ANNEXES TO THE:

THEMATIC REVIEW ON COASTAL WETLAND HABITATS AND SHRIMP AQUACULTURE

CASE STUDIES 7-13

A Report Prepared for the

World Bank, Network of Aquaculture Centres in Asia-Pacific,
World Wildlife Fund and Food and Agriculture Organization of the United Nations
Consortium Program on Shrimp Farming and the Environment

Preparation of this document

The research reported in this paper was prepared under the World Bank/NACA/WWF/FAO Consortium Program on Shrimp Farming and the Environment. Due to the strong interest globally in shrimp farming and issues that have arisen from its development, the consortium program was initiated to analyze and share experiences on the better management of shrimp aquaculture in coastal areas. It is based on the recommendations of the FAO Bangkok Technical Consultation on Policies for Sustainable Shrimp Culture[1], a World Bank review on Shrimp Farming and the Environment[2], and an April 1999 meeting on shrimp management practices hosted by NACA and WWF in Bangkok, Thailand. The objectives to the consortium program are: (a) Generate a better understanding of key issues involved in sustainable shrimp aquaculture; (b) Encourage a debate and discussion around these issues that leads to consensus among stakeholders regarding key issues; (c) Identify better management strategies for sustainable shrimp aquaculture; (d) Evaluate the cost for adoption of such strategies as well as other potential barriers to their adoption; (e) Create a framework to review and evaluate successes and failures in sustainable shrimp aquaculture which can inform policy debate on management strategies for sustainable shrimp aquaculture; and (f) Identify future development activities and assistance required for the implementation of better management strategies that would support the development of a more sustainable shrimp culture industry. This paper represents one of the case studies from the Consortium Program.

The program was initiated in August 1999 and comprises complementary case studies on different aspects of shrimp aquaculture. The case studies provide wide geographical coverage of major shrimp producing countries in Asia and Latin America, as well as Africa, and studies and reviews of a global nature. The subject matter is broad, from farm level management practice, poverty issues, integration of shrimp aquaculture into coastal area management, shrimp health management and policy and legal issues. The case studies together provide an unique and important insight into the global status of shrimp aquaculture and management practices. The reports from the Consortium Program are available as web versions (http://www.enaca.org/shrimp) or in a limited number of hard copies.

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[1] FAO. 1998. Report of the Bangkok FAO Technical Consultation on Policies for Sustainable Shrimp Culture. Bangkok, Thailand, 8-11 December 1997. FAO Fisheries Report No. 572. Rome. 31p.

[2] World Bank. 1998. Report on Shrimp Farming and the Environment – Can Shrimp Farming be Undertaken Sustainability? A Discussion Paper designed to assist in the development of Sustainable Shrimp Aquaculture. World Bank. Available on: www.enaca.org/shrimp.

Contents

Case Study 7: Silvofishery Farming Systems in Ca Mau Province, Vietnam

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Background

Ca Mau Province (8º 34' to 8º 57' N, 104º 43' to 105º 25' E) is part of the lower Mekong Delta region land area, and the southernmost province of Vietnam. In common with most of the Mekong Delta, the province is relatively flat topographically, much of the lying within the intertidal zone between about MSL + 1 m and MSL – 1 m. Prior to the Vietnam – American war Ca Mau was covered extensively by mangrove forests, most of which were destroyed by defoliants sprayed during the war. During this period about 80% of the 44,900 ha of mature *Rhizophora* forest in Ca Mau was destroyed by herbicides (Hong and San 1993) Following the reunification in 1975, natural regeneration and extensive replanting, mainly with monocultures of *Rhizophora apicul*ata, led to the partial recovery of mangrove vegetation. More recently, however, rapid expansion of coastal shrimp aquaculture has contributed to, but is not entirely responsible for the loss of more than half the mangrove forest that existed in Ca Mau and Bac Lieu provinces in 1982. In the 10 year period from 1982 to 1992, the area of mangroves decreased by about 40,000 ha (48%) in Ngoc Hien district of Ca Mau Province, while the area of shrimp ponds increased to more than 30,000 ha (Binh 1994).

In addition to supporting coastal capture fisheries and providing protection from storms, mangrove forests currently supply much of the material used for rural housing and most of the firewood needs for domestic heating in the province. In response to these resource and land use issues, 22 State Fisheries Forestry Enterprises (SFFEs) were established in 1986, where both shrimp and mangrove wood are produced by individual farmers on small holdings. While these enterprises appeared initially to offer a partial solution to the problems of conflicting land use and environmental quality, farm production and income has declined in recent years.

The central Government is responsible for overall policy with respect to mangrove and other coastal resources in Vietnam. Within this overall policy framework, provincial Governments have some degree of independence in formulating and implementing more specific policies and management strategies relating to provincial land use options. Provincial Forestry and Fisheries Departments, together with Enterprise Managers are responsible for year-to-year and day-to-day management of forestry and fisheries activities. In practice, the lines of responsibility and decision making often overlap between national and local government agencies, leading to some conflict in goals, policy and management issues between forestry and fishery sectors.

In 1991, the Provincial People's Committee of the then Minh Hai Province (Now subdivided into the two provinces of Ca Mau and Bac Lieu) took the decision to classify mangrove forestlands into three types, and to implement a participatory forestry policy (Decree No. 64-QD/UB on 28 March 1991). This was supplemented by a further decision to decentralise forest management to the private sector and to organisations (Decree No. 02/CP on 15 January 1994). In practice there have been difficulties in implementing these policies, resulting in a continuing loss of mangroves through illegal cutting by both landholders and itinerant workers. This resulted in the imposition of a total ban on the cutting of mangroves in Ngoc Hien District in 1996 (The ban was removed in mid-year 1999).

This case study describes a collaborative research study to assess the main factors affecting the yield of shrimp and mangrove wood in mixed shrimp culture-mangrove forestry farming enterprises in Ngoc Hien District, Ca Mau province, southern Vietnam (Fig. 1), and to evaluate options for improving farm production and income sustainably within existing environmental and socio-economic constraints. Much of the description of the farming systems and practices has been taken from a published article by the same authors (Johnston et al. 1999).

Case Study Analysis

General Description of the Site

The two State Fisheries-Forestry Enterprises (SFFEs) covered by this case study, LNT 184 (abbr. 184) and Tam Giang III (abbr. TG3) are situated in the Ngoc Hien District of Ca Mau Province (Fig. 1). Both enterprises border the Cua Lon River which transects the province from the South China Sea to the east and the Gulf of Thailand to the west (Fig. 1). Both enterprises are situated on relatively flat, low-lying, swampy land, most of which is flooded by tides for 180 – 360 days per year. Mangroves are the dominant vegetation on the tidally flooded land.

Soils in both enterprises are predominantly medium to heavy clays consisting of about 50% clay (< 4 um in size) and 50% fine silt (4-17 um in size) down to a depth of at least 50 cm. Soil salinity ranges from about 20‰ up to 35‰. Wet soil pH ranges from about pH5 to pH7, with dry soil pH in the range of pH4.5 to pH6.5. Consequently these soils are mildly acidic, and there is evidence of potential acid sulphate conditions in some areas.

The area experiences a pronounced wet season from May to November, and a dry season from December to April, with an annual average rainfall of about 2400 mm (Table 1).

Table 1. Mean annual values for climatic parameters, based on records from the Ca Mau weather station for the years 1971 - 1998.

Parameter	Value
Average temperature (ºC)	27
Minimum temperature (ºC)	19.6
Maximum temperature (ºC)	35.5
Relative humidity (%)	83
Precipitation (mm)	2,366
Evaporation (mm)	836
P/E ratio	2.8

There has been a rapid increase in the human population in Ngoc Hien District since the early 1980s. From 1983 to 1992 the population of Ngoc Hien almost doubled in size (Hong and San 1993), so that by 1993 an estimated 9,600 households had settled on former mangrove forest land, of which about 6,800 had settled illegally, encroaching on more than 30,000 ha of mangroves to build shrimp ponds (Binh, 1994). In 1996, SFFE 184 was estimated to have 1,018 farming households, with a total population of about 7,000 people, while the smaller Tam Giang III enterprise had 236 farming households representing 1,007 people. Most farming households are relatively recent immigrants from elsewhere, the average residence time in both enterprises being about 5 years (as of 1996).

Land use policy and planning issues

Mixed shrimp - mangrove forestry farms in Ca Mau Province generally range in size from 2 -17 ha of which, under the original government policy, 70% was allocated for mangrove forest, 20% for ponds, and 10% for housing and other domestic purposes. However, the provincial government has recently proposed changes to these guidelines to increase the proportion used for aquaculture, housing and other domestic purposes to 40% of the farm area. In practice, this will probably result in more than 40% of household land being used for aquaculture and domestic purposes, as past experience suggests that farmers tend to stretch the limits set by local authorities.

This decision is in line with a policy to increase provincial aquaculture exports from USD 145 million in 1999 to USD 500 million by 2005. This is expected to be met in part by switching about 50,000 ha of land in Dam Doi, Cai Nuoc and a part of Tran Van Thoi districts to mixed rice (wet season) - shrimp (dry season) farming systems from the present rice only production cycle.
Provincial forestry policy has traditionally focussed predominantly on the production of timber and fuel from mangroves in Ngoc Hien District and, to a lesser extent from, Melaleuca forests which are extensive in the western part of the province. However, rising land levels in some parts of Ngoc Hien District are likely to require a re-thinking on forestry and land use policies.

All waterways in Ngoc Hien District carry high levels of suspended sediment. These suspended sediments are very small in size, about 50% being clay of less than 4 microns in size and the remaining 50% being fine silt of 4 microns to 17 microns in size. Historically, these sediments presumably originated in the catchment of the Mekong and its tributaries, and were carried south by currents in the South China Sea, the heavier sand and coarse silt particles settling out before reaching the Ca Mau Peninsula. Locally, fine sediment in waterways also comes from erosion of the eastern coastline, and erosion along the edges of waterways caused by tidal flows and boat traffic, both of which are also sufficient to keep most of the fine material in suspension. Under the relatively static conditions in ponds, a proportion of this sediment settles out on the bottom of the pond. Ponds need to be cleaned at least annually to maintain an appropriate water depth for shrimp culture. Provincial regulations forbid this material to be pumped back into the waterways (though this is often done surreptitiously) and so legally this sediment has to be deposited somewhere on the farm. In the large extensive mixed farming systems of Ca Mau it is usually deposited in adjacent mangrove areas.

This, together with the processes described in the preceding sections of this case study, suggest that land levels overall are rising in mixed shrimp farming-mangrove forestry enterprises in the south-eastern parts of Ca Mau province. The consequences of this can be seen elsewhere further inland in the province, where mangroves have almost entirely disappeared or have been reduced to a thin veneer of a few metres in width adjacent to waterways. To some extent these changes are inevitable, because they form part of the pattern of landbuilding that occurs naturally in many mangrove dominated estuaries. However, the speed with which they have taken place, and are continuing to take place in Ca Mau, has accelerated as a result of the development that has occurred in the province over the past two to three decades, of which aquaculture is a significant part.

The impact of these changes are likely to be felt within two to three decades, and will have far reaching impacts on farming and other land use practices in Ca Mau province, and on related policies. Changes likely to occur within the next 20 years include:

- A decline in wood production from mangrove forest.
- A shift from traditional and extensive aquaculture to improved extensive and semi-intensive aquaculture. This will involve the gradual disappearance of the present mixed farming system, which will not be economically or environmentally sustainable under the joint influence of declining mangrove forest yields and the management requirements for improved extensive or semi-intensive aquaculture. Intensive aquaculture in Ca Mau may not be an option owing to poor water quality, unless new, more cost effective, environmentally sustainable technologies for managing this become available.

- Diversification of farm outputs, which increasingly are likely to include terrestrial forestry, horticulture and cash crops, along with polyculture or the concurrent culture of aquatic species other than shrimp.

Farming Systems and Practices

There are two main farming systems, which for present purposes will be called 'mixed' and 'separate'. Ponds in both systems consist of a series of long (250-800m), narrow (3-4m wide) parallel channels dug either through (mixed) or adjacent (separate) to forest and separated by levees. In mixed systems, the levees are vegetated by mangroves and are similar in principle to the tambak aquaculture systems used in Indonesia. In the separate system, pond levees are bare with the ponds located near waterways at the front of the farm, while mangroves are usually grown on a separate area at the back of the farm (Figure 1). Ponds are generally shallow, ranging from 30 cm to 1 m water depth, with a mean of 50 +/- 11.5cm. Each pond is connected to the waterway by one or sometimes two sluice gates. Those farmers with access to investment tend to use cement sluice gates, usually about 1 m in width, whereas poorer farmers use wooden sluice gates of about 0.8 m in width.

Traditionally, shrimp culture in Ca Mau Province has been primarily extensive, based on the tidal recruitment and harvest of wild penaeid and metapenaeid shrimp from local waterways, with little or no supplementary feeding, aeration, water pumping or soil treatment. The predominant species cultured are *Metapenaeus ensis* and *M. lysianassa* (80% harvest) with *Penaeus indicus* the next most important species (7-10%). Stocking densities are generally low, between 1 and 5 post larvae/m^2. This is reflected in annual shrimp production, which is low and highly variable ranging between 100 and 400 kg/ha/yr, with mean shrimp yields of 286 +/- 106 kg/ha/yr. Some farmers stock part of their pond with hatchery reared postlarvae of *Penaeus monodon*, but most have had variable success owing to the poor quality of hatchery reared postlarvae, widespread mortality from shrimp viral diseases, and inappropriate management practices.

Production Schedule

Most farmers follow a similar aquaculture management protocol (Figure 2). During February and March the ponds are drained and sludge that has accumulated on the pond bottom (about 20-30 cm annually) is removed and placed on adjacent levee banks. Placement on levees causes leaching of acid sulphate soil into ponds during the wet season. This problem is continuing due to lack of appropriate land on which to place the excavated mud. Costs vary depending on whether the pond bottom is cleaned manually (16,000 – 20,000 VND per 3 x 36 m channel), or with a dredge (100, 000 – 120,000 VND per channel) (14,000 VND ~1USD in March 1999). The majority of farmers excavate the ponds themselves and although the benefits of cleaning the pond bottom annually are well known (Some farmers clean their ponds twice a year), most farmers clean their ponds only every few years owing to their lack of financial capital.

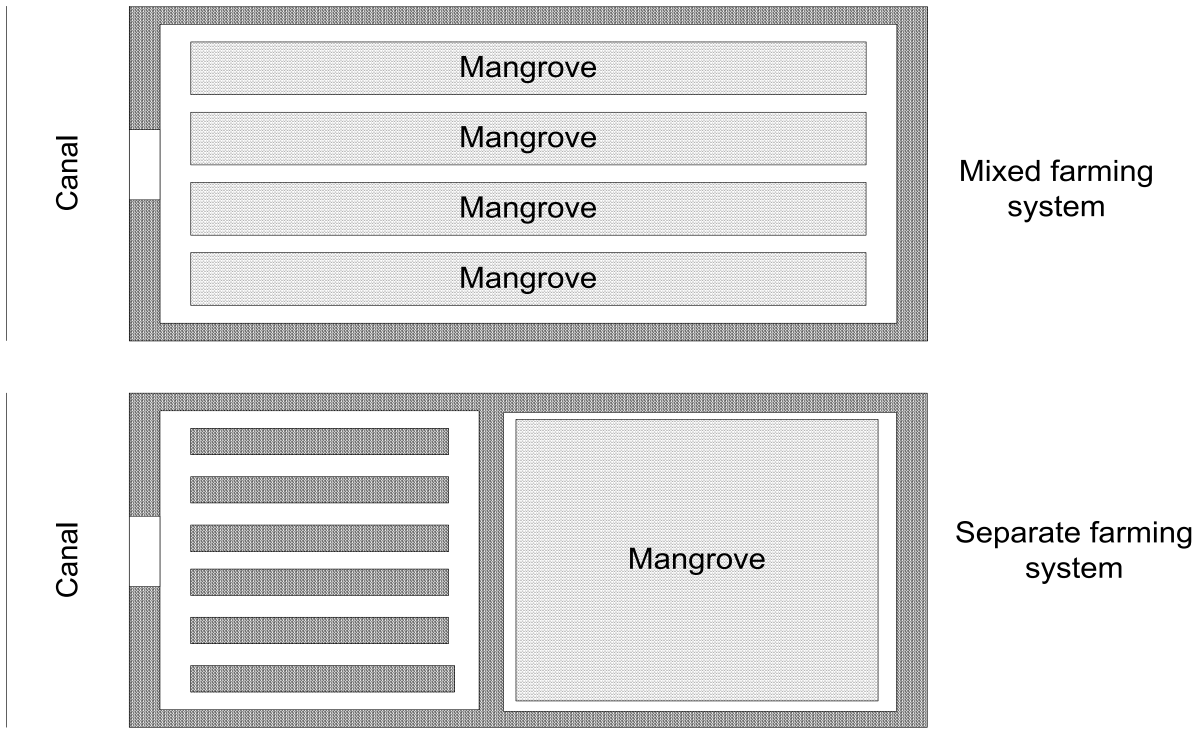

Figure 1. Schematic diagram of mixed and separate farms.

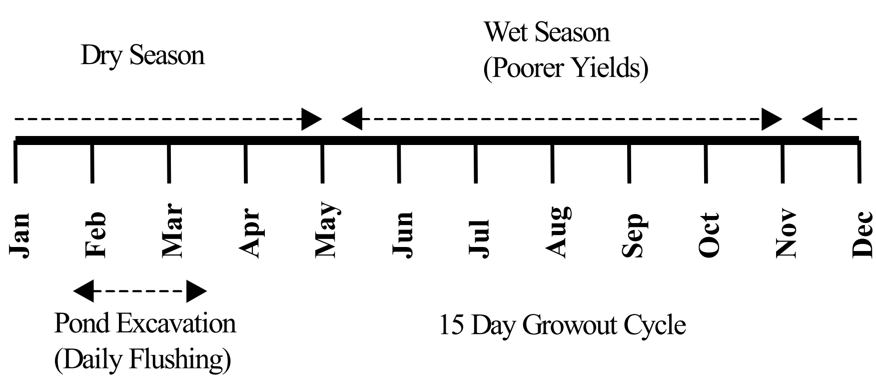

Figure 2. Shrimp culture management practices throughout a typical year. Some farmers will also excavate ponds between June and September if money is available

After cleaning the pond bottom, the ponds are either allowed to dry out, or are flushed daily by leaving the sluice gate open. This free flushing is believed to be linked with good yields for those farmers who practice it. During free flushing, a wide mesh net is placed at the sluice gate to capture fish and large shrimp from the river during the flood tide whilst allowing shrimp post larvae and juveniles into the pond. On the following ebb tide shrimp from the ponds are also harvested in the net. Hence a double harvest and single recruitment occurs per day. Following excavation, ponds are filled during the first spring tide in late March - early April and a 15 day grow out cycle is initiated. However, some successful farmers leave the shrimp to grow for 1.5 months with regular recruitment every 15 days. The resultant harvest is one of the biggest for the year.

During each 15 day growout cycle, recruitment and harvest occurs on consecutive flood and ebb tides for 3 - 5 days of the spring tide period (Figure 3). During recruitment the sluice gate is opened to allow shrimp to enter the pond on the flood tide. A mesh screen is placed at the front of the sluice gate to prevent predators from entering the pond. After recruitment the sluice gate is closed and a conical bag net up to 7m long, is placed at the front of the gate with its mouth facing into the pond. The gate is re-opened on the ebb tide and shrimp/fish/crabs are harvested in the net. Ponds are drained to approximately 20 cm depth after which the sluice gate is closed and then reopened for the next recruitment. This continues day and night until spring tides have passed. The sluice gate is then closed for a 10-12 day growout period during the neap tides. Water exchange is limited during this time,

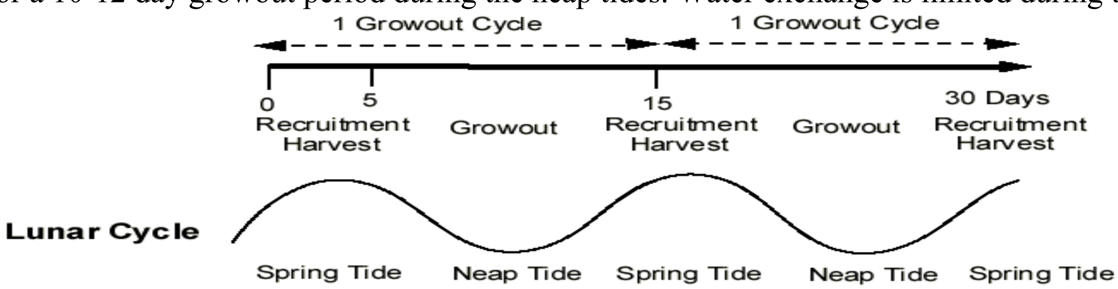

Figure 3. Schematic diagram of the 15 day grow out cycle for shrimp culture in Ca Mau province. During a single growout cycle recruitment and harvest occurs concurrently over 3-5 days of spring tides followed by approximately 10-12 days growout during the neap tides. Recruitment and harvest is then repeated on the next spring tide. This 15-day cycle is repeated throughout the year.

although the first two boards may be removed to allow approximately 20 cm water exchange. Recruitment and harvest is repeated during the next spring tide period. This 15 day cycle continues for the remainder of the year (Figure 3).

Recruitment and Harvesting Technique

Although recruitment for the majority of farmers is just an opening of the sluice gate on the flood spring tide, successful farmers have optimised the recruitment potential and survival of wild seed by adopting techniques based on their behaviour. Prior to the tide turning, these farmers open the sluice gate on the ebb tide which concentrates post larvae at the entrance of the sluice gate due to the water turbulence. When the water level in the canal rises to nearly equal that inside the pond, the post larvae swim against the gentle out-flowing current and into the pond. This gentle current prevents any damage and at the same time the turbulence attracts larvae to the gate. Hence a greater number of larvae are recruited and a higher proportion survive once in the ponds.

The traditional harvesting technique used by farmers involves capturing shrimp and fish exiting the pond on the ebb tide in a bag net which extends into the canal from a frame within the sluice gate.

Mangrove Forestry

Mangroves are a major source of timber and thatching for houses and other buildings throughout much of the Ca Mau Peninsula. They are also the main source of fuel, providing local communities with both fuelwood and charcoal for cooking. Based on the projected demand for firewood of 954,000 m^3 in Ca Mau and Bac Lieu Provinces in year 2000 and timber yields from mangrove forests of about 12 m^3 ha^{-1} y^{-1} (Hong and San 1993), it is estimated that about 80,000 ha of mangrove forest will be required to meet just the fuelwood demands in these provinces by the end of this century. The remaining area of mangroves in Ca Mau and Bac Lieu Provinces is not known accurately, but is probably in the vicinity of 50,000 ha or less (Hong and San 1993). Much of this remaining forest, particularly older stands, was damaged by Typhoon Linda in October 1997.

Depending on the size of their farm, most farmers have 4-8 ha of mangrove forest, which they are required by provincial policy to manage for wood and fuel production. Failure to meet this requirement may result in the lease being revoked before it expires, or not renewed after 20 years. However, financial returns to farmers from aquaculture are much higher than those from mangrove forestry. Hence, most farmers are keen to expand their ponds into areas presently set aside for forestry.

Under the current forest management policy, *Rhizophora apiculata* is planted at an initial density of 20,000 ha^{-1}, with thinnings by 20-30% at 5, 10 and 15 years, and the final harvest at 20 years. Stands planted at 20,000 ha^{-1} begin to self-thin at about 5 years of age, so the timing of the first thinning is most appropriate. However, a thinning rate of 20-30% is much too low. Stands thinned manually by only 30% at 5 years of age begin to self-thin again at about 8 y of age, two years before the next scheduled manual thinning at 10 years of age. Trees lost through self-thinning represent a substantial loss in potential wood production unless they are removed immediately after death. This cycle is repeated at each of the subsequent thinning at 10 and 15 years of age, in each case self-thinning commencing about 2 years after the previous manual thinning.

At 10 years of age, when the second thinning is carried out, trees have an average stem diameter of 6 cm. With a nominal 30% thinning rate, thinnings yield about 30 m^3 of wood ha^{-1}. Wood removed at the second thinning is used for smaller poles (valued in June 1998 at about USD 30-40 m^{-3}), firewood (USD 6.40 m^{-3}) and charcoal production (USD 115 per metric tonne). At 15 years of age, when the third manual thinning is carried out, the trees have an average stem diameter of 8-9 cm. With a nominal 30% thinning rate, thinnings yield about 44 m^3 of wood ha^{-1}. Wood removed at the third thinning is used for larger poles (Valued in June 1998 at about USD 50 m^{-3}), firewood (USD 6.40 m^{-3}) and charcoal production (USD 115 per metric tonne).

By 20 years of age, when the final harvest is carried out, stand density has fallen to about 1,500 ha^{-1} as a result of natural self-thinning, because stands that have been thinned manually by 30% at 15 years of age begin to self-thin again at 18-19 years of age. Trees harvested at 20 years of age have an average stem diameter of 11-12 cm, the final harvest yielding about 180 m^{-3} of wood ha^{-1}.

Impact of Aquaculture on Mangroves

Aquaculture development in Ca Mau Province has had a significant impact on the hydrology of mangrove areas. Many of the remaining mangroves are surrounded by levee banks, or situated in areas where tidal access is hindered. In mixed farms, where mangroves are enclosed within a levee surrounding the farm, normal tidal flooding and flushing is prevented by the more or less constant water level in the pond. Flooding and flushing of mangroves in these farms is further hindered by the usual practice of placing soil excavated during pond construction along the edge of the adjacent mangrove areas. Reliable estimates of the frequency and duration of flooding for mangrove areas in Tam Giang III and LNT 184 enterprises are not available. However, based on general field observations it is probable mangrove areas within the ponds of mixed farms are rarely flooded. The situation for mangrove areas located outside the pond on farms using the separate farming system is less clear, but field observations again suggest that many areas are flooded for not more than about 2-3 days per month.

Impact of Mangroves on Aquaculture

Farmers who use the mixed mangrove-pond farming system report that shrimp yields decrease when mangroves within the ponds reach 8-10 years of age. This is attributed by farmers to a lack of light through shading of the pond canals by the forest canopy. However, shading by mangrove canopies is probably not significant, given that the water in the pond is already highly turbid, and the water transparency is usually less than 20 cm. Mangrove leaves have a very high tannin content, and a more likely explanation is that the decomposition of leaves that have fallen into the pond canals leads to relatively high levels of tannin, particularly near the pond bottom where shrimp usually feed. Regardless of the mechanisms involved, most farmers respond to the decline in pond production by cutting back the mangroves along the edge of the pond channels.

It is clear from the foregoing that extensive mixed farming systems in Ngoc Hien District present a number of environmental and production problems, and that they require management compromises to be made that are not optimal for either shrimp culture or mangroves. These problems will become even more serious as farmers shift from extensive culture of wild shrimp to improved extensive and semi-intensive culture of *P. monodon* in response to government policy for the aquaculture sector, and to socio-economic pressures.

Management Interventions to Improve Farm Production and Income

Improved Extensive Wild Shrimp Culture

A number of factors are responsible for low yields from traditional extensive culture of wild shrimp. Some common problems and simple, common sense, inexpensive practices to address them include:

- Many ponds are too shallow and have high rates of leakage, resulting in water levels of less than 50-60 cm between lunar cycles. This is often compounded by narrow, poorly maintained channels inside the pond. As a consequence, the water volume in the pond is too small to buffer changes in water quality between topping up on lunar spring tides. This can lead to excessive diurnal changes in water temperatures and oxygen levels during period of high insulation in the dry season, and to rapid changes in salinity and pH during heavy rain in the wet season (Johnston et al. 1999). Re-digging the pond to an average water depth of 1 m, reducing leakage where possible, and careful attention to regular cleaning of the pond bottom and other general pond maintenance activities between crops, would improve water quality management overall and contribute significantly to better conditions for shrimp health in the ponds.

- Poor recruitment of wild seed, leading to low stocking densities. This is partly a result of declining wild seed stocks in local waterways, especially of higher value Penaeid species like *P. merguiensis* and *P. indicus*. Hence, smaller, lower value metapenaeid species like *M. ensis* and *M. lysianassa* make up more than 80% of the harvest (Johnston et al. 2000). However, the almost universal practice of recruiting wild seed on the flood tide every 15-day lunar cycle, followed by harvesting on the ebb tide of the same tidal cycle, also leads to a significant loss of recent recruits (Johnston et al. 2000).

Furthermore, harvesting every 15 days means that a significant proportion of the shrimp harvested are relatively small, and therefore of low value. This harvesting schedule is carried out chiefly to provide farmers with a regular source of income and reduce the perceived risk of high mortality when shrimp are allowed to growout for longer. In practice this management technique represents little more than subsistence capture fisheries.

While little can be done to redress the harvest imbalance between metapenaeids and penaeids, a change in the recruitment and harvest cycle to improve recruitment and extend the growout period is suggested. This involves topping up the pond and recruiting on flood tides every 15 days, coupled with harvesting larger shrimp using 'tom te' or 'against water current' techniques (Johnston et al. 1999). This would minimise large losses of recently recruited juveniles from bagnet harvests on ebb tides, and increase the size (and value) of the harvested shrimp. In practice, it has proven to be difficult to change farmer perceptions of the benefits of changing to this management strategy.

Improved extensive and semi-intensive culture of P. monodon

Prior to 1994, improved extensive culture of hatchery reared *P. monodon* post larvae was widely practised, but since then most farmers have experienced severe financial losses from *P. monodon* culture. This has been due to a combination of poor water quality, unhealthy or poor quality post larvae from local hatcheries, poor handling techniques during transport and at stocking, poor management during growout, and a significant increase in the incidence of shrimp diseases.

