more than 80% of the enterprise area. Here forest management aims to produce a final yield 200 m^3 wood ha^{-1} when harvested at 20 y. Fisheries products come from capture fisheries only; pond culture is not practised.

Fisheries-forestry farming system. In this system, practiced in **Tam Giang III** and **SFFE 184 Enterprises**, farm households are officially assigned 5-10 ha of land on which they must carry out both shrimp culture and forestry. Two different farming models are practiced in Tam Giang III.

- Separate pond (20-30% of farm) and forest (70-80% of farm) areas.
- Combined shrimp farming-mangrove forestry on the same area of land. Shrimp culture is carried out in canals or channels dug in the forest. The area for shrimp farming (canals, channels and levees) is restricted to 20-30% of the total farm area.

Separate and combined models are both used in Tam Giang III, but most farms in 184 use the combined model.

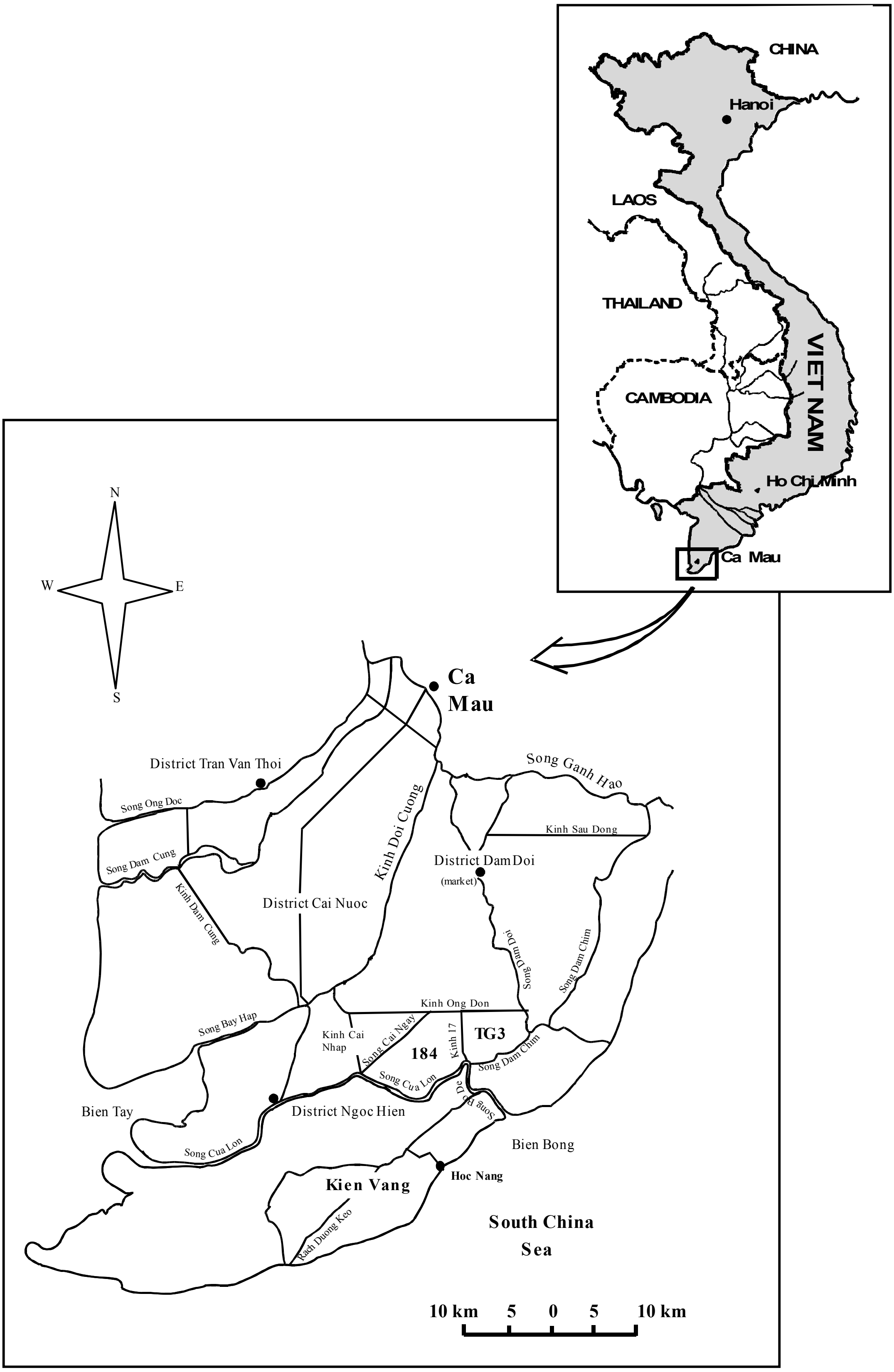

Figure 1. Map showing the location of enterprises TGIII and 184 in Ca Mau province of southern Vietnam (situated on the Ca Mau peninsula). Both enterprises were formerly in Minh Hai province, which was recently subdivided into Ca Mau and Bac Lieu provinces.

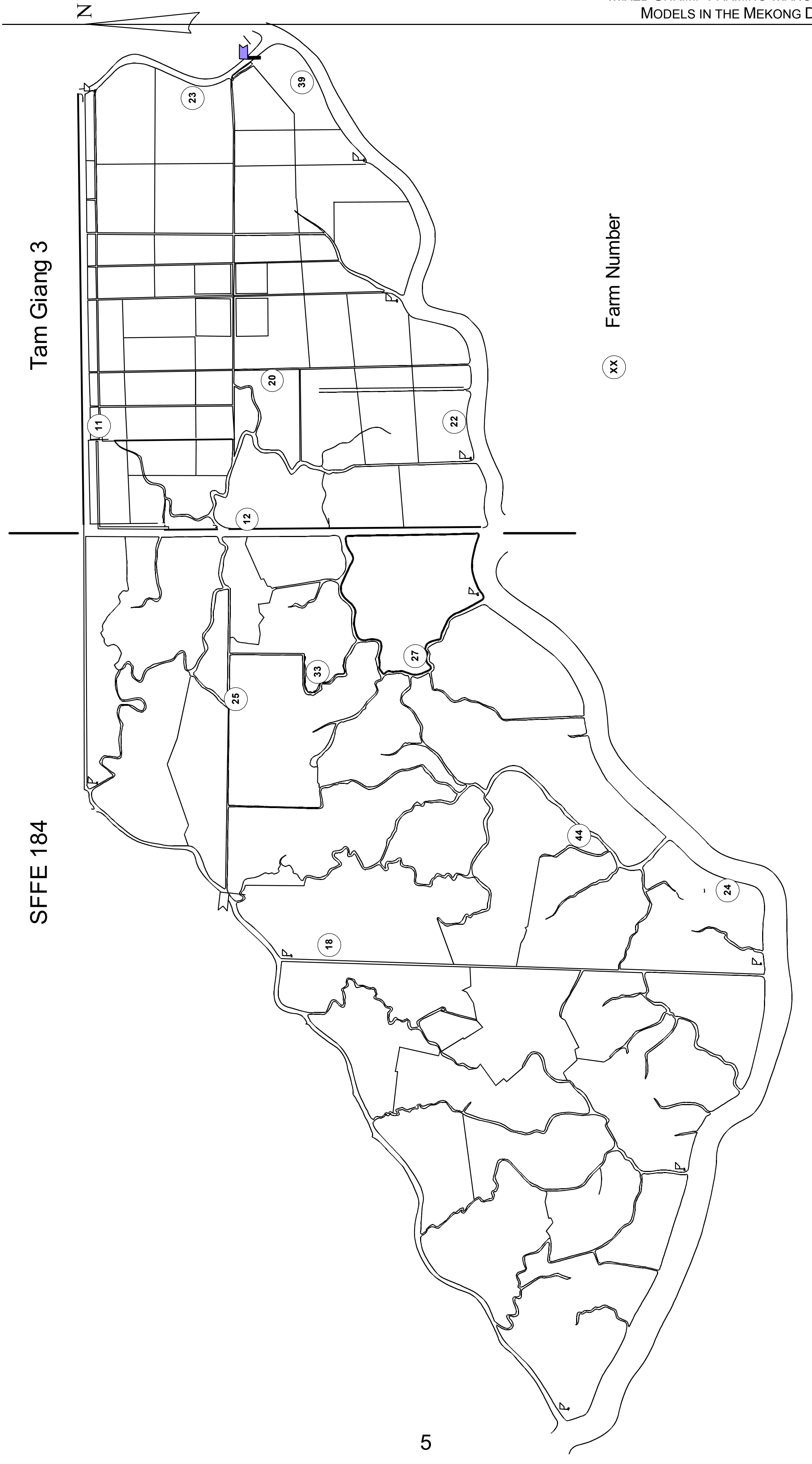

Figure 2. Map of SFFE 184 and Tam Giang 3 Enterprises indicating the location of farms selected for the baseline survey and subsequent experiments.

Fig. 3. Flow chart of project activities.

