REHABILITATION OPTIONS FOR ABANDONED SHRIMP PONDS IN THE UPPER GULF OF THAILAND

Md. Zakir Hossain[1]

Key words: Abandoned shrimp farms, integrated mollusk-shrimp-fish, mangrove plantation, salt production

Introduction

In recent decades, the coastal zone of Thailand has been affected by increasing population and economic pressures manifested by a variety of coastal activities (notably aquaculture, and in particular, shrimp farming). Shrimp farming and the tourist industry boom (also connected with coastal beaches and islands) have obviously had great impacts on the country's economic growth in the last two decades. Interestingly both these sectors have developed side by side over the last 25 years.

Extensive shrimp farming in Thailand has evolved since the mid-1920s. But the introduction of intensive and super-intensive shrimp farming after 1985 made Thailand the world's largest producer within five years. This rapid development did not proceed smoothly and occurred vertically as well as horizontally. As a result, the *boom and bust* of this unsustainable but highly profitable venture has resulted in many abandoned shrimp farms. In 1995 there were 20 800 ha of abandoned shrimp farms in Thailand (Figure 1) incurring an economic loss of about THB[2] 5 000 million (Anon, 1995). A more recent report has indicated that there were 40 000 ha of abandoned shrimp farms in the Upper Gulf area alone (Anon, 2000).

An abandoned shrimp pond can be defined as a shrimp pond, which after a period of production becomes unproductive due to disease and/or environmental degradation, and then loses the farmer's attention.

Figure 1. An abandoned shrimp pond

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[2] 1 USD = 39 Thai Baht, March 2005

The onset of shrimp farm abandonment has become a major coastal zone management issue and utilization of these sites is a challenge for the country, coastal zone managers, and locals. In most cases after abandonment, the farms have reverted to traditional extensive shrimp farming or fish farming. Among the many other options the two most common are conversion to salt pan production and mangrove replantation; the latter option is facilitated via government incentives. Some farmers have started a new integrated system of mollusk-shrimp-fish farming in their abandoned shrimp farms but the system lacks definition.

To date the best option has not been identified and except for the monitoring of the growth of replanted mangrove on abandoned shrimp farms no study or assessment has been carried out to assess the better utilization of these disused areas. Furthermore, rehabilitation or re-use of the farms is sometimes difficult because of the prevailing environmental conditions. Thus there is a need to find alternatives that provide quick and reasonable income for the farmers concerned.

Study area: the Upper Gulf of Thailand

Location of the study area

Samut Sakhon Province (latitude 13°12'N-13°40'N and longitude 100°20'E-100°30'E), which was selected as the study site for this research, is one of the Upper Gulf Provinces of Thailand where rapid development of intensive shrimp farming developed in the mid-1980s. This province was the first in Thailand to develop intensive shrimp farming. After yields peaked in 1989, production in approximately 80 percent of the farms in the province dropped dramatically due to the deterioration of environmental conditions (Phillips, 1992; Anon, 1995). Many farms at that time reverted to the traditional extensive system (Jenkins et al., 1999).

Samut Sakhon Province is 28 km southwest of Bangkok (Figure 2), and occupies an area of 872 km^2. It has a 41-km-long coastline. The province is generally characterized by low land of the muddy coastal plain through which the Tha Chin River flows from the north. In addition a number of natural and man-made canals are found. In the southern part of the province, primarily low-lying land parallels the coastal area; it is used for salt production and shrimp farming.