However, intensification of shrimp culture forms a major part of national and local government policy for aquaculture development in the lower Mekong delta. Several small-scale experimental trials of semi-intensive culture of P. monodon in Ngoc Hien district have given encouraging yields (1-2 t ha^{-1} y^{-1}). However, it is not yet clear whether such yields (Or higher yields) will be sustainable in all parts of the district over the longer term, and the environmental implications for widespread adoption of semi-intensive shrimp culture have yet to be assessed. In addition, there are several other constraints on the widespread, rapid and successful shift to semi-intensive shrimp culture in Ngoc Hien district.

Semi-intensive culture is much more capital intensive than the present extensive culture system, and carries with it a significantly higher risk of severe financial loss if a crop fails. Most existing small-scale farmers in Ngoc Hien district have limited capital to invest in the changes to their farms that will be needed to carry out semi-intensive culture successfully and would be seriously affected financially by a failure over the first few crops. Furthermore, the ability of most farmers to borrow capital at reasonable rates of interest is severely restricted by their lack of collateral, due in part to the lack of land tenure and the short term nature of their farm lease (20 years).

Many farmers already manage their extensive farms poorly, few have had experience of *culturing P. monodon* successfully, and even fewer have had any experience in semi-intensive culture of *P. monodon*. With the low educational level of most farmers, and the general lack of fisheries extension support in Ngoc Hien District, it will probably take some time for many farmers to acquire the new skills and experience needed to carry out semi-intensive aquaculture successfully.

It is already clear that in Ngoc Hien District, *P. monodon* will grow to about 40-50 g in weight over a three-month growout period. Thus the key to improving the yield from this species is to increase the overall survival rate, which is commonly about 1%, and seldom greater than 10% in Ngoc Hien District. Small-scale trials, working with several farmer groups in Ngoc Hien District, are presently underway to improve the survival rate. These involve the following:

- Re-digging ponds, or parts of them, to a water depth of 1 m.
- Training farmers in selecting high quality seed.
- Implementing sound nursery management practices, including feeding.
- Conducting trials on feeding during growout.
- Training farmers how to manage water quality within existing environmental, infrastructure and economic constraints.
- Training farmers how to monitor shrimp health and growth.
- Advising farmers on how to implement step by step improvements to pond design and management based on household economic circumstances.

Semi-intensive culture using hatchery-reared post larvae 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.

Forestry

Clearly, there are a number of problems with current silvicultural practices. Firstly, the initial planting density is too high, leading to self-thinning of the forest at an early age of around five years. Secondly, the timing and degree of manual thinning are inappropriate, because stands begin to self-thin again within 2-4 years after having been thinned manually. It is estimated that a reduction in planting density to 10,000 ha^{-1}, and a thinning strategy designed to avoid stands undergoing self-thinning, together would increase average annual wood production from mangroves by between 10% and 30%.

In addition to lower economic returns from mangrove forestry compared with aquaculture, two other issues also contribute significantly to farmer perceptions about the value of mangrove forestry. Firstly, few farmers have security of land tenure, because land ownership by farmers in Ca Mau Province is rare; most farmers are granted a 20-year lease that may or may not be renewed. With the current 20 year forestry rotation, those farmers who plant mangroves in the first year of their lease can expect to harvest within the period of their lease, whereas those who do not plant in the first year of their lease can benefit from the final harvest only if their lease is renewed. This is a strong disincentive for farmers to manage their allocated area of mangrove forest for maximum production.

Secondly, most of the forestry profit currently comes from the final harvest. In order to gain a regular annual income from mangrove forestry, farmers need to harvest a proportion of their mangroves annually, ideally this proportion being equal to 1/rotation length (In the present case 1/20). This requires that each farm have stands of mangroves with a range of ages up to the maximum age at harvest, presently 20 years. However, with only 4-6 ha of mangroves, most farms are too small for this approach to work well, and in most cases the mangrove stands on any particular farm are of similar age. Based on current production estimates and prices, individual farming households would need at least 200 ha of mangrove to earn an annual net income of USD 1,000 from mangrove forestry alone.

It is clear from the foregoing discussion that the participatory mangrove forestry programme and mixed mangrove-shrimp farming systems have not worked well for small-scale farmers in Ngoc Hien District, and have not arrested the continuing loss of mangroves in the province. This contrasts remarkably with the Matang mangrove forest in the state of Perak in Peninsular Malaysia, where the original mangrove forest area gazetted for forest production at the end of last century, about 40,000 ha, has decreased by only about 250 ha (Gan 1985). In 1985, the annual tangible produce from forest products and associated fisheries in Matang was estimated to be about 152.4 million MYR (equivalent to 40.1 million USD) (Gan 1985). Less tangible benefits to environmental quality, employment and social equity have not been quantified, but are likely to be very significant (White and Cruz-Trinidad 1998). Part of the success of Matang can be attributed to three key factors:

- The Matang mangrove forest is a essentially a single intact entity comprising 19 independently gazetted more or less contiguous forest reserves, not a series of very small forest areas scattered over a much wider area.
- The Matang forest is controlled by the State of Perak. Forest management policies, and day-to-day management and regulatory control are the responsibility of a single authority, in this case the Perak Forestry Department.
- The whole area has been mapped and divided into smaller working compartments, for which there are detailed inventories that form the basis for the overall management plan.

Tam Giang III Enterprise in Ngoc Hien District and the Bai Boi (coastal) area on the south-western tip of Ca Mau Peninsula still have some relatively large contiguous areas of mangrove forest. However, aquaculture ponds have made significant inroads into the mangrove forest in both areas, particularly in Tam Giang III Enterprise, where mixed shrimp-mangrove farming systems are common. It is suggested that shrimp ponds be progressively removed from the inner parts of both Tam Giang III Enterprise and the Bai Boi area, and these areas returned to mangroves. It is also suggested that mangrove forests in these areas be returned to the enterprise or other local institution, which should be given full responsibility for the management of forestry activities. There may also be opportunities to restore larger contiguous tracts of mangrove forest on land with a suitable tidal regime in some other enterprises. Shrimp ponds should not be permitted within mangrove areas that are designated for forestry production.

Extensive replanting of mangroves along the south-eastern coastline of Ca Mau Province as part of the World Bank Coastal Wetlands project may improve coastal protection and overall environmental quality. However, most of the replanting will be carried out in the coastal protection zone, within which forestry activities will not be permitted.

It is not certain that Ca Mau Province will be able to meet its projected timber and fuelwood needs from mangrove and Melaleuca forests even if larger contiguous areas of mangrove forest are established. Furthermore, the topographic changes outlined above suggest that an increasing proportion of these requirements will have to be met by terrestrial forestry in the future. A number of exotic hardwood species, notably Eucalyptus, as well as softwood species like Acacia, grow quite well in Ca Mau Province on moderately saline soils that are rarely flooded by tidal waters. There may well be other indigenous and exotic tree species that are equally, or more suitable for timber and fuelwood production under local conditions.

Diversification and Risk Reduction

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 fruit tree, vegetable and other cash crops on levee banks and other elevated areas.

Conclusions

Coastal aquaculture and land use in Ca Mau Province are presently at a cross-road. Expansion of aquaculture production and a relatively rapid shift from extensive culture of wild shrimp to more intensive culture of *P. monodon* and perhaps other hatchery reared species may lead to a deterioration in environmental quality and increasing land use conflicts. Coupled with this, changes in population demography and land level will require a flexible land use policies and management based on social equity, sound predictions of changes in land levels with respect to sea level, and environmental considerations. The social and economic costs of developing and implementing land use policies that take account of expected future trends may now be high, but the costs will be immeasurably greater in the future if inappropriate land use options based on a short-term perspective are adopted.

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Case Study 8: Mixed Shrimp Farming-Mangrove Models in the Mekong Delta-Socio-economic Study Component

By

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Introduction

This case study covers the socio-economic component of the second (extended) phase of ACIAR/RIA-2/NACA Project (P.N. 9412) "Mixed shrimp farming-mangrove forestry models in the Mekong Delta". The project has been carried out in the two State Fishery-Forestry Enterprises (SFFEs), viz., Tam Giang III (TGIII) and 184, both located in the Ngoc Hien District, Ca Mau Province, Vietnam.

The first phase of the project (1996-98) achieved its two technical objectives of investigating the main factors limiting shrimp and wood production (See case study 8), and identifying improved culture options for these systems. The project has been extended into the second phase (until September 2000), to achieve the other objective of assisting national and provincial authorities to transfer project results and recommendations to coastal farming communities in the lower Mekong Delta. In this regard, it was deemed necessary to conduct an in-depth socio-economic study of sample farmer communities in the two Enterprises to assess the benefits and constraints relating to the implementation of the project recommendations by farmers, and to recommend an appropriate institutional framework that would enable effective adoption of these recommendations. In addition, it is hoped that the information on socio-economic conditions of farmers practising silvo-aquaculture, gathered through this study, may be of use to a number of other projects currently on-going or planned in the Mekong Delta. These include the World Bank-funded project for the Rehabilitation and Development of Wetlands (which also includes a component funded by the Danish government through Danida); and the Rehabilitation of Mangrove Forest Project (E-RMFP; now in an extension phase), funded by the Dutch government.

Aims and Objectives

The broad aim of the present study is to assess the social and economic benefits and constraints to implementing the technical recommendations developed in the earlier phase of the project.

The specific objectives, based on the Terms of Reference for the socio-economic study component, were as follows.

- To prepare a framework for carrying out an economic analysis of mixed farming system management practices, based on the technical recommendations developed by the ACIAR Project FIS/94/12.
- To identify social and economic benefits and constraints to implementation of these technical management recommendations.
- To assess institutional constraints to implementation of these management recommendations, and recommendations for overcoming such constraints where possible.
- To provide recommendations on the optimal institutional arrangement to support farmers in improving benefits from their mixed farming systems, and how this institutional structure(s) be developed, and to provide an analysis of the requirements to support and manage risk in poorer households.
- To provide recommendations on how to promote farmer groups and improve local management of resources (including co-management possibilities).

- To identify strategies to ensure benefits from improved management strategies reach the poorer farm households and their members.

An additional task of following up on the 12 farming households interviewed earlier in 1998 under the previous socio-economic survey could not be achieved due to time and logistics constraints.

Methods

Two farmer groups were selected for the study, one each in TGIII and 184. The selection was made based on the ease of communication with the group members during a preliminary field visit in November 1999 with the ACIAR/RIA-2/NACA project team, including Dr. Philip Hirsch (consultant and supervisor for the socio-economic study component), Dr. Barry Clough (Australian project leader) and Dr. Tran Thanh Xuan (Vietnamese project leader).

Three additional visits, each lasting 3 to 10 days, were made during November 1999 to January 2000. A total of 23 farmers (13 in 184 and 10 in TGIII) belonging to the two groups participated in the study. The following methods were used to gather information.

- Semi-structured interviews.
- Group-based participatory rural appraisal (PRA) techniques.
- Interviews with key stakeholders.

In addition, personal observations made during the visits were recorded and, where possible, brought up during discussions with the farmers.

In both the groups, experimental trials are under way to assess the effectiveness of employing project recommendations. These trials are conducted by a local staff of the Research Institute for Aquaculture No. 2 (RIA-2), under the supervision of Dr. Clough and Dr. Xuan. Two farmers in each group are selected for the trials, one receiving full financial support (Covering costs towards pond deepening, seed, feed, and equipment for shrimp production and trial monitoring), and the other partial support (covering all of the above except pond deepening). In each group, attempts were made to target the full- and partial-trial participants[3]and three to five control farmers (i.e. not part of the trials) representing, respectively, an economically well-off, medium and less well-off farmer category.

Semi-Structured Interviews

Of the 23 farmers, 11 (five in the TGIII Group and 6 in the 184 Group) were interviewed individually using a semi-structured interview scheme with a set of guideline questions.

The semi-structured interviews focused on the resources and demands in a farming environment and the farmer's perception. Resources, such as physical, biological, financial, temporal, legal, institutional and human, were grouped into the following levels: home-based, farm-based, community-based, SFFE-based and external. Demands included capital inputs as well as demands in the household economy. The farmer's ability and/or constraints to adopt the

[3] The partial trial participant in TGIII had withdrawn from the trial, and the one in 184 could not be interviewed.

recommendations could be assessed by comparing resource availability with demands in the farm-household economy.

Farmer perception on the following was assessed:

> *Risks in shrimp farming, future value, poverty, other stakeholders (other farmers, PL vendors, hatchery operators, enterprise managers, government agencies, extension staff, etc.), and externalities in the shrimp farming-mangrove environment.*

The trial participants' perception of risks in shrimp farming was compared with that of the control farmers in order to assess the farmers' confidence in adopting the recommendations. The perception of future value showed the farmers' appreciation of the profits from mangrove harvests at the end of the 20-year contract. Since the trees on most farms were planted 8 to 10 years ago, the harvest is expected to be carried out in 10 to 12 years' time.

The farmer's perception of poverty revealed economic constraints to survival, largely relating to the risky and increasingly capital-intensive nature of shrimp farming. It also gave a crude indication of the economic strata within each group. This helped in identifying the poorer farmers within the group, who were followed up for in-depth interviews. The farmer's perception of different stakeholders showed their relative importance, roles and reliability. Perception of externalities in the shrimp-mangrove environment showed mainly the sources and significance of factors affecting shrimp yields. In addition to the above, the control farmers were asked to comment on each of the project recommendations for improved shrimp farm-mangrove management. This exercise was attempted to assess the farmers' confidence in the recommendations, and their willingness to adopt them. The farmers' knowledge of the recommendations in itself indicated the extent of information flow within this group.

Group PRA Interviews

The group PRA exercises were conducted using the following tools:

- Focus group discussions with farmers
- Trend analysis
- Gender analysis
- Seasonal calendar
- Problem web
- Daily activity chart

The trend analysis brought out temporal changes in the major factors affecting farming operation and living conditions. The gender analysis helped to understand the roles of men and women in carrying out on-farm and household activities (Division of labor) and in economic decision-making at the household level. The seasonal calendar highlighted major events during a typical year, showing seasonal variations in resource availability, use and constraints. The problem web helped in tracing the root causes of the problems identified by the farmers. The daily chart provided a general picture of activities in a typical 24-hour cycle during spring tides when the main water exchange and harvesting take place.

Stakeholder Interviews

Interviews were conducted with the following stakeholders:

- Shrimp hatchery operators in Nam Can.
- Vendors at Vam Dam market, the nearest market for the two groups.
- The officer conducting the project trials.
- Leaders (managers) of the two enterprises.
- The head of the Ngoc Hien District Department of Fisheries, Nam Can.
- Deputy director of the Provincial Department of Agriculture and Rural Development in Ca Mau.
- Deputy director of the Minh Hai Sub-Institute for Fisheries Research in Ca Mau.
- Deputy director of the Minh Hai Wetland Forest Research Centre, Ca Mau.
- Manager of the Extended-Rehabilitation of Mangrove Forest Project, Ca Mau.
- The head of the Provincial Fisheries Extension Service, Ca Mau.

Data Constraints

A number of constraints related to data collection were evident. Firstly, there was limited time available to conduct the study, so that all aspects of the issues could not be dealt with. Secondly, the farmers were not always available during visits, especially in the TGIII group. Thirdly, data on incomes from shrimp farming were found to be imprecise due to a high frequency of harvest (Every spring tide for most of the year), lack of record keeping habit among the farmers, and large fluctuations in harvested quantities. Although a general harvesting pattern can be identified in each of the two groups (see "Seasonal Calendar"), the number of harvests carried out varied from farm to farm, depending on capital capacity for stocking and pond preparation, water quality, pond leakage, and pond management. Attempts to estimate quantities harvested annually using average yields were unsuccessful, as farmers could not remember the number of harvests.

Similar yield and income data are also collected by the officer from the sub-institute of RIA-2 (The Minh Hai Sub-Institute for Fisheries Research in Ca Mau). Since these data are collected on a more regular basis, we felt that they would be more reliable than our estimates. The copies of questionnaire responses for the target farmers were provided by the RIA-2 officer. For the economic analysis presented in this report, these income data are used together with the data on household expenses collected during the semi-structured interviews. The MHSIFR data also suffers from some handicaps. First, income from all sources are sometimes not recorded, including income from shrimp trade in some TGIII Group farmers. Second, this data pertains only to farm inputs and income; household expenses (food, clothing, house repairs, education, transportation, etc.) are not accounted for.

As for stakeholder interviews, one important stakeholder group missed out in the interviews was the representatives of the government banks in Ca Mau, who could not be reached due to time constraints and some logistical problems in contacting them in advance. Information about bank loans was instead accessed from interviews with the farmers, Enterprise managers, officials at DARD in Ca Mau, and from literature available.

Results

Background Information on State Forestry and Fisheries Enterprises

TGIII and 184 are among the 18 State Fishery-Forestry Enterprises (SFFEs) currently operating in Ca Mau province. Most SFFEs were set up in the early- to late-1980s. Following massive mangrove forest destruction for shrimp farming in the Mekong Delta during the 1980s, mixed shrimp-mangrove systems were promoted through SFFEs (Binh et al. unpublished). The SFFEs issue land parcels (3-5 ha each) to individual farmers, who are required to plant and raise mangroves (almost invariably *Rhizophora* spp.) on at least 70 percent of the area; the remaining 30 percent is used for aquaculture ponds and homestead. Mangroves are harvested at the end of the 20-year cycle and replanted again.

The SFFEs are under the direct supervision of the provincial and district arms of the Department of Agriculture and Rural Development (DARD). In each Enterprise, a management committee (comprising mostly former government officials) runs the day-to-day operations. Most derive their income from sharing mangrove harvest profits with farmers, and from shrimp culture on plots belonging to the committee.

Directives since 1993, particularly the Law of State Owned Enterprises (Decree 388), have made the SFFEs commercially independent and self-financing, and limited the scope of control of the state and province (World Bank 1999; ADB 1996). However, following the sharp decline in shrimp yields since 1994, and the ban on mangrove cutting in 1996 (Which was later removed in mid-1999), many SFFEs experienced cash flow problems. As a result, in 1997 six SFFEs (including the TGIII) were reclassified by the Ca Mau's Provincial People's Committee from State-Owned Enterprises into Forest Protection and Management Boards (World Bank 1999). These SFFEs now depend on government grants for their administrative expenses and return revenues from forest cutting and tax collection to the provincial government. The remaining, including SFFE 184, are still independent, self-financing production units.

Although declining shrimp yields and the mangrove cutting ban were the main reasons for seeking government support, other factors such as management efficiency, resource availability and the size of the Enterprise (which also determines the amount of land and mangrove resources available) are probably also significant. The TGIII, for example, is much smaller in size than the 184. According to Mr. Vinh, Deputy Director of DARD, Ca Mau, in some Enterprises mangroves are too young to be harvested, so that those Enterprises were not able to generate enough income to meet their budget.

Administratively, an Enterprise is divided into zones, which are further divided into groups. A group is the smallest administrative unit not only of the Enterprise but also in the national administrative system of villages, communes, districts and provinces. A group may consist of between 10 and 50 farming households living in a given area. The two Enterprises TGIII and 184, together with SFFE Ngoc Hien come under the jurisdiction of the village of Tam Giang.

Land Tenure

All land in Vietnam belongs to the government and the maximum land tenure is for 50 years. The SFFEs hold the land under a 50-year lease (The "red" book), and in turn issue land parcels of 3-5 ha on average to farming families on a 20-year lease (The "green" book). Both types of leases are renewable and allow for inheritance. Land under the 20-year lease, however, cannot be sold, but can be returned to the Enterprise, which must compensate the farmer for the labour and financial investment he/she has made in the land. In practice, this means the green books are traded between farmers, with the approval of the Enterprise, with the "buyer" paying the assessed value of the plot. The new holder may negotiate the lease with the Enterprise, particularly the profit-sharing arrangement for mangrove harvest and the duration of the lease, which can be either extended for another 20 years, or used for the remaining years under the old contract.

Elsewhere in Vietnam, the green book can be used as a collateral for formal (bank) credit, but farmers in SFFEs cannot access government loans without the approval of Enterprise managers who act as guarantors.

Discussions with farmers revealed that there is probably a high turnover of farming households. According to one estimate, as many as 7 out of 10 original residents have left and their plots taken by new migrants or existing farmers. Although this estimate could be somewhat exaggerated, it does indicate a trend of both high turnover and land consolidation. Enterprise officials attribute the frequent trading of leases to the latter. There is a tendency among Enterprise managers to encourage consolidation, since forest/aquaculture income from a 3-5 ha plot is considered an insufficient incentive for forest conservation. Land consolidation trend appears to be stronger in SFFE 184 than in TGIII. According to the managers in the respective Enterprise, about 5 percent of land leases change hand each year in 184, while in TGIII only 1-2 households leave each year. Statistics on new settlements and land consolidation at the Enterprise level were not available, and it was not possible to check data at the village level. The village-level data may be somewhat mis-representative of the more recent trends, since farmers in the Enterprises are required to register with the village administration after five years of residence, and most do not wish to be registered immediately.[4]Out-migration trends, on the other hand, probably have set in a little after the sharp drop in shrimp revenue since 1994.

Farm Characteristics

The TGIII Group farms are located on the main river, the 184 Group farms on a canal (Canal No. 17) separating the two Enterprises (Figure 1). All the farmers in the TGIII group practise the separate system of shrimp farming-mangrove forestry, in which shrimp ponds are outside the mangrove area. The 184 group farmers, on the other hand, practise the mixed system wherein the ponds are located within the mangrove area (see Case Study no 8 and AIMS/RIA2/NACA 1999a for details of the two systems).

[4] From interviews with farmers and Enterprise officials, January 2000.

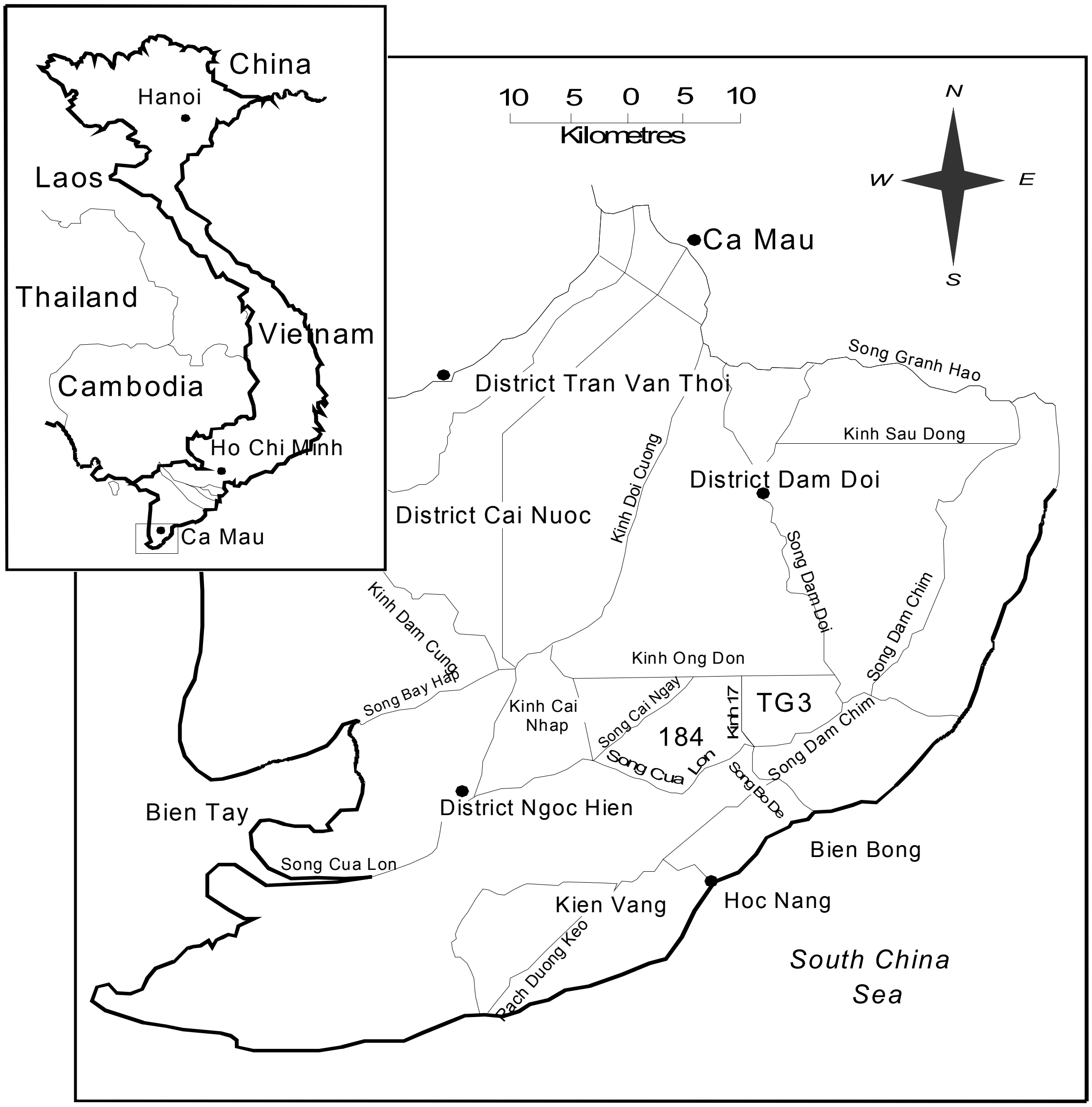

Figure 1. Map of Ca Mau Province, showing the location of Tam Giang III (TG3) and SFFE 184 Enterprises.

The information below on farm and farmer characteristics is based largely on semi-structured interviews. The farm and pond water surface areas were generally larger and pond depths greater in the TGIII Group than the 184 Group farms (Table 1). Depths of most ponds range between 0.6-1.2 m, but generally are shallower than project recommended depths of at least 1 m and up to 1.5 m for 30% of the water surface area for ponds with a leakage problem. Depths are slightly greater in the TGIII group, possibly because several ponds are dredged using machines (suction-pumps), which, in turn, can be attributed to the relative affluence of the farmers in that Group who can afford the higher costs of deep dredging. Although, an additional factor could be the availability of open levees in the separate system to place the dredged mud; in the mixed system levees are occupied by mangroves. Discharging dredged mud into public waterways is now illegal, since it may deteriorate water quality. Observations elsewhere in the two Enterprises showed, however, that this practice is not uncommon, especially when dredging was carried out using machines, despite reported cases of wrongdoers being fined.

Table 1. Characteristics of the Farms in the Two Study Groups

Farm No.	Land area (ha)	Mangrove area (ha)	Pond water surface (ha)	Taxable area (ha)	Mangrove			Av. Pond Depth (m)
					Age (year)	Dbh (cm)	Density (trees/ ha)	
TG III (Main river)								
1	7.80	3.6	1.5	3.7	7	9	10,000	0.74
2	7.30	3.6	1.0	3.7	6	5	10,000	0.67
3	5.00	2.5	1.7	2.5	7	5	10,000	0.84
4	6.70	3.2	1.4	3.7	3	3	10,000	1.26
5	5.20	3.2	1.1	2.0	4	3	10,000	1.21
Av. TGIII	**6.40**	**3.22**	**1.34**	**3.12**	**5.6**	**5**	**10,000**	**0.94**
184 (Major canal)								
1	8.06	4.0	1.56	4.0	9	7	8,000	0.68
2	4.50	2.7	0.71	1.8	9	8	10,000	0.78
3	3.40	2.4	0.55	1.0	11	-	10,000	0.94
4	4.50	3.0	1.00	1.4	10	11	10,000	1.05
5	5.50	3.0	1.40	2.4	9	10	12,000-15,000	0.60
6	3.90	2.7	0.60	1.2	9	10	13,000	0.70
Av. 184	**4.98**	**2.97**	**0.97**	**1.97**	**9.5**	**9.2**	**10,000-11,000**	**0.79**

Source: Land areas and pond depths: MHSIFR data; mangrove age, dbh and density: survey data.
Notes: All values as reported by farmers; dbh: diameter at breast height; depths are uneven in all ponds.

All the farms studied in the TGIII group have cement gates (at least two each, except one with a single gate), while in the 184 group, half of the farms have cement gates (two each), and the rest have a single wooden gate each (Table 3 below). According to the farmers, cement gate lasts for 6 or more years, with minor repairs and maintenance during its life. A wooden gate, on the other hand, may last only about 8-12 months.

Farmer and Community Characteristics

Migration History
High profits from shrimp farming was the primary motivating force behind the massive population influx to the lower Mekong Delta during the 1980s and the early-1990s. Since 1994, however, there has been a sharp decline in natural shrimp yields while production of hatchery-reared *P. monodon* is beset by disease outbreaks and high shrimp mortality.

Most of the farmers interviewed settled at the present location during 1989-1991 or later. The year of migration to the present location was much more varied in the TGIII than in the184 group (Table 2). Of the five farmers interviewed in TGIII, one has been living there since 1978 and two other migrated in 1993-94, while all except one of the six farmers interviewed in the 184 group joined the Enterprise during 1989-91. The only newcomer (1997) in this group lives provisionally on a farm he has rented from the land-holder (absentee landlord) who lives elsewhere.

Shrimp farming was the main reason for migration for at least 5 of the 11 farmers interviewed (in both the groups). Three others, who are former government officials, received a free land parcel each from the government. Two farmers came in search of land and livelihood. One farmer did not specify the reason for migration. Except for the three (former) government officials (Including one soldier), all others "purchased" land at various prices. One government official also "purchased" additional plots.

Table 2. Duration of Farmer Residence (unit: years to 2000).