	Year 1												Year 2												Year 3											
	(1/7/95 - 30/6/96)												(1/7/96 - 30/6/97)												(1/7/97 - 30/6/98)											
Activity	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
General																																				
Appointment - Project Scientist					■	■	■	■	■																											
Startup Workshop		■																																		
Staff training			■	■																																
Equipment purchase/installation			■	■	■																															
Extension														■																						
Final w orkshop																																				■
Reports												■												■												
Internal mid-term review													■																							
Database training													■																							
Research (Vietnam)																																				
Socio-economics																																				
Socio-economic survey										■	■																									
Shrimp culture																																				
Survey of pond/w ater quality						■	■	■	■	■	■	■	■	■	■	■	■																			
Post larval recruitment study														■	■	■	■	■	■	■	■	■								■	■	■	■	■		
Pond yield survey													■	■	■	■	■	■	■	■	■	■														
Management practice survey																												■	■							
Pond liming and grow out manipulations																						■	■	■												
Pond stocking trials																													■	■	■	■	■			
Intensive nutrient dynamics studies																■						■	■						■	■						
Shrimp disease																																				
Pilot disease assessment & w orkshop													■	■																						
Full disease risk survey																						■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Diversification of farm outputs																																				
Crab stocking trials																						■	■	■	■	■	■	■	■			Repeat				
Forestry/Silviculture																																				
Survey of forest production rquirements		■																																		
Forest biomass & grow th studies									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
Forest thinning trials																		■	■	■	■	■	■	■	■	■	■	■	■							
Synoptic soil survey									■	■	■	■	■	■	■																					
Tidal measurements													■	■	■	■	■	■	■	■	■	■	■	■	■											
Intensive forest canopy studies																					■	■														

Description of Research

Research was carried out in 5 key areas:

Socio-economic conditions and contraints

Shrimp pond ecology

Mangrove forest silviculture

Shrimp disease incidence and risks

Diversification of farm outputs through crab culture

The first three of these components were described in the project proposal. The last two components were added in about midway through the project in response to a request from Vietnam in the face of declining shrimp yields in 1994-95, apparently associated with an outbreak of disease in the Ca Mau Peninsula. These additional components were implemented with assistance from Dr. Clive Keenan of the Bribie Island Aquaculture Centre (crab culture), Dr. Pornlerd Chanratchakool of the Aquatic Animal Health Research Institute, Bangkok (shrimp disease), and Dr. Nguyen Van Hao of the Research Institute of Aquaculture No. 2, Ho Chi Minh City (shrimp disease).

Socio-economic Conditions and Constraints

A broad ranging socio-economic survey was carried early in the project (Fig. 3) to assess current socio-economic circumstances, and to obtain data on farm management practices and problems. The survey was based on a questionnaire developed by NACA and modified to suit the purposes of the present project. This survey was carried out chiefly by staff of Can Tho University. A smaller scale follow up survey of selected farms was carried out in 1998 (Appendix XI).

Shrimp Pond Ecology

Early in the development of the detailed project work plan it was decided to carry out a broad scale baseline survey of pond conditions in farms at different locations in Tam Giang III and 184 enterprises, in order to gain some insight into enterprise-wide spatial variability in environmental conditions in ponds, and as a pre-requisite to the selection farms for specific studies and experimental manipulation. As originally envisaged, this sampling program was to involve 15 farms in each of Tam Giang III and 184 Enterprises (giving a total of 30 farms). However, it became clear that such a sampling program was logistically impossible within available resources, and the number of farms was subsequently restricted to 6 in Tam Giang III Enterprise and 6 in Enterprise 184 (Fig. 2). The baseline survey involved sampling for water quality and for components of food chains (phytoplankton, zooplankton and zoobenthos). Some characteristics of these farms are given in Table 1.

Table 1. Characteristics of farms involved in base line survey and subsequent experiments

Enterprise	Farm ID	Latitude (N)	Longitude (E)	Farm Owner	Farm Location	Farm Type	Farm Area (ha)	Pond Area (ha)	Sluice Gate Width (m)	Sluice Gate Type
TGIII	11	8.85	105.19	Mr Dung	canal	separate	11.6	1.7	1	cement
TGIII	12	8.83	105.19	Mr Hoang	river	mixed	13	2.6	1	cement
184	18	8.12	105.13	Mr Viet-Hong	river	mixed	10.06	3.56	1	cement
TGIII	20	8.82	105.21	Mr Liem	canal	mixed	3.8	0.5	0.8	wood
TGIII	22	8.79	105.20	Mrs Anh	river	separate	10	1.1	0.8	wood
TGIII	23	8.83	105.25	Mr Hung	river	separate	1.8	0.68	1	cement
184	24	8.76	105.14	Mr Kiet	river	mixed	6.3	2.1	1	cement
184	25	8.83	105.16	Mr Hai	canal	mixed	7.4	4.44	1	cement
184	27	8.80	105.17	Mr Cui	canal	mixed	17	5.9	0.8	wood
184	33	8.81	105.17	Mr Tung	canal	mixed	7.14	2.74	1	cement
TGIII	39	8.80	105.23	Mr Thanh	river	separate			0.8	wood
184	44	8.78	105.15	Mr Lon	canal	mixed	4.2	2.4	0.8	wood

Several more intensive studies were also carried out, chiefly by AIMS staff. An intensive study of within pond variability in water quality parameters was carried out in October 1996 (see Appendix II) to confirm that existing sampling protocols were robust; diurnal and depth profiles of key water quality parameters (temperature, salinity, dissolved oxygen, pH) were measured in October 1996 and again in March 1997 (Appendix II); and intensive studies of pond biogeochemistry and nutrient budgets were carried in October 1996 and May 1997. A final sampling was carried out in November 1997, mainly at the expense of the Commissioned Organisation, in order to complete robust nutrient budgets for shrimp ponds in the study area.

An investigation of shrimp seed recruitment to ponds was initiated in August 1996. Sampling for this study was carried out by staff of the Research Institute for Aquaculture No. 2. Monthly sampling according to the lunar cycle continued until April 1997 (Appendix III). Data on shrimp seed loss during harvesting operations, and on pond yields were collected concurrently with the recruitment study (Appendix IV).

Pond manipulation experiments to test the effect of liming on pond water quality and increasing the length of the grow out period were initiated in March 1997. The background and design for these experiments is given in Appendix V. An experiment was conducted to determine the optimal densities and overall success of *P. monodon* culture as an alternative to stocking wild shrimp (Appendix VI). An assessment of the feasibility of stocking hatchery reared larvae was important as wild shrimp supplies have declined in recent years and are relatively unreliable. Preliminary data suggested yields were greater at farms on rivers than farms on small inner canals. As water quality is similar between locations the possibility of differences in post larval recruitment between these locations was investigated (Appendix VII)

Finally, detailed data were collected on farm management practices on both successful and unsuccessful farms, in order to assess the impact of management practices on pond yields (Appendix I).

Mangrove Forestry/Silviculture

A broad ranging survey of the soil conditions and tidal flushing of mangrove forests was carried out to assess whether soil conditions might be a major limitation to growth. In addition to providing information on soil factors that might potentially limit the growth and yield of mangrove forest, this survey also provided complementary data to the general water quality survey relevant to the suitability of the area for shrimp culture.

Forest growth rates were measured in 72 permanent plots established in stands of various ages from 6 to 37 years. Most stands sampled had been initially planted at a density 20,000 stems per hectares. Plots were re-measured in March – June 1996, after one year of growth.

The analytical approach taken was to model these stands of different age as a chronological sequence in the growth of a 'typical' planted mangrove stand in Ca Mau Province, and then compare the modelled rate of growth with direct measurements over a period of 1 year.

Thinning trials involving thinning by 20%, 30%, 35% and 50% were also established in stands of differing ages in order to assess optimal thinning strategies. Unfortunately, Typhoon Linda struck the project area in November 1997, destroyed a large number of trees in the thinning trial before the plots had been re-measured. However, these plots may still yield useful data in the longer term.

These studies were complemented with more intensive studies of canopy structure, light absorption and photosynthesis, in order to evaluate optimal thinning strategies using modelling techniques.

Shrimp Disease

The shrimp disease component was initiated midway through the project in response to widespread mortality of shrimp in the project area in 1994-96. An initial disease risk assessment and farmer extension workshop, carried out by Dr. Phillips (NACA) and Dr. Pornlerd (AAHRI) in July 1996, identified

- the need for a more extensive assessment of the incidence of shrimp disease (particularly the white spot virus) in the area,
- the need to enhance the capability of Vietnam to carry out histopathological and PCR testing for shrimp disease,
- the need to train extension workers and farmers in the recognition of diseased animals and management techniques to minimise the risk of disease.

A research program to address these issues was formulated (Appendix X), and training and research activities were commenced in May 1997.

Crab Culture

Given the apparent loss in shrimp production from disease, options for alternative aquatic animal culture species were also explored. Of the options available, crab culture appeared to be the most promising, particularly as some farmers in the area were already fattening crabs successfully. Following the success of ACIAR Project PN9217, Dr. Clive Keenan was requested to prepare a research program to assess the carrying capacity of mangrove forest for mud crabs, and to investigate further the technology for producing hatchery reared crab seed (Appendix IX). These trials were initiated in April 1997, but unfortunately were badly affected by Typhoon Linda in November 1997. The stocking trials were repeated in January 1998.