Major land-use changes in the study area

The study area was fully covered by mangroves and shrubs until major human activity commenced (Hossain, 2001). According to local people, time-line analysis, and direct observations of present land uses, three major historical land-use changes have occurred in the study area (Figure 3). The first land-use change took place more than 75 years ago when local people started solar salt production. Conversion of salt pans into shrimp farms started in 1947, following a decrease in salt prices (Anon, 2000). The second major land-use conversion occurred after 1975, when marine shrimp exports caused prices to increase and the Thai Government adopted a policy to develop Penaeidae hatcheries. Local people, as well as outsiders, became more interested in marine shrimp farming. The rapid expansion of marine shrimp farming started in this area after 1986, with government support via tax incentives and new technology. This accelerated when the Taiwanese shrimp industry crashed (Hossain, 2001; Anon, 2000). Local people and outsiders converted their extensive shrimp farms into intensive shrimp farms. The entire mangrove area had been encroached by shrimp farms before 1989. At the start of intensive shrimp farming in 1985/1986, production was high (>2 000 kg/ha), which attracted many people to this enterprise. The venture was profitable (US$15-16/kg) but crashed in only five years. Use of the same water sources, unwise feed management, use of contaminated feed (from trash fish), industrial and urban pollution, and poor site selection resulted in about 90 percent of the shrimp farmers in this region going out of business. A problem tree showing the causes and effects of shrimp farm abandonment is given in Figure 4.