Farm No.	TGIII	184
1	10	11
2	22	11
3	6	9
4	7	10
5	10	3
6	-	11
Average	**11**	**9**

Source: Survey data

According to the farmers interviewed, a trend of outmigration has set in during the past several years. As mentioned earlier (see Land Tenure), new in-migration may probably be still occurring, but at any rate, a significant number of farmers are "selling" off their land, largely due to their inability to repay debts incurred from failure in shrimp farming.

Economic Status

During the household visits, most farmers in the TGIII Group appeared relatively well off in comparison to those in the 184 Group. Within the latter, some farmers are apparently poorer than the others. Nearly all of the poorer farmers in 184 rely on fishing and collecting snails from the wild, for additional income. They were also the ones whose farms have wooden sluice gates, and their overall investment for pond improvement was generally lower than the farmers with cement gates (Table 3). One poorer farmer in the 184 Group is now relying only on natural shrimp recruitment, as he is unable to purchase hatchery-based seed of black tiger shrimp (*Penaeus monodon*) and cannot afford the necessary pond improvement.

Table 3. Comparison of Investments in Shrimp Farms by Gate Type (unit: million VND)

Farm No.	TGIII			184		
	No. and type of gate/s	Cost of gate construction	On-going investment	No. and type of gate/s	Cost of gate construction	On-going Investment
1	3 (cement)	18.00	11.80	2 (cement)	5.00	16.35
2	2 (cement)	7.35	10.04	2 (cement)	6.00	14.16
3	2 (cement)	6.00	16.54	2 (cement)	7.00	11.01
4	2 (cement)	7.00	13.51	1 (wooden)	0.70	8.78
5	1 (cement)	4.60	5.91	1 (wooden)	0.50	2.80
6	-	-	-	1 (wooden)	1.00	7.85
Avg.	**-**	**8.59**	**11.56**	**-**	**3.37**	**10.16**

Source: Data on gates: from surveys; data on farm investment: from MHSIFR data, except for farm no. 5 and 6 in SFFE 184, which are from survey data.

Group Dynamics

The level of co-operation and solidarity among group members appeared to be higher in the 184 group than in the TGIII group. For example, during one of the visits the survey team witnessed farmers in the 184 group helping each other repair dykes breached by a high tide the previous night. This help was also extended spontaneously to a farm whose owner was away at that time. In the TGIII group, on the other hand, even though most farmers replied positively when asked about solidarity in the group, there was little evidence supporting this claim. On the contrary, one farmer mentioned the lack of sufficient co-operation within this Group. Socialisation, by visiting each other's houses and sharing meals, drinks, and farm produce, was more often observed in the 184 Group than in the TGIII Group.

Information about project recommendations also appeared to flow more easily in the 184 Group than in the TGIII Group. For example, control farmers in the 184 Group said they consult the trial participants on project recommendations and have already begun adopting some of the less capital-intensive recommendations (see "Farmer Perception of Recommendations"). In the TGIII Group, while all the three control farmers have adopted some of the project recommendations (e.g., growing PL in a nursery pond, feeding the juveniles, etc.), the information was accessed from different sources, not necessarily always from the project trial participant. One control farmer in this group was unaware of the composition of the project-recommended feed (Boiled fish and egg) for shrimp juveniles, and has been instead using a recipe he learnt from a booklet supplied by a research team from Cantho University in 1994.

Household Economics

The semi-structured interviews attempted to cover the various aspects of a farm-household economy, including capital inputs, household expenses and activities. The main items of expense include: social activities such as attending weddings and death anniversaries, food, clothing, house maintenance, and others, of which food and household essentials (Soap, spices, lamp oil, etc.) were the largest items of expense followed by expenses on children's education in TGIII, and social activities in 184. The expenses tend to cluster around the 11th to 1st Lunar months, as in this period the wedding season coincides with the major dredging and stocking season. It is a period of higher financial demand (deficit).

Accurate data on income from shrimp farming and other economic activities was difficult to obtain. High fluctuations in shrimp yield, high harvesting frequency (Every 15 days), and the reluctance or inability of farmers to keep a record of farm income and capital inputs are some of the factors that make it difficult to obtain data on farm incomes. Farmers were unable to recall quantities of shrimp harvested each time during the previous year or even number of harvests carried out; often the averages given appeared to be either too high or too low (Probably the highest or the lowest yields achieved?). The project officer from the Minh Hai Sub-Institute for Fisheries Research, overseeing the project trials, also keeps a record of capital inputs, harvest amount and income from shrimp farming. Since this data is collected more regularly over a one-year period, it may be more reliable to use when attempting an economic analysis.

Generally, levels of income are low, though there are apparently substantially wide income disparities within each of the two groups. In both the groups, the full-trial participants appear to be the most affluent in the group. Most farmers, especially in the 184 group, however, appear to be making a bare minimum, and with hardly any surplus for further farm investment. In most cases, it is quite clear that the capital-intensive nature of shrimp farming, along with repeated crop failures, have led to increasing indebtedness and poverty (see also Economic Analysis).

Income Sources and Diversification

Most farmers in both Groups rely solely on the income from shrimp harvest, though after the Typhoon Linda, there has been increasing income diversification through activities such as crab farming, growing vegetables, raising domestic animals, picking snails, crabs, vegetables and other edible plants in the wild.

There were a few notable differences in the forms of diversification among the farmers. Those with some capital access have diversified into crab farming, animal raising and fruit trees planting (which requires a water-well), and a few in shrimp trading or transport activities that require a varying degree of capital inputs. Less affluent farmers were diversifying into activities that do not require capital, such as picking snails, crabs, vegetables and other edible plants from the wild. A few poorer farmers also worked as labourers, carrying out farm dredging for other farmers.

Credit

The credit system to which the farmers in the two groups have access can be grouped into five categories:

Credit from State banks (viz., Bank for Agriculture and Rural Development and Bank for the Poor), Credit from private lenders (informal, but very high interest rates), Credit from formal or informal community based systems, such as People's Credit Fund and ROSCA (hoi), Indirect credit in the form of purchase of post-larvae and household necessities from vendors, and Credit from relatives and friends.

Credit From Banks

All the farmers interviewed were in debt to a varying degree. In most cases, however, the debt in question was the soft loan issued by the Vietnam Bank for the Poor in early 1998 for recovery from the damage caused by Typhoon Linda, which struck the Ca Mau peninsula in November 1997. These loans, with a monthly interest rate of 0.5 percent (6% per annum), are due in April-May 2000. The interest rate has been increased this year to 0.75 percent per month, and the Enterprises are urging farmers to prepare for repayment by the scheduled dates.

Credit From Private Lenders

Credit from private lenders carries exorbitantly high interest rates, 7-15 percent a month or even higher. Loans from private lenders are usually small amounts borrowed in times of emergency, and repaid within a short period of time. Private lenders generally advance loans to farmers they already know and those with a satisfactory credit-worthiness. At least two farmers in 184 reported having borrowed from a private lender an unspecified amount at the rates of 8% and 10% per month, respectively.

Farmer Perception

The results of the risk assessment exercise in the semi-structured interviews show that farmers participating in the project trial tend to have a higher level of confidence in the harvest of their shrimp crop than those in the control group.

Perception of Different Groups

Enterprise

The farmers in both Enterprises indicated a general lack of trust toward the Enterprise and in the profit sharing arrangement for mangrove harvest, in particular. Since forests are, in most cases, below harvesting ages the farmers have no experience of profits from mangrove harvests. Where thinning was carried out, profits were negligible (pers. comm., officer implementing project trials).

The distrust toward the Enterprise originates partly from the fact that there is no aquaculture extension service from the Enterprise, or any help toward improving the farmers' livelihoods, apart from the two loans in securing which the Enterprise acted as a guarantor. The Enterprise officials admitted the lack of extension officers for aquaculture. With the assistance from the district Department of Fisheries in Nam Can and the Provincial Aquaculture Extension Office in Ca Mau, aquaculture training sessions are held for farmers in different areas in the district. According to the TGIII Enterprise officials, such training sessions are being conducted in the

Enterprise. However, the farmers in the groups studied had not attended or even heard of such training courses.

The Enterprise officials, on the other hand, indicated a lack of trust in the farmers' ability to improve productivity, which they blamed on the farmers' low education level and lack of technical knowledge and experience in shrimp farming. Together this results, according to the Enterprise officials, in an ineffective use of investment, for which reason they are reluctant to act as loan guarantors for more bank credit.

Farmers, therefore, turn to private lenders in time of need for loans with very high interest rates raging from 6-10% a month. The interest rates may vary depending on the level of acquaintance between the lender and the borrower, and the latter's credit-worthiness. Farmers, who are unable to pay back loan in time, gain a low reputation and find it difficult to borrow again.

There was also a feeling among the Enterprise officials and some of the more successful farmers that many shrimp farmers generally concentrated only on quick profits from shrimp farming, and were reluctant to diversify into other income generating activities that could lead to a more sustainable livelihood.

Perception of Externalities

Farmers in both Enterprises perceived that leaf litter from the mangrove forest has an adverse impact on the yield of shrimp. The leaves decay in the water, releasing tannin and other chemicals and increasing acidity. This complaint was more often made by farmers in the 184 group who practise the "mixed system". The blocking of sunlight (Shading of the pond surface) and wind by trees was also a frequently made complaint in the 184 group. Farmers in this group want to convert their ponds to a separate system, but appeared unaware of the costs involved.

Agrochemicals from paddy fields, particularly from the nearby Dam Doi district were also blamed for adversely affecting water quality and shrimp yields. Rain is said to affect shrimp yield through its diluting effect. Farmers, however, do not consider rain a serious problem, because water exchanges are frequent. None of the farmers mentioned temperature as a factor affecting shrimp yield. For most farmers, the link between water temperature and pond depth was apparently new knowledge.

Policies

Land Tenure

Land in Vietnam is owned by the government, and leased to individuals or entities. The longest lease available is for 50 years. Within the Enterprises, as mentioned earlier, land is leased to farmers on a 20-year basis (The "green card" or the "green paper"), while the Enterprise management holds the 50-year lease (The "red card" or paper).

Although a 1994 legislation at the national level (Decree No. 2/CP, issued on 15 January 1994) allows individuals to hold forest lands, including mangroves, for "sustainable utilisation" under a 50-year lease, farmers in SFFEs are unable to access this lease for at least two reasons. First, 50-year leases have already been issued to the Enterprises, which then issue land plots to individual farmers under a 20-year lease. Second, given the past experience of rampant mangrove destruction following the dismantling of the former communes or farmer collectives, the provincial governments fear that land privatisation may lead to another wave of mangrove destruction.

Some agencies, particularly banks, are reportedly in favour of granting farmers in Enterprises 50-year leases. Under the current 20-year lease, farmers cannot apply for loans directly, but need the Enterprise to act as a guarantor. Given the poor performance of many farmers in repaying loans, Enterprises are generally unwilling to procure more loans for farmers fearing further indebtedness and loan defaults.

Current land regulations at the Enterprise levels allow farmers to hold more than one parcel of land, but do not allow subdivision, or subleasing. However, it is apparent that subleasing is probably not uncommon; poor farmers who cannot afford to “purchase” land, resort to informal tenancy agreements with absentee land-holders. Obviously, the number of such agreements does not enter official statistics, so that despite being poor, the tenancy farmers are likely to miss out on the various poverty alleviation schemes and are unable to access official loans or assistance, such as the Typhoon Linda recovery loan advanced in 1998 by the Vietnam Bank for the Poor (VBP). They are also unlikely to draw any benefits from mangrove plantations.

A few developments concerning land tenure may need to be followed up. One of these is the possible impact of the forthcoming World Bank project on Coastal Wetlands Protection and Development in the Mekong Delta. One of the components of this project is the restructuring of the SFFEs in the coastal buffer zone. A project document highlights the case of the SFFE May 10 (in Soc Trang), which broke up six years ago, and its land was distributed to the resident farmers. Whether or not (and if it does, to what extent) the restructuring of Enterprises in the coastal zone will have impact on Enterprises outside this zone (Such as TGIII and 184) is difficult to say at this juncture.

Another development is the proposed plan of the DARD to provide infrastructure facilities to households. According to the Deputy Director of DARD’s Ca Mau provincial office, under this plan, groups of farmers in the SFFEs will be relocated within the Enterprise in areas where facilities such as schools, hospitals, proper housing etc. will be set up. The new housing areas will be close to the farms (Within 4-5 km), so that farmers can visit their farms on a daily basis. DARD is now seeking external funding for this plan.

While it is true that infrastructure facilities are greatly needed, the plan for relocation of farmers will need a careful study. Shrimp farming, unlike land-based agriculture, necessitates the farmer’s continued on-farm presence for monitoring and surveillance; this is particularly the case with the form of shrimp farming in the Mekong Delta, with its dependence on spring tides for water exchange and harvest. Emergency situations where heavy rains or high tides breach dykes are not uncommon and usually need immediate attention. Whether the farmer will be able to look after the farm day and night while living some distance away is a question that needs to be addressed before implementing this plan.

Taxation

Tax on aquaculture land is based on the shrimp farm area (including dykes and pond water surface area), and not on the basis of productivity. Generally the tax is higher than the tax on agricultural land.
The land tax (on aquaculture land) is three-tiered. It is highest for a low-lying (shallow) land area, and subsequently lower for farms on higher grounds. The highest tax rate (for low-lying areas) is equivalent to the tax rate for second class agricultural land. Farmers in the TGIII Group complained that the tax rate is high when compared to the agricultural land in the neighbouring districts.

The mangrove plantation area is not taxable, but a resource tax (4% in TGIII and 5% in 184) applies to the gross harvest income.

Credit
The perception that loans are used ineffectively and the failure of most farmers to repay previous loans have made Enterprise leaders reluctant to help seek additional loans for farmers. Banks, however, appear to be willing to provide more loans and are pushing for the granting of red cards (50-year tenure) to farmers in SFFEs, so that they can access loans without requiring help from Enterprise leaders.

People with genuine credit needs, thus, have few other options than to turn to private lenders as a last resort. Due to very high interest rates, these loans are generally small (a few hundred thousand VND) and of shorter maturity periods. Those who are unable to pay loans, mostly due to repeated failure in shrimp farming, lose their credit-worthiness and usually end up in a more desperate situation, as they cannot get loans even from private lenders. Many are then forced to leave the Enterprise.

Mangrove Forest Policies
The mangrove policy of the province was set out in the Decision No. 64 of 1991 of the Minh Hai government. The Decision was passed in the light of the new migrants from elsewhere in the country. The goal of the Decision 64 is to restore forest on 75 percent of the area, and set aside 25 percent for aquaculture. Another objective was to distribute income from forestry between individuals and institutions. The farmer receives up to 80 percent of the profit from final harvest, and 100% from thinning.

The provincial government decides which area in the province is to be thinned. The process of applying for permission and conducting the thinning is as follows: The Enterprise submits an application to the Department of Agriculture and Rural Development (DARD), which then sends it to the Provincial Committee. The Committee reviews the application and submits it to the chairperson for decision. The government lays out the thinning policy. The Earlier Decision of 1986 allowed first thinning at the age of 7 years, based on the research conducted in Northern Vietnam. But this was scrapped after it was found that the farmers thinned only good trees, leaving bad trees. Currently the first thinning is carried out in 10-year-old forests.

Uncertainties related to thinning age, costs involved when calculating final profit sharing, and the overall policies regarding thinning and harvesting, as well as distrust toward the Enterprise have led to a general perception among farmers of mangroves as a burden rather than a future income source. The 10 year waiting period before the first thinning is viewed as too long, nor is thinning at an earlier age considered profitable. Further, because land plots are rather small, and profits per ha from shrimp harvests are low, there is a clear tendency to increase pond area at the expense of the forest.

In view of the wide-spread forest clearance, a forest cutting ban was enforced in 1996, under the Decision No. 351 passed in November 1995. The ban was later lifted in the middle of 1999. However, uncertainties remain about the age of thinning. To make the policy of mangrove protection more effective, there is a need to identify and provide more incentives for forest protection. Some of these are already given in the project recommendations. For instance, changing the plot structure to one with stands of different ages (5 or 10 age groups), so that mangroves can be harvested more frequently, is an option worth considering. There is also a great need to provide more information about mangroves and their ecological significance and links with shrimp farming, especially for wild shrimp stocks.

Household Registration and Residence Status
The farmer's household registration is managed by the village administration. One of the criteria to be accepted for residence registration is that the farmer has been residing in the area for at least 5 years.

The core problem in both Enterprises is poverty. The problem web exercise conducted in TGIII revealed that the root causes of poverty in the group include:

- Indebtedness (old unpaid debts).
- Tenure (green card: inability to access bank loans without Enterprise help).
- Lack of technical know-how in shrimp farming.
- Weather and other inexplicable factors affecting shrimp yields.
- Higher land tax on aquaculture than agriculture.
- Large families (many children).

In the 184 Group, the problem web revealed the following as the root causes:

- Population pressure.
- Government policies on mangrove (inability to thin or harvest forest) and land tenure (inability to access bank loans).
- Mangrove plantations too young to harvest (no income).
- Lack of capital for pond improvement and seed purchase.
- Lack of technical know-how in shrimp farming.
- Lack of extension services.
- Incompetent quality control on shrimp seed.
- Dependence on shrimp seed vendors for credit-purchase (low quality seed and indebtedness).
- Water quality impacts on shimp production from agrochemicals, pesticides and rain.
- Lack of water well to grow plants and raise animals (income diversification).
- Lack of capital and increasing indebtedness, land tenure within the Enterprises that prevents direct access to bank loans, as well as lack of technical know-how are the common causes in both the Groups. In addition, large family size or population pressure

are also mentioned as a cause of poverty, even though in both the Groups, at least among the farmers participating in semi-structured interviews, the average family size of is 5, close to the national average (Phillips et al. 1999).

Discussion

There is clearly a vicious circle of poverty, indebtedness, production failure and more indebtedness, which affects a significant number of farming households in the Enterprises. Those who succumb to this vicious cycle are obviously the less successful ones with low technical know-how or experience in shrimp farming, but also those with few alternative income sources and no access to capital. The lack of technical know-how often leads to ineffective or wasteful use of resources (e.g., stocking shrimp at high densities to compensate for mortalities, which ironically, may be caused, at least partly, by high densities). Lack of capital and access to formal, low-interest credit, on the other hand, forces farmers to purchase capital inputs such as shrimp post-larvae on credit from informal sources at exorbitantly high interest rates. With fluctuating production, repeated crop failures, and a lack of alternative income sources, the end result is growing indebtedness and more poverty. Uncertain land tenure, inavailability of marketing channels and lack of incentives for diversification, as well as uncertain income from mangrove plantation, together with low community bonds due to a relatively recent settlement history, only add up to the larger problem of poverty and indebtedness.

Some farmers who have migrated to these areas for purely speculative reasons (in search of lucrative profits from shrimp farming) may, in some cases, have additional plots of land elsewhere. In the two groups visited, at least two farmers (one in each group), had plots of agricultural land elsewhere, one even had a shrimp farm in another Enterprise. Within the Enterprises too, land consolidation has been happening. Obviously, it is the more successful shrimp farmers, or those engaged in high-income generating activities such as trading in shrimp, who are usually able to “buy” more pieces of land. Since mangrove incomes from a small plot of land are not sufficient incentive for forest conservation, Enterprises generally welcome (and probably encourage) land consolidation. Generally on most smaller plots, the required 70:30 forest-to-farm ratio is often breached, with shrimp farms occupying much more than 30 percent of the area.

Among the poorest of the poor are those who are not even able to “buy” a small piece of land for themselves. Some of these, as one case in the study groups suggests, live on lands “rented” from official landholders. Such “sub-leasing” is illegal and therefore not allowed, but probably not uncommon, though its extent is hard to estimate. Such a tenant farmer falls outside all the safety nets for the poor (including the loans from the Bank for the Poor). Extension services too may not reach such farmers.

Recommendations

Based on the above, this study makes the following recommendations:

Training and Extension

Sustainable income is obviously the most important need for sustainable livelihood, and in this it is difficult to wean the farmers away from shrimp rearing, high profits from which was the motivating force for most farmers who have settled on the Enterprise lands. To improve shrimp yields, therefore, extension and training is necessary. Currently, the local district-level fisheries offices, with help from the sub-institute (Minh Hai Sub-Institute for Fisheries Research), a few days training is given to farmers. However, the number of farmers is so large, that the training has not reached most farmers yet. Therefore, in addition to this training program, Enterprises can be given a role in training and extension relating to shrimp farming.

Credit

Growing indebtedness is a major problem affecting most farmers. Most farmers need small amounts of cash during culture period to meet daily expenses and also for capital inputs such as shrimp fry, nets, dredging etc. However, under the current practices of high stocking and high mortalities, most farmers suffer repeated crop failures and this only leads to further indebtedness. The study team shares the perception of some Enterprise officials about the ineffectiveness of loans in the absence of proper technical know-how about shrimp farming. At the same time, the question of high-interest informal credit farmers access as a last resort is also important. A large number of farmers are already in debt to banks and it is quite likely that debts from informal sources may also be large.

Therefore, some mechanism for advancing small, short-term loans should be devised. Preferably, such loans for a specific activity such as shrimp farming can be advanced in a package that also includes some training. This, however, may be a difficult task given the low capacity and manpower at the existing extension and training services, unless the capacity of the Enterprise staff can be enhanced to act as providers of training and extension.

Some groups in the two Enterprises are members of the People's Credit Fund schemes, and most groups have the informal rotating savings and credit associations (ROSCA or hoi in Vietnamese).

In accessing formal credit, the current structure which requires the Enterprise to act as a guarantor is rather cumbersome. The reluctance of Enterprise officials to act as a guarantor is probably due not just to their perception that loans are ineffectively used and farmers end up in debt, but also to high transaction costs, unless a sufficiently large number of farmers apply for loans at the same time.

One option the study team considered was to tie loan repayment to incomes from mangrove cutting; i.e., using assessed value of mangrove income as a collateral. However, given negligible to zero profits from thinning and the long wait period before the final harvest (20 years), this option seems impractical. If incomes from thinning and harvesting can be improved using the project recommendations, this should be considered as a viable option.

Income Diversification

Farm Production

Since shrimp farming, even in the extensive systems typical of the Mekong Delta, comes with its risks of production failures and high capital requirements, it is advisable to have more diversification of farm income. Our study found that farm households have surplus time and labour that can be effectively used for income-generating activities if proper incentives, training and extension services are provided. Subsistence-type simple diversifications such as growing vegetables and fruit trees can be undertaken without very high capital inputs. There is certainly a great potential for growing salt-tolerant cash crops on dykes and levees and also for raising farm animals such as chicken, ducks and pigs. The latter, however, need some capital inputs which many farmers lack. Crab culture is catching up among many farmers as a supplementary income source.

A few other options would be polyculture of fish and shrimp, or monocultures of fish and shrimp in adjacent ponds. Some farmers are considering shifting to fish culture (sea bass), if shrimp culture fails again this year. The capital input costs are, however, high, and farmers may need proper technical advice before launching this new venture.

Market Access

Currently most farm produce (vegetables, crabs and fish) is sold at the local market, where there is still room for additional supply which currently comes from other provinces, particularly in the dry season. Local markets may not be able to absorb large amounts of production if diversification is encouraged on many farms. Markets as far as Can Tho, if not up to Ho Chi Minh City can be reached if proper collection and transportation systems are in place, and if farmers are guaranteed reasonable prices.

Enterprises can be encouraged to undertake collection and marketing of farm produce. The Provincial DARD has considered this issue, and in the opinion of one official at DARD, the many commitments most Enterprises have make them unwilling to take additional responsibilities. Incentives should be developed for Enterprises to take up a role in organising collection and transport of farm produce to markets. Such collection systems may also include shrimp, which are currently collected by private traders (primary traders) and often sold at high prices to secondary traders at illegal collection points.

Mangrove

Profits from mangrove thinning appear to be negligible, and even the anticipated profits from final tree harvest do not serve as incentive for mangrove conservation. According to one estimate given by Enterprise officials at TGIII, current harvest income from a one-hectare plot of 20-year old mangroves (planted at an initial density of 10,000) is about 50 million VND. The costs are about a third, or around 16-17 million VND. When the remaining is divided 60:40 or 70:30 between the Enterprise and the farmer, the farmer is likely to receive about 10 to 13 million VND from the one hectare plot.

The long waiting period before the final harvest (20 years after planting) and the general feeling of insecurity among farmers about the actual profit sharing with the Enterprise shape the farmer perception of mangroves as a liability or burden than a future income source, even though they derive such direct or indirect benefits as wood for fuel and construction and feeding grounds for crabs. Farmers practising the “mixed” shrimp-mangrove system are particularly apprehensive about mangrove benefits, largely because of the impact of mangrove leaf litter on water quality and the blocking of sunlight and wind from reaching the ponds as the trees mature. Most farmers want the area under mangroves to be reduced and converted to shrimp farm. Indeed, a significant number of farms have less than 70 percent of the area under mangroves. There was some evidence of cutting of mature trees for incidental purposes (such as house repairs or as planks for crossing pond canals). However, because of regular patrolling by Enterprise officials, most farmers ensure that mangroves are protected from large-scale theft or other dangers to the trees.

It is recommended to review the profit sharing arrangements as well as provide more incentives for mangrove conservation. These include the compensations for planting labour about which there was a general dissatisfaction among the TGIII group farmers (no payments were made in 184, since labour costs are supposedly included in the final profit sharing arrangements). The World Bank project has a sub-component on providing more incentives for mangrove protection, including increasing financial assistance under the present protection contracts. It will be interesting to see how these developments will affect Enterprises outside the coastal protection and buffer zones.

An additional recommendation for mangroves would be on increasing species diversity in a small section of the land-holding, and is again in line with a proposed activity in the World Bank project. Currently virtually all plantation is of *Rhizophora* spp. for economic reasons. However, a small section of the land holding, preferably at the back where it shares the border with the neighbouring land plots, can be devoted to a mixed forest with a variety of mangrove plants. Obviously, however, the ecological aspects of mangroves and the natural zonation patterns need to be taken into consideration.

Few farmers were aware of the importance of the ecological functions of mangroves, particularly as nursery grounds for fish, shrimp and other aquatic species. This ecological as well as other non-monetary benefits of mangroves need to be stressed and awareness about these can be increased through extension. The RMFP, which is now in its extended phase, has prepared some excellent extension material on the importance of mangroves and on developing and managing mangrove-shrimp aquaculture systems.

Implementation of Project Recommendations

Farmers generally agree to most recommendations the ACIAR project has suggested for shrimp farming as well as mangroves. The only major exceptions were adoption of low stocking densities, a longer growout period with harvesting after 45-60 days (instead of 15 days), and the use of the Tom Te or other “against the water current” harvesting techniques during the spring tide water exchanges. The reasons for these are described below.

The heavy shrimp mortality during the growout seems to be the main factor that drives farmers to stock at higher densities. Ironically, though, higher stocking densities themselves may lead to high mortality due to competition for food, water fouling and self-predation. These factors have been identified by the previous studies under this project (Clough et al. 2002). There is a need to increase awareness among farmers about the ineffectiveness of high-density stocking.

The reluctance to shift to a longer growout period is due to the forgone harvest income from the 15-day harvests. Moreover, most farmers believed that yields from Tom Te and similar techniques are far less than suggested (less than 30% of the regular 15 day harvest). Tom Te is also believed to deteriorate water quality by creating turbulence in the pond. From the description of use of this technique by more successful farmers, given in the earlier project reports (ref from termination report?), it appears that both low yields and the alleged turbulence are probably due to farmer inexperience with the finer points of the technique. If this is really the case, then more training may be necessary from the more successful farmers.

For most of the other recommendations related to shrimp farming, the major constraint was the lack of capital (e.g., for pond deepening, nursery, feeding). The project recommendations and constraints or farmer responses to these are listed in Appendix 6.

Implementing most recommendations would require small financial support, where capital is the major constraint (e.g., digging the pond, good quality post-larvae, etc.), and training and extension. Institutional reforms are necessary both at the Enterprise levels as well as provincial or national government levels.

Aknowledgement

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Case Study 9: Costs and Benefits of Mangrove Restoration

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Introduction

Restoration of existing areas of damaged, routinely harvested or destroyed mangrove forests have been recently estimated to cost between US$3,000/ha and US$510,000/ha (Spurgeon 1998). Unfortunately these estimates are primarily derived from a single secondary source and are referred to as "…costs for planting mangroves…" (Spurgeon 1998) (emphasis added). As noted by Turner and Lewis (1997) and Lewis (1999) hydrologic restoration without planting is often preferred as planting of mangroves often fails due to what Lewis and Marshall (1998) refer to as the "gardening" approach to mangrove restoration. This approach emphasises planting of mangroves without first investigating the reason why mangroves are not present in the first place. This can be the most expensive approach to restoration since any investment is wasted when planted seeds or seedlings fail to survive. Natural recolonization of areas with restored hydrology, such as reconnected abandoned shrimp aquaculture ponds, occurs quite rapidly if mangrove forests are present in the vicinity and natural production of propagules is sufficient (Stevenson et al. 1999). Brockmeyer et al. (1997) report costs of just US$ 225/ha for successful hydrologic restoration and secondary succession in restoring mangrove forests along the Indian River Lagoon in Florida, USA.

In consulting the original literature on mangrove restoration (Watson 1928; Noakes 1951; Chapman 1976; Lewis 1982; Hamilton and Snedaker 1984; Lewis 1990a; Lewis 1990b; Crewz and Lewis 1991; Cintron-Molero 1992; Saenger and Siddiqi 1993; Siddiqi et al. 1993; Field 1996 and Lewis 1999) one finds few discussions of the costs of restoration. Because of this historical lack of data on cost effective restoration, and "lessons learned", many myths about mangrove restoration persist. The tiny two page paper entitled "Mangrove mythology" (Snedaker 1987) is one of the few classics in "myth busting." In it, Jane Snedaker proposes a true or false test with five questions. These are:

- Mangroves require salt water to develop and grow.
- Mangroves extend shorelines.
- Mangroves build up land.
- The red mangrove (*Rhizophora* spp.) is the most valuable species.
- Some mangrove forest types are more important than others.