Research Results

The main results and conclusions are summarised below:

POND DESIGN AND MANAGEMENT (APPENDIX I)

Results

- Ponds are generally too shallow (mean of 50 cm and < 30 cm during neap tides). Water level fluctuates markedly (up to 73 cm in 15 days) due to water leakage problems. Pond depth was positively correlated ($r = 0.62$; $p<0.05$) and maximum fluctuation in pond depth was negatively correlated with yields ($r = - 0.55$; $p<0.05$).
- Water quality changes more rapidly and to a greater degree when ponds are too shallow or their water level fluctuates markedly.
- Farms with deep ponds (1 m) and a stable water level (no water leakage problems) have higher yields than farms with shallow ponds and fluctuating water levels.
- A preliminary analysis suggests that harvested shrimp are marginally bigger (equivalent to one months growth of 1 cm) after a 60 day growout period, compared to the 15 day growout period traditionally employed. However, total yields over the 60 days using a 15 day growout cycle were substantially higher than yields from the 60 day farms. That is, the increase in shrimp size after 60 days did not outweigh the monetary benefits of multiple 15 day yields. (Refer Appendix V)
- Management options are restricted by the need to rely on tidal cycles for recruitment and harvesting (must be carried out on spring tides).
- The current practice of recruiting natural seed, followed immediately by harvesting on the same tidal cycle leads to a significant loss of recently recruited seed, which substantially reduces the potential stocking density and pond yields.
- No active method is employed to ensure that all animals recruited in one cycle are harvested at the end of that cycle.
- Successful farmers adopt specialised harvesting techniques which remove only large shrimp from ponds and leave small ones to grow in ponds for up to 4 months. The size of shrimp harvested (50-60cm) is consistent with shrimp remaining in ponds for up to 4 months.
- Material excavated during pond construction is piled on internal levees. The placement of potentially acid sulphate material on levees can lead to a decrease in pond pH during the wet season.
- Fine sediment that settles on the pond bottom is often not cleaned out between crops.
- A combination of only 1 sluice gate and a relatively large total pond area subdivided into channels by internal levee banks contributes to poor water circulation and mixing.
- Farmers who manage their farms well can be successful. (The three most successful farms also happen to located on main waterways, where seed stocks appear to be highest).

- Heavy reliance on shrimp for income – lack of diversification so the risk to farmers is high.
- Some farmers have been successful in raising *P. monodon* from hatchery reared post larvae.
- Presently, there appears to be a serious lack of effective extension advice to farmers on good pond design and farm management practices.

Implications and Conclusions

- Current recruitment and harvest techniques need to be improved to reduce PL losses and improve stocking density.
- Pond water leakage must be controlled and minimised. This will allow farmers to maintain pond depth of at least 1m and reduce water level fluctuations, both of which will lead to more stable water quality.
- Farmers should clean the pond bottom at least once, and preferably twice per year.
- Adopt specialised harvesting techniques such as the "against water current technique" to maximise the size of shrimp harvested and allow small juveniles to remain in ponds for growout.
- Diversify into cash crops, crab culture and possibly fish culture to broaden the income base and reduce risk to farmer income from losses due to shrimp disease.
- Improve extension to farmers by establishing a more educated and consistent extension service.

WATER QUALITY (APPENDIX II)

Results

- Pond water quality is not significantly different from canal or river water quality.
- Pond water quality is generally characterised by
  - ♦ Low to moderate dissolved oxygen concentration (3.7 ± 0.15 mgL^{-1}; drops to 1 mgL^{-1})
  - ♦ Low chlorophyll *a* concentration (0.14 ± 0.05 μgL^{-1})
  - ♦ Low phytoplankton densities (5562-17928 $cellsL^{-1}$)
  - ♦ High levels of suspended solids (0.3 ± 0.03 gL^{-1})
- 8 of the 12 farms surveyed have potentially acid sulphate soils (dry soil pH<4).
- Extreme seasonal fluctuations and diurnal fluctuations in dissolved oxygen, total suspended solids, pH and salinity. DO becomes critical prior to dawn (1-2mgL^{-1}). Rapid fluctuations in water quality appear to have an adverse effect on shrimp health and pond yield.
- Water quality deteriorates significantly in the wet season.

- Dissolved oxygen, chlorophyll *a* and pond bottom eh improved marginally with an increased 60 day growout due to a longer residence time of pond water (promotes phytoplankton growth).
- Water quality did not differ significantly between mixed and separate farming systems.
- There was greater variability in water quality parameters (within ponds) in mixed than in separate systems, due mainly to differential shading by the mangrove canopy.
- Acidic pH due to high organic load through mangrove litter fall (bacteria reduction and oxidation) and possible exposure to acid sulphate soils.
- High levels of ammonia at some farms (0.13 ± 0.02 mgL^{-1}). Ammonia concentration negatively correlated with yields ($r = -0.63$; $p<0.05$)

Implications and Conclusions

- Water quality overall is not good, but it does appear to be good enough to permit higher yields than presently; it should permit stocking densities up to about 1-2 animals m^{-2}.
- The most important factor in improving yields and to reduce the risk of disease is to reduce fluctuations in water quality. Fluctuations in water quality can be reduced by increasing the volume of water in the pond and by maintaining a stable water level. The minimum water depth in ponds should be not less than 0.7-1 m. Where necessary, ponds need to be deepened and leakage reduced. It may also be desirable to reduce or eliminate internal levees, partly because these reduce the water volume, partly because they are often a source of acid which is washed out by rain, and partly because they hinder water circulation and mixing. On the other hand, internal levees do increase the effective feeding area available to shrimp, which could be important in ponds where shrimp are reliant on natural food supplies.
- An improvement in water clarity by reducing the level of suspended solids would enhance phytoplankton growth, thereby increasing dissolved oxygen levels. By reducing leakage there is less need to top up ponds during neap tides, increasing the residence time of water in the pond. This will promote settlement of suspended solids, albeit slowly, and allow greater phytoplankton growth (but note next point). Adopt minimum water exchange during neaps and maximum exchange during springs.
- The use of a settlement pond to improve water clarity may not be cost-effective. Judging from the particle sizes on the surface of mangrove soils, about 80% of the suspended material is less than 17 microns in size, and about 40% is less than 4 microns in size. The settling rate for particles of these sizes is quite slow, even under static water conditions, so that a long residence time in the settlement pond may be required in order to effect a significant improvement in water clarity. Given the leakage problems of many ponds and the poor quality of water sources outside the pond, it may be more cost-effective to avoid a settlement pond and adopt a minimum water exchange strategy in the culture pond, as outlined in the previous point.
- Shrimp should not be stocked at the beginning of the wet season as water quality deteriorates significantly at this time. Other crops, including fish and agricultural

crops, might be planted at this time, and ponds stocked again with shrimp in September-October when wild recruitment is high and water quality has stabilised.

FOOD SUPPLY (APPENDIX II)

Results

- Low phytoplankton densities (5562-17928 cellsL^{-1}).
- Moderate zooplankton densities.
- Moderate zoobenthos densities.

Implications and Conclusions

- Zooplankton and zoobenthos densities appear to be adequate to sustain the current low natural stocking densities, and are likely to be sufficient to support stocking densities up to about 1-2 animals per m^2.
- Phytoplankton densities are too low and are consequently contributing to the low DO levels in ponds.

SHRIMP SEED SUPPLY (APPENDIX III, VII)

Results

- Recruitment of natural shrimp seed was generally low, with significant seasonal variability (peaks in October-November and March-April). Stocking density of ponds is low (mean 1.5 PL/m^2)
- Over the short term, natural seed recruitment peaked every 30 days on the no moon phase of the lunar cycle.
- Natural shrimp seed recruitment appears to be significantly better at farms on rivers and main canals compared to farms on small, inner canals.
- Low value *Metapenaeus* spp. represent more than 80% of the seed recruited.
- Most seed is about 10 mm in length.
- A significant proportion of the wild seed recruited on the incoming tide was lost from ponds during harvesting on the ensuing ebb tide.

Implications and Conclusions

- Low and unreliable stocks of wild seed are significant factors limiting pond yield on farms that do not stock with hatchery reared PLs.
- Reliance on low value *Metapenaeus* spp. fundamentally limits the yields and income potential of farms. Hatchery reared *P. monodon* should be considered.

- The traditional practice of recruiting wild seed on incoming spring tides, followed by harvesting on the ensuing ebb tide is highly inefficient, and is a major factor in low stocking densities of wild seed within extensive ponds.

SHRIMP YIELDS AND HARVEST CHARACTERISTICS (APPENDIX IV)

Results

- Yields vary considerably between farms and throughout the year with two peaks in March-May and July-October.
- Mean shrimp yields and resulting incomes are 286 kg/ha/yr and 388 USD/ha/yr, respectively. This is typical of extensive farming in Vietnam, although it is relatively low compared with other extensive farming systems in SE Asia.
- Despite the low overall yields some farmers are highly successful achieving yields above 1500 kg/ha/yr. Their success appears to be based primarily on better pond management (water quality conditions are generally similar between farms).
- Secondary products increase farm yields by 24% and farm income by 14%.
- Yields are positively correlated with pond depth ($r = 0.68$), negatively correlated with the maximum fluctuation in pond depth ($r = -0.55$) and negatively correlated with ammonia concentration ($r = -0.63$). Deep ponds (>1m) with a stable water level are essential for high shrimp yields.
- *Metapenaeus ensis* and *M. lysianassa* are the dominant species harvested (>80% of total shrimp harvested) followed by *P. indicus* (7-9 % of shrimp harvested).
- The size of shrimp harvested is small with a total body length of approximately 50mm.