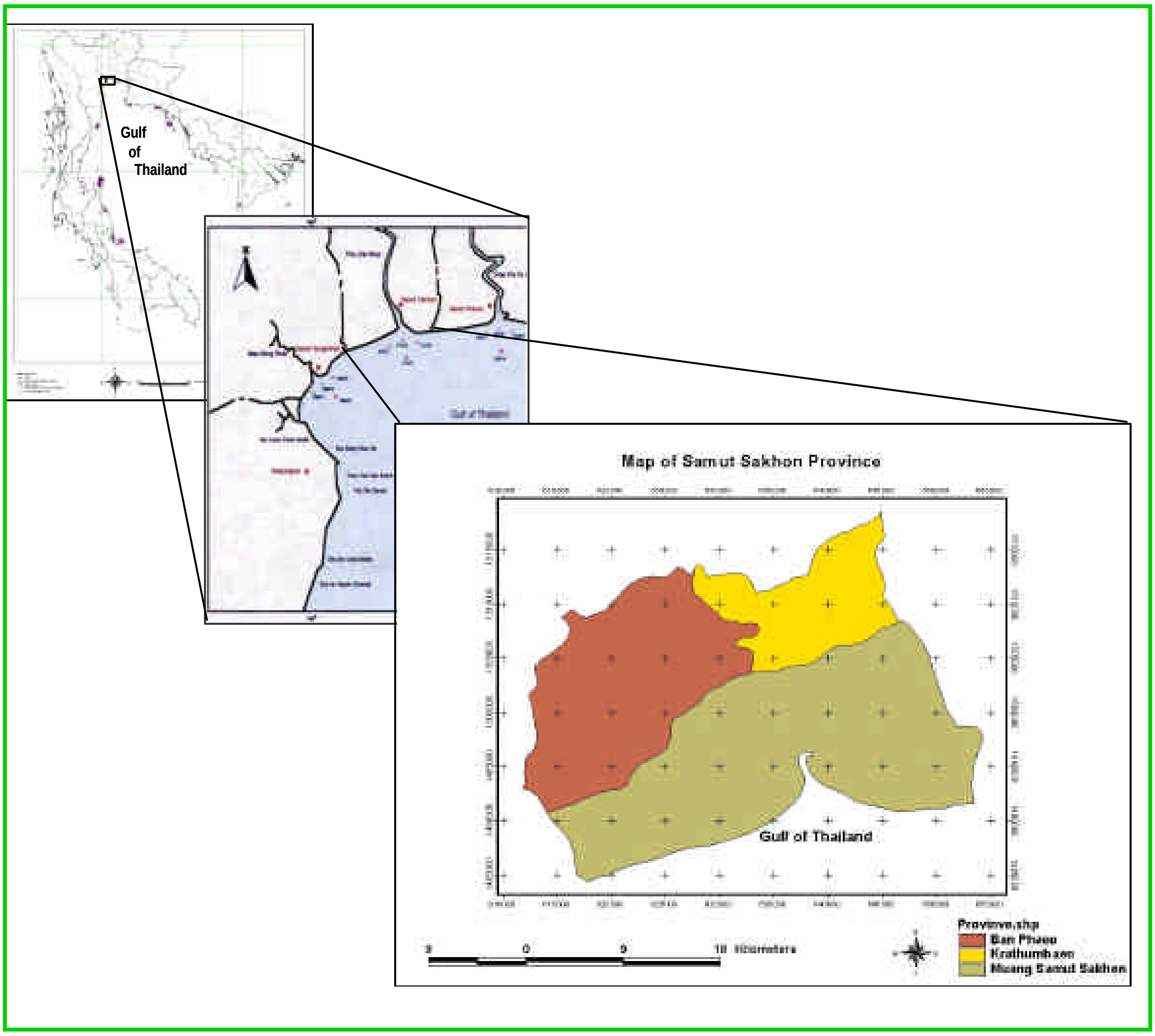


Figure 2. Study area showing geographic location and administrative boundaries

After 1993 all intensive shrimp farming stopped in the study area and the third major land-use change transpired. The salt pans that had been converted to shrimp farms reverted to salt production. The topsoil and dikes of most intensive shrimp farms were sold for the construction of houses and roads. Mangrove plantation was initiated via the government in 1993 and local people were encouraged to participate. The first two major plantations were carried out in 1997 and 2000. The government successfully planted 480 ha, mostly with *Avicennia* sp., and also announced monetary incentives (US$415/ha) nationally for people who were prepared to carry out mangrove plantation on their own land or on abandoned shrimp farms.