How would you answer? In fact, all are common myths, and all are false!

Much of what is "known" about mangroves and in particular mangrove restoration, is based upon such myths. It is not surprising then that attempts to restore mangroves often fail to achieve the stated goals or fail completely. Similar myths about the value, both intrinsic and of direct impact to economic activities of man still persist. As recently as March 30, 2000, the Jakarta Post reported that 80,000 ha of "wasteland" (Actually mangroves) had been converted to the "..worlds largest integrated shrimp farm…" at Lampang, Sumatra.

We will attempt to shed some light on additional myths mangroves and discuss the real costs and benefits of mangrove restoration, and how to minimise the first while maximising the second. As noted by Spurgeon (1998).

If coastal habitat rehabilitation/creation is to be widely implemented, greater attempts should be made to find ways of reducing the overall costs of such initiatives; devise means of increasing the rate at which benefits accrue; and to identify mechanisms for appropriating the environmental benefits (p. 382).

Why Restore

Mangrove forests are coastal plant communities that are part of a larger coastal ecosystem that typically includes mud flats, seagrass meadows, tidal marshes, salt barrens and even coastal upland forests and freshwater wetlands (i.e. peatlands), freshwater streams and rivers. In more tropical climates coral reefs may also be part of this ecosystem. They are critical habitat for many species of fish and wildlife, serve as coastal fish and shellfish nursery habitat, and produce large quantities of leaf material that becomes the basis for a detritus food web (Hamilton and Snedaker 1984, Lewis et al. 1985). Once established, they can serve as coastal protection from hurricanes and typhoons, and riverine mangroves help remove pollutants before they enter adjacent coastal waters. In spite of these documented ecological functions, mangrove forests have been dredged and filled for decades to provide other coastal uses, like ports and housing.

It is estimated that there are 181,399 sq km of mangrove forests in the world (Spalding 1997) and major historical losses have occurred. In the Philippines the losses are estimated at 60%, Thailand 55%, Viet Nam 37% and Malaysia 12%. The total area lost in just these four countries is estimated at 7,445 sq km. Anecdotal estimates are that up to 50% of all mangroves that historically existed may have been lost to date and that current rates of loss may be as high as 1% per year.

In the United States, where much of the pioneering work on wetland restoration technology has been done (see Lewis et. al. 1995) mangroves naturally occur in three states, Florida, Louisiana and Texas. They have been introduced in Hawaii, but probably never naturally occurred there. They are also present in the U. S. Virgin Islands, Puerto Rico and several Pacific Ocean territories.

The largest forests are in Florida, where approximately 200,000 ha remain from an estimated historical cover of 260,000 ha (Lewis et al. 1985). These forests contain three species, the red mangrove (*Rhizophora man*gle), the black mangrove (*Avicennia germinans*) and the white mangrove (*Laguncularia racemosa*). The buttonwood (*Conocarpus erectus*) is a transition zone species. In Texas, only 2,000 ha exist (Moulton et al. 1997). Louisiana mangroves are very limited, with only several hundred hectares of the cold tolerant black mangrove located around Grand Isle. Puerto Rico has just 6,410 ha of mangrove remaining from an original mangrove forest cover estimated to have been 24,310 ha (Martinez et al. 1979). These figures emphasise the magnitude of the loss, and the magnitude of the opportunities that exist to restore areas like mosquito control impoundments in Florida back to functional mangrove ecosystems (Brockmeyer et al. 1997). These opportunities, and a growing interest in wetland restoration, combined with strong legal requirements to replace any wetlands lost to permitted development activities have created a heightened interest in cost effective mangrove restoration.

Key Terms and Principles

Restoration or rehabilitation may be recommended when a system has been altered to such an extent that it can no longer self-correct or self-renew. Under such conditions, ecosystem homeostasis has been permanently stopped and the normal processes of secondary succession (Clements 1928) or natural recovery from damage are inhibited in some way. This concept has not been analysed or discussed with any great detail in mangrove forests (Detweiler et al. 1976, Ball 1980, Lewis 1982 are the few exceptions) and thus restoration management has, unfortunately, emphasised planting of mangroves as the primary tool in restoration, rather than first assessing the reasons for the loss of mangroves in an area and working with the natural recovery processes that all ecosystems have.

Even the use of different terms and confusion in their meaning also adds to the difficulty in determining which of these projects actually succeeded in restoring a previously existing mangrove forest (ecological restoration) or converting a natural mudflat into mangroves (habitat substitution as described in Erftemeijer and Lewis 2000). For example the terms "replanting" and "reafforestation" are commonly used. "Replanting" would seem to mean planting a second time after an initial "planting". Similarly, "reafforestation" would seem to mean planting a second time after a first effort at "afforestation". Afforestation is a widely used term in forestry and refers to planting of trees in areas that have not previously been forested. What would be a better approach? How often are the existing stresses determined before trying to just plant? The answer to this latter question is "all too rarely."

The term "restoration" has been adopted here to specifically mean any process that aims to return a system to a pre-existing condition (whether or not this was pristine) (sensu Lewis 1990c and Lewis, this volume), and includes "natural restoration" or "recovery" following basic principles of secondary succession.

Ecological restoration is another important term to include in this discussion and has been defined as "the process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems" (Jackson et al. 1995) and differs from simple restoration in having four key steps: (1) judgement of need; (2) an ecological approach; (3) goal setting and objective evaluation of success in meeting those goals and (4) acknowledgement of limitations in our knowledge to complete the process.

Ecological restoration of mangrove forests has only received attention very recently (Lewis 1999). The wide range of types of projects previously considered to be restoration, as outlined in Field (1996), reflect the many aims of classic restoration which may include replanting mangroves for future harvest as wood products. Ecological restoration does not include future exploitation that may degrade, even temporarily, the ecological functions of a mangrove forest. Ecological restoration also includes a view of the proposed plant and animal community to be restored as part of a larger ecosystem with other ecological communities that also have functions to be protected or restored as mentioned above. Salt flats and mud flats, which, despite appearances, do have seasonal wildlife and fisheries values (Lewis 1990a) are particularly vulnerable to characterisation as "low value habitats" and have historically been converted to mangroves with the intention of increasing their ecological "value". This increasingly is being questioned as a good ecological management practice (Erftemeijer and Lewis 2000).

It is also important to understand that mangrove forests occur in a wide variety of hydrologic and climatic conditions that result in broad array of mangrove community types (Figure 1). In Florida, Lewis et al. (1985) have identified at least four variations on the original classic mangrove zonation pattern described by Davis (1940), all of which include a tidal marsh component dominated by such species as smooth cordgrass (*Spartina alterniflora*) or *saltwort (Batis maritima*) (Figure 1). Lewis (1982 a, b) describes the role that smooth cordgrass plays as a "nurse species", where it initially establishes on bare soil and facilitates primary or secondary succession to a climax community of predominantly mangroves, but with some remnant of the original tidal marsh species remaining. This has been further generalised by Crewz and Lewis (1991) (Figure 2) as the typical mangrove forest for Florida where tidal marsh components are nearly always present.

Mangrove forests have been rehabilitated to achieve a variety of goals, for instance to meet commercial purposes (silvaculture) (Watson 1928) for restoring fisheries habitat (Lewis 1992, Aksornkoae 1996), for sustainable multiple community use purposes, or for shoreline protection purposes.

It is possible to restore some of the functions of a mangrove, salt flat, or other systems even though parameters such as soil type and condition may have altered and the flora and fauna may have changed (Lewis 1992). If the goal is to return an area to a pristine pre-development condition, then the likelihood of failure is increased. However, the restoration of certain ecosystem traits and the replication of natural functions stand more chance of success (Lewis et al. 1995).

Choice of Restoration Techniques

It has been reported that mangrove forests around the world can self-repair or successfully undergo secondary succession over periods of 15-30 years if: 1) the normal tidal hydrology is not disrupted and 2) the availability of waterborne seeds or seedlings (propagules) of mangroves from adjacent stands is not disrupted or blocked (Watson 1928; Lewis 1982; Cintron-Molero 1992).

Because mangrove forests may recover without active restoration efforts, it has been recommended that restoration planning should first look at the potential existence of stresses such as blocked tidal inundation that might prevent secondary succession from occurring, and plan on removing that stress before attempting restoration (Hamilton and Snedaker 1985, Cintron-Molero 1992). The second step is determine by observation if natural seedling recruitment is occurring once the stress has been removed. Only if natural recovery is not occurring should the third step of considering assisting natural recovery through planting be considered.

by direct planting on mudflats and in existing seagrass meadows (Silliman University 1996, Lewis 1999, de Leon and White 1999). Plant survival varied from 0 to 66 % in a subsample of planted sites covering 491 ha, averaging 19% in Bohol and 17% in Cebu.

On the other hand, careful data collection by Duke (1996) at an oil spill site in Panama showed that "…densities of natural recruits far exceeded both expected and observed densities of planted seedlings in both sheltered and exposed sites" (emphasis added). Soemodihardjo et al. (1996) report that only 10% of a logged area in Tembilahan, Indonesia (715 ha) needed replanting because "The rest of the logged over area…had more than 2,500 natural seedlings per ha" (emphasis added).

Lewis and Marshall (1997) have suggested five critical steps are necessary to achieve successful mangrove restoration.

1. Understand the autecology (individual species ecology) of the mangrove species at the site, in particular the patterns of reproduction, propagule distribution and successful seedling establishment.
2. Understand the normal hydrologic patterns that control the distribution and successful establishment and growth of targeted mangrove species.
3. Assess the modifications of the previous mangrove environment that occurred that currently prevents natural secondary succession.
4. Design the restoration program to initially restore the appropriate hydrology and utilise natural volunteer mangrove propagule recruitment for plant establishment.
5. Only utilise actual planting of propagules, collected seedlings or cultivated seedlings after determining through Steps 1-4 that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilisation, or rate of growth of saplings established as goals for the restoration project.

These critical steps are often ignored and failure in most restoration projects can be traced to proceeding in the early stages directly to Step 5, without considering Steps 1-4. Lewis and Marshall (1997) refer to this approach as "gardening," where simply planting mangroves is seen as all that is needed. Another common problem is the failure to understand the natural processes of secondary succession, and the value of utilising nurse species like smooth cordgrass in situations where wave energy may be a problem. The recently introduced "encased replanting" technique (Riley 1995, Riley et al. 1999) for mangroves is an example of technological fix that has not been documented to work in medium to high wave energy sites in spite of the claims. Caution is advised with any "new" mangrove restoration technology that refuses to acknowledge the known and widely published science of mangrove restoration in favour of unproven technology.

The single most important factor in designing a successful mangrove restoration project is determining the normal hydrology (depth, duration and frequency of tidal flooding) of the existing natural mangrove plant communities in the area in which you wish to do restoration. The normal surrogate for costly tidal data gathering or modelling is the use of a tidal benchmark and survey of existing healthy mangroves. When this is done, a diagram similar to that in Figure 2 will result. This then becomes the construction model for your project.

Construction can be as complicated and expensive as excavation of fill, or backfilling of an excavated area, to achieve a target restored site with the same general slope, and the exact tidal elevations relative to a benchmark as the reference site, to insure that the hydrology is correct (Lewis 1990a). Another form of this hydrologic restoration, which is much less expensive, is to reconnect impounded mangroves to normal tidal influence (Turner and Lewis 1997, Brockmeyer et al. 1997). In fact the costs quoted by Brockmeyer are the lowest published costs at USD

225/ha. Figure 3 compares this cost with similar estimates by Lewis (1999), King and Bohlen (1994)(recently updated by King 1998) and Teas (1977). These estimates range over three orders of magnitude! The key differences are: (1) the amount of soil material that needs to be excavated to restore or create the correct hydrology and; (2) the use of natural secondary succession without planting (or modifications such as hand collection and dispersal of seeds or seedlings without planting) versus costly nursery development and hand planting of young seedlings, or worst the use of very expensive 1-2 meter tall older saplings (Teas 1977).

Benefits

Table 1 (modified from Spurgeon 1998) lists valuations of selected mangrove benefits from four sources cited by Spurgeon (1998) (Christiansen 1982, Lal 1990, Ruitenbeek 1992 and Gammage 1994) plus three additional sources (Nielson et al. 1998; Cabahug et al. 1986, Sathirathai (1998)).

Table 1. Valuation of selected mangrove benefits (modified from Spurgeon 1998)

Benefit	Value (US$/ha/yr)	Value (US$/ha/50 yr)	Source	Location
On-site sustainable fisheries	126	6,300	Ruitenbeek (1992)	Irian Jaya
On-site crustacean and mollusc harvests	126	6,300	Nielson (1998)	Viet Nam
On-site sustainable harvest, all products	500*	12,500	Cabahug (1986)	Philippines
Fish products	538	26,900	de Leon and While	"
Vicinity fish harvests	1,071**	53,550**	Cabahug (1986)	"
Vicinity shrimp harvests	254**	12,700**	"	"
Vicinity mollusc harvests	675**	33,750**	"	"
Vicinity crab harvests	720**	36,000**	"	"
Off-site fisheries	189	9,500	Christensen (1982)	Asia
Off-site fisheries (managed)	147***	7,350***	Sathirathai (1998)	Thailand
Off-site fisheries (open)	92***	4,600***	Sathirathai (1998)	Thailand
Other products (e.g. fruits, thatch)	435	21,750	"	"
Sustainable forestry	756	37,800	Gammage (1994)	El Salvador
Charcoal	378***	18,900***	Sathirathai (1998)	Thailand
Biodiversity (capturable)	20	1,000	Ruitenbeek (1992)	Irian Jaya
Total direct use value	2,505****	125,250****	Sathirathai (1998)	Thailand
Waste assimilation	7,833	391,600	Lal (1990)	Fiji

* Page 453 in Cabahug (1986).
**Derived from Table 62-III in Cabahug (1986).
*** Assuming a conversion rate of 38 baht/ USD 1.
**** Mean value assuming a conversion rate as above.

Conclusions

Successful ecological restoration of mangrove forests is feasible, has been done on a large scale in various parts of the world and can be done cost effectively. Rational decisions can be made as to the most cost effective methods to use based upon specific site conditions and goals of a project. The benefits that can be derived from restoring a specific forest area appear, based upon this literature review, to represent a significant positive cost benefit ratio.

Lewis (in press) however, has pointed out that the failure to adequately train, and retrain coastal managers in the basics of successful coastal habitat restoration all too often leads to projects "destined to fail, or only partially achieve their stated goals." This would obviously result in a negative cost benefit ratio. He quotes the National Academy of Science of the United States in their report entitled “Restoring and Protecting Marine Habitat - The Role of Engineering and Technology” (National Academy of Science 1994) as stating that “the principle obstacles to wider use of coastal engineering capabilities in habitat protection, enhancement, restoration and creation are the cost and the institutional, regulatory and management barriers to using the best available technologies and practices.”

This lack of training also leads to a routine failure to look for the most cost effective means of achieving restoration goals. Cost effective here means the least cost alternative that achieves both successful restoration, and those target ecological and economically important functions identified as restoration goals.

It is unfortunate that much of the research into mangrove restoration that has been carried out to date has been conducted without adequate site assessment, documentation of the methodologies or approaches used and the real costs of the work. Subsequent follow-up or evaluation for success in achieving these aims is essentially non-existent. Unsuccessful (or only partially successful) projects are rarely documented. A common methodology approach of documentation should be developed for habitat restoration projects. Those involved could then begin to learn from successes and failures, act more effectively, and generate those benefits listed here in a cost effective manner. Once this kind of information reaches a wider target audience, including politicians and other decision makers, the value of preserving existing mangrove forests will be obvious, and hopefully prevent the current large scale need to restore damaged forests in the future. But at least, when restoration is considered, it won’t result in unnecessary expenditures of public funds for badly designed and expensive restoration efforts.

The simple application of the five steps to successful mangrove restoration outlined by Lewis and Marshall (1997) would at least insure an analytical thought process and less use of “gardening” of mangroves as the solution to all mangrove restoration problems. Crewz and Lewis (1991) in examining the critical issues in success and failure in tidal marsh and mangrove restoration in Florida found that the hydrology, as created or restored by excavation to the correct tidal elevation, was the single most important element in project success.

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Case Study 10: Rehabilitation and Management of Shrimp Ponds Constructed in Acid Sulphate Soils

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Abstract

The success of shrimp farms depends largely on good site selection criteria, and an understanding of the principles of land capability assessment, disease control, water management, and farm practices that minimise on- and off-site degradation of soil and water. Although disease and poor water quality are well known constraints on shrimp farming, the role of sediments in pond productivity and as a cause of poor pond water quality is not. Acid sulphate soils (ASS) are one of the principal causes of poor pond water quality and unsustainable production. These acid producing soils commonly occur in mangroves and other coastal wetlands that are developed for shrimp farming. Soil and water pH in ASS-affected ponds may be as low as pH 2 but usually less than pH 5.0. Pond waters are also affected by elevated concentrations of aluminium, iron, manganese and in some cases arsenic, released from the soil under acid conditions. Acid released from ASS cause high PL mortality, poor growth rates, dyke leakage, loss of nutrients, clarification of pond waters and a range of environmental impacts. Acid sulphate soils present one of the greatest farm management challenges because of their capacity to produce acid over many years. In this paper we outline the problem of ASS in shrimp farming and discuss past and present management strategies. The focus of the paper is an Australian Centre for International Agricultural Research-funded study on the rehabilitation and management of ASS-affected shrimp ponds in Indonesia.

Introduction

Shrimp farming is one of the most rapidly developing coastal industries in the Asia Pacific region and has the potential to transform local, regional and national economies. On the other hand, poor shrimp production and abandoned farms, associated with inappropriate farm practices and environmental limitations, can lead to socio-economic problems and environmental degradation (Gugga and Finger-Stitch 1996; Sammut 1999). Shrimp farming relies on land and water resources that are already under pressure from other human activities. Pond production is affected by a number of environmental problems that can be intensified by development. Surprisingly, sediment-water interactions and engineering limitations of coastal soils, are often ignored or under-stated in site selection criteria or unrecognised as factors in poor production and the abandonment of farms (Sammut 1999). An understanding of the characteristics of pond soils to sustain shrimp production cannot be over emphasised (Smith 1993, 1995 and 1996).

Acid sulphate soils (ASS) are now recognised as one of the main sediment constraints on sustainable shrimp farming and other coastal land use (Poernomo 1992; Sammut 1999). These acid-producing sediments are usually harmless to the environment in natural landscapes such as mangroves and coastal wetlands where they usually occur (Dent 1986). However, when excavated for shrimp farming or drained for agriculture, urbanisation and industry, they produce significant amounts of sulphuric acid and mobilise toxic metals (Sammut et al. 1996a). Shrimp ponds constructed in ASS are often abandoned or produce low yields due to high PL mortality rates, poor growth rates, increased disease prevalence and high pond management costs (Simpson and Pedini 1985; Poernomo 1992; Sammut 1999). In many ASS-affected farms, these impacts have been blamed on other factors because farmers and researchers have been unaware of ASS.

The worldwide extent to which ponds have been affected by ASS is unknown but at a minimum can be correlated with the area of mangrove cleared for shrimp farming. It is important to note that ASS also occurs in non-mangrove environments shaped by estuarine processes and capped by alluvium or succeeded by other vegetation communities. Although the use of mangroves is now discouraged, largely for environmental reasons, acidified ponds remain a problem. Despite the move away from constructing ponds in mangrove soils, the activity still occurs in developing countries thereby creating new ASS-related production problems and further environmental degradation. The constraints that ASS imposes on shrimp farming, although well known in scientific circles, are often unknown to farmers who enter the industry. Problems with communication of research findings, inadequate or a lack of suitable site selection criteria that address ASS, and poor environmental decision making processes, have led to inappropriate land use in ASS.

This paper discusses ASS-related problems in shrimp farming, the socio-economic and environmental impacts of acidified ponds, and reviews strategies for rehabilitating and managing ponds in ASS. We also discuss an Australian Centre for International Agricultural Research-funded (ACIAR) project in Indonesia that is currently developing and assessing methods of rehabilitating ASS-impacted ponds.

A Brief Overview of Acid Sulfate Soils

Acid sulphate soils usually occur in Holocene-age coastal landscapes and can also be preserved in Pleistocene units, which have maintained oxygen-deficient groundwaters. Following the postglacial marine transgression, sea levels rose rapidly but slowed around 6,500 years ago (The Holocene Stillstand). Over the last 6,500 years coastlines advanced seaward due to infilling of embayments and progradation of high-energy coastlines. In low energy environments such as embayments, mangroves and tidal wetlands, sedimentation was accelerated by vegetation, which trapped and stabilised sediments. Iron pyrite (FeS_2), the acid producing mineral in ASS, formed and accumulated during this period of coastal sedimentation (Dent 1986). Sulphate from tidal waters was reduced to sulphides in the presence of iron. This bacterially mediated process occurs in the reducing environments found in coastal wetlands and continues today in mangroves, saltmarshes and other tidally influenced landscapes (Sammut 1996a). As mangroves expand other vegetation communities succeed them and the landscape evolves further due to alluvial processes (Roy 1984). Consequently, pyrite can be found in landscapes that are buried by metres of alluvium and with no present-day tidal influence. The concentration of pyrite is greatest at depth where the original estuarine sediments are preserved (Sammut et al. 1995).

Pyrite can remain stable for thousands of years if maintained beneath a reducing watertable (Dent 1986). In an unoxidised state, pyrite-bearing coastal sediments are described as potential acid sulphate soils (PASS). The soil texture may be sandy through to clayey but is most often recognisable as a grey, estuarine gel or clay (White et al.

1997). The concentration of pyrite may range from < 0.05% (Common in sands) up to 15% (Clays only). On exposure to oxygen, pyrite oxidises and produces sulphuric acid which acidifies the soil, ground water and eventually surface waters (Sammut 1996a). The proton acidity may be partly or entirely neutralised by bases in the soil, but is usually produced in quantities that exceed the acid neutralising capacity of the sediments (Dent 1986). The acid also liberates metals such as aluminium, iron and manganese; these metals can contribute to the production of mineral acidity which causes further drops in pH.

Shrimp Pond Construction in ASS

Shrimp pond construction has occurred in ASS because of good access to a source of brackish water, the low cost of waterlogged land and the conversion of pre-existing fish ponds to shrimp production. The problems associated with construction of ponds in ASS have been understated or poorly understood, and ASS continues to be excavated for shrimp ponds in many countries. In most cases, farmers are unaware of the potential problems and do not know of ASS. Ponds are usually constructed by removing a layer of soil to construct a dyke and deepen the pond. If PASS is used, the dyke material oxidises, produces sulphuric acid and acidifies the pond waters either through direct contact with the acidified dyke or through acidic runoff. In mangrove soils the material will most likely contain pyrite whereas in older landscapes the pyrite bearing sediments may be much deeper. To a lesser degree, acid may be supplied to the pond through the lateral movement of acidified groundwaters in heavily disturbed landscapes, particularly if groundwater abstraction or land drainage occurs. The attenuation or elimination of tidal exchange through dyking reduces acid neutralisation and allows the pond bottom soils to oxidise during pond maintenance and dry out periods. Oxidation may be enhanced by tillage or reworking of pond bottoms (Singh 1982). The production of iron monosulfides may add to the potential acidity. Iron monosulfides oxidise rapidly when exposed to oxygen.

Aaso (1998) found that the re-use of pond bottom sediments and nearby mangrove soils in dyke maintenance and reconstruction led to long-term acid problems in shrimp ponds. Although the acid and toxic metals are progressively leached from old dyke materials, the fresh material added new acid-producing sediments to the dyke, particularly to the surface layers, which are in contact with pond waters and runoff.

Other land use on ASS includes rice production (tidal and seasonal), fish farming, logging, sugar cane, grazing, oil palm production, integrated cropping, light industry and urbanisation. The success of these depends on the severity of the actual acidity, local hydrology, the level of land disturbance, and, in the case of agriculture, the acid tolerance of the crops. Tidal rice production is not severely affected by ASS because the soil is flooded by freshwater in the wet season, and salt water in the dry season thereby restricting the oxidation of pyrite and neutralising and efficiently leaching minor acidity (Dent 1986). Aluminium toxicity and reduced phosphate availability can affect seasonal rice production. Rain-fed rice has been successfully grown where high watertables are maintained or acid tolerant strains have developed (Dent 1986). Grazing lands have been severely affected by ASS mainly due to extensive land drainage which increases the production and export of acid. In Australia, large-scale estuarine acidification has occurred because of complex drainage works on coastal plains (Sammut et al. 1996a). The areas are used by the cane and grazing industries and are sometimes rezoned for aquaculture.

Shrimp Production Problems in ASS

Degradation of Dykes and Pond Bottom Sediments

Once exposed to oxygen, ASS undergoes a series of chemical and physical changes most of which are irreversible and harmful to the environment and negatively affect shrimp production. Dykes present a greater acid-producing problem than pond bottoms because the upper profile is permanently exposed to oxygen. Pond bottoms are usually always submerged and experience reducing conditions through most of the crop cycle. Dykes undergo a series of chemical and physical changes that are related to the steps in pyrite oxidation and acid production.

Soil ripening occurs in dykes when the fresh, wet sediments begin to dry; drying causes marked changes in clayey dyke soils. Irreversible loss of soil water occurs when the microstructure of the soil collapses after drying out (Dent 1986). In mangrove muds and gels, soil shrinkage can be dramatic due to the high water content (60%) before drying. The affected soils lose their cohesive strength and may become unstable. Ripened dyke soils constructed from mangrove sediments can slump or easily erode in the wet season and require regular rebuilding, compaction and in some cases chemical treatment.

Besides the dramatic changes in soil pH which may occur in pyrite-bearing dyke soils, other chemical changes may result. If the exchangeable sodium percentage is high, the leaching of soluble salts may create an unstable soil structure (Dent 1986) that may increase erosion and dyke instability. On the other hand, soils high in pyrite may be more stable because the release of soluble calcium may replace sodium exchange sites; sodium disperses sediments making them prone to erosion, particularly tunneling of the dyke. Alternatively, aluminium-induced flocculation in severely acidic soils may also improve soil stability because aluminium displaces sodium in the soil matrix thereby limiting dispersion and increasing flocculation.

In heavy clays, soil cracking increases the lateral movement of water from one pond to another. Pond water level management is difficult and poor quality water may enter the pond from an adjacent pond or from degraded groundwaters. The risk of disease transmission has not been investigated but may occur under such conditions due to the lateral movement of water carrying disease-causing propagules.

Erosion, due to a lack of adequate vegetative cover on severely acidified dykes and surrounding areas, is also a common occurrence. In ponds constructed in ASS that we have worked on in India and Indonesia, erosion on acidified dykes is a problem in the wet season. These ponds are affected by splash and rill erosion, and in abandoned ponds gullies may form. During the crop cycles, water circulation causes undercutting and slumping, and in some cases the dyke may collapse spilling the crop into nearby ponds or the estuary. In dispersable soil, dyke collapse commonly occurs because of tunnel erosion.

Pond walls and dykes may also become affected by salts that release acid when re-submerged (Dent 1986). For example, $FeSO_4$, $Al_2(S0_4)3$ and $NaAl(S0_4)_2$ may accumulate during the dry season and prolonged dry outs, and then dissolve when the pond is filled releasing acid to the system. Similarly, jarosite ($KFe_3(S0_4)(OH)_6$), a straw-coloured oxidation product can also release more acidity over the longer term. Oxidation of iron also adds iron the to the system and may stain pond bottoms and dykes.

Changes in Water Quality

Waters in contact with ASS will equilibrate with the soil and are characteristically moderately to strongly acidic (pH 2-4) but may become weakly acidic (pH 5 – 6) following prolonged leaching of the dykes. However, persistent acidification may occur due to the use of unoxidised sediments to repair dykes during pond maintenance (Aaso, 1998). Similarly, acid may be produced through the oxidation of iron monosulfides which are formed when sulphate in pond waters are reduced in the organically rich pond bottom sediments. Water acidification occurs when the acid neutralising capacity of the pond water is exceeded by proton and mineral acidity. The oxidation of iron may also add to the acidification and smother the pond with iron oxyhydroxides.

Acidified pond waters tend to be clear (< 3 NTU) due to aluminium flocculating suspended sediments (Sammut, 1999). At pH < 3.5 the water may have no apparent colour, but at higher pHs the water may be green or blue due to light refraction from metal complexes. On windy days, oxyhydroxides remain in suspension causing the water to turn red or orange. Simpson and Pedini (1985) noted that elevated iron and aluminium concentrations strip phosphorus from the water and reduce beneficial algae. The phosphorus is bound to the pond sediments by these metals and released when liming artificially raises pH.

Metal concentrations in acidified waters may be appreciably larger than acceptable limits for the maintenance of aquatic organisms. For example, Sammut et al. (1996) reported aluminium concentrations greater than 90 mg l^{-1} in the estuaries of eastern Australia.

Shrimp Health Problems

Shrimp mortality rates are high in acid affected ponds and may occur within hours if pH changes rapidly or if PLs are stocked into already acidified waters. The probable cause of death is gill damage. Sammut (1998) showed that acid causes lamellar fusion, and a number of degenerative changes in the gills of fish. Similar effects have been observed in shrimp (Dr J.M.P.K Jayasinghe, National Aquatic Resources Agency, personal communication, 1996). Sammut (1998) showed that at pH 5.1, aluminium concentrations of only 0.5 mg l^{-1} could cause severe gill damage in fish. At pH 5.1 the most toxic species of aluminium are present, whereas at pH 3, aluminium occurs as Al^{3+} which appears to have an ameliorative effect. At this pH, proton acidity is the harmful component and can cause mortality in gilled organisms within minutes of exposure (Sammut et al. 1996b).