Implications and conclusions

- Reliance on small low value Metapenaeids fundamentally limits the income potential of farms. This coupled with poor and unreliable wild seed recruitment contributes significantly to low shrimp yields. Farmers should consider stocking with hatchery reared larvae to increase shrimp yields considerably
- It is possible to increase shrimp yields to the level already attained by successful farmers by improving management techniques, particularly the maintenance of deep ponds with a stable water level and improving pond design.
- Diversification into cash crops and fish/crab culture should improve overall farm production as well as reduce the risk associated with reliance on shrimp.
- To optimise shrimp yields a separate silvo-fisheries farm model is recommended.

OPTIMAL STOCKING DENSITIES FOR HATCHERY REARED *PENAEUS MONODON* (APPENDIX VI)

P. monodon postlarvae suffered high mortality due to the stress incurred during transportation to the farm and the high incidence of MBV. Water quality problems at stocking also contributed. However, the large size attained by shrimp which survived, indicates that with improvements in transportation techniques, and PL quality and water quality, particularly at time of stocking, *P. monodon* culture is a viable option in Ca Mau province. The experiment should be repeated in future.

CRAB CULTURE COMPONENT (APPENDIX IX)

Experiments on optimal stocking densities for crabs did not yield significantly useful results. The first stocking trials were destroyed by Typhoon Linda. These were repeated in January 1998. However, the results were not conclusive quantitatively, because of an apparently low survival rate, which may have been an artifact of the method used to capture the crabs at the end of the experiment. Overall the growth rates were disappointing, mean crab weight increasing by only about 2.5 times over the 3 month stocking period, compared to other trials in the Philippines where weights increased by more than 30 fold over a period of 4 months (Appendix IX).

Notwithstanding the poor growth result obtained in this study, crab culture is still considered to be a potentially productive and profitable activity for some farmers. However, the wild crab population could be severely decimated should many farmers diversify to crab culture, given present problems with hatchery (see Appendix).

DISEASE COMPONENT (APPENDIX X)

Results

- White Spot Syndrome Virus (WSSV) was simultaneously present in wild shrimp seed and *Acetes* spp. during January, April and May. Monodon Bacilovirus (MBV) was present in wild seed all year round, and was detected more often in the separate farming system than in the mixed farming system.
- WSSV was present in harvested shrimp in most samples, particularly those collected in the rainy season and in the middle of the dry season. MBV was present in harvested shrimp all year round, with greater prevalence in the rainy season.
- Mass mortality occurred four times in the 1-year sampling period - in January, June, July and October. This was associated with the presence of WSSV at high percentage and intensity.

Implications and conclusions

The most important conclusion to be drawn from the results is that the disease risk was significantly higher around the peak of the wet season in July and August, and again in the months October, November and December, the middle of the dry season. These peaks in disease incidence correspond to the two extremes in the water quality regime. In the peak months of the wet season, low pH and rapid changes in salinity are likely to stress shrimp and predispose them to disease. And in the middle of the dry season, above average water temperatures may predispose the animals to disease. These extremes of water quality partly result from the poor design of ponds, most of which are too shallow and do not have an adequate water volume to minimise fluctuations in water quality. In consequence, an improvement in pond design, considered in more detail elsewhere (Appendices I , VIII and X), is considered a key first step to minimising the risk of mortality from disease.

SOCIO-ECONOMIC CONDITIONS AND CONSTRAINTS (APPENDIX XI)

Results

- Of the 211 respondents, 21 were women, the average age of the household head was relatively young at 44 years, the average family size was 5 persons, and the average residence time in the enterprise was only 4.2 years.
- Most farmers lacked long-term land rights ("red book" certificate), in general having only temporary contractual leases for their land, usually for 20 y but sometimes for up to 30 y ("green book").
- Most farms (94%) were operated almost exclusively using family labour, with an average of 3.3 labour persons per household, of which close to 50% were male and 50% were female.
- Education level was generally low, with most heads of households having only primary education. On average, farming families had only 4.6 y of experience in aquaculture.
- Aquaculture and fishery were the primary source of income for 87% of families, while only 2.5% of families received their main income from mangrove forestry. Average annual farm income was about 12.1 million Dong per household per year, but about 39% of the households surveyed had incomes below the UNDP (1995) poverty level.
- Farm households employing traditional techniques, dependent on wild seed only, had lower incomes than extensive farm households where farmers stocked with hatchery seed. However, traditional farmers tended to have less debt than extensive farmers, owing to the need for extensive farmers to borrow capital to purchase seed and carry out pond improvements, and the greater risk of financial loss should the crop fail as a result of disease or poor water quality.
- Farmers identified a number of problems:
  - ♦ High mortality (low production) of shrimp, their main source of income, which they attributed to poor water quality/soil conditions and to disease.
  - ♦ A lack of capital, and the difficulty/high cost of borrowing, to carry out improvements to the culture system. The difficulty and high cost of borrowing is correlated with the lack of collateral because most farmers have no long-term

land rights ("red book"), which is one of the factors limiting their opportunity to borrow through formal banking channels where interest rates are lower.

- Poor, and in some cases no access to technical and extension advice on aquaculture.
- Limited direct income from mangrove forestry. This is related to a number of issues, such as the present ban on the cutting of mangroves, the lack of long term land rights and a relatively short lease of about 20 years on their land, the relatively young age of mangroves on many farms, and the need to wait for at least 8-10 years to gain income directly from mangrove products (even if the present ban on cutting is relaxed).

Implications and conclusions

Overall, farm incomes are low, even by Vietnamese standards, owing mainly to poor returns from aquaculture for technical reasons explained elsewhere in this report. This is compounded by the low educational level of most farmers, farmer inexperience with aquaculture, lack of access to technical advice, lack of access to capital, and forest management policies that exacerbate the limited income from mangrove forestry. Technical recommendations for improving farm income through better culture techniques, forest management practices and diversification of farm outputs are provided elsewhere in this report. The adoption and implementation of these technical recommendations by farmers is closely interlinked with educational, social and economic conditions. In particular, better educational opportunities, more flexible and accessible credit arrangements, and greater access to regular technical advice and support are considered to be key factors in the willingness and capacity of farmers to implement farm management strategies that will provide higher and more sustainable farm incomes and alleviate the poverty cycle.

NUTRIENT BIOGEOCHEMISTRY (APPENDIX XII)

Results

Ponds

- Intensive short-term studies of nutrient cycling and the pond environment gave results that were consistent with those obtained from the broad scale survey, namely low water pH (down to pH 4.5 in the wet season) and dissolved oxygen levels and seasonally variable salinities. There was a marked vertical stratification in temperature, dissolved oxygen and pH, suggesting poor circulation and water stagnation. In addition, the ratio of photosynthesis to respiration (P/R ratio) was negative, indicating that pond waters were heterotropic, which is again consistent with the low chlorophyll concentrations and phytoplankton densities observed during the baseline survey of water quality and pond environment.
- Pond sediments were characterised by low organic carbon and nitrogen contents, which was reflected also in low rates of organic matter decomposition in pond sediments. The lack of carbon as an energy source for microbial decomposition is

consistent with the sediments being generally oxic (not anaerobic), the lack of free sulfides and the presence of oxidised forms of sulfur and nitrogen in bottom sediments.

- While low rates of sulfate reduction suggest that the rate of pyrite formation is slow, pyrite was nevertheless the main form of solid phase iron and sulphur (being up to almost 6% by dry weight), indicating potentially acid-sulfate soil conditions.
- Studies of the fluxes of N and P across the pond bottom-water interface suggest that the pond bottom is a sink for rather than a source of these nutrients.
- There was no evidence of denitrification.

Mangrove forest

- Decomposition of sediment organic matter in mangrove forest soils was dominated by aerobic respiration, as was also found for pond bottom sediments. Sulfate and metal reduction were minor pathways, and there was no evidence for methanogenesis. This is consistent with the positive soil redox potentials, the absence of free sulfides and methane in the pore water, the presence of nitrate and nitrate at depths down to 40 cm, the excess of sulfate relative to chloride in pore waters and the low soil pH.
- Overall, rates of total carbon oxidation and sulfate reduction were slow, as in other mangrove forests, when compared to salt marshes and seagrass beds where rates of total sediment mineralization and sulfate reduction are much greater on average. This comparatively slow remineralization of organic matter in mangrove systems implies immobilization with subsequent conservation of essential nutrients.

Implications and conclusions

The results essentially confirm those of the other studies, showing that water quality and the pond environment are not optimal for shrimp culture. Low pH and dissolved oxygen levels, coupled with the heterotrophic nature of the ponds (i.e. more carbon is being consumed that is produced within the pond), and an apparent net loss of carbon and nitrogen from the ponds suggest that shrimp culture could be unsustainable over the longer term without additional inputs of fertilizer and/or organic matter. However, this still needs verification.