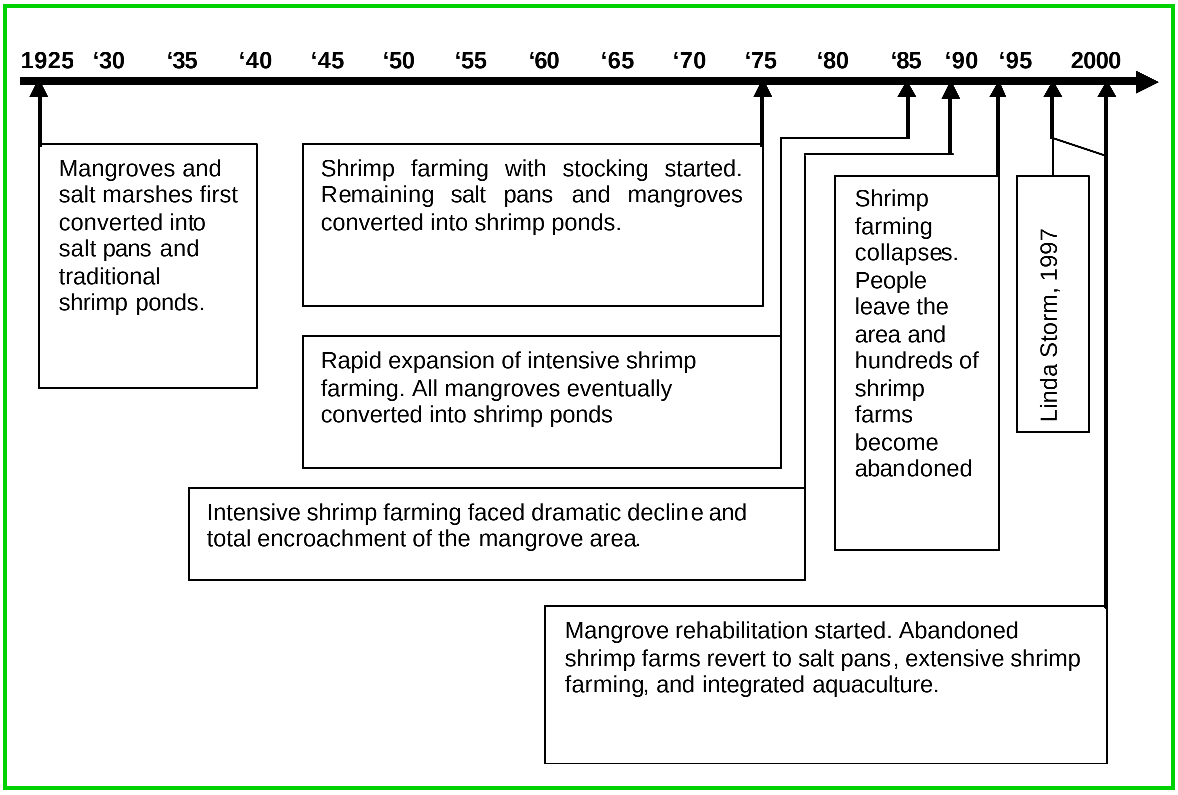


Figure 3. Time-line of land-use changes in the study area (1925-2000)

Extent of abandoned shrimp farms in the study area

The number of shrimp farms started to increase in 1947 with a sudden fall in salt prices; they grew slowly until there were 1 102 farms in 1985. However numbers steadily increased after 1985, reaching 2 269 farms (11.9 percent of the country’s total shrimp farms) in 1989 encompassing an area of 12 134 ha (16.1 percent of the country’s total shrimp farming area). The provincial shrimp farming area was 8 156 ha in 1985 (Figure 5), which rose 48.77 percent in 1989. This was generated by the establishment of new farms and the development of old farming areas. In 1989 there were 413 farms (3 306 ha) under extensive farming, 584 farms (2 963 ha) under semi-intensive farming, and 1 272 farms (5 865 ha) under intensive farming. Within four years (1985-1989) the number of shrimp farms had increased 106 percent in Samut Sakhon Province.

After 1990 the number of shrimp farms started to decrease steadily due to environmental problems and the spread of diseases; by 1995, there were 1 664 abandoned shrimp farms with an area of 8 390 ha. An estimated 73 percent of shrimp farms and 60 percent of the shrimp farming area were abandoned between 1989 and 1995. Of these abandoned shrimp farms, about 93 percent were semi-intensive and 88 percent were intensive farms.