Singh et al. (1985) and Simpson and Pedini (1985) reported that finely divided iron oxyhydroxides could clog the gills of fish and shrimp in ASS-affected ponds.

Poor growth rates have also been reported in weakly acidic ponds (Simpson and Pedini 1985; Singh et al. 1985). Poor growth may result from appetite suppression, the loss of beneficial algae and stress from exposure to poor water quality.

Past Studies on the Remediation of ASS

There have been country-specific studies on the amelioration and management of ASS over the last two decades (Tan 1983; Singh 1982; 1985; Simpson and Pedini 1985; Singh et al. 1988). Although these studies have achieved some success in the short-term management of acidity, longer-term amelioration has not been adequately addressed and differences across soil types have not been widely recognised. These studies have also focused on intensive systems and the methods used are not always practical or cost-effective for semi-intensive or extensive systems. Similarly, there have been no studies on the rehabilitation of disused ponds in ASS landscapes. Current management methods can be broadly grouped into the following areas:

Chemical Neutralisation

The most common method of chemical neutralisation is liming or the application of dolomite, calcite and magnetite (Tan 1983; Simpson and Pedini 1985; Golez 1995). Chemical neutralisation has limited benefits when directly treating pond water because acid is regularly transported into the pond, thereby depleting the neutralising agent. Water exchanges also remove lime from pond waters. Up to 90 tons of lime per ha may be required in severely acidified soils (Tan 1983). Liming is used on the pond bottom, dykes and canals feeding the pond (Neue and Singh 1984; Singh and Poernomo 1984). Some success has been achieved in reducing the toxicity of metals and reducing acidity using filter press muds, fertilisers, rice hull ash, and organic wastes (Tan 1983; Neue and Singh 1984). These methods influence cation exchange capacity of soils and bind toxic metals. Studies on the liming requirements of freshwater catfish ponds by Boyd (1979) were a model for the practice of liming shrimp ponds in ASS (Lin 1986; Kungvankij et al. 1990; Boyd 1992; Limsuwan 1993). These workers estimated rates of lime application to earthen ponds for use prior to stocking and during the growout season. However, the long-term amelioration of acidity was not addressed although the problems of drying out pyritic sediments were recognised.

Water Management and Seawater Flushing

Seawater is often used to neutralise, dilute and remove acid and iron flocs. However, the amount of acid generated by ASS can overwhelm the acid neutralising capacity of seawater. For example, 150 exchanges of seawater would be required to neutralise each 10 cm of acidic soil in a 1 ha by 1m deep shrimp pond (Simpson and Pedini 1985). Such a high number of exchanges may be impractical and could increase the risk of importing pathogens and lead to the loss of nutrients and alkalinity. The environmental impacts of seawater flushing must be evaluated for it to be an acceptable method of management. Water level management is also used to maintain a hydraulic gradient towards the dyke thereby restricting the movement of acid into the pond (Kungvankij et al. 1990). The use of seawater to neutralise acid sulphate soils is currently a major topic of debate in Australia.

Forced Oxidation and Leaching

Forced oxidation and leaching works on the principle that the oxidisable component of the pond environment can be forced to oxidise during the drying phase and then acid is neutralised and removed with flushing. The method is impractical for sediments with high pyrite concentrations, such as estuarine clays (Dent 1986), due to slow oxidation rates, and may lead to soil structure decline. The effects of the leachate on the local environment must be addressed.

Capping, Compaction and Lining

Compressed laterite is sometimes used to create a barrier between ASS and the pond water and also to reduce contact of runoff with ASS. Compaction of dykes is usually unsuccessful because it is not performed properly (Kungvankij et al. 1990). The use of surrogate soils may also reduce dyke leakage and in some cases may be used to completely rebuild the dyke. Plastic liners have also been used to create a barrier between acidic dykes and pond waters. Plastic liners can be costly, unsightly and present other problems, particularly at the sediment-water interface where nutrient cycling and reduction processes are important; plastic liners remove this important zone.

Remediation and Management of ASS: Indonesian Case Study

In this section we discuss a research project on the remediation and management of ASS-affected ponds in Indonesia. The project is funded by ACIAR and co-ordinated by the School of Geography, the University of New South Wales, Australia, and the Research Institute for Coastal Fisheries (RICF), Maros, Indonesia. The work is incomplete but we discuss the objectives, the rehabilitation approaches, and the predicted benefits of the work.

Background to Shrimp Farming in Indonesia

There are approximately 380,000 ha of coastal lowland developed for brackishwater aquaculture in Indonesia with a remaining 140,000 ha under consideration for further development. Table 1 summarises unpublished pond survey data and shows that a large number of ponds are constructed in ASS or have been abandoned. It was impossible to elucidate the cause of abandonment because farmers could not relate production problems to any specific factors. Approximately 120,000 ha of lowlands have been developed specifically for shrimp production whilst many of the remaining fin-fish and polyculture ponds will be converted to shrimp production (Hanafi and Ahmad 1999). The main shrimp production areas are Sumatra, Java, Kalimantan, Sulawesi and Bali, and about a third of the smaller islands are also producing shrimp. The total annual production of milkfish and milkfish/shrimp polyculture is shown in Figure 1 and export of shrimp produced from monoculture systems between 1992 to 1996 is shown in Figure 2. More recent data were not available. Clearly from Figure 2, there has been a steady growth in brackishwater aquaculture, and although fin-fish still dominates, in the last three years fish farms have been redeveloped for higher value shrimp production. The average increase in brackishwater aquaculture has been 10.8% per annum.

Table 1. Distribution of ASS affected pond and abandoned pond.

Province	Existing tambak (Ha)	ASS-affected pond (Ha)	Abandoned pond (Ha)
Sumatra	69,846	35,000	7,000
Java	193,175	19,000	110,000
Bali-NTT	7,242	not known	700
Kalimantan	6,998	3,500	700
Sulawesi	102,577	45,000	10,000
Maluku/Irian Jaya	224	110	20
Total	**380,062**	**102,610**	**128,420**

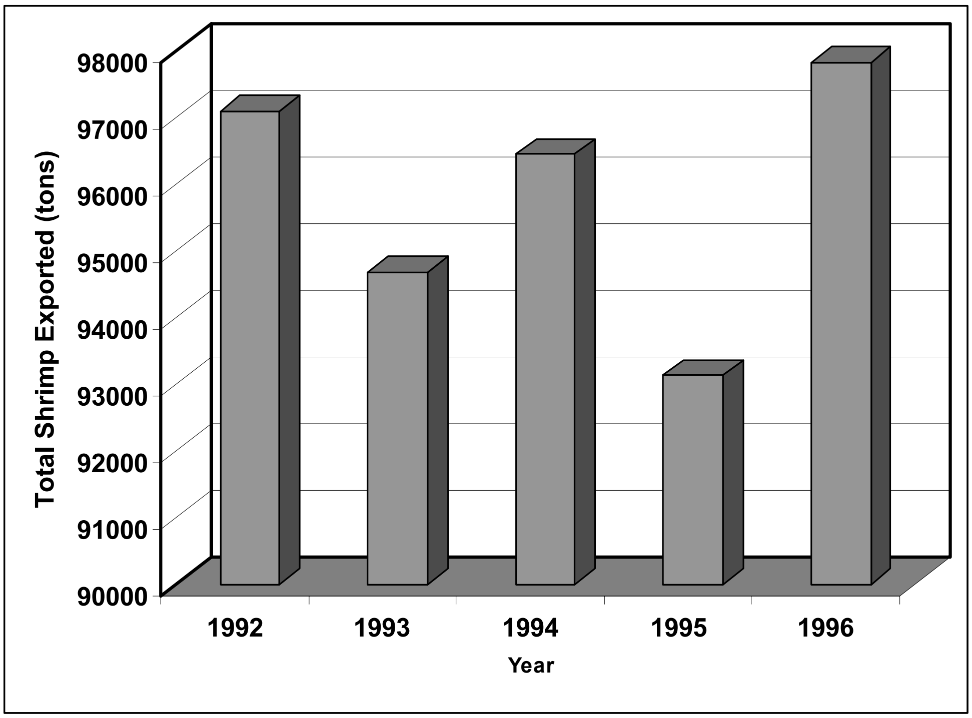
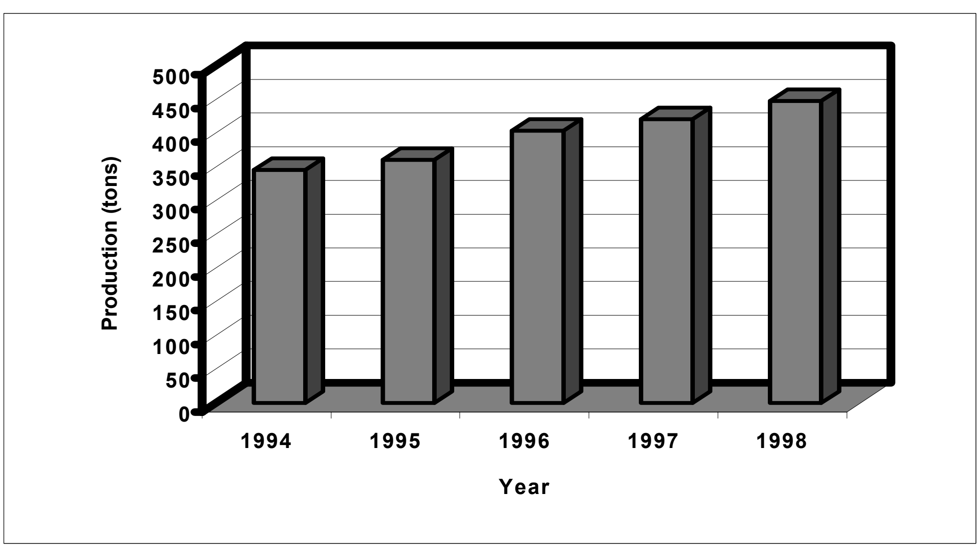


Figure 1. Annual production of milkfish and milkfish/shrimp polyculture systems in Indonesia.

Figure 2. Annual shrimp production in Indonesia between 1992 and 1996



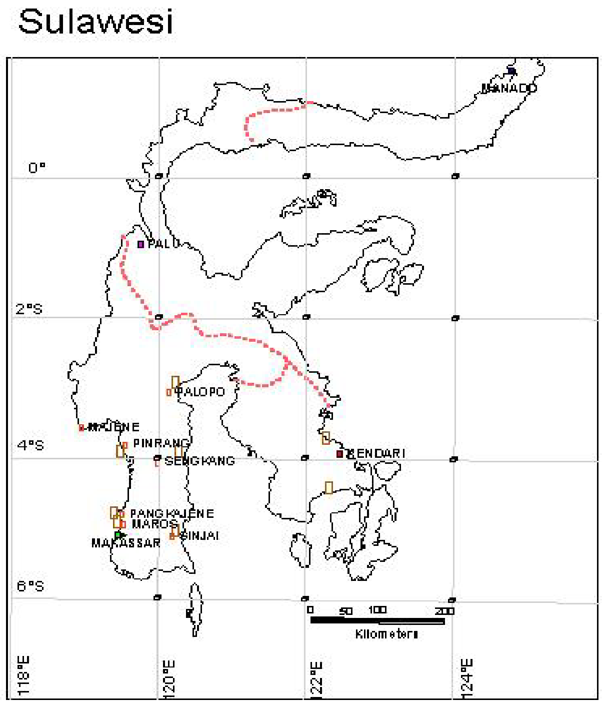
There are more than 100,000 Indonesian families involved in brackishwater aquaculture using a variety of ponds sizes: < 2 ha (46.58%), 2-5 ha (31.37%), 5-10 ha (14.70%) and 10 ha (7.35%) (Hanafi and Ahmad, 1999). These ponds are all constructed in coastal lowlands. Ponds in Java, Sulawesi, Bali, Nusa Tenggara Timur and the Maluku islands are predominantly mineral soils (Hanafi and Ahmad, 1999) which include ASS. By contrast, Sumatra and Kalimantan are dominated by peaty soils but may include pyritic sediments at some locations and in areas to be developed for the "1 Million ha" and "50,000 ha" programs initiated by the Indonesian Government. These two development programs involve the conversion of marginal land to aquaculture and other coastal land use.

In Indonesia, acidic soils have been a constraint for production in all major farming areas and are increasingly a problem in the transmigration zones where new ponds are being constructed in low-lying pyritic sediments that develop into ASS. Many farmers are unaware of the ASS hazard and have attempted to replace rice production and other land uses with shrimp farms.

Pond abandonment rates in Indonesia have climbed over the last ten years due to the expansion of shrimp farming in unsuitable coastal landscapes, particularly mangroves and coastal wetlands. Although the need for sound site selection criteria has been emphasised (Poernomo 1982; Ritung and Widjaja-Adhi 1994), many farmers are unaware of limiting factors such as ASS or are unaware of the site selection criteria.

Ponds stocking densities average between 3 to 4 PL per m^2 for extensive farms, 10 to 25 PL per m^2 for semi-intensive farms and 30 to more than 40 PL per m^2 for intensive culture. The stocking densities often reflect the availability of PLs from hatcheries that in recent years has been unreliable because of disease and poor quality broodstock. Pond walls and dykes are rebuilt or recapped at the end of each crop using pond bottom sediments or nearby soils. Ponds are limed prior to stocking and occasionally during the crop cycle. In most cases lime is added without any predetermined liming requirement or water quality monitoring.

In 1996 the authors undertook reconnaissance visits to major shrimp farming areas in Maros, Pangkep, Pinrang, Luwu, Siwa and Wajo in South Sulawesi (Figure 3) to investigate the extent of shrimp ponds in ASS. With the exception of Pinrang and Pangkep, all sites were severely affected by ASS and farmers reported production problems but could not identify causes. Farmers did not follow any site selection criteria and were unaware of ASS or sediment-water problems that occur in coastal lowlands.



Produced by Tarunamulia, RICF

Figure 3. Project study sites in South and South East Sulawesi.

The socio-economic and environmental impacts of ASS have not been quantified but include family breakdown, altered village structure, changes in the labour force, bankruptcy, reduced land ownership and reduced educational and employment opportunities. These impacts are in contrast to those of sustainable farms in non-ASS landscapes. There is an urgent need to assess the socio-economic and cultural impacts of shrimp farming in Indonesia so that sound-planning policy can be developed. Although our study is assessing the socio-economic, gender and cultural impacts of remediation, it does not quantify past problems or fully examine the long-term effects of shrimp farming on culture and society. Such studies are needed to protect intergenerational equity and culture and are as important as economic and environmental sustainability.

Objectives of the Study

The overall objective of this project is to increase long-term production of shrimp and improve opportunities for fish production in small-farm, extensive aquaculture systems in Indonesia and to test the application of remediation methods to higher yielding systems. Both abandoned and degraded active ponds are the focus of the study, although aspects of sediment management studies will be useful to new ponds not constructed in ASS. More specifically, the objectives of the project are:

To develop and assess cost-effective, low-technology methods of treating and managing soil acidification associated with disturbance of ASS.
To build the research and training capacity of collaborating agencies.
To develop site selection criteria that also address sediment issues such as ASS.

To produce both technical and farmer manuals to assist uptake of the research findings.

Study Sites

Study sites were selected at Maros, Pangkep, Pinrang, Sinjai, Wajo and Luwu regency, South Sulawesi and Sampara and Tianggea district, Kendari regency, South East Sulawesi (Figure 3). These study sites represent different chemical and physical attributes of ASS and enable us to test remediation methods under a range of hydrological conditions and farming practices.

Most of the shrimp farms are extensive or incorporate some of the semi-intensive management practices. The farms are family run and owned,

Capacity Building and Training

Soil management in coastal aquaculture is a specialised area and depends on resources normally available to the agricultural and soil sciences. To meet the project objectives, the resource and skill base at the RICF, was enhanced. A soil and water laboratory, dedicated to research on ASS, was established, and staff trained in ASS analysis and field methods. In particular, project staff, research officers from other agencies, and extension officers were trained in field assessment of ASS, soil-sampling methods, laboratory analyses, data interpretation and mapping methods. It was evident during project development stages that many scientific and extension officers were unfamiliar with ASS. Since August 1999, project staff at RICF and collaborators have developed the necessary expertise to undertake the research.

Capacity building and training at RICF has had several spillover benefits including:

- The provision of a national testing centre for ASS.
- Retraining of other researchers and extension officers.
- Advisory service for shrimp farmers and other land users.
- Improved grant capture.
- Technical support to other sediment-related projects.
- Technical support to coastal development projects.
- A focal point for the development of extension material.

Our next stage of training will involve more sophisticated mapping methods using GIS and Remote Sensing tools.

Research Activities and Achievements

Background Soil Studies and Soil Mapping

Soil maps and digital terrain models have been produced for each of the field sites to assess soil variability and to select ponds for experimental work. Prior to our study there were no detailed soil surveys of shrimp farming areas in South Sulawesi, and the extent and characteristics of ASS were unknown. Soil data on pH, potential acidity, metal concentrations, soil moisture, organic content, texture, mineralogy and salinity have been collected and archived in a database which will be used by our project as well as a number of other land development and management projects. Isopleth maps of key soil attributes have been produced for oxidised and unoxidised soil layers using MAPINFO GIS software. Each soil profile has been levelled into an assumed datum and terrain surveyed into the same datum. Terrain models for each location were produced using SURFER and other software. We are now expanding our soil mapping to determine the extent of abandoned and ASS-affected ponds in Indonesia and to identify areas to manage. These maps will be useful to other coastal management projects.

Chemical Neutralisation Trials

Lime requirements for ASS-affected ponds are being determined by a modified method of Menon (1973). The method considers the NV (neutralising value) and ER (Efficiency rate) of the soils and so far we have only tested the effectiveness of the liming requirements under laboratory conditions. We are also interested in the effects of lime on the release of acid from secondary sources such as salts produced in ASS. The results of different types of available commercial lime as follows:

Table 2. Different commercial lime requirement (ton/ha) to raise pH to 6.5

Type of lime	Textural classes	
	Fine texture (clay soil) t/h	Coarse texture (sandy soil) t/h
$CaCO_3$	6.6	3.2
$CaMg(CO_3)_2$	5.9	2.9
$Ca(OH)_2$	3.0	1.5

As can be seen from Table 2, lime requirement for clay is higher than for sand, due to its low porosity, the presence of acid producing minerals, and higher concentrations of pyrite that continue to release acid. Generally, the fine clay soils need double the lime of sandy soils. Soil pH increases more rapidly in oxidised and ripened soil because much of the acid producing pyrite has already been oxidised; in raw ASS the initial acid release is high and overwhelms the acid neutralising capacity of the lime. Farmers, usually unaware of the oxidation process, will force oxidation of ASS before liming, otherwise valuable lime is lost on water exchanges without reacting with acid produced later in the crop cycle. A secondary effect of liming is the release of nutrients that are otherwise unavailable under acidic conditions.

Our preliminary field trials, undertaken to assess the practicality of liming, suggests that in extensive systems, liming should be concentrated on the dykes.

We are refining our methods for estimating liming requirements to address potential acidity from unoxidised pyrite and oxidation products that release secondary acidity. Furthermore, we are considering the effects of metal coatings on lime as well as the effectiveness of different lime particle sizes and application methods.

Bioassays on Toxicity of Soil Leachate

A series of rapid bioassays were developed to test the toxicity of soil leachate from treated soils across the variety of methods being trialed. Rapid bioassays enable us to estimate the time taken for 100% mortality between treated and untreated soils taking into account the effects of dissolved oxygen and salinity. The effects of some of our proposed treatments can be tested under laboratory conditions before attempts at the pond level. The rapid bioassays are also integrated into our field trials to help differentiate between the effects of disease and our treatments. Disease remains a problem at our experimental sites and it could confound our interpretation of data in the remediation trials.

Our studies so far suggest that forced oxidation and leaching creates toxic waters that must be chemically neutralised to improve pond waters and protect off-site environments. Forced oxidation and leaching is not recommended without the addition of methods for treating the leachate. Current bioassays are investigating the effects of chemically neutralised leachates on PLs. Effects on growth rates will be determined under field conditions during a complete growout period.

Assessment of Integrated Farming Systems

At Lamasi Pantai district, Luwu, South Sulawesi and Sampara district, Kendari, South East Sulawesi, the high year-round rainfall leaches and flushes available acidity from the dyke soils. Farmers are taking advantage of the high rainfall and reduced available acidity by planting vegetables, citrus and other crops on the dykes. The farming practice depends on the availability of large, wide dykes, and flood-free conditions. The residual acidity is limed enabling crops to grow and minimising water acidity. Integrated cropping provides an alternative cash crop that may supplement a successful shrimp production cycle or ensure that some income is generated should the shrimp crop fail. This diversification occasionally uses fish monoculture and fish/shrimp polyculture. Our project is assessing the benefits of this farming approach.

Culture of Gracillaria verucosa and PL Rearing in ASS-Affected Ponds

The renewal of traditional land use in degraded ponds is also be assessed by this project. Before shrimp farming expanded, coastal aquaculture in Indonesia focused on tilapia culture, the cultivation of seaweed, *Gracillaria verucosa* and milkfish. In South Sulawesi, some farmers have abandoned shrimp production but returned to polyculture of seaweed and milkfish; both are reasonably successful in large, weakly acidic ponds that are flushed by high rainfall and occasional seawater exchanges. The milkfish control algal growth improving the production of seaweed and reducing the intensity of labour required to separate seaweed from non-marketable organic material. However, in many cases, the taste of milkfish is affected and the market does not accept the fish.

At Sinjai and Marana (Maros District) we are testing the hypothesis that seaweed culture can improve water quality in degraded ponds. In view of this, we are also assessing the use of seaweed ponds to grow PLs to juvenile size for restocking in non-ASS ponds. At Sinjai, we have achieved a 25-66% survival rate in ponds managed for seaweed cultivation and no chemical neutralisation of acid. At the Marana experimental station we have achieved a 66-90% survival rate due to weaker acidity. PLs are reared in floating cages (3x5x1 m) known locally as hapas, using stocking densities of 9,000 to 12,5000 PLs per hapa. The price of PL-15 is Rp 20,- per PL and Rp 50,- to 75,- per juvenile.

Ten hapas need around 200 m^2 of pond, which will generate 70,000 juveniles with an average stocking density of 10,000 per hapa and a survival rate of 70%. This method can be managed by one family and returns Rp. 4,000,000,- within two weeks period of rearing.

Development of Site Selection Criteria

Although site selection criteria for shrimp farming exist in Indonesia (Poernomo, 1992), they were developed before the understanding of ASS was advanced. Existing criteria do not address total actual acidity, total potential acidity, the depth of pyritic layers, inherent acid neutralising capacity of sediments, soil texture, and geomorphic principles and field methods for identifying ASS. A common error in site selection and land capability assessment is the prediction of long term acid production or a lack of understanding that soil pH falls in ASS when they are excavated. Thus, in the past, farmers have measured a soil pH near 7 in unoxidised sediments without recognising that the soil experiences a dramatic fall in pH when excavated.

We are improving site selection criteria by including:

- Basic field tests for the identification of ASS.
- Outlining methods of collecting and handling soil samples for laboratory analysis.
- Identifying field indicators of ASS such as the presence of *Thallasina anomla*, jarosite, soil colour and vegetation type.
- Identifying geomorphic controls on ASS.
- Developing matrices to interpret field and laboratory data.
- Outlining simple quantitative laboratory methods for testing ASS.
- Developing land capability classification for coastal shrimp farming.

These will be integrated with other site requirements such as water resources, other soil factors, carrying capacity and accessibility.

Production of Technical and Farmer Manuals

Technical manuals are being developed to address more scientific aspects of soil remediation and management in shrimp farming but will include information relevant to farm management. The latter will be presented in more technical detail than in the farmer manuals. The manuals overlap and compliment site selection criteria and may include the criteria as an appendix. The manuals are however, focusing on remediation and management for already degraded ponds. The technical manuals will cover the following areas:

- Field assessment of acid sulphate soils.
- Field assessment of key chemical and physical constituents of soil.
- Methods of collecting soil samples.
- Sample handling and storage.
- Laboratory analyses.
- Soil survey and site evaluation including land capability mapping and classification.
- Applications of GIS and Remote Sensing to site evaluation.
- Matrices to assist interpretation of soil data.
- Site selection criteria.

Aspects of the technical manuals will be re-written in a farmer manual. The farmer manual will include:

- Simple methods for testing PASS and ASS.
- Simple site assessment methods.
- Sample collection for laboratory analysis.
- Matrices for interpretation of laboratory data.
- Methods of soil remediation.
- Pond soil management (low tech).
- General aspects of pond management.
- Site selection criteria

The manuals will be printed in English and Bahasa Indonesia and reviewed and edited by the Assessment Institute for Agricultural Technology (AIAT) and ACIAR.

Research Uptake

High costs of dissemination, language barriers, and the complexity of the science often limit communication and adoption of research findings. Similarly, effective methods of management may be too expensive or require resources that are not available to farmers. At the outset, the ACIAR project has focused on the development and refinement of low-coast technologies because the target group is small family-run businesses. Nevertheless, we intend to enhance the technologies for application to intensive farming systems in view of the increasing move towards this production system by family-run businesses.

To ensure that the research adequately addresses the needs of small farmers to achieve maximum uptake of the findings, the project relies on the expertise and input of AIAT, known locally as the Balai Pengkajian Teknologi Pertanian (BPTP).

The research will be used to rehabilitate abandoned and active farms with low production rates. Farmers from Maros, Pangkep, Pinrang, Luwu and other areas on South Sulawesi are currently involved in the project. Ultimately, particularly through the activities of AIAT, the research findings will be adopted for:

- Strategic planning purposes.
- Site selection criteria.
- Policy development.
- Environmental management.
- Development of better practices for the local industry.

The AIAT is co-ordinating the development and application of the technology and will play a greater role in the final stages of the project and continue after the project is completed. The cost of extending the project outcomes and ensuring that extension officers are adequately trained, is the responsibility of AIAT with guidance and assistance from the research team.

There are currently 17 offices of AIAT at the provincial level and the number should increase dramatically by the final year of the project. AIAT's primary roles are:

- Appraisals of projects in agro-ecological zones (AEZs).
- Priority setting for R and D.
- Technology transfer activities.
- On-farm adaptive research and testing of technologies.
- Tropical socio-economic and technical studies.

Predicted Economic Impacts of the Study

Economic Impacts of Proposed Trials

This section of the report was prepared with help from Dr Godfrey Lubulwa from the ACIAR Economic Assessment Unit.

The overall predicted economic impact is positive because the research will lead to higher productivity through:

- Longer pond-life and reduction or elimination of demand for new ponds.
- Reduced on-farm management costs.
- Reductions in, or elimination of, shrimp diseases associated with poor water quality.
- Replacement of low-production systems, such as milkfish, with shrimp monoculture.
- Significantly improve quality of water discharged from the ponds thereby minimising environmental impact and enabling farmers to meet development control criteria.

The remainder of this section details these economic impacts with reference to the specific methods of management to be developed and tested. The aim of the section is not to compute a rate of return or a monetary value of benefits but to describe, semi-quantitatively, the factors that may determine the size of the economic impact. This impact is likely to depend on at least the following factors:

- The nature and size of the problem addressed by the project.
- The cost of industry practices before research.
- The nature of the technology the project proposes to develop.
- The adaptive research lag before farmers can use the technology.
- The likely level of uptake by farmers in Indonesia and Australia.
- The spillover benefits to other countries.

The Nature and Size of the Problem Addressed by the Project

There are two main types of positive impacts likely to come from this project. First, there is likely to be an impact on the prawn/shrimp industry. Second, there are major environmental benefits to accrue from this project. The nature of the problem from an industry perspective has been described earlier in the project, and summarised in Table 3 to include the following:

The use of shrimp ponds constructed on acid sulphate soils reduces the yields of shrimp per hectare.
Pond degradation reduces the quality of pond produce from high value shrimp to low quality low price milk-fish.

Pond degradation also leads to increased losses due to higher mortality rates and lower growth rates than those on non-ASS ponds.
The impact of ASS on pond water quality increases the costs of producing shrimps because farmers incur additional costs for disease control and for managing sedimentation.
Sedimentation from ASS reduces the economically productive life of ponds.

The column headed 'Current levels in ASS ponds WITHOUT research' indicates the levels under current practices. The levels in the column headed 'Potential levels in ASS ponds WITH research' are at this stage guesstimates and indicate the potential gains from research.

Table 3 summarises the nature and size of the environmental problem addressed by the project. The environmental problem associated with current industry practice can be detected from the composition of ponds in the different countries. The small percentage of monoculture shrimp ponds is an indicator of pond water quality. As the pond water quality deteriorates, it becomes imperative for farmers to use poly-culture ponds to ensure economic viability. On the extreme end of the environmental problem is the number of abandoned ponds. The on-site environmental negative impacts are easier to measure and quantify. However, associated with shrimp production in ASS ponds are major off-site environmental problems which are more difficult to measure but which must not be ignored.

The Cost of Industry Practices Before Research

Table 3 and 4 indicate that the current industry practices are associated with two types of costs; Table 4 focuses on the private costs. Some of the private costs are directly measurable in terms of cash outlays. Others like shortened pond life and eventual abandonment of ponds due to pond degradation can be estimated using the benchmark of production of shrimp in non-ASS ponds.

The unit price of shrimp may increase due to better quality shrimp produced under improved pond conditions both in Australia and Indonesia.