Some changes to present management practices may shift the carbon and nutrient balance sufficiently to improve shrimp production. These include:

- Reducing water exchange, by reducing the frequency of draining ponds, and simply topping up to replace leakage would significantly decrease the loss of nitrogen and carbon from ponds.
- Reducing water exchange and simply topping up to replace water lost through leakage should reduce the input of suspended sediment, allow a longer period for suspended sediment to settle out, leading to an improvement in water clarity and primary production (increase inputs) and lower bacterioplankton abundance and production.

- Better design of the levees (to minimize erosion) would result in lower burial rates of particulate matter.

FOREST SOIL CONDITIONS AND FLOODING FREQUENCIES (APPENDIX XIII)

Results

- Soils at most sites consisted predominantly of clay and fine silt (particle size < 16 µm). It is noteworthy that all plantation stands on these soils had significantly less roots above ground than stands of comparable age growing on soils with larger sized particles in Malaysia.
- Wet soil pH at most sites in all enterprises was within the normal range for mangrove soils (pH 6.0 to pH 7.0). Only 6 of the 36 sites sampled had low soil pH (pH 5.5 to pH 6.0) when wet. These sites were randomly distributed over SFFE 184 and Tam Giang III Enterprises, with no consistent geographic pattern.
- Dry soil pH (values less than pH 5 are an indication of potentially acid sulphate conditions) fell in the range pH5.0 to pH6.5 at all except 5 sites where the dry pH was less than 5.0. Again, these 5 sites with low dry pH were randomly distributed in both SFFE 184 and Tam Giang III Enterprises, without any consistent geographic pattern.
- Soils in the area are not anaerobic. Only 2 sites (one each in SFFE 184 and Tam Giang 3 Enterprises) had a soil redox potential of –200mV or lower.
- Soil salinity was higher than 30‰ at only 2 of the 36 sites sampled, the remaining sites having soil salinities ranging from about 20‰ to 30‰.
- Total soil nitrogen ranged from 0.1% to 0.5% by weight at all but one site, which had an unusually high level of nitrogen (0.75%).
- Total soil phosphorus ranged from about 0.1% to 0.25% as P_2O_5 by weight.
- The optimal flooding frequency for *R. apiculata* appears to fall between 150 and 250 days per year. Stem diameter and stand volume both decline at flooding frequencies outside this range.

Implications and Conclusions

- Soil physico-chemical conditions overall are generally favourable for mangrove growth.. Soil pH, Eh and water content are unlikely to be factors limiting the growth of mangroves in the area.
- The very high clay content of soils in the area appears to restrict root development. While poor root development might be expected to reduce growth rates, the measured rates of growth were not significantly lower than those reported for plantations of *R. apiculata* growing on less clayey soils in other countries in SE Asia.
- A small improvement in growth rate, and hence a shortened harvest rotation, might potentially be achieved at lower soil salinities (<20‰), but the salinity conditions cannot be modified under the present tidal and climatic conditions.

- Nitrogen and phosphorus are not considered to be major factors limiting growth, although in the case of phosphorus, the level of availability to mangrove trees is not known. Application of phosphatic fertilizer may improve growth rates, but given the cost of fertilizer in Vietnam, the cost-benefit ratio of this would be unfavourable.
- Most stands of *R. apiculata* sampled fell within the optimal range for flooding frequency. This species will grow at lower rates outside the optimal range of 150 to 250 days per year. However, particular care needs to be taken to avoid planting this species on sites where the flooding frequency is less than 50 days per year.

FOREST GROWTH AND YIELD (APPENDIX XIV)

Results

- Plantations of *R. apiculata* grow in height at an average annual rate of about 0.8m per year up to an age of 15-20 years, after which the rate of height growth progressively declines. This is about 10% lower than plantations of the same species in the Matang mangrove forest of Peninsula Malaysia.
- Stem diameter and stand density are inversely related. Most stands are undergoing natural self-thinning under current silvicultural practices.
- The mean annual diameter increment remains constant at about 0.6 cm per year in stands planted at 20,000 ha^{-1}, at least up to the age of 36 years. A constant rate of diameter increment over such a wide range of age is most unusual and was not expected. The results strongly suggest that growth is restricted by higher than desirable stand densities owing to the fact that stands are mostly undergoing self-thinning.
- Individuals in a *R. apiculata* plantation lose their capacity to expand the crown if thinned after the age of about 20y. Therefore, thinning after this age will not improve the growth rate or yield of the forest. In fact, thinning of older aged forests increases the probability and extent of damage from high winds (e.g. typhoons).
- Of the stands sampled, only those over 20 y of age produced significant quantitities of seed (propagules). The 35 y old seed stand in Tam Giang III Enterprise had the highest seed production, with an average of 680,000 per hectare. One hectare of this stand would produce sufficient seed to replant about 68 hectares at a planting density of 10,000 per hectare, and only 34 hectares at a planting density of 20,000 per hectare. One hectare of 21 y old forest would produce enough seed to replant about 40 hectares at 10,000 per hectare, whereas one hectare of a 12 y old forest would produce enough seed to replant only about 4 hectares at 10,000 per hectare. In general, older stands of 20 y or more were the most seriously damaged by Typhoon Linda.
- General observation indicates that many mangrove areas in Tam Giang III and SFFE 184 Enterprises, and particularly those within mixed farming systems where the forest is surrounded by levees, are now at an elevation that is above the tidal flooding level. This is partly because soil excavated to make the channels for shrimp culture, and the spoil cleaned from the pond at the end of each cropping cycle, is placed on the levees or platforms where mangroves are grown. It is also partly due to natural trapping of fine sediment by the mangroves themselves. Rising land levels can be expected to

reduce the growth rate and yield of mangroves, for which there is already evidence in some areas within Ca Mau and Bac Lieu Provinces.

- The thinning trials commenced late in 1996 were severely damaged by Typhoon Linda in November 1997, and no data are presently available. However, the plots were remeasured immediately after the typhoon, and it is expected that further monitoring will yield data on the effects of thinning on stand growth, as well as providing useful information on the recovery of mangrove forests from typhoon damage.

Implications and Conclusions

- Current silvicultural management practices do not optimise wood production from mangrove forests in Ca Mau Province. Project results suggest that yields and farmer incomes could be improved by 15-20% by planting at an initial density of 10,000 ha^{-1}, thinning to 5,000 ha^{-1} at 7-8 years, thinning again at 12 years to a density of 2,000 ha^{-1}, with a final harvest at 20 years. The net pre-tax profit to farmers from this management strategy is estimated to be 4,600-5,500 USD ha^{-1} over the full rotation of 20 years, which equates to an average annual pre-tax income of 230-270 USD ha^{-1} y^{-1}. Furthermore, with a slight change to the thinning strategy, it is possible to reduce the rotation period to about 17 years with the same average annual pre-tax income. The latter would help to reduce farmer concerns about having to wait so long for a return from their forestry operations.
- A more regular income from mangrove forest products could be obtained if farmers staggered their planting schedules, so that each farm had stands of 5 or more different ages. If, for example, a farmer had a total of 5 ha of mangrove land with stands of 4, 8, 12, 16 and 20 years, each of 1 ha in area, then 1 ha would be harvested and 2 ha (8 and 12 y old stands) would be thinned every 4 years. Alternatively, the planting schedule could be staggered to give stands of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 years of age, each of 0.5 ha in area; this would allow 0.5 ha to be harvested and 1 ha to be thinned (again at 8 and 12 years) every 2 years. Both these planting options provide a more regular income from forest products, and also mean that the labour requirement and cost is spread more evenly from year to year.
- The adoption of the planting, thinning and harvesting schedules suggested above would however require a more flexible forest management policy than presently applies.
- There may be a shortage of seed for future mangrove afforestation because of recent typhoon damage to the main seed stands. This could impact on the afforestation component of the World Bank/DANIDA Coastal Wetlands Project.
- If the rate of sedimentation in mangrove areas continues to exceed the rate of sea level rise, then much of the area presently used for growing mangroves is expected to become unsuitable in the future. This might be partly offset by newly developing mudflats potentially suitable for mangroves along some parts of the coastal fringe, but the net effect is likely to be a reduction in the area suitable for mangrove silviculture. This needs to be monitored and considered carefully in longer term land use planning, particularly in relation to shifting from mangrove silviculture to the silviculture of terrestrial wood crops in areas where the land level is now, or is

expected in the future to be, above that suitable for mangrove silviculture. The suitability of alternative terrestrial forest species also needs assessment. Some species of *Eucalyptus*, for example, grow well in Ca Mau Province, but their leaves contain many aromatic oils that may be toxic to shrimp.

- Project results suggest that the growth rate is faster in stands planted at 10,000 ha^{-1} up to the age of about 8-9 years when they begin to self thin (compared to stands planted at 20,000 ha^{-1} which begin to self-thin at 4-5 years of age). It is expected that this higher growth rate would be maintained, at least for the first 15-20 years, if stands were thinned manually to avoid overcrowding and natural self-thinning. However, this has not been demonstrated experimentally in the present project. It is therefore recommended that experimental trials with different planting densities be carried out to validate this interpretation of the data.