It is also probable that Indonesian farmers may be able to replace milkfish production with more valuable shrimp thereby increasing their economic return. At present more than 90% of farmers in some areas are using milkfish-shrimp polyculture systems because of pond degradation and producing only 100-200 kg of shrimp per ha and 500-600 kg of low value milkfish per ha. This represents Rp 3,999,000 (at pre-economic crisis values) per ha per crop under polyculture. RICF estimates that if ponds are improved to allow conversion from polyculture to monoculture, there is a potential for Rp 7,500,000 per ha per crop or an increase of Rp 3,600,000. Clearly, an improvement in shrimp production will provide high economic gains.

Table 5 summarises the technology proposed by this project. It is difficult to estimate the cost of these technologies before the research is done and whether the costs will be affected by reapplication of the technology over the life of the ponds. At this stage though it is possible to give a rough indication of the impact of these technologies on the variables that are important to shrimp farmers. The estimates were generated from discussions with shrimp farmers in Indonesia. All technologies are associated with new added costs to the farmers. However, the technologies are expected to significantly reduce the 'before research' production costs and to increase yields of shrimp ponds. The reductions are mainly related to reduced management costs and less restocking and feed application in ponds. Thus on balance the technologies are likely to be beneficial to the farmers.

The short-term benefits to Indonesia and other developing countries are expected to include reduced demands for land, improved shrimp production, confidence in the industry, and improved socio-economic conditions. Over the long-term, it is expected that developing countries will be able to achieve sustainable shrimp production and experience improvements in local and regional economies.

Table 3. The nature of the research problem from a prawn farmer's perspective

Variable affected	Current levels in ASS ponds WITHOUT research	Potential change in levels in ASS ponds WITH research
Pond Yields (kg/ha)		
Shrimp or prawn	100-200	500-800
Milk fish	500-600	1,000 -2,000
Prices of pond products ($A/kg)		
Shrimp or prawn	8 to 12.7	10-14.5
Milk fish	0.6	1-1.8
Mortality rates (%)		
Shrimp or prawn	50-70 (100% in PLs)	30-40
Milk fish	20-35	10-20
Shrimp not marketable because of soft shell syndrome (%)	20-30	<15
Added costs of disease control due to ASS ponds ($A/ha)	800	Nil
Added costs of sediment control in ASS ponds ($A/ha)	110	Nil
The economically productive life of a pond	1-2 years	15

Table 4. The nature of the research problem from an environmental perspective

Variable affected	Current levels in ASS ponds WITHOUT research (Indonesia)	Potential spillovers (global)
Total pond area (ha)	360,000	
Ponds on ASS area (ha)	180,000	Reduced abandonment rates.
No of active monoculture shrimp ponds (%)	74%	Increased productivity.
No of active polyculture (shrimp/milkfish) ponds (%)	93%	Increased monoculture activities.
Ponds abandoned (ha/ pa)	At least 100,000	Currently 15,000 abandoned – increased rehabilitation may reduce abandonment.
Nature of off-site environmental impact	Sediment accumulation, turbid effluent water	Less environmental impacts; cleaner image for industry.
Demand for land for new ponds	60,000	Reduced demand because of increased pond life and productivity.

Table 5. The principal technology proposed under this project.

Component of the proposed technology	Any added costs as part of uptake (Yes/No)	Impact on before research costs	Impact on yields
1. Acid neutralisation	Yes, 10-15%	Reduce production costs – up to 40% (more in some cases)	Increase, 30-90%
2.Minimum impact sea water flushing	Yes, 5%	Reduce production costs – up to 20%	Increase, 30-80%
3. Surrogate soils as capping agents	Yes, 25%	Reduce production costs – up to 40%	Increase, 30-70%

Conclusion

The problem of ASS is not new nor is it lacking in technical information to identify it. The main challenges are the remediation of degraded ponds and educating planners, policy developers, scientists and farmers on the difficulties of expanding the industry in ASS impacted areas. ASS are one of several types of soil that can limit shrimp production.

It is important to note that our work is designed to address existing ASS-related pond degradation and to ensure that these soils are considered in planning and development of coastal lowlands. The methods we are developing do not encourage the use of ASS for new ponds through their application to freshly excavated sediments. On the contrary, the proposed site selection criteria and methods of land capability assessment will identify ASS so that shrimp farmers can avoid them. We hold the view that ASS is best left in their natural state for in most cases ASS occur in environmentally important wetlands, more than usually in an unoxodised and harmless state. It is likely that the construction and management of new ponds in ASS is likely to be less cost effective than in alternative landscapes. Fortunately, increasing changes in coastal zone policy may soon see ASS landscapes protected from most coastal development.

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Case Study 11: Mangrove Reforestation and Aquaculture Development: A Case Study from Thai Binh, Vietnam

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General Background

The Red River Delta in northern Vietnam supports millions of people, many of whom live in the coastal zone where they still depend heavily on the land and water for their economy, which is based largely on agriculture, salt-making, fishing and aquaculture. About nine coastal provinces in northern Vietnam (Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh. Thah Hoa, Nghe An, Ha Tinh) are vulnerable to typhoons, which strike the coastline each year, generating average wind speeds of 72-108 km/hr, with extremes of 125-160 km/hr. There is a corresponding rise in tidal height of up to 2.5 m, plus waves of up to 2m high. The combination of high winds and tidal surges can cause massive flooding of agriculture land, destruction of buildings and crops and loss of fishing boats, domestic animals and human life. The impact of typhoons in Vietnam has been aggravated in recent years by the extensive destruction of mangrove forests; these were cut down for wood extraction and to reclaim new coastal land from the sea.

Recently, mangrove reforestation/afforestation has been promoted in several provinces of the Red River Delta to provide coastal protection from typhoons and to support the aquatic resources, which have suffered a serious decline because of mangrove habitat loss and over-fishing. One reforestation project funded by the Danish Red Cross/Danida in Thai Binh and Nam Dinh provinces, has since 1994 planted more than 4,500 ha of mangrove forest in some 25 coastal communes. This undertaking has required considerable local organisation involving the community leadership (Commune People's Committees), the Vietnam Red Cross (VNRC) organisation, which is supported by many members within the communes, and the local poor people.

Table 1. Main Reasons for Mangrove Reforestation/Afforestation Projects in Northern Vietnam.

Human Related Activities	Mangroves were earlier destroyed for land reclamation, firewood collection and, more recently, for shrimp farming. Coastal land is protected by sea-dykes, all hand-built with high repair costs. The coastal communities are very poor (local economies depend mainly on salt, rice, fishing); mangroves add to the resource base for the local economy. Aquaculture has high economic potential in coastal areas, but is still based on low technology methods utilising very extensive ponds and wild aquatic seed (shrimp, crab, fish); mangroves can protect aquaculture ponds and enhance seed availability.
Natural Events/ Disasters	High rates of coastal accretion prevail in the Red River Delta provinces. Significant seasonality in climate (cold winters, hot, wet summers). Frequent typhoons (about 10 per year). Seawater flooding by typhoon storms represents a major risk to food security (crops destroyed and land salinated).

It is widely accepted in Vietnam that the best form of protection from typhoons involves (a) upgrading of the sea dykes by raising their height and strengthening them with rock revetment on the seaward facing slope, and (b) planting a mangrove buffer zone in front of the sea dyke system to reduce the water velocity and wave strength striking the defences and to absorb some of the wind energy if the mangrove trees are tall enough. According to engineering studies for the UN Food for Work Programme (FWP), a sea-dyke in northern Vietnam with good mangrove forest protection could last up to 50 years - compared to only 5-10 years for a dyke without mangroves.

The mangrove buffer zone should be at least 100m wide, but in localities with extensive intertidal mudflats it can be as much as 1-2 kms wide. Such areas are also popular for coastal aquaculture because it is easy to construct large, tidally fed ponds along the landward margin of the mud flat in front of the sea dyke system.

Background to the Project

The project concept was developed by the Thai Binh Red Cross (TBRC) in 1988 after it was decided that TBRC should support disaster prevention activities because of the exposed condition of the coastline of Thai Binh Province. Consultation by TBRC officials with several communes of Thai Thuy District in this province revealed that local people considered mangroves to be beneficial to coastal protection. This case study refers to the project activities in Thai Binh Province, which began in 1994. There has been a subsequent expansion of mangrove planting into neighbouring Nam Dinh Province.

Thai Binh is a coastal province located centrally in the Red River delta. Following a particularly bad typhoon in 1986, a project was proposed by the Thai Binh Red Cross to plant mangroves to protect the coastal zone and to improve the environment. A first phase was undertaken in 1994-1996, supported by Danida funds allocated to the Danish Red Cross. This involved the planting and protection of 2000 ha of Kandelia mangroves in front of the sea-dykes protecting five communes in Thai Thuy District along almost 26 kms of coastline (average width of the mangrove buffer zone 800 metres). In a second phase of the project (1997-2000), up to a further 6000 ha of mangrove are being planting in three neighbouring coastal districts in Thai Binh and the neighbouring province of Nam Dinh (Tien Hai, Giao Thuy and Nghia Hung districts).

These planting targets were achieved through good organisation and training of the local people. Poor families provided the labour for planting, they received training in mangrove planting and were paid for their work. The families chosen to participate in the project were selected on the basis of well-publicised criteria (e.g. announced on local radio); these included:

- Being poor.
- Living near the sea-dyke.
- Having family labour available (for planting).
- Being members of the Red Cross Association.

The selected families were paid directly by TBRC to plant propagules and protect the mangroves for two years. There was a land allocation of five hectares per family, given in the form of a lands-use rights contract of 20 years duration. Arrangements for guarding the plantations were decided by each commune.

Table 2. Basic Socio-economic Statistics for Thuy Hai Commune (1999).

Socio-economic Indicator	Breakdown	Statistic
Main occupation (% of Households)	Agriculture	Nil
	Salt	36
	Fisheries	51
	Service	13
	Others	9
Population Data	Households	1,173
	People	4,694
	Male	2,230
	Female	2,464
	Better off households (RH)(%)	5%
	Medium households (MH)(%)	85%
	Poor households (PH) (%)	10%
	Supported households under the poverty line	117
Education	Primary-school classes	18
	Secondary-school classes	12
	Students	931
	Teachers	35
Health care	Health centers	1
	Medical staff	8

The mangrove species chosen was *Kandelia candel* because propagules for planting are available locally in the drier winter season when families have less agricultural work; this species is also easy to plant (the propagules are simply pushed 30 cm into the mud). Attempts to produce seedlings of another mangrove species, *Sonneratia caseolaris*, in nurseries failed initially because management of the nurseries proved inadequate.

The worst typhoon to hit Thai Binh Province for 10 years struck on 23-24 July, 1996, dramatically confirming the need for the project. At least nine people died as a result of the typhoon. Damage was estimated to be 581 billion VND for Thai Binh Province as a whole, and 130 billion VND in each of the two coastal districts of Thai Thuy and Tien Hai (VNRC statistics).

First hand evidence obtained by visiting the area immediately after the typhoon confirmed that (a) the planted mangroves survived the storm, although some seedlings were washed away; (b) there was no major damage to the sea dykes, or large scale incursion of seawater into agricultural land; (c) even the aquaculture ponds in front of the main sea dykes suffered only minor physical damage which was repaired within 2-3 days; (d) the local people of Thai Thuy were certain that the mangrove plantations helped to reduce the typhoon’s damage, especially to the sea dykes and aquaculture ponds, by suppressing the waves.

Site Description and Human Activities

The coastal area of Thai Thuy is accreting rapidly. The accretion (land-building) process stems from the deposition of alluvial sediments carried down by the tributaries of the Red River flowing west to east to the coast. One estimate suggests that 250 to 300 ha of new coastal land are formed every five years. This is apparently quoted from the Agriculture and Water Sources Department, but the basis of this figure could not be determined. Undoubtedly, the mangrove plantations will accelerate new land development; already local people are mentioning a noticeable increase in the mud layer of the intertidal zone where the mangroves have been planted. It is also certain that, with time, the inner intertidal areas will be suitable for aquaculture ponds, or if a new outer dyke is built - for agriculture. In fact in the 3-5 years since the mangroves were planted, the area of coastline converted for aquaculture has expanded enormously. Such developments cannot be attributed to the mangrove reforestation programme, but productivity and the feeling of confidence the local farmers have in their investment in aquaculture has clearly been boosted as a result of the mangroves.

Social and Economic Issues

Based on advertised selection criteria, poor families were chosen for the work of planting the mangrove, which was done by first collecting the propagules (Early seedlings) of the selected species (Mainly *Kandelia candel*) and bringing them to the planting sites. Each family was assigned a 5 ha area of mudflat. They were paid a small amount for planting this with mangrove propagules, plus an annual payment for two years to protect the site from damage. No activities are permitted in the mangrove plantation sites for this first two year period. Thereafter, the families have been allowed to collect small fish, crabs and shrimp by hand from the mangroves, but no organised fishing with nets is permitted and no cutting of the trees is allowed. The income from collecting aquatic products, especially mudcrab seed (*Scylla* species), is a popular seasonal occupation which has raised the income of many poor people.

The crab seed are sold to pond owners who culture mudcrabs and shrimps to marketable size, all of which is contributing significantly to the economy of the communes.

The project has helped the local community of each commune to erect signboards explaining the rules for mangrove protection, and the allowable and disallowable activities in the plantations. There are publicised penalties for any infringements of the rules. Each commune has also organised a team of guards (Often retired soldiers) who operate from a guardhouse provided by the project. These men patrol the plantation areas by foot and by boat (Provided by the project) to check for any violations. The families involved in the project will also report anyone seen damaging the mangroves. Illegal fishing gear is confiscated by the guards and a record book is maintained in which violations are reported. After the project support period of four years, the cost of maintaining the guard teams will become the full responsibility of the community. The long-term need to protect the mangroves may lead to the introduction of a licensing system for collecting aquatic products, or conducting aquaculture, with some of the revenues generated from this being used to support the guard system. Education of the local people regarding the value of the mangrove forests to them is another means to help ensure that the mangrove-aquatic resources are protected and used in a sustainable manner.

Major Lessons Learned

The primary developmental objective of this project was to protect coastal communities from the natural disasters associated with typhoons. The secondary objectives included improving the environment and increasing the supply of seafood and other economic products. Thus the project did not set out to promote and enhance coastal aquaculture per se, but rather this happened as an economically attractive way for the local people to benefit from the improved environment created by mangrove planting and the increased availability of aquatic organisms, especially mud crabs.

The most significant potential problem is that aquaculture only benefits the most enterprising or wealthy sectors of the community. Those of the poorest households are unlikely to benefit greatly from aquaculture directly as they do not have either the collateral to invest in a pond or the technical knowledge or labour to manage it successfully. Thus the role of poorer households is either by providing labour for pond construction and repair, harvesting or by collecting seed to be sold to the pond owner. Collecting and dealing in crab seed involves both men and women, young and old. At present with the farming of crab, the only seed supply available is from the coastal area, in particular the mangrove plantations. Thus crab production can support a substantial percentage of the local community. With the presence of the mangrove, there has been a perceived increase in the number of crab seed available for aquaculture, measurable by the increase in collectors, dealers and crab farmers in the project communes.

However, shrimp farming is being strongly promoted, primarily from the district level with promotion workshops, promising high cash returns to those who invest. If shrimp farming is successful then hatchery production of shrimp seed will remove the need for both seed collectors and dealers that have been employed by the crab industry. In addition, shrimp are more susceptible to disease and large financial losses can be incurred fairly easily. Some pond owners who were interviewed have already experienced heavy losses in investing in shrimp. Thus most of those pond owners interviewed remain with some crab production to spread the risk losing money by keeping the diversity of species farmed to a maximum.

Benefits of the Mangrove Plantation to Aquaculture

Mangrove primarily protects the coastal crab ponds from structural damage, reducing the cost of repair significantly. Since the majority of the ponds are constructed in front of the sea dyke in order to obtain the best water quality they are also the most prone to damage. As aquaculture requires high investments in order to gain any return, any financial loss due to storm damage will be significant. One farmer explained that flooding of the ponds or loss of shrimp/crab stock due to disease is recoverable but the costs to repair a badly damaged pond is almost impossible to recover from. Those farmers interviewed generally felt “safe” with the presence of the mangrove to protect their ponds. The significant number of ponds in most communes visited located in front of the sea dyke but directly behind the mangrove reflects the general attitude of safety felt.

The increase of aquatic products, especially baby crab was also mentioned as a direct benefit to the aquaculture ponds created by the mangroves. Those ponds which relied on natural supply now tended to stock some crab seed as they have become plentiful in the last year (19980. The mangrove is seen as providing the habitat for small crab and shrimp to live in thus making them easier to catch.

Another indirect benefit is that the strict mangrove guarding system has also provided some security from poaching from those ponds near the plantation areas. This means that the pond owners regard the ponds near the mangrove as good sites as they can reduce the cost of their own guarding requirements as incidental guarding is provided by the mangrove protection team.

Benefits of Mangrove Reforestation

Based on the performance of the *Kandelia* mangroves planted in Thai Thuy District in 1994-95, it is clear that within 4-5 years, *Kandelia* can form an impressive forest protection belt against seawater flooding of homesteads and agricultural land during typhoons. The families in the project area feel better protected because of the mangroves. Moreover, all the evidence to date suggests that the variety and supply of economically valuable aquatic species, especially the mud crab *Scylla*, has increased as a result of mangrove reforestation/afforestation. These improved conditions have also stimulated an acceleration in the development of coastal aquaculture, since the mangroves help to protect aquaculture ponds and are regarded by the local people as contributing to the supply of aquaculture seed (Crabs, shrimp and certain species of fish) and feed sources for aquaculture (Molluscs, trash fish, small mangrove crabs, etc.).

The main beneficiaries from the boom in aquaculture are: fishermen/aquatic seed collectors, aquaculture producers/workers (pond operators and clam farmers) and seafood dealers. Some of the poorest people are those that go out daily to collect crab seed, clams and other species, which they sell to the pond operators or to dealers.
The situation in one commune, Thuy Hai, has been monitored since 1996. Thuy Hai, has no agricultural land and has depended traditionally on fishing and salt production for its economy. The official statistics indicate that these activities support 51 and 36% of households in the commune, respectively. About 10% of the commune's 1173 families are below the poverty line, while only 5% are classified as relatively wealthy. Over the last several years aquaculture has been promoted heavily to increase the overall wealth of the commune.

Aquaculture in Thuy Hai is based heavily on rearing of mud crabs. Hand collecting for crab seed from the mangroves is a popular activity for many poor people. Collectors tend to be women and children earning some additional income for their household. It has been said that the mangroves look like a small town lit up at night with lanterns carried by the large number of collectors who catch crabs in the peak season. People can earn about VND 30,000 (USD 2.20) from one collecting trip, but this can increase to VND 100,000 to 200,000 in the peak season (July to September). There is a perception among the local people that there is up to ten times the number of crab seed now than was available in 1996, with the majority being found in the mangrove plantation.

The majority of aquaculture ponds in Thuy Hai commune are situated in front of the main sea-dyke but behind the mangrove plantation. Those pond owners who have the ponds adjacent to the mangrove forest requested that they be permitted to remove a strip of mangrove to rebuild their pond dykes. The commune accepted this proposal and planted a new strip of mangrove in front of the old mangrove to make up what was lost in pond reconstruction.

In general, the ponds used for coastal aquaculture in the Thai Binh Province vary in size from as small as $1200m^2$ in Thuy Hai Commune to about 50 hectares for the more traditional extensive pond culture practices. The smaller ponds, which are generally situated closer to the sea-dyke, are stocked mainly with shrimp and crab, but in some instances with seaweed and fish; these are all introduced as 'seed' into the pond. The larger ponds are totally dependent on natural (wild) seed entering the pond with the in-flowing tidal water when the sluice gate is opened (i.e. "trapping and holding"). One exception is the seeding and harvesting of Gracilaria, and which gives employment to local daily labour, often women.

There is a definite trend occurring in the coastal communes, noted in Thai Thuy since 1996 and being repeated elsewhere, for the larger ponds to be sub-divided and to be operated on a "semi-intensive" basis using selected species of seed purchased from hatcheries (tiger shrimp), or from dealers (crabs). Potentially, profits are much higher from semi-intensive aquaculture (hence its fast development), but requires careful management, including attention to seed selection, feeding, water exchange, and to disease and other risks. As such progression is probably inevitable, it means that for the poorest people, the benefits to be gained from coastal aquaculture will be mainly through employment (pond labour), seed collection, and ancillary work - such as transporting seed, feed and other aquaculture products. However it is interesting that many of the small-scale dealers who trade in crab seed (buying daily from the collectors) are women; many women also trade in clams and other species. The middle income families who have invested in aquaculture ponds were, in many cases, only salt producers before. Thus the direct and indirect beneficiaries from coastal aquaculture represent a wide section of the local community, including the poor.

Drawbacks Associated with Mangrove Rehabilitation

Very few drawbacks were expressed by the local community regarding the mangrove forest, however one issue was raised, namely the use of insecticides to reduce the problems of fouling on the young mangrove trees by barnacles and oysters. The insecticides both reduce the seed available by killing off young shrimp, fish and crab in the mangrove area and can be detrimental to pond production if the insecticide in introduced into the pond water is exchanged.

There is one major risk for the communities, especially for the poor fishermen/aquatic collectors, who depend on free access to the fishing areas. This is that larger-scale investment in aquaculture by richer people, or those financed from interests outside the local area, will result in some mudflat areas being fenced of for private use. This is already happening in parts of Nam Dinh Province in the case of clam farming areas. As a result fishermen have further to travel to reach the remaining communal collecting areas. Some clam producers and others are against mangrove rehabilitation because they claim it makes the habitat less suitable for clam rearing. However this is largely an issue which can be solved by consultation on coastal land allocation and awareness-building regarding the benefits of shared protection and use of the mangroves and their associated aquatic resources.

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Case Study 12: TCEP/DANCED Experiences in Mangrove Replanting and its Effects on Intertidal Biodiversity in the Ranong Biosphere Reserve, Thailand

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Abstract

An abandoned shrimp farm and degraded mangrove forest site were replanted with four different mangrove species in Ranong, Thailand. To assess the development and ecological function of these plantations, they were compared to a natural mixed mature mangrove reserve forest area using intertidal macrofauna (Crustaceans and molluscs) as ecological indicators. The sites were a natural mature forest, four single species plantations 4-5 years old (*Rhizophora apiculata, R. mucronata, Bruguiera cylindrica* and *Ceriops tagal*) on an area previously allocated for charcoal production and a 7 year old mixed *Rhizophora* spp. plantation and a 7 year old *Bruguiera/Ceriops* plantation in an abandoned shrimp pond. The macrofauna were sampled from a 100 m^2 vegetation quadrat at each of the sites in July-August, 1999. The crustaceans were sampled quantitatively by three 15 minute timed catch periods and the molluscs were sampled in three $1m^2$ quadrats. Thirty crustacean species and thirty four mollusc species were recorded in total. The macrofauna abundance, species number, diversity and composition were different between the sites. The mature forest was dominated by sesarmid crabs, and pulmonate and Neritidae gastropods, whereas the plantations were dominated by ocypodid crabs, *Littoraria*, *Assiminea* and *Cerithidea* gastropods. The results from this study provide valuable information on the ecological impact of mangrove reforestation. In conclusion, abandoned shrimp farms can be replanted and recolonized with a diverse macrofauna, increasing the productivity and ecological functioning of the area. The regain in ecological value to abandoned shrimp ponds by replanting could also be applied to many other coastal regions in Southeast Asia.

Introduction

In recent years there has been a great deal of attention given to the impact of coastal shrimp culture on mangrove ecosystems. These include the destruction of mangrove forests, land acidification and salinisation, pollution of coastal waters, depletion of coastal fisheries, the erosion of shorelines and the construction of canals and dikes that irreversibly alter the hydrological characteristics of the area (Primavera 1991; 1993; Macintosh 1996). Many of the valuable indirect attributes of mangroves which help to sustain coastal aquaculture, for example: nutrient and organic matter export as a food source (Leh and Sasekumar 1984); nursery and breeding sites (Sasekumar et al. 1992; Barbier and Strand 1998); and buffer zones against coastal erosion and salinity intrusion (Lugo and Snedaker 1974; Othman 1994; Tri et al. 1998) are lost because of the conversion of large areas of mangrove to shrimp farms. The large-scale conversion has then often resulted in ecological damage and economic failure. Shrimp farms have experienced significant problems due to poor water quality, poor site selection, acid sulphate soils and disease, leading to shrimp mortality and eventual farm abandonment (Stevenson and Burbridge 1997; Stevenson et al. 1999). The few estimates available of the scale of shrimp pond disuse and/or abandonment emphasise the magnitude of the area involved (Stevenson 1997; Lewis 1998; Stevenson et al. 1999). Therefore the opportunities to rehabilitate abandoned shrimp ponds are significant.

Rehabilitation of mangrove forests is feasible and has been done successfully in various parts of the world (Field 1996). However there are few attempts reported on rehabilitating abandoned shrimp ponds (Lewis 1998). Research into mangrove reforestation has often been carried out without adequate site assessment and subsequent evaluation of the success of replanting on the ecological function of the system (Field 1996).

Mangrove reforestation is often done as monospecies plantations. Biodiversity has been described as important in maintaining genetic richness, ecological functioning and the resilience of the ecosystem (E.g. Schulze and Mooney 1993; Heywood 1995; Naeem and Li 1997). Experiments with artificial ecosystems (Naeem et al. 1994; 1995; 1996) and cultivated grass plots (Tilman et al. 1996) have indicated that more diverse ecosystems are more productive. The nature of the relationship between biodiversity and ecological function in mangrove ecosystems is unknown (Ashton 1999). Therefore it is important to assess different monospecies plantations and mixed species plantations in different habitats in comparison to natural mixed mangrove forests (Osborn and Polsenberg 1996).

The biota of mangroves are intrinsically linked to the ecological processes within the ecosystem. The vegetation contributes substantially to habitat complexity and the diversity of the dependent fauna (Hutchings and Saenger 1987; Lee 1998). The mangrove detritus provides an important food source for many associated mangrove fauna (Rodelli et al. 1984; Robertson 1986). The dominant macrofauna in the mangrove ecosystem are crustaceans and molluscs (Jones 1984; Hutchings and Saenger 1987). They play an important role in the ecological functioning of a mangrove ecosystem (Lee 1998; 1999). They form an important link between the primary detritus at the base of the food web and the consumers in the higher trophic levels (Macintosh 1984; Jiang and Li 1995) and are thus involved in nutrient recycling within the ecosystem. The fauna are also thought to have affects on the vegetation structure, through burrowing activities (Smith et al. 1991) and predation on mangrove propagules (Smith 1987). To assess the ecological function of the mangrove system the dominant macrofauna (Crustaceans and molluscs) could be used as ecological indicators.

Thailand has had a long history of shrimp farming (NACA 1994) and is a good example of where shrimp ponds have had a large impact on the mangrove ecosystem (Macintosh 1996). Thailand lost 50% of the total mangrove resource between 1975 and 1991 (Spalding et al. 1997) and almost 40% was due to aquaculture (Macintosh 1996). Concern about the loss of mangroves has led the Thai government to make a number of legal and policy measures for mangrove protection and sustainability. This includes declaring the mangrove forests surrounding the area of Ranong Province a UNESCO Man and the Biosphere (MAB) Reserve in 1997 (Thulstrup 1998). The Ranong mangrove ecosystem in South West Thailand covers an estimated area of about 11.5 km^2 (Spalding et al. 1997). The Ranong mangroves are not pristine but they have retained a significant level of biological diversity and productivity (Macintosh et al. 1991). Different mangrove sites were successfully replanted following different forms of exploitation: an abandoned shrimp pond and a degraded forest site previously designated as a concession area for timber extraction for charcoal production. Mangrove crustacean and mollusc species composition, abundance and diversity were recorded to assess the ecological development of each site as a result of reforestation.

Methodology

Study Sites

This study was carried out at three sites in the Klong Ngao mangroves ($9^o5'$N and $98^o3'$E) near Ranong, Thailand in July and August 1999 (Figure 1). Site 1, a mixed natural mangrove forest close to the Mangrove Forest Research Centre was used as a control/reference site. There are six mangrove species in this mature mangrove forest: *Ceriops tagal*, *C. decandra*, *Rhizophora apiculata*, *Sonneratia alba*, *Xylocarpus granatum* and *X. moluccensis*. Site 2, a disused tin mining site is not included in this paper. Site 3 was previously designated as a concession area for timber extraction for charcoal production. After the area had been clear-felled it was planted in November 1994 with four monoculture species plantations, *R. apiculata* (3Ra), *R. mucronata* (3Rm), *Bruguiera cylindrica* (3Bc) and *C. tagal* (3Ct). *C. tagal* and *B. cylindrica* all died after the first year. The problem was that these two species could not compete with a massive growth of weeds in this area. The weed species were *Finlaysonia maritima* and *Acanthus ilicifolius*. *C. tagal* and *B. cylindrica* were replanted in November 1995 and greater care given to weeding the site thereafter. This resulted in about 90% survival of the new seedlings in 1996. Site 4, is an abandoned shrimp pond (abandoned due to water quality and isolation problems). The shrimp farm had been abandoned for approximately three years before the area was replanted in June 1992 with 4 species *R. apiculata, R. mucronata, B. cylindrica* and *C. tagal*. Species were planted randomly in a mixed style at 0.1 m x 0.1 m and 0.5 m x 0.5 m intervals (Poonsri 1998). There is a mixed *Rhizophora* spp. stand (4R) and a mixed *Bruguiera/Ceriops* stand (4BC).

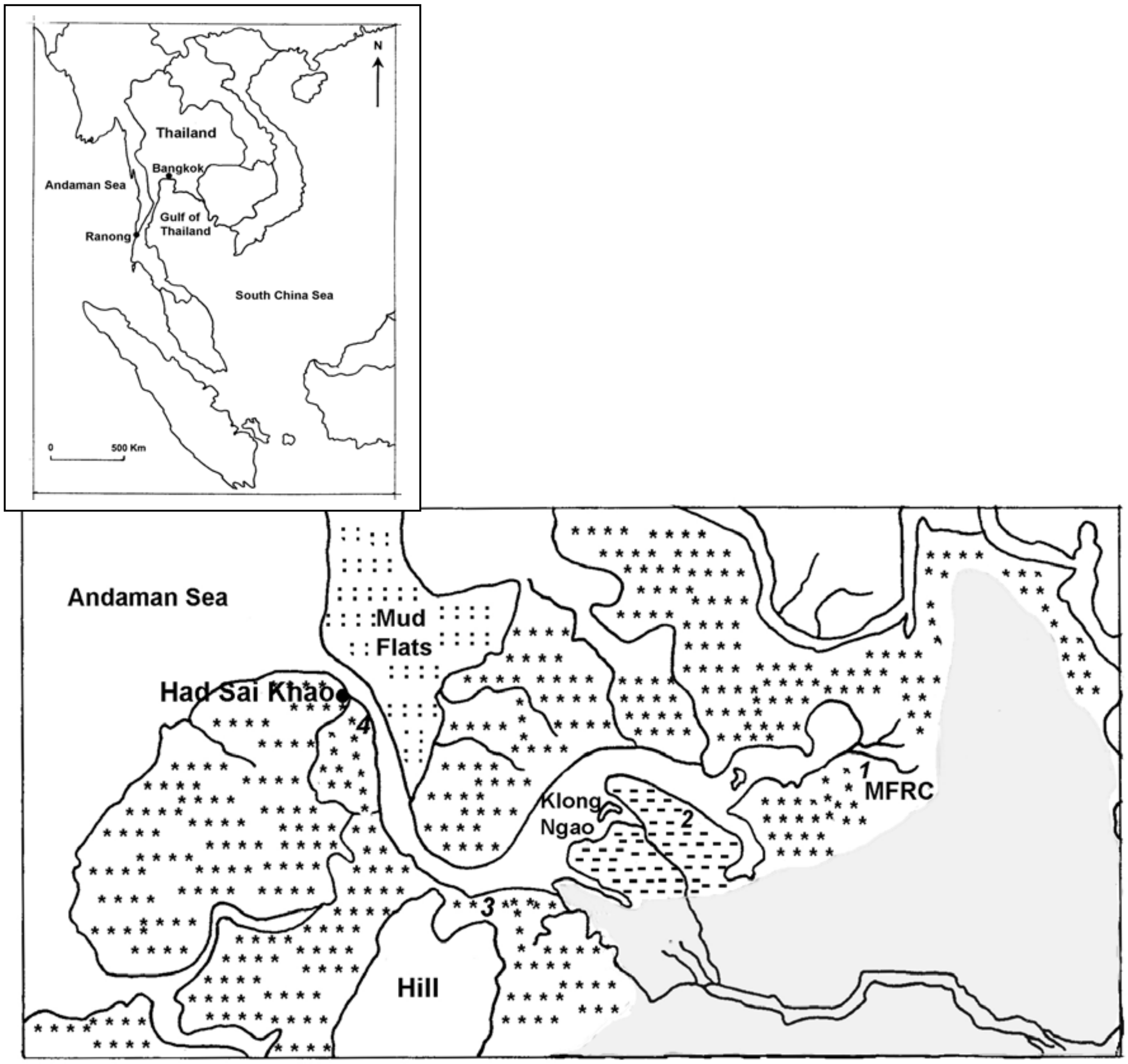


Figure 1: The location of the study sites (1 to 4) along the Klong Ngao, Ranong Province, Thailand. MFRC = Mangrove Forest Research Centre, * = mangrove forest,- = disused tin mine area, shaded area includes other areas like shrimp ponds, charcoal kilns and infrastructure.

Biotic Data

At each study site a 100 m^2 vegetation quadrat (10 m x 10 m) was sampled. Within each quadrat, the total number of tree species and the number of individuals within each species were determined. The diameter (in mm) of each tree was recorded using callipers and from this the cross-sectional area, or basal area (BA), was calculated for each tree to give an indication of biomass.

Sampling the crustacean population has many problems associated with it. The method devised by Ashton (1999) was used to obtain a good representative sample. This method is not labour intensive in the field, so more replicates can be sampled, thus decreasing variance and a larger area can be covered to include a number of different habitat types. The samples are collected to enable the species to be identified later in the laboratory and the samples are done quantitatively to enable comparisons of relative abundance (Ashton, 1999). Three independent time-based samples were conducted in every 100 m^2 vegetation quadrat. The three collection periods were 15 minutes and as many crustaceans and types of species were caught as possible; this was best done by hand using a trowel and a plastic beaker. To prevent bias on common, small and slow moving crabs more time and effort was allowed and required for catching unusual, big and fast moving crabs when they were observed. The area covered in each 15 minute timed period was approximately a third of the 100 m^2 quadrat (Ashton, 1999). The crustaceans were put in labelled plastic tubs and carefully transported back to the laboratory so that none of them lost any appendages due to stress. They were then preserved in 4% formalin for species identification by Peter Hogarth (York University, U.K.).

Mollusc species were recorded within three 1 m^2 quadrats in each 100 m^2 vegetation quadrat. The mollusc quadrats were placed around tree species and the abundance and diversity of mollusc epifauna on the mud surface and at intervals up the tree were recorded. Specimens were collected in labelled sealable plastic bags and were preserved in neutralised 70% alcohol. Keys in Van Benthem-Jutting (1956), Brandt (1974) and Reid (1986) were used to identify the mangrove molluscs.

Data Analysis

The total abundance, species number and Shannon diversity was calculated for the trees, crustaceans and molluscs at each site. The crustacean and mollusc fauna was separated into major family groups, for crustaceans, grapsid crabs and ocypodid crabs and for molluscs, pulmonates, Neritidae, Littorinidae, bivalves and others. To determine significant differences between the sites for the family groups' abundance and species number a one-way analysis of variance was performed. When the data were not normally distributed a Kruskal-Wallis test was used.

Results

Vegetation

The vegetation characteristics for each 100 m^2 study site are shown in Table 1. The density of trees was very high at site 4 with values approximately three times higher than the other sites, this is because the trees were planted by school children at 0.1 m x 0.1 m in places. At site 3 the trees were planted at a more natural density similar to that at the mature forest (site 1) at about 36 per 100 m^2. The mean diameter was greatest at the natural forest where there were mature trees with large girths, the maximum diameter recorded was 541 mm for a *Sonneratia alba*. The *Rhizophora* stands at site 4 and 3 were the next greatest, followed by the *Bruguiera* and *Ceriop*s stands. The stand basal area follows a similar pattern to the diameter values, however because of the high densities at site 4 the basal area is greater than site 3. The seven year old stands at site 4 have a basal area of about 20-30 % of the mature forest.

Table 1: Summary of the tree density, diameter, basal area (BA), species number and diversity for each 100 m^2 site.

Site	1	3Ra	3Rm	3Bc	3Ct	4R	4BC
Age	40	5	5	4	4	7	7
Stand Density	33	44	23	28	48	133	190
Mean Diameter (mm)	90.2	26.9	32.4	18.2	24.3	33.8	21.2
Stand BA (cm^2)	4303	258.9	195.5	87.4	236.3	1394	853.4
Stand Species number	6	1	2	2	1	6	6
Stand Diversity (H')	1.36	0	0.18	0.15	0	0.87	0.79

Ra = Rhizophora apiculata, Rm = R. mucronata, Bc = Bruguiera cylindrica, Ct = Ceriops tagal, R = mixed Rhizophora spp., BC = mixed B. cylindrica and C. tagal.

The mature forest has the highest vegetation diversity with H' = 1.36, followed by moderate values at site 4. A few individuals of *Avicennia* spp. have naturally colonised these sites, plus there are also a few *Rhizophora* spp. in the mixed *Bruguiera/Ceriops* stand and vice versa, where seedlings may have got mixed up at planting. The Shannon diversity indices were very low for site 3 because the monocultures were dominated by their mangrove species. Site 3Rm had one *R. apiculata* individual and site 3Bc had one *Aegiceras corniculatum* individual.

Crustaceans

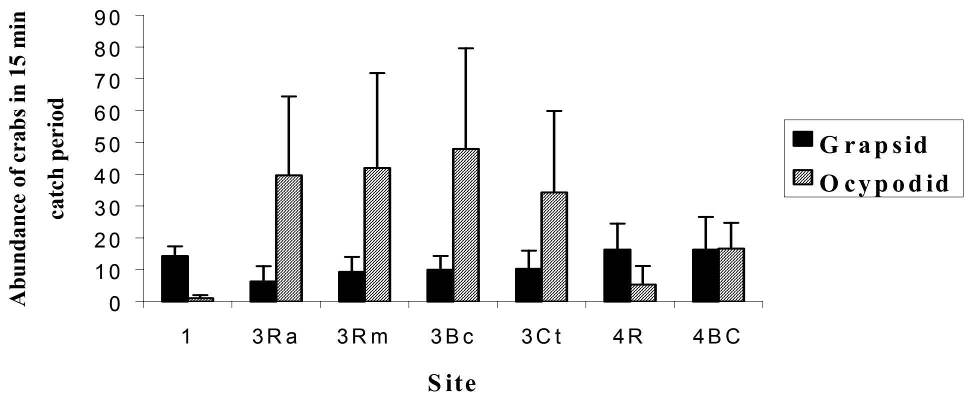
Thirty crustacean species were recorded in total from the Ranong study sites. Sixteen species were grapsid crabs all belonging to the subfamily *Sesarminae*. Ten species were ocypodid crabs, six of which were *Uca* spp. Two species were Xanthidae and two species were Diogenidae. The abundance, species number and diversity of the crustacean species was different between the sites (Table 2). The highest density was recorded from the *Bruguiera cylindrica* stand at site 3. All the stands at site 3 had high crustacean densities (100). The natural mixed mature forest had the lowest crustacean density but the highest Shannon diversity.

Table 2: Total crustacean density, species number and diversity for each site, from three 15 minute catch periods

Site	1	3Ra	3Rm	3Bc	3Ct	4R	4BC
Density	46	142	157	178	143	65	99
Species number	12	14	12	10	16	6	10
Diversity (H')	2.11	1.19	1.66	1.73	1.87	1.11	1.51

The crustacean composition of grapsids and ocypodids was also different between the sites (Figure 2). Ocypodid crabs, in particular *Uca* species, dominated all the four mangrove species plantations at site 3. At the mature forest grapsid crabs (all Sesarminae) were the dominant group in both species number and abundance. The mixed *Rhizophora* stand at site 4 showed a similar community structure to site 1 but the number of sesarmid crab species was lower, *Sesarma onychophor*a being the dominant opportunist species.

The mixed *Bruguiera/Ceriops* stand at site 4 has similar species numbers and abundances of grapsid and ocypodid crabs. There were no significant differences in the grapsid crab species number and abundance or ocypodid abundance but there were significant differences in ocypodid crab species number ($F = 4.97$, $P<0.01$) between sites with the lowest numbers recorded at the mature forest.



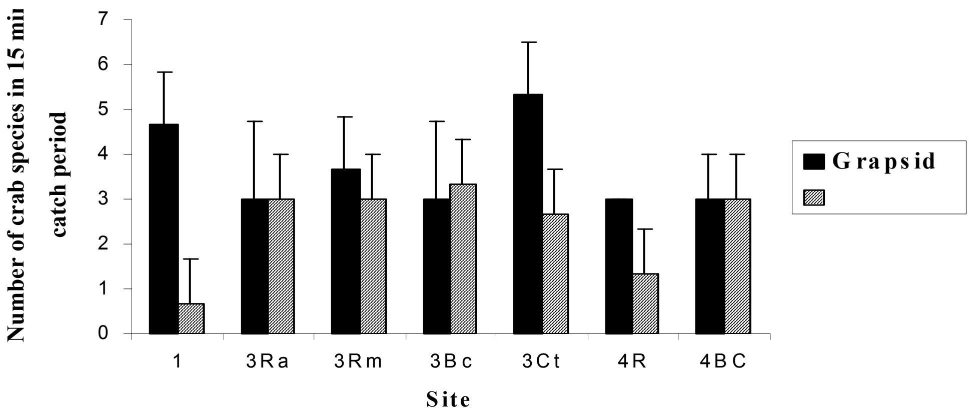


Figure 2. Mean crustacean abundance and species number + S.D. for a 15 minute catch period in each 100 m^2 site

Mollusc

Thirty four mollusc species were recorded in total from the Ranong study sites. Eight species were Pulmonates (lung air breathing gastropods), four species were Neritidae, six species were Littorinidae, four species were bivalves and the other 12 species were predominantly Assiminea (5) and Cerithidea (4) species. The total abundance and diversity of the mollusc species was different between the sites (Table 3). The lowest densities were recorded at the mature forest. The highest density but lowest diversity was recorded from the Ceriops tagal stand at site 3. This was due to a dominance of Cerithidea alata (42). The highest diversity was recorded from the mixed Rhizophora plantation at the reforested shrimp pond (H' = 2.4).

Table 3: Total molluscan density, species number and diversity for each site, from three $1m^2$ quadrats.

Site	1	3Ra	3Rm	3Bc	3Ct	4R	4BC
Density	23	45	59	67	77	72	39
Species number	10	8	13	9	8	16	13

Diversity (H')	2.04	1.63	2.15	1.70	1.36	2.39	2.14

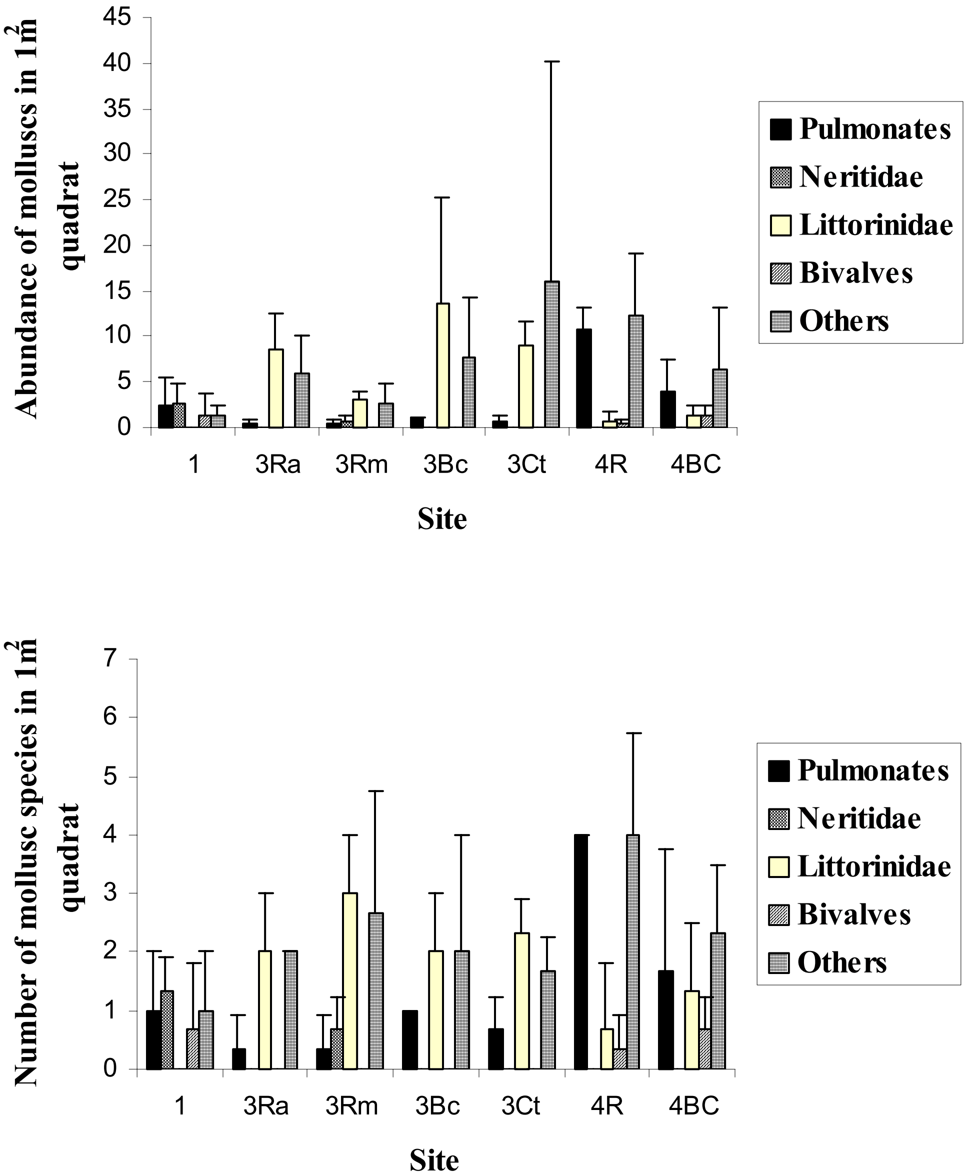


Figure 3. Mean mollusc abundance and species number + S.D. for a 1m^2 quadrat in each site.

The mollusc composition at each site is shown in Figure 3. *Littorinidae, Assiminea* and *Cerithidea* species were dominant at site 3. *Littorinidae* abundance and species number were significantly different between the sites (F = 4.1, $P<0.05$ and F = 3.7, $P<0.05$, respectively). The mature forest and the mixed *Rhizophora* stand at site 4 had lower *Littorinida*e abundances than site 3Bc and the mature forest had lower *Littorinida*e species number than site 3Rm. Pulmonates and *Neritidae* were dominant at site 1, their large size making them particularly obvious. Pulmonates are also dominant at site 4, but the composition differs to site 1 by there being more juvenile specimens and smaller individuals. *Neritidae* abundance and species number was significantly greater at the mature forest ($\chi^2 = 16.5$, $P<0.05$ and $\chi^2 = 16.7$, $P<0.05$, respectively). Bivalves (*Enignomia aenigmatica, Geloina* spp.*, Sphenia* spp. and oysters) were only found at the mature forest and the reforested shrimp pond sites, but there were no significant differences recorded due to their low numbers.

Discussion and Conclusions

The results show that abandoned shrimp ponds and degraded mangrove areas can be reforested and the areas repopulated with a diverse fauna, increasing the productivity and ecological functioning of the area. The trees planted at the shrimp pond are dense and have a large basal area/biomass, which provides a habitat structure and food source for the macrofauna.

The plantations in the shrimp pond are seven years old but the tree diameter is similar to that of 4 and 5 year old trees on a degraded forest area (Site 3). As the age class of mangrove trees increases, the mean diameter increases and the density decreases (Gan 1995). Silvicultural experience in Malaysia for production of timber for charcoal has resulted in *Rhizophora* seedlings being planted at 1.2 m intervals and having thinning procedures at 15 and 20 years (Gan 1995). The high density of trees at the shrimp pond shows that the success rate of the planted seedlings was high, and much higher than expected. The high density may account for the lower diameter than expected or there may be limiting factors for mangrove trees in shrimp ponds. There is a paucity of ecological experiments on degraded mangrove ecosystems, especially shrimp ponds and applied research is needed at testing decisions for enhancing mangrove ecosystem rehabilitation (Field 1999).

The plantations have different macrofaunal species compositions, abundance and diversity to the natural mixed mature forest. The habitat factors of vegetation age, density and diversity are not discernible between the sites, and environmental parameters have not been described, so it is not possible to assess what are the principal components for macrofaunal diversity. However, the mixed *Rhizophora* plantation at the shrimp pond is most similar to the mature forest both in terms of tree basal area and diversity but also for crustacean and mollusc species composition, abundance and diversity. Ashton (1999) showed that the crustacean and mollusc community structure changed with the age of *Rhizophora* spp. stand (cleared to 30 years old) in the managed Matang mangrove forest in Peninsular Malaysia. The highest diversity of macrofauna was found at intermediate aged stands (7 to 10 years old), because of the increase in environmental heterogeneity (open and forested areas). Mature (30 years old) monoculture plantations of *Rhizophora* spp. showed no significant change in mollusc diversity when compared with more diverse forests but that crustacean diversity was much reduced (Ashton, 1999). The different monoculture species at site 3 have different macrofaunal community structures associated with them even though they are adjacent (200 m maximum distance). For example site 3Ct has a higher grapsid species number than the other plantations. An increase in habitat diversity could be significant in increasing faunal diversity. Further understanding of the relationships between biodiversity and ecosystem function in mangrove ecosystems is necessary to improve rehabilitation, restoration, conservation and management of mangrove ecosystems.

The differences between the sites are only significant for ocypodid crab species number, Littorinidae and Neritidae species number and abundance. From previous studies (Ashton 1999) ocypodid crabs are commonly found in disturbed open areas and grapsid crabs prefer more mature forests. Ocypodid crabs are still dominant at site 3 where the forest is still more open and young (4 to 5 years old). With time it would be interesting to see how the macrofauna community structure changes. It has been observed that *Littoraria* spp. like to graze on young mangrove leaves (Reid 1986). This could account for the high species numbers and abundances at site 3, low numbers at site 4 and complete absence at site 1. Juvenile macrofauna, in particular the gastropods *Assiminea* spp. and pulmonates were abundant at the plantations. These will provide an important food source to crabs and fish and in this respect the plantations play an important ecological function in the mangrove ecosystem from the start.

Comparisons of macrofauna with other studies are difficult because the scope and methods were not similar. Frith et al. (1976) recorded 36 crustacean species and 27 mollusc species from the Phuket mangroves, Thailand and Sasekumar (1974) recorded 14 grapsids, 15 ocypodids and 24 gastropods in the Selangor mangroves, Malaysia. The crustacean and molluscan species recorded are similar to those listed from previous studies in Thailand and elsewhere in Southeast Asia (Brandt 1974; Sasekumar 1974; Frith et al. 1976; Macintosh et al. 1991; Ashton 1999).

Several methods have been employed in other studies for estimating crab abundance. Macintosh (1984) observed crabs on the surface and recorded densities of 10-70 crabs m^{-2} in Peninsular Malaysia mangroves. Averages of 5-80 m^{-2} for ocypodids and 4-12 m^{-2} for grapsids have been recorded in Southeast Asia (Macintosh 1988). This is in comparison to an average density of 27 ± 25 ocypodid crabs and 12 ± 6 grapsid crabs caught per 15 minute catching period in this study. Quantitative comparisons of crab abundance are possible with a previous study by Ashton (1999). In a 7 year old managed *Rhizophora* spp. forest in Peninsular Malaysia ocypodid crab abundance was recorded at 3 ± 3, ocypodid species number 2 ± 2, grapsid abundance 4 ± 5 and grapsid species number 2 ± 1 crabs caught per 15 minute catching period (Ashton 1999). These values are all lower than those recorded from the 7 year old *Rhizophora* plantation in the shrimp pond, except ocypodid crab species number (Figure 2). Densities of mollusc species were found to be comparable with values published for densities in other Southeast Asian mangroves, where the methods used were similar (Sasekumar, 1974; Ashton, 1999). An exception being pulmonate abundance and species number were three times greater at the *Rhizophora* plantation in the shrimp pond than in a 7 year old *Rhizophora* plantation in Matang, Peninsular Malaysia (Ashton 1999).

Crustaceans and molluscs could be used as ecological indicators to assess the success of reforestation. The discriminating species between the plots were mainly ocypodid and grapsid crabs. The mature forest was dominated by grapsid crabs and the plantations by ocypodid crabs. Molluscs are not as discriminating and obvious as crabs, although large pulmonates could be used as indicators of mature more landward mangrove forest. Sesarmid crabs have been proposed as keystone species (Smith et al. 1991; Lee 1998) because they have a significant impact on the bioturbation of the habitat and on the nutrient recycling within the system. The concept of ecological indicator species could be developed as a tool for mangrove conservation and management but more research is needed on the ecological role of macrofauna in the mangrove ecosystem before this can be applied.

When the shrimp pond and concessionary forest was initially planted, crabs from the nearby forest were seen moving into the plantations and building burrows around the base of the seedlings (Macintosh, pers. obs.). Further crab species may enter later as spawn but this initial colonisation maybe important for repopulation of the site. Therefore it maybe important for mature forest sites to be in the vicinity for macrofaunal recruitment and to restore ecological functioning. This necessitates that mature mangrove forest areas should be conserved. Preservation of the remaining mangroves in degraded mangrove habitats is an important environmental priority.

The Thai government has recognised the importance of preserving mangrove forests and has banned further conversion of mangroves to shrimp farms, as well as measures to reduce the environmental impact from the existing farms. However, unless such legislation is rigorously enforced, the conversion of mangroves will continue in Thailand and elsewhere.

The results from this study provide valuable information on the ecological impact of mangrove reforestation, which could be applicable to many other coastal areas in Southeast Asia and may help by increasing replanting and rehabilitation of mangroves in abandoned and disused shrimp ponds to regain ecological value.

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Case Study 13: Mangrove Rehabilitation after Shrimp Aquaculture: A Case Study in Progress at the Don Sak National Forest Reserve, Surat Thani, Southern Thailand

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Introduction

Recent decades have seen a rapid development of aquaculture along the coasts of Thailand. Although originally practiced only around Bangkok and only extensively for subsistence and local market demands, aquaculture has expanded enormously during the past two decades and shifted towards the highly intensive culture of the black tiger prawn *Penaeus monodon* for export.

During the past 35 years, most of Thailand's mangrove forest area was given into concession to logging companies for charcoal production. Unsustainable logging practices by many of the concessionaires and later rapid development of intensive aquaculture have been identified as the two main causes for the loss of over 54% of Thailand's mangroves in less than three decades. The shrimp farming sector, though yielding very high short-term financial profits, has contributed to environmental problems related to water pollution and sludge disposal and is plagued by viral diseases, acid sulfate soils and dropping production figures throughout the country.

In many cases, intensive shrimp farming has been characterized by a boom-and-bust cycle of rapid expansion followed by a crash. As a result the farmers migrated from the Inner Gulf of Thailand down south. This shifting cultivation, combined with degradation from unsustainable logging practices, have left behind large areas of abandoned ponds and degraded wasteland. In many areas the price for this economic development was paid by the local communities, who in the process lost their resource base on which their subsistence livelihood depended. The ownership and user right of the "land of the commons" appeared negotiable for influential individuals and the status of a forest reserve or logging concession area could change overnight into a privately "owned" shrimp farm.

Coastal areas within Don Sak district of Surat Thani Province are a typical example of the processes described above. Specifically within the Don Sak National Forest Reserve the 2,400 ha (15,000 rai) of mangrove forest that originally occurred here has been reduce to approximately 160 ha (1,000 rai), whereas the remaining 2,240 ha (14,000 Rai) consists largely of abandoned ponds, clearfelled (degraded) wasteland and a limited number of active shrimp ponds. A total of 1,967 ha of this 2,240 ha are publicly owned land within the boundaries of the Reserve. The local community in the adjacent villages has lost a highly productive natural resource base and there is no sense of resource ownership.

The Mangrove Forest Management Unit of the Royal Forest Department in Surat Thani, keen to restore the mangroves in this area, has developed a good relationship with the local communities. Local written arrangements have been negotiated by the forestry officials and village headmen with some of the former ("illegal") land-owners to surrender the abandoned pond lands back to the government for replanting. The RFD, The Surat Thani Shrimp Farmers Association, a group dedicated to sustainable shrimp aquaculture, and Wetlands International-Thailand Programme in conjunction with Lewis Environmental Services, Inc., are proposing to apply the current state-of-the-art hydrologic restoration planning to apply the most cost-effective technology to the mangrove restoration projects proposed here. A small grant from the Rockefeller Brothers Fund in June of 1999 has allowed this preliminary report to be prepared.

The benefits from the proposed mangrove rehabilitation programme to the marginalised local communities would significantly improve if accompanied by the development of income-generating activities, particularly through the development of small-scale silvo-fisheries, crab-culture, bee-keeping and other mangrove-related livelihood activities. An appropriate mechanism should be designed for the sustainable financing of such community development initiatives, e.g. through micro-credit schemes or a revolving fund.

Investment by the shrimp farmers of part of their profits in restoration of environmental damage would certainly contribute to a greener image of their industry. If combined with measures and technologies to achieve a greener production process, the local shrimp farmers - through their well-established association - may not only boost their environmentally sensitive image but ultimately qualify for an eco-label of their shrimp products that may have major competitive advantages on the international export market. The involvement of a large international environmental organization (Wetlands International) in the project could give the necessary support and publicity that may accelerate the process of such a label (formally or even informally). Certain consumer associations in the US, Europe and Japan have even indicated to be interested in informally established shrimp product certifications and would be prepared to pay a higher price for eco-labeled shrimp. A formal Thai Green Label Scheme was launched in August 1994 by the Thailand Environment Institute (TEI) in association with the Ministry of Industry, but this scheme has so far only awarded environmental certification to specific products and services, not including foods, drinks and pharmaceuticals. At various international forums related to the shrimp industry, however, such eco-labeling is placed high on the discussion agenda and often leads to heated debates between industry representatives and environmentalists.

Background

Regional Setting

The Don Sak National Forest Reserve (99^{o} 40' East, 9^{o} 19' North) is located in Surat Thani Province in the Upper South Region of Thailand just east of Ban Don Bay and southwest of Ko Samui Island in the Gulf of Thailand (Figures 1, 2, and 3).

The regional watershed of the study area is the Tapi-Phum Duang River headwaters and covers 11,585 km^2. Several smaller local watersheds, including that of the Don Sak River drain directly into the study area. The coastline of the wider study area is deeply indented with numerous bays and estuaries. The largest and most important is Ban Don Bay which has previously been studied by Paw et al. (1988) and its migratory shorebird use has been documented by Tunhikorn and Round (1996).