ASSESSMENT OF THE CAPACITY OF MANGROVE FOREST TO FILTER POND WASTE

The role of mangroves as filters for nutrient enriched prawn farm effluent was identified as an objective in the Project Proposal. However, there are a number of arguments against carrying out such a study in the project area of Ca Mau Province.

- There is no significant difference in water quality between ponds and the waterways from which ponds are filled and into which pond effluent is discharged. This suggests that pond water quality is highly dependent on the water quality in the rivers and canals and that pond effluent does not significantly affect the quality of water in the waterways. Little can be done to improve the quality of water in waterways at the local level, because it is determined chiefly by large scale physical and anthropogenic factors.
- Levels of dissolved inorganic nutrients in pond and canal water are relatively low, and currently do not pose a significant risk to shrimp culture and, in any case, are not the main factors limiting pond production. There would be little point in passing effluent over mangroves as pond water nutrients are often lower than that in water ways and therefore would not promote mangrove growth any more than natural tidal inundation.
- Topographic studies indicate that water levels in most ponds are generally a little lower than the level of surrounding mangrove forests. This means that in most cases water would have to be pumped from the ponds into the surrounding mangrove forest in order to utilise mangrove forest as a filter for pond wastes. Furthermore, given the low inorganic nutrient levels in pond effluent, effective stripping of nutrients and other wastes would require significant re-engineering of pond discharge outlets to spread water over a large surface area of mangrove forest. Even with such re-engineering, removal of nutrients and other materials from pond waste is uncertain.
- The experimental protocols and monitoring required to effectively demonstrate removal of nutrients and other materials from pond effluent by mangroves would be difficult logistically and expensive to carry out in the project area. Furthermore, rigorous monitoring would need to be carried out for a period of at least 4 years in

order to demonstrate quantitatively the capacity of mangroves to filter pond effluent, at the current low levels of dissolved inorganic nutrients in pond effluent.

- These arguments indicate that the benefits of using mangroves to filter pond effluents in the project area are likely to be marginal, while the costs (both experimentally and to the farmer) are likely to be high.

ASSESSMENT OF FARMING SYSTEMS

Over the farms sampled, average shrimp yields per unit water surface area were slightly higher on farms employing a separate farming system (ponds separated from mangroves) than on farms using an integrated, or combined, farming system (where shrimp are cultured in channels cut through mangrove forest), but the difference was not significant statistically. Farms of either farming system that have well-designed and maintained ponds, and where farmers are good managers, gave shrimp yields per unit water surface area that were well above average. Conversely, there are many farms of either system where shrimp yields were well below average. This highlights the important conclusion that pond design and maintenance, and management practices are far more important in determining shrimp yields than the type of farming system employed.

Similarly, forest production per unit area of forest was not significantly different statistically between farming systems, although there may be some loss of potential production on farms using the integrated, or combined, farming system if farmers cut back the mangroves along the edges of the channels at about 6-7 years of age, when some report a fall in pond yields which they attribute to shading by the mangrove canopy. This effect was not investigated in the present project. However, if pond yields in integrated farming systems do indeed decline when the adjacent forest reaches 6-7 years of age, it is more likely to be due to leaching of tannins from accumulated leaf litter on the pond bottom. Mangrove leaves are well known to have a high tannin content (this can be up to 30-40% by dry weight). Shading by mangrove canopies is unlikely to have much effect on light availability in a system where light is essentially limited by high levels of fine sediment suspended in the water column.

The main potential benefit from using a separate farming system (pond separate from mangroves) is that the pond can be managed optimally for aquaculture and the forest managed optimally for wood production, without having to make a compromise in managing one to accommodate the other. A second advantage of a separate farming system is that mud crabs can be cultured in the forest with significantly less risk of transmitting shrimp viral diseases, for which crabs are known to be vectors.

As pointed out above, the evidence suggests that well managed mixed shrimp-mangrove farms and well managed separate shrimp-mangrove farms (pond separated from mangroves) presently can be equally productive in terms of both shrimp and wood production. However, it is questionable whether mixed shrimp-mangrove farming systems will be unsustainable in terms of mangrove wood production over the longer term. Land levels within both enterprises appear to be increasing at a faster rate than sea level and many mangrove areas are already at or above the upper level considered to be optimal for the growth of *R. apiculata*. Indeed there is already evidence of significantly reduced growth rates on more elevated land in both Bac Lieu and Ca Mau Provinces.

Use of Results

This project has produced a substantive and quantitative set of baseline data on water quality, the availability and population structure of shrimp seed, pond management practices, forestry resources and silvicultural practices. This data set has influenced the scope and design of the monitoring component of the World Bank/DANIDA Coastal Wetlands Project proposed for the same area of southern Vietnam beginning in 1999. It will also provide a baseline for the monitoring program proposed within that project.

The research findings provide quantitative evidence, previously unavailable for Ca Mau Province, that supports a number of widely held views on some of the key problems and issues relevant to shrimp farming in this area. For some time these views have formed the basis for recommendations to improve shrimp yields and for extension advice in the lower Mekong region. Planners, researchers and extension officers at Government, University and provincial levels now have a sound scientific basis for recommendations to improve shrimp production and for investigating a number of alternative culture options for mixed shrimp farming-mangrove forestry farming systems in the lower Mekong Delta.

Project results and recommendations will be used to prepare information for dissemination to farmer families, community leaders and groups, and extension workers. More technical information will be published nationally and internationally to disseminate project results to the scientific community. Results from this project will also be disseminated on a wider regional scale through NACA.

Publications

Published

Alongi, D.M., P. Dixon, D.J. Johnston, D.V. Tien and T.T. Xuan. 1999. Pelagic processes in extensive shrimp ponds of the Mekong delta, Vietnam. *Aquaculture* 175: 121-141.

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In Press

Alongi, D.M., F. Tirendi, L. A. Trott. Benthic decomposition rates and pathways in plantations of the mangrove, *Rhizophora apiculata*, in the Mekong delta, Vietnam. *Marine Ecology Progress Series*.

Alongi, D.M., D.J. Johnston and Tran Thanh Xuan. Carbon and nitrogen budgets in extensive shrimp ponds of the Mekong Delta, Vietnam. *Aquaculture Research.*

Clough, B., D. Johnston, Tran Thanh Xuan and M. Phillips. Mixed shrimp farming-mangrove forestry models in the Mekong Delta (ACIAR-MOFI Project FIS/94/12). *Proceedings of the Concluding Workshop on Environmental Indicators Pilot Study, Cantho University, March 1999*.

Johnston, D., B. Clough, Tran Thanh Xuan and M. Phillips. Mixed shrimp - mangrove forestry farming systems in Ca Mau Province, Vietnam. *Aquaculture Asia*.

Submitted

Clough, B., Dang Trung Tan, Do Xuan Phuong and Dang Cong Buu. Canopy leaf area index and litterfall in stands of the mangrove *Rhizophora apiculata* of different age in the Mekong Delta, Vietnam. Submitted to *Aquatic Botany*.

In addition, a further 6 papers have been identified, some of which are in preparation.

Follow-Up

Although the project has successfully identified the primary factors responsible for declining shrimp and wood yields and proposed management strategies to improve yields, there are a number of areas which need further attention. These are outlined below.

Research

- **Wild Seed Recruitment** - Data collected during the "Post Larval Recruitment" study showed that wild stocks of shrimp seed are low and seasonally variable in the Ca Mau province. However, this recruitment study, initiated in August 1996, was terminated prematurely in March 1997 so that long term recruitment patterns could not be determined. Consequently, it was not possible to comprehensively assess seasonal patterns in the availability of wild shrimp seed throughout an entire year. The option of repeating measurements of post larval recruitment within this project was not considered worthwhile as it was to terminate before another full calendar year could be recorded. To fully understand the potential productivity of farms in Ca Mau province and whether seasonality in recruitment significantly affects productivity, there needs to be more comprehensive monitoring of wild stock seed supply over an extended time period of at least 2 years. Investigations into moon phase and tidal effects on seed recruitment should also be considered for possible management implications.
- **Evaluation of Silvofisheries Farming Systems** - Yield and water quality data collected in this project suggested that separate farms were more successful than mixed farms. Therefore a separate silvofisheries model was recommended. However, an economic analysis of the inputs (costs) and outputs (production) needs to be done at both farm types (mixed vs. separate) to determine whether net profits are also higher at separate farms (consistent with yield data, gross production collected in this project). This study would also provide accurate assessment of farm productivity. The inputs and outputs of improved extensive culture also need to be documented.
- **Sustainability of mixed silvofisheries farming systems** - Of more fundamental importance, however, is the sustainability of the mixed shrimp-mangrove forest farming system. This is in question because sediment deposition on the internal levees and platforms on which mangroves are grown within ponds is raising the level of these areas above the range considered to be optimum for the growth of *R. apiculata*. Consequently the growth and yield of plantations of this species is expected to decline in mixed shrimp-mangrove farming systems. This project did not measure or monitor the rate of accretion directly, nor investigate its likely impact on the sustainability of these systems. However, such information is of critical importance for future land use planning within Ca Mau Province, for assessing alternative land use options for timber production, and for developing appropriate farm designs that have the flexibility to evolve gradually in response to the change in

landform while providing farmers with a sustainable source of income above the poverty level. This question must be of the highest priority, is in urgent need of a separate investigation, and warrants serious consideration as a new and independent project.