The study area has a sub-tropical monsoonal maritime climate with an annual average temperature of 31°C. The coldest month is January, the warmest May. The average annual number of hours of sunshine is approximately 2,000. Rainfall is seasonal and varies considerably between years, 1,500-2,500 mm/year. Most of the precipitation occurs during the fall monsoon, when the coastal area is also subject to typhoons. The tropical climate and the extensive coastline with its numerous sheltered bays and muddy inlets create ideal conditions for the development of mangrove forests. This area historically had one of the most extensive and richest variety of mangrove forests along the Gulf coast of Southern Thailand, although it is much reduced today (Figures 2 and 3), due to conversion to other uses such as shrimp farms or salt ponds, and erosion due to the overall reduction in total area and thus the ability of the total system to function as a means of coastal erosion control.

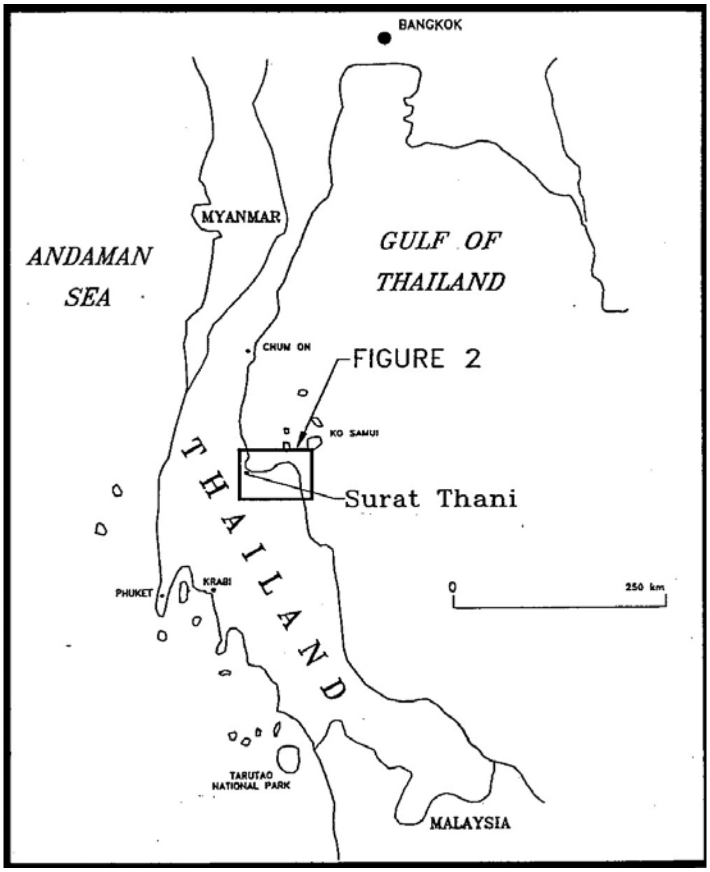

Figure 1. Location map, Surat Thani, Thailand.

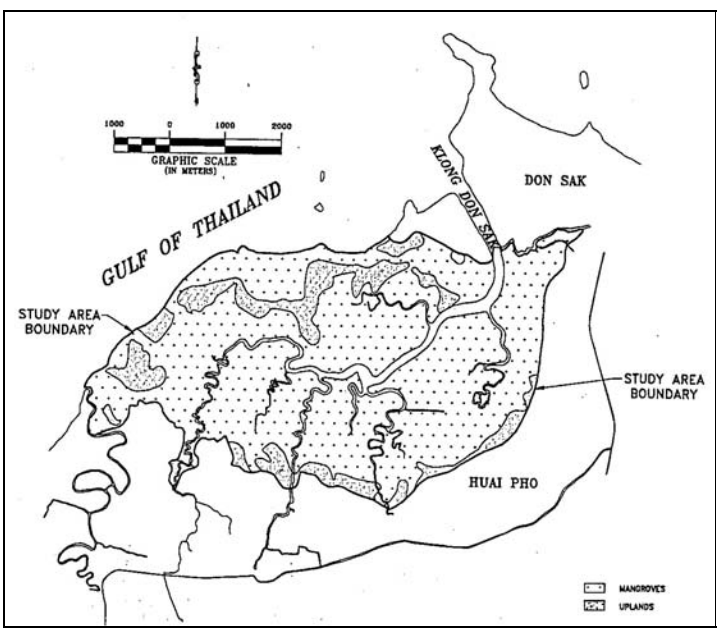

Figure 2. Historical distribution of mangroves in the Don Sak National Forest Reserve, 1971.

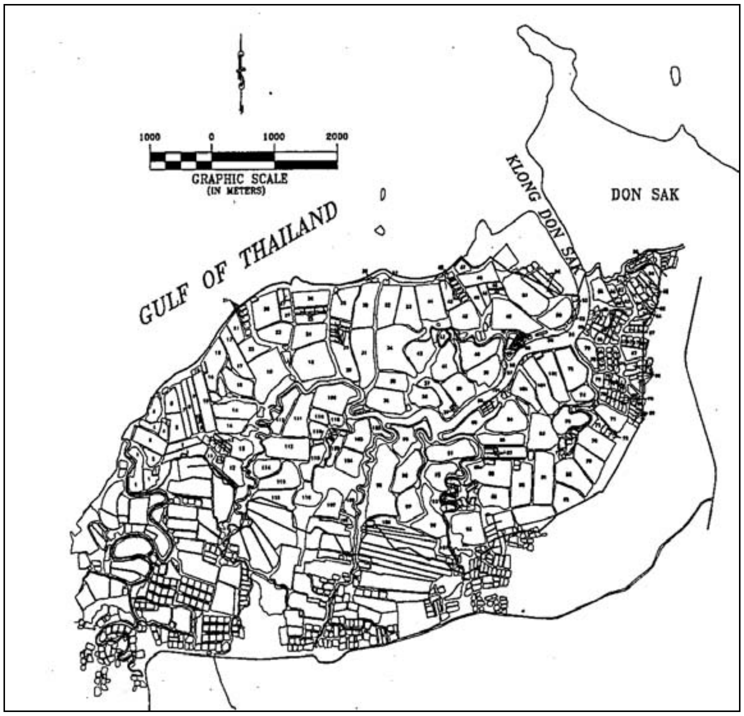

Figure 3. Current distribution of mangroves and shrimp aquaculture ponds in the Don Sak National Forest Reserve (1999).

Socio-Economic Data

Surat Thani Province consists of 19 districts with 1,012 villages over an area of 12,891 km2. The 1997 population was 861,233, up from 583,137 in 1979.

The Provincial government is under an appointed Governor, with some government agencies having District offices, such as the Fisheries Office. The economy is resource based, with agriculture and aquaculture the dominant industries. Table 1 lists the important export and import items for the Province.

Table 1: Import/Exports for Surat Thani in 1998 (Provincial Statistics Office Annual Report, 1999)

Item	Value (US$)
Exports	
Aquaculture Products	63,878,058
Palm Oil, Coconuts	46,581,475
Minerals	19,041,124
Rubber	14,560,993
Asphalt	475,694
Total	**144,537,544**
Imports	
Diesel	11,067,078
Benzene	2,210,329
Ammonia	1,025,517
General Cargo	618,226
Other	83,280
Total	**15,004,430**

The Don Sak District has 35 villages with a total population of 33,680. It is the second largest shrimp-producing district in the Province.

Land Use

Land use in the Don Sak District is dominated by rubber plantations, rice paddies, coconut plantations and shrimp farms (Sawangphol and Wattayakorn 2000). Shrimp farms have increased from 249.6 ha in 1977 to 8,088 ha in 1998.

Throughout the study area much of the coastal zone is very heavily used. In many areas mangroves and other forests have been depleted over the years and replaced with large-scale agricultural land and aquaculture ponds. Since then most of the former coastal plain (the area between the present day mangroves and the bottom of the plateau escarpment) was used for irrigated rice and small-scale vegetable farming. Fruit farming and forestry are practiced on the upper plateau. In most cases the agriculture is very intensive and very little land is set aside for other activities.

Aquaculture development in the coastal zone is also very intensive and highly developed. Along the coast in the study area aquaculture is the dominant land use. Large fish and shrimp farms (100-150 ha in size) have been constructed in the former intertidal zone, most of which are currently abandoned. Meanwhile on higher grounds, intensive shrimp farms have been constructed, the further development and operation of which is still continuing at a fast pace in the wider Surat Thani region. Investment in development of intensive aquaculture ponds is high as the ponds need intense management including a heavy lime application to reduce the effects of high acidity from the acid-sulfate soils. In many other sites along the east coast of the study area, aquaculture development in the former intertidal zone has led to acute development of acid-sulfate soils and regular flushing, draining, liming and plowing of aquaculture ponds is necessary. In an attempt to combat high acidity, the trend in recent years has been to site aquaculture ponds further inland. This has created problems for water supply and loss of agricultural land.

In many areas traditional techniques of extensive aquaculture in mangrove areas and harvesting fish and shellfish at netted sluice gates on the falling tide was used. Many of these extensive ponds have been abandoned in recent years, after their brief use for intensive shrimp production failed, due to disease problems and water pollution problems.

Natural Resources

The Don Sak area has a tropical monsoonal climate. Other climatic and geological factors such as relatively high rainfall, suitable soils and an indented, sheltered coastline ensure that the intertidal communities are rich in biodiversity and variety.

Because the Don Sak area and other parts of the Southern Thailand coastline are just 9° north of the equator and the forested intertidal ecosystem is therefore species rich and complex as with true tropical mangrove forests in the Pacific. The establishment and growth of mangroves in southern Thailand is luxuriant due to moderate winter air and water temperatures, high annual average rainfall (2,000 mm). A total of 51 species of mangroves and associated vegetation occur in Southern Thailand (Aksornkoae *et al*. 1992). The mangrove forests in the Don Sak area are dominated by *Avicennia marina*, *Avicennia alba*, *Sonneratia alba, Xylocarpus granatum, X. moluccensis, Bruguiera sexangula, B. cylindrica, B. parviflora, B. gymnorrhiza, Rhizophora apiculata, R. mucronata, Ceriops tagal and Excoecaria agallocha*

Mangrove forests and their intertidal sand- and mudflats have traditionally provided a wide range of values and functions for the communities along these coasts. These include innumerable products for exploitation by man such as food stuffs (fish, shellfish, molluscs, fruits, etc); timber, fuel wood and construction materials; medicines, fish poisons and dyes. They function to prevent saltwater intrusions in coastal areas (maintaining freshwater drinking supplies for communities and irrigation waters). They also provide coastal protection (from storm waves and strong winds), provide important nursery and spawning areas for innumerable species of commercially important fish and shellfish, process biodegradable matter to support nutrient inputs and filter pollutants to prevent degradation to offshore fisheries, sea grass and coral reef communities (Platong 1998).

During storms and typhoon events the mangroves absorb much of the wave action and power, providing protection for the landward edge. Research has shown that mangrove forests can absorb up to 80% of the wave energy during storm events.

Coastal wetlands are very biologically diverse areas due to the wide range of available habitats and ecosystems for the development of life. In tropical and sub-tropical areas this is even more so where mangroves and their associated intertidal flats are the most biologically diverse coastal ecosystems. The warm inshore waters and submerged reefs provide habitats for many fish and shellfish, a huge variety of other marine invertebrates and plants such as seagrasses and seaweeds. In southern Thai waters nearly 300 species of coastal and estuarine fish have been recorded - these include mangrove/mudflat dependent families such as *Gobiidae*, *Scatoplagidae* and *Engraulidae*. Nearly 2,000 species of mangrove and mudflat invertebrates including 50 species of crabs occur in the region and many of these are also commercially important. The intertidal flats of southern Thailand also support a very high diversity of invertebrates and are critical staging and feeding areas at least 63 species of migratory shorebirds including the Red-necked Stint, Long-toed Stint, Marsh Sandpiper, Curlew Sandpiper, Pacific Golden Plover and Lesser Plover (Tunhikorn and Round 1996). However, poaching of birds for food and other purposes is reportedly common.

The sheltered environment of the mangrove forest and its high and diverse nutrient supply also support a large number of other species many of which have high economic value. These include species of fish, prawns, shellfish, crabs and mantis shrimp which breed and live in the mangrove habitat and adjacent mudflats as well as species which migrate off-shore to spawn and feed.

Mangrove forests are of vital importance for the maintenance of coastal and near-shore fisheries production, and for the supply of nutrients, fish- and shrimp seed to coastal aquaculture. Some 11 species of high economic value, including eel, octopus, three shrimp species, 19 species of molluscs, and 7 species of grapsid crabs are reported from the study area. Food chain species include 26 zooplankton species, 97 phytoplankton species, 159 diatom species and 133 insect species.

Subsistence fisheries and non-timber forest products which remain un-recorded in the official statistics include “low” quality fish such as mudskippers, bivalve molluscs, gastropods, brachiopods, and many crustaceans (Table 2).

In recent years these resources have become an important means of supplementary income for villagers (women in particular) as they can sell surplus harvests on the open market. In coastal areas of Southern Thailand, women and children specialize in harvesting one or more of 19 species of edible molluscs collected from mangroves and mudflats (Plathong and Sitthirach 1998).

Table 2: Some coastal fauna of subsistence importance in the Don Sak District.

Molluscs	
Glauconome chinensis	Razor shell *Pharella acuminata*
Geloina erosa	*Tellina* spp.
Meretrix meretrix	*Mactra* spp.
Fan mussels *Pinna* spp.	Pacific cup oyster *Crassostrea gigas* (cultivated)
Gastropods	**Brachiopods**
Ellobium polita	*Lingula lingula*
Natica maculosa	
Crustaceans	**Benthic worms**
Mangrove crab *Scylla serrata*	*Siphunculus nudus*
Mantis shrimp *Harpiosquilla spp.*	

Honey and bees wax production in mangroves is another important economic value of these forests. When *Aegiceras corniculatum* are in bloom (March-May) local farmers and villagers set up their bee-hives adjacent to the mangroves.

Despite these important functions and values, mangroves have been under constant pressure for development and over-utilisation since the early 1960s. At that time, Thailand still had 376,900 ha of mangrove forests. By 1996, this area has dwindled to 167,582 ha, a 55.5% decrease (Charuppat and Charuppat 1997). For Southern Thailand, the area of mangroves has decreased from 334,000 ha in 1961 to 161,674 ha in 1996 (-48.3%). For Surat Thani Province, the area of mangrove has decreased from 25,600 ha in 1961 to 2,204 ha in 1993 (Plathong 1998), a 93% decrease.

Management Issues

Historical Land Use in the Don Sak National Forest Reserve

Wongbandit (2000) has reviewed the historical land use patterns and laws relating to the changing land use patterns in the Reserve. In that review it is noted that the Reserve was established in 1964 under the National Forest Reserve Act.

Following that action, concessions were given by the government for cutting of mangroves for charcoal production. This probably led to the first large scale removal of mangroves from the Reserve. Although replanting was required as part of the concession, it apparently did not occur. Another concession was granted, and the now degraded forest was illegally sold to new investors interested in conversion of the forest to shrimp aquaculture ponds.

Realizing that aquaculture within the Reserve might require a permit, the new “landowners” applied for permits to construct ponds. When the permit process became bogged down, they built them anyway. Attempts to then enforce the existing regulations by RFD were then met with “strong protests” and to quote Wongbandit “as a result, most part of the Don Sak mangrove forest was converted into shrimp ponds as it is today…In 1991, a legal blow hit the illegal shrimp farmers…when the Cabinet issued a resolution (23 July 1991 order to the National Forest Policy Committee) …This made RFD refuse to give permission to the illegal shrimp farmers in conducting shrimp aquaculture…some farmers still ignored the government policy and the RFD’s legal position, but when the shrimp price in the world market had gone down, many of them left their business.” The abandonment of many of these ponds has also been caused by increasing incidences of viral diseases and water quality problems, driving the risks involved in shrimp business in this area beyond acceptable limits.

While shrimp prices have increased in recent years, the illegal aquaculture has not returned to the Reserve largely through the efforts of local villages efforts to protect what was left (Sathirathai 1998), and by RFD enforcing the law, not by arresting violators, but by stopping heavy equipment from entering the forest as per the 1991 Cabinet Resolution. Without the equipment to maintain dikes, potential illegal operators are stymied. Subsistence use and low production extensive aquaculture still persist, and an investigative committee report by RFD in 1996 produced the attached Figure 4. Most of the abandoned and disused ponds look like that pictured in Figure 5, but some are undergoing restoration as shown in Figure 6.

Mangrove Restoration in Southern Thailand

Plathong (1998) discusses mangrove restoration efforts in Southern Thailand in Chapter 6 (pages 58-68) of that publication. According to the cabinet decision of 1991, mangrove forest restoration was supported as a project of the RFD as part of the CRMP and given a budget of US$ 30 million. The goal was to restore 40,000 ha between 1992-1996, 81.4% of this (32,544 ha) in Southern Thailand. This effort was primarily to be accomplished through planting of mangrove seedlings in clear-cut forests and on unvegetated mudflats in front of existing remnant fringes of mangroves.

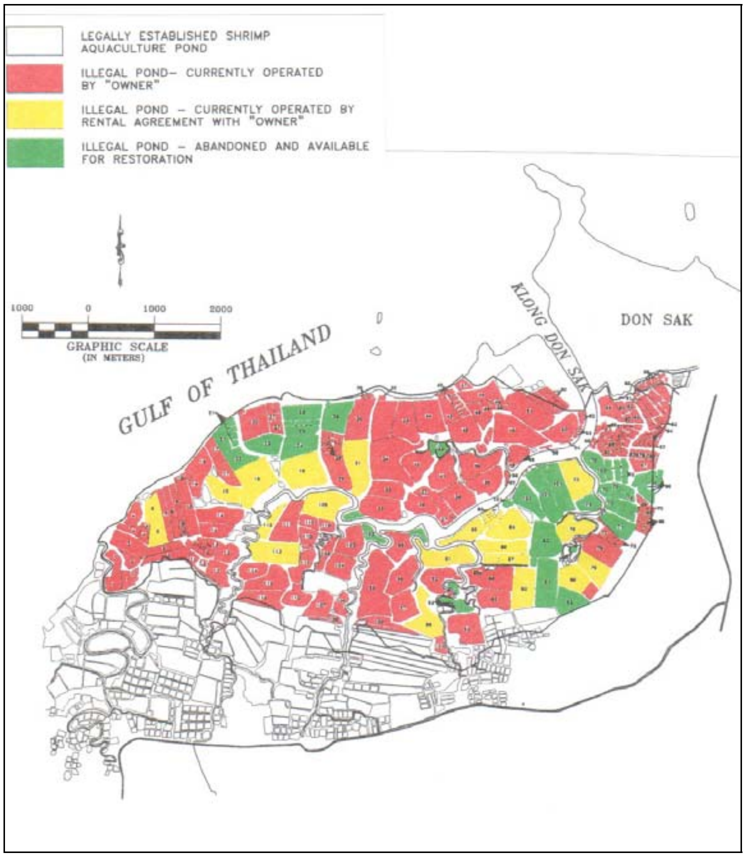

Figure 4. Status of aquaculture ponds in the Don Sak National Forest as of 17 November 1996. showing areas of ponds in four categories: (1) white = legal ponds; (2) red = illegal but in current operation by an "owner"; (3) yellow = illegal but operated by rental agreement and (4) green = illegal and apparently abandoned and therefore subject to rehabilitation or restoration.

Figure 5. Typical view of an abandoned shrimp aquaculture pond in the Don Sak National Forest Reserve.

Figure 6. Successful plantings of *Rhizophora apiculata* propagules at the Don Sak National Forest Reserve restoration project after three years of growth.

Mangrove restoration activities have been largely concentrated on the direct planting of the nursery grown seedlings or elongate propagules of *Rhizophora* spp. on unvegetated mudflats. It is difficult to determine how much of this goal was actually accomplished. Plathong (1998) states that the RFD reported 11,009 ha planted in Southern Thailand (Table 3). Additional data is difficult to locate. As Plathong (1998) notes that RFD "is unable to justify the success of the plan because the replanted mangrove areas are just in seedling stage. There is no report that replanting mangroves are survived or destroyed by natural factors and human. The data being recorded are only the planted area and the amount of areas planned to be replanted" (p. 59).

Table 3. Mangrove planting in Southern Thailand (1991-1995)(hectares).

Province	1991	1992	1993	1994	1995	Total
Chumporn	-	160	-	272	224	656
Surat Thani	112	256		362	160	890
Nakhon Sri Thammarat	112	104	320	400	373	1,308
Phatthalung	-	-	-	-	-	-
Songkhla	-	-	-	-	-	-
Pattani	-	-	32	-	-	32
Phang Nga	-	343	35	189	488	1,098
Phuket	-	-	136	80	19	235
Krabi	-	110	184	240	-	534
Trang	-	267	208	256	403	1,134
Satun	-	293	272	384	157	1,106
Ranong	-	-	160	303	480	943
Totals	**224**	**2,136**	**2,067**	**3,382**	**3,200**	**11,009**

(Plathong 1998)

In addition "the Agriculture Department joined with the private sector in a mangrove replanting project for the King's 50th anniversary jubilee…The target was 31,724 Rai (5,076 ha) in 57 areas. The Petrolium Authority of Thailand (PTT) replanted mangrove forest in Southern Thailand…between 1995-1997 about 11,062 rai (1,770 ha)…" It is not easily to compare the success of mangrove replanting…because they are not the same scale e.g. species, number of areas, location, timing and budget for maintenance after replanting." We would add that even the use of different terms and confusion in their meaning also adds to the confusion about which of these projects actually succeeded in restoring a previously existing mangrove forest, or converting a natural mudflat into mangroves. For example the terms "replanting" and "reafforestation" are commonly used. "Replanting" would seem to mean planting a second time after an initial "planting". Similarly, "reafforestation" would seem to mean planting a second time after a first effort at "afforestation". Afforestation is a widely used term in forestry and refers to planting of trees in areas that have not previously been forested.

Concerning afforestation, it is questionable whether the widespread attempts to convert existing natural mudflats to mangrove forests, even if they succeeded, represent ecologically sound restoration. Similar efforts in the Philippines, as reported by Custodio (1996), under "Threats fo Shorebirds and their Habitats", state that "Habitat alteration in the wake of unabated increase in human population is still the most important threat to shorebirds in the Philippines. Some of the alteration, however, has been due to activities which were of good intention. An example of this is the mangrove 'reforestation' programme which covered the feeding grounds of shorebirds in Puerto Rivas (Bataan) and parts of Olango Island" (p. 166). With these words in mind, it is worthwhile to note that Tunhikorn and Round (1996) state that "…Thailand is a major wintering and passage area for Palaeartic waterbirds. Large numbers of shorebirds are found both along its coastline, in mudflat and mangrove habitat..."" and describe the intertidal mudflats, onshore prawn ponds, salt-pans and some remaining areas of mangroves along the Gulf of Thailand as "(P)probably the single most important site for shorebirds in the country" (p. 123). Finally they describe the major threat to wintering shorebirds at Khao Sam Roi Yot National Park in Prachuap Khiri Khan province as modifications to "the hydrology and topography of coastal areas … by intensive prawn farming during 1988-1993" (p. 124). In their review article on this matter, Erftemeijer and Lewis (2000) further commented that "planting mangroves on mudflats would represent habitat conversion" rather than habitat restoration, and strongly caution against the ecological wisdom of doing this.

Status of Restoration Efforts in the Reserve

Preliminary field work and review of RFD reports indicate that several of the numbered ponds in Figure 3 have undergone some mangrove restoration efforts. Pond # 81 was opened to tidal connection and planted with *R. apiculata* propagules in 1997. There is some discrepancy in the records about its size, but it appears to be about 25 ha. An unnumbered pond south of Pond # 81 was planted in 1995 as part of the King's Centennial Celebration. Pond # 83, and the two ponds # 101b and c have been planted with *R. apiculata* propagules in 1998-99 but are not freely connected to tidal action (Only a single gated tidal opening exists). They total about 50 ha in size. Ponds # 25 and # 27 were being planted when visited in September of 1999. Total size for the two was about 20 ha. No visible tidal connections were seen at that time. Thus at least 95 ha of ponds have undergone some level of rehabilitation, although only 25 ha of this area appears to be properly connected to tidal influence to insure the best ecological restoration.

Records in English are not available and the exact hectarage of planted mangrove areas is thus difficult to determine. The Royal Forest Department indicates that their records show that 190.4 hectares of mangrove plantings took place between 1995-1999 in the Reserve, and that another 104 hectares is being planted in 1999-2000. Thus up to 300 hectares may have been planted to date. No monitoring reports are available, so the success or failure of these plantings is unknown. Visually, some of the ponds show high survival of *Rhizophora* propagule plantings (Figure 6).

Future Restoration Efforts

All of the above has guided our proposed mangrove forest restoration towards "hydrologic restoration" as described by Turner and Lewis (1997), Lewis (1998), Lewis and Marshall (1998), and Stevenson *et al.* (1999).

Hydrologic restoration of mangroves implies the use of the five sequential steps to successful mangrove restoration as described by Lewis (1998):

1. Understand the autecology (individual species' ecology) of your target restoration species
2. Determine the normal hydrology of those species
3. Determine if that hydrology has been modified and how it was modified
4. Restore normal hydrology

5. Only plant mangroves if natural secondary succession by mangroves does not occur at a rate or density sufficient to satisfy predetermined success goals

The success of this approach is quantitatively described by Lewis and Marshall (1998) and Stevenson et al. (1999) in the natural recovery and revegetation of an abandoned shrimp pond in Costa Rica after natural breaching of its outer dikes. Additional examples are also shown from abandoned ponds in the Philippines.

The application of the basic principles of hydrologic restoration to restoration of abandoned shrimp ponds in the Don Sak National Forest Reserve is expected to result in better fisheries and wildlife habitat restoration at a cost of 50% to 66% less than current costs, and similar reductions in the time required to complete restoration projects.

Current cost estimates provided by the RFD are that excavation of dike openings and plantings, of primarily *Rhizophora apiculata* unrooted propagules is 4,200 baht/rai or US$691/ha (at 38 baht/US$1) It is proposed to design the future restoration project to emphasize optimum placement of excavated openings in both the upland edge and the seaward edge of the ponds to reconstruct the historical tidal creek system of the forest. A 1971 vertical black and white aerial photograph and similar maps are available to use as templates for the restoration. It is estimated that the cost of restoration could therefore be reduced to US$200-300/ha, since natural propagule recruitment would replace active planting. Stevenson et al. (1999) have shown that natural propagule recruitment in an abandoned shrimp aquaculture pond in Costa Rica resulted in the same species mix, and 64.2% of the basal area of a control forest within 10 years of pond opening and without planting. This approach to pond restoration would also provide for a diverse species assemblage of mangroves rather than a monoculture.

Restoration of abandoned ponds would also facilitate their role as biofilters for the effluents from shrimp farms located upstream of the restored areas in less sensitive habitats. Several authors have discussed the role of mangroves as biofilters for shrimp aquaculture effluents (Robertson and Phillips 1995, Rivera-Monroy et al. 1999) and estimates for the amount of needed biofilter area of mangroves for 1 hectare of intensive shrimp aquaculture range from 0.04 to 22 ha.

Proposed Programme

Short-Term Objectives

The short-term objectives of the proposed programme are:

1. Strengthen the capacity of RFD staff and related agencies in managing and protecting the mangroves of the study area by training relevant government personnel for the conservation and management of mangroves.
2. Enhance the extension tasks of RFD to undertake conservation education programmes amongst local communities, by developing conservation education and awareness programmes among coastal communities on mangrove ecosystem conservation and its importance in supporting coastal communities.

3. Manage the coastal natural resources through community participation and enhance agricultural production.
4. Rehabilitate degraded patches of mangrove forests for protection against coastal storms, tidal stream erosion, protection and improvement of water quality and thus the protection of agriculture and fisheries activities, by hydrologic restoration of 800 ha of mangrove forest.
5. Enhance the capacity of RFD to deal with potential aquaculture and mangrove management conflicts through improved community involvement.
6. Establish models of sustainable natural resource exploitation to generate income for reserve management activities, by working out with local families as the main stakeholders a modality of effective mangrove forest protection and management, with unambiguous identification of shared responsibilities and benefits.
7. Investigate coastal pollution and determine if mangrove restoration can help alleviate this problem.

Long-Term Objectives

The long-term objectives (goals) of the proposed programme are:

1. Establish an effective natural protection belt against destructive storm surges and typhoons of the coastline of the study area in order to protect the coastline, fishponds, agricultural land and settlements from typhoon damages.
2. Improve the socio-economic conditions of the coastal communities, thereby contributing to poverty alleviation by enhancing the productivity of the coastal mangrove ecosystem in terms of fisheries and aquaculture.
3. Expand the study area under mangrove forest and enhance its management by establishing The Surat Thani Community Forest, to include the Don Sak National Forest Reserve and adjacent publicly owned lands currently existing as disused or abandoned shrimp aquaculture ponds constructed in former mangrove forests, with a total area of 22,000 ha, including 15,000 ha of mangrove and 7,000 ha of tidal streams and intertidal mudflats.

Implementation

The first phase of the project will be completed in June of 2000 with the submission of the final project report to the Rockefeller Brothers Foundation. This report will summarise all activities to date and include the Phase 2 proposal for general consideration for funding by a number of funding organisations.

The Phase 2 program proposal is being co-ordinated with Wetlands International, the RFD, the new Songkla University campus in Surat Thani and the Surat Thani Shrimp Farmer's Association. In addition, a proposed program entitled "Reducing loss of mangrove forests and biodiversity through promotion of sustainable and environmentally sound shrimp farming" was prepared by the United Nations Environment Program (UNEP), East Asia Seas Regional Coordination Unit (EAS/RCU) in Bangkok for funding by the Global Environmental Facility and is currently under consideration. Funding will be sought to assist in the implementation and documentation of this Phase 2 program as appropriate as this UNEP program proceeds.

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