- **Yield Data Collection** - Yield data was collected sporadically throughout the project and was not collected simultaneously through time with highly changeable water quality parameters (except in the manipulation experiment) nor with an extensive list of physical parameters including farm location (only extensive dataset available is from the socioeconomic survey which did not include location data and was total yield for the year not yield through time). Therefore a comprehensive dataset of water quality and physical parameters versus yield through time needs to be collected to verify data collected in this study and that of Binh *et al*. (1997).
- **Population Dynamics of Shrimp in Ponds**. The 40 mm size difference in shrimp being recruited and harvested within the 15 day growout cycle indicates that post larvae grow for up to 4 months in ponds before they are harvested. The population dynamics of shrimp in the ponds is currently unknown and would provide valuable information on their survivorship and growth rates (over an extended period) and how these are related to pond water quality parameters. This will provide a greater understanding of pond productivity through time and provide information on conditions in ponds that are optimal for growth and survival.
- **Hatchery Status and Improvement in PL Quality** - low and unreliable seed stock recruitment into ponds fundamentally limits the productivity of shrimp farms in Ca Mau province. To improve shrimp yields markedly, the option of stocking hatchery reared larvae needs to be seriously considered. However, the quality of hatchery reared post larvae is presently highly variable. An assessment of hatcheries in Vietnam is required where species cultured, their health status, infrastructure and culture practices are documented. This will provide information on areas that need to be addressed to improve post larval quality. Training of extension officers and hatchery technicians in culture techniques, disease risk management and PL transportation methods needs to be conducted as well as extension workshops for farmers in nursery and growout techniques.
- **Repetition of the Hatchery PL Experiment** – for shrimp yields to increase dramatically, stocking with hatchery reared *P. monodon* should to be seriously considered and implemented. Due to failure of the PL hatchery experiment it is necessary to repeat the study to determine the optimal transportation and growout techniques as well as optimal stocking densities of hatchery reared *P. monodon*. This is necessary to promote *P. monodon* as a low risk and highly successful supplement to wild stock culture. *P. indicus* should also be trialled as another high value alternative species.
- **Improvements to Pond Management**
  i) ***Reduce Pond Leakage*** - Pond leakage has been identified as a major factor influencing shrimp yields as it is responsible for shallow pond depth and fluctuations in water level which have led to marked fluctuations in water quality. Options to minimise pond leakage need to be investigated. The

most important of these is sluice gate design as the majority of water escapes through this structure. For example, two sets of boards that fit snugly and promote pond bottom drainage should be trialled. Other options to reduce leakage are netting, cement, secondary ditches and liming around the sluice gate to prevent boring by animals such as crabs and gobies.

ii) ***Extended Growout Period*** - The manipulation experiment demonstrated that an extended growout period of 60 days improved certain water quality parameters (due to increased residence time and reduced flushing). However, it was not economically viable to have a a single recruitment, compared with the multiple recruitments of the 15 day growout cycle. Therefore, an extended growout of up to 60 days but with continual recruitment every 15 days (drain pond first with net over sluice gate on outgoing tide to enable recruitment on incoming tide) should be trialled. This will improve water quality whilst maximising shrimp numbers and size to be highly competitive with 15 day cycles. Recruitment every 15 days will also provide good water exchange on a regular basis. Incorporation of moon phase behavioural patterns into management technique, such as recruiting on a full moon and harvesting on a new moon, should also be considered.

iii) ***Reduce Post Larval Loss During Harvest*** - The post larval recruitment study revealed that a large number of post larvae were being lost during traditional harvests on the outgoing tide. Harvesting options which may reduce these losses include a) the against water current technique; b) traps specific for large adults such as the "opera house trap" and c) fully drain the pond and replace all harvested juveniles and post larvae. All of these techniques are designed to cull only the large shrimp from ponds and leave the juveniles and post larvae for continued growth. However, these techniques need to be trialled to determine whether they in fact reduce post larval losses, increase stocking density and ultimately improve yeilds. The likelihood that a 15 day growout cycle using only the against water current harvesting technique would maximise shrimp stocking density, increase the size of individual shrimp harvested and raise the overall income potential of farms obviously is worthy of further investigation.

iv) ***Diversification*** - Diversification into cash crops and crab culture has been recommended to supplement income in times of poor shrimp yields, broaden the income base for farmers and reduce the risk associated with shrimp farming. For either option to be embraced successfully by farmers a number of areas need to be investigated. Soil, elevation and water requirements as well as growout techniques of various cash crops need to be determined as does the viability (profitability) of individual crop types. There are opportunities to utilise levee banks more effectively to produce cash crops such as pineapple, coconut and, perhaps on a smaller scale, vegetables (which require a supply of fresh water). The optimal stocking density and growout techniques for mud crabs needs further investigation and research into the culture of crab larvae in hatcheries encouraged. Options for the culture of fish and molluscs also need to be investigated.

v) ***Settlement Pond*** – The costs and benefits of using a settlement pond are still unclear, and may vary considerably from place to place, depending on water quality and on the degree of leakage from ponds. This option needs further investigation to determine whether suspended solids settle out sufficiently to promote phytoplankton growth. If so, the feasibility of filling shrimp ponds from the settlement pond and the resultant improvements in Chl *a* and phytoplankton densities should be assessed as well as the longer term improvements in water quality and shrimp yields.

8. **Gut Content Analysis** - A stable isotope study of shrimp gut contents should be conducted to determine their diet and stocking densities possible based on natural food supplies in the ponds.

9. **Assessment of the benefits of alternative planting densities.** The forestry studies to date strongly suggest that an initial planting density of 20,000 ha^{-1} is much to high, and results in early self thinning of stands and a reduced growth rate. However, it has not been clearly demonstrated that lower planting densities will actually result in an increase in the growth rate. It is therefore strongly recommended that a further experiment be conducted to test this important conclusion. In particular, it is recommended that trials be carried out with planting densities of 5000, 7500, 10000, 15000 and 20000 ha^{-1} to unequivocally demonstrate which planting density provides the best early growth rate of mangrove forests in Ca Mau. Such trials could not be instigated within the time frame of this project, but given their low cost and maintenance requirement, they should be well within the capacity of local authorities to support.

Training and Extension

This project has achieved its objective of identifying the main factors limiting shrimp and wood production, and has put forward a series of simple and cost-effective recommendations for improving farm production and income security. However, the project has not yet achieved another of its objectives, that of assisting national and provincial authorities to transfer project results and recommendations to coastal farming communities in the lower Mekong Delta. In the longer term the success of the project will be judged by its impact on the ultimate beneficiaries, the coastal farming communities of Ca Mau and nearby provinces.

This final project report contains probably the most comprehensive data set and interpretation available on mangrove-aquaculture systems in the lower Mekong Delta. These data, plus the experiences from the project of working with farmers, extension workers and provincial authorities in Ca Mau and Ministry of Fisheries (RIA II), represent a valuable corpus of knowledge which can be helpful to a number of new projects being planned for the lower delta provinces. These will be more developmentally orientated than the ACIAR study and can benefit especially from the scientific information now available on how the mangrove-aquaculture systems function, and the main constraints on their productivity and sustainability.

An extension of the project for a period of 1 year would enable it to assist national and provincial authorities to develop the materials and a strategy to ensure the transfer of project results to farmers, both in the shorter and longer terms. Drawing on the combined experience and resources of present project staff and collaborating agencies, together with additional inputs from other institutions with appropriate expertise and experience, an extension of the project for 1 year would focus on:

- The preparation of appropriate extension materials for provincial extension officers and for farmers, based on the findings and recommendations of the project.
- Training a core group of provincial extension officers to a high level of competence.
- Developing linkages with other existing and planned new projects in the lower delta provinces, so than other projects can build on the results and experience of the present ACIAR project, thereby maximising spillover benefits. This is seen as a key activity in ensuring long term benefits to farming communities from the present project. The more developmental orientation of planned new projects in lower Mekong Delta would provide an appropriate channel to maximise spillover benefits.

Recommendations for Extension and Policy

SHRIMP CULTURE				
Recommendation	**Priority**	**Actions**	**Costs/Benefits**	**Risks**
Improve pond water and sediment quality in order to maintain a healthy pond environment.	Highest – other recommendations for improving shrimp yields will provide limited benefits unless this recommendation is also implemented.	Dig the pond to a water depth of 1 m.	A deeper area for shrimp to “escape” to when pond water levels are low. Provides an area expected to have clearer water, and more stable water quality.	Possible exposure of potentially acid sulfate soils, which if deposited on levees within ponds or in mangrove areas could cause a deterioration in water quality over the first 1-2 y through acidification.
		In ponds with a high rate of leakage, dig 30% of the pond water surface area to a water depth of 1.5 m. Dig 1 channel (to a depth of 1.5 m) between this deeper area of the pond and the sluice gate.	More stable water quality and pond environment.	
		Maintain a high water level by reducing leakage, especially around the sluice gate.	More stable water quality and pond environment.	None.
		Reduce the amount of water drained on 15 d wild shrimp harvest cycles, or preferably replace 15 d harvest cycles with 30 or 45 d harvest cycle for wild shrimp. Top up pond water level and recruit wild shrimp seed on 15 d lunar spring tides.	Better water quality (clearer water) and more stable pond environment. Better shrimp health and survival.	Less regular income from wild shrimp harvest. Higher mortality because of overstocking.

SHRIMP CULTURE

Recommendation	Priority	Actions	Costs/Benefits	Risks
		Ensure that material excavated during pond construction or cleaning is placed on areas where it cannot subsequently influence the pond or mangroves. Ideally all pond spoil should be deposited in one area to build up a larger area of land above the tidal limit on which terrestrial trees and other crops can be grown	Reduced risk of acidification of pond water from potentially acid sulfate soils. Increased area of high land available for terrestrial trees and other cash crops. Relatively high labour cost.	None.
Improve stocking techniques for *P. monodon* seed	High	Check quality of PL visually at time of stocking. Stock only with the largest and healthiest PL (at least PL15). Discard the rest. Aim initially for 20-30% survival rate.	Better survival and less risk of stocking with diseased PLs.	Difficult to get 'healthy' seed.
		Use a nursery area/pond of 10-20% of the final water surface area.	Better survival.	None.
		Aim for a final stocking density of 1-2 m^{-2}. Do not overstock. Stock into nursery area/pond at 10-20 times the density finally required in the growout pond.	Better survival and larger shrimp at harvest.	None.
		Acclimate PL to pond water temperature and salinity for not more than 30 min with vigorous aeration.	Higher survival rate.	Higher mortality if acclimation period is more than 30 min.

SHRIMP CULTURE				
Recommendation	**Priority**	**Actions**	**Costs/Benefits**	**Risks**
		Count number of PL stocked	Knowledge of the actual stocking rate.	Higher mortality if counting is not done quickly.
		Stock into the nursery pond/area in the late afternoon or evening.	Reduced stress and improved survival.	None.
		Feed juveniles daily in nursery pond for 20-30 days.	Critical for improved survival. Costs are low if fed with a mixture of boiled fish and chicken egg.	Overfeeding could lead to a deterioration in pond environment.
		Monitor survival and growth in nursery pond weekly, and in growout pond every 10-15 days.	Gives warning of health problems. Can be used to harvest before mortality results in the loss of the whole crop.	None.
Improve wild shrimp stocking and harvesting	High	Do not drain the pond to harvest every 15 d. Instead, recruit wild seed on 15 d lunar spring tides, and harvest using “Tom te” or “against water current” harvesting techniques. Drain pond after 45 or 60 days for a full harvest.	Improved recruitment and stocking densities of wild shrimp. Harvested shrimp are larger and of higher value.	Farmers may not receive the same regular income as from the traditional 15 d harvest cycle. May not be effective at some times of the year. Possible increased risk of mortality due to higher stocking densities.

MANGROVE SILVICULTURE.

Recommendation	Priority	Actions	Costs/Benefits	Risks
Select an appropriate planting density and improve thinning practices.	High	Plant at a density of 10,000 ha^{-1} or 7,000 ha^{-1}. Current policy is to plant at 10,000 ha^{-1}.	Increased growth rate by avoiding self-thinning at an early age. Less risk of damage to remaining trees by avoiding the need to thin at 5 years. Reduced propagule and labour costs.	Trees planted at 7,000 ha^{-1} may produce multiple stems. It is not yet clear whether this will reduce the total wood yield, but multiple-stemmed trees are likely to be less valuable for poles.
		If planted at 10,000 ha^{-1}, thin to 5,000 ha^{-1} at 7-8 years, with a second thinning to 2,000 ha^{-1} at 12 years. Harvest at 18-20 years. If planted at 7,000 ha^{-1}, thin to 3,000 ha^{-1} at 8-9 years, with a second thinning to 1500 ha^{-1} at 13 years. Harvest at 18-20 years.	Higher growth rate and yield by avoiding self-thinning. Greater economic return.	None.
Gradually phase in a staged planting schedule that allows farmers to haved stands of different ages.	High	It is recommended that farmers gradually move to having stands of either 5 different ages (with an area for each age class equal to 1/5 of the total mangrove area; each age class separated by an interval of 4 years) or 10 different ages (with an area for each age class equal to 1/10 the total mangrove area; each age class separated by an interval of 2 years).	Farmers will receive a more regular income from mangrove forestry. The work load and labour costs are spread more evenly between years. Provides greater flexibility in responding to market demands for different forest products. Greater farmer incentive to manage their mangrove forest.	Some short term loss of forest production and potential farm income because of the need to harvest some mangroves prematurely. However, this can be minimised by gradually phasing in the recommended staged planting schedule. Initial reluctance of farmers to implement.

MANGROVE SILVICULTURE.				
Recommendation	**Priority**	**Actions**	**Costs/Benefits**	**Risks**
				Government may not change present policy.
Change present forest policy to allow more farmers more flexibility in managing their mangrove forest	High	Remove the current ban on cutting of mangroves.	Farmers will derive income from mangrove forestry, and will therefore have more incentive to protect and manage their mangrove areas. Greater farmer confidence in mangrove forestry .	Government may not implement these recommendations.
		Adapt overall forest management policy to provide the flexibility to implement the actions listed above		

FARM DIVERSIFICATION.

Recommendation	Priority	Actions	Costs/Benefits	Risks
Develop a long term strategy for land use and resource allocation that takes into account expected changes in topography and land forms.	High	Carry out an assessment of sedimentation and erosion and the consequent expected changes in land forms and topography.		
		Implement policies that promote a gradual transition in land use based on expected changes in land form and topography	Costs of implementation are difficult to assess, but the long term costs of no implementation are likely to be much greater. Benefits – greater and more sustained national, provincial and farm production and income.	Long-term planning will not be carried out, with consequently higher long term costs and less sustainable agricultural production than would be the case if effective long-term policies were implemented.
Utilize high land (above the tidal limit) more effectively for planting terrestrial trees and crops.	High	Plant salt tolerant fruit and timber trees on levees and other high land above the tidal limit. Plant annual cash crops during the wet season.	A greater, more evenly distributed and sustainable farm income. A reduction in the risk that failure of any one crop will cause economic hardship.	The choice of which species to grow is critical. Alternative species need to be salt tolerant and possibly drought tolerant. Growing some tree species (eg. Eucalyptus) on levees within and around ponds may contaminate ponds with compounds that are potentially toxic to shrimp.
Culture crabs in mangrove areas	High	Stock crabs at low density (<=1 per 20 m^2) to minimise self-predation and avoid the need for feeding. Monitor growth to assess the need for supplemental feeding.	A greater, more evenly distributed and sustainable farm income. A reduction in the risk that failure of any one crop will cause economic	A widespread shift to crab culture/fattening could have a serious adverse impact on wild crab populations.

FARM DIVERSIFICATION.				
Recommendation	**Priority**	**Actions**	**Costs/Benefits**	**Risks**
			hardship.	
Culture fish in ponds.	Low	Polyculture of shrimp and fish together, or culture of fish alone, could be trialled, especially during the wet season.	In principle, could provide additional income and reduce the risks associated with dependency on shrimp culture, but actual costs and benefits not yet clear.	Market prices for mullet and tilapia may not justify culture of these species. Sea bass also may not be economic.

ECONOMIC, SOCIAL AND EXTENSION POLICY ISSUES

Recommendation	Priority	Actions	Costs/Benefits	Risks
Improve the security of land tenure for farmers	High	Change policy to permit longer land leases or provide options for farmers to acquire ownership of land	Greater security of land tenure for farmers, which is expected to provide more incentive for farmers to plan long term farm development and manage their farms more wisely. Land ownership would enable farmers to use land titles as collateral for loans from institutional lenders.	The recommendation might not be adopted.
Assist with credit arrangements to improve farms.	High	Provide a line of credit to Enterprises, which in turn could act as lenders to farmers for farm improvements at low interest rates.	Greater access by farmers to credit at reasonable interest rates, particularly those who do not have security of land tenure.	Lack of funds to implement. Governmental and/or institutional reluctance to implement.
Improve delivery of timely extension advice to farmers	High	Increase the number of provincial extension officers	Potentially more frequent on-farm visits and more timely extension advice.	Extension officers may not be willing to make frequent on-farm visits without additional incentives.
	High	Develop and progressively refine extension materials for provincial extension services and farmers	Costs are relatively small (many extension materials are already available from government and university institutions). Benefit will be better trained extension officers and more effective dissemination of extension advice to farmers.	Some extension materials may not be relevant to the situation in Ca Mau Province. Some extension materials may be appropriate for farmers.

ECONOMIC, SOCIAL AND EXTENSION POLICY ISSUES

Recommendation	Priority	Actions	Costs/Benefits	Risks
	High	Provide ongoing and effective training to upgrade the skills of extension officers	Costs will depend on the kind and frequency of training. Benefits will be a better trained extension team with up-to-date knowledge.	Lack of appropriate materials for training. Lack of effective trainers.
	High	Provide additional budgetary support for provincial extension activities.	Costs will depend directly on the level of funding. Benefit – the delivery of more frequent and timely extension advice to enterprise officials and farmers.	Additional support will not be provided. Extension officers will not take the initiative to use additional funds for more frequent farm visits.

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