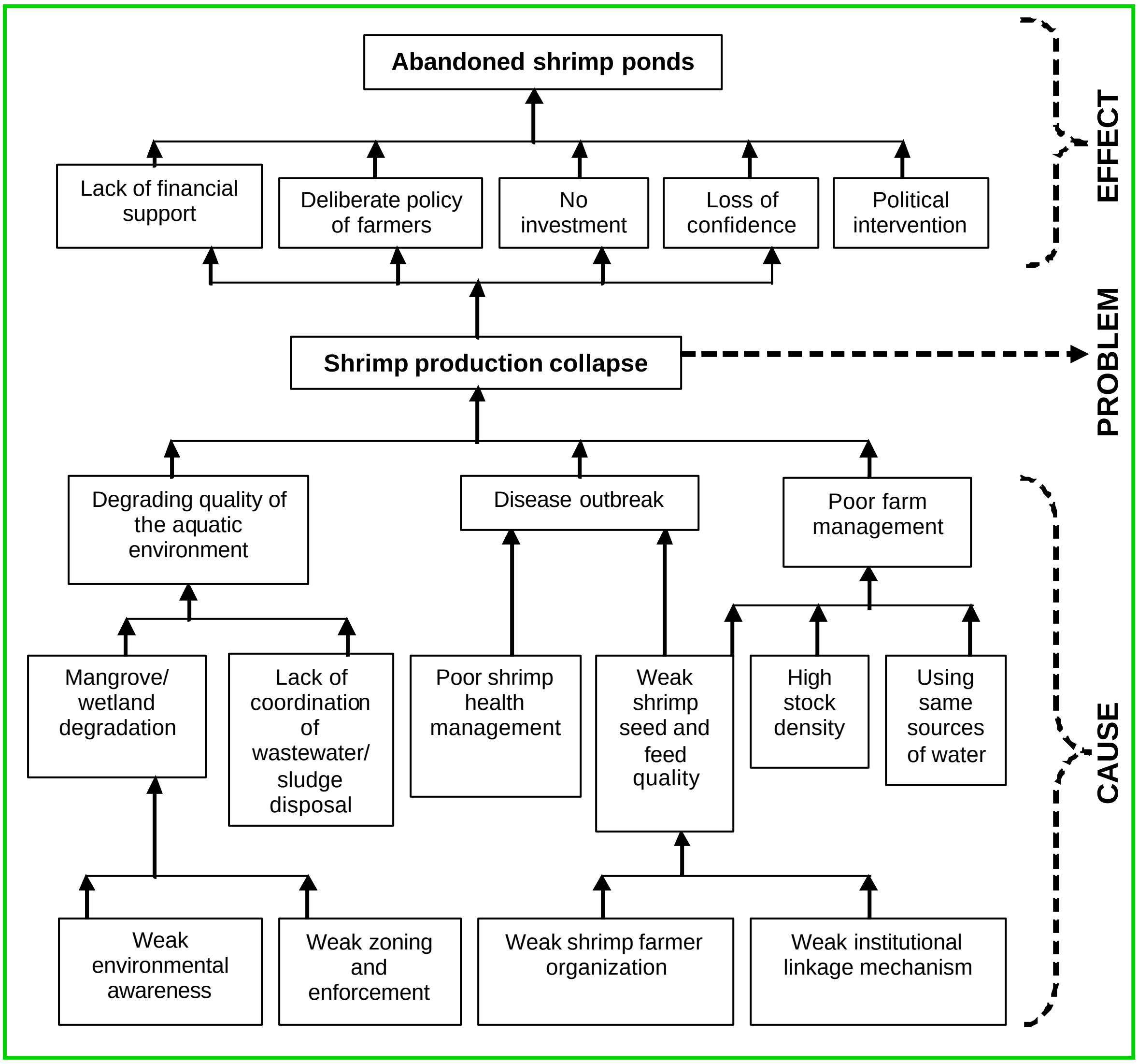


Figure 4. Problem tree for shrimp farm abandonment in Thailand

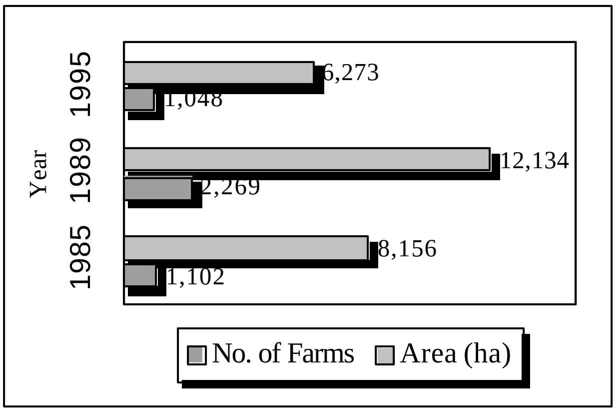


Figure 5. Changes in number of shrimp farms and area from 1985 to 1995

Methodology of the study

The methodology used for this study involved rapid rural appraisal (RRA) integrated with environmental survey and laboratory analysis. The study was carried out using direct observation, key informant semi-structured interviews, environmental parameter measurement, and water and sediment analysis. An overview of the methodological approach is shown in Figure 6. Data collected through surveys, direct observation, and laboratory analysis were then analysed using participatory rural appraisal (PRA) and RRA tools, descriptive statistics, PRIMER multivariate analysis, and cost-benefit analysis. A SWOT (strengths, weaknesses, opportunities, and threats) analysis was also conducted to compare different rehabilitation options. Finally, recommendations were made after assessing government policy and laws; erosion and disaster mitigation strategies were taken into consideration. Erosion and disaster issues were considered important because the area is prone to periodic erosion and tropical cyclones.

To compare the economics of integrated farm and salt production with the mangrove replantation option, the net present value (NPV) of the latter was computed using the market price of potential wood available in one hectare of mangrove minus the plantation cost. It is important to mention that such wood products would only be available for selling in the market at 10 to 12 years after plantation. As this study is considered a preliminary step for finding options for the management of abandoned shrimp farms, the recommendations are based on environmental and economic findings as well as farmers' choices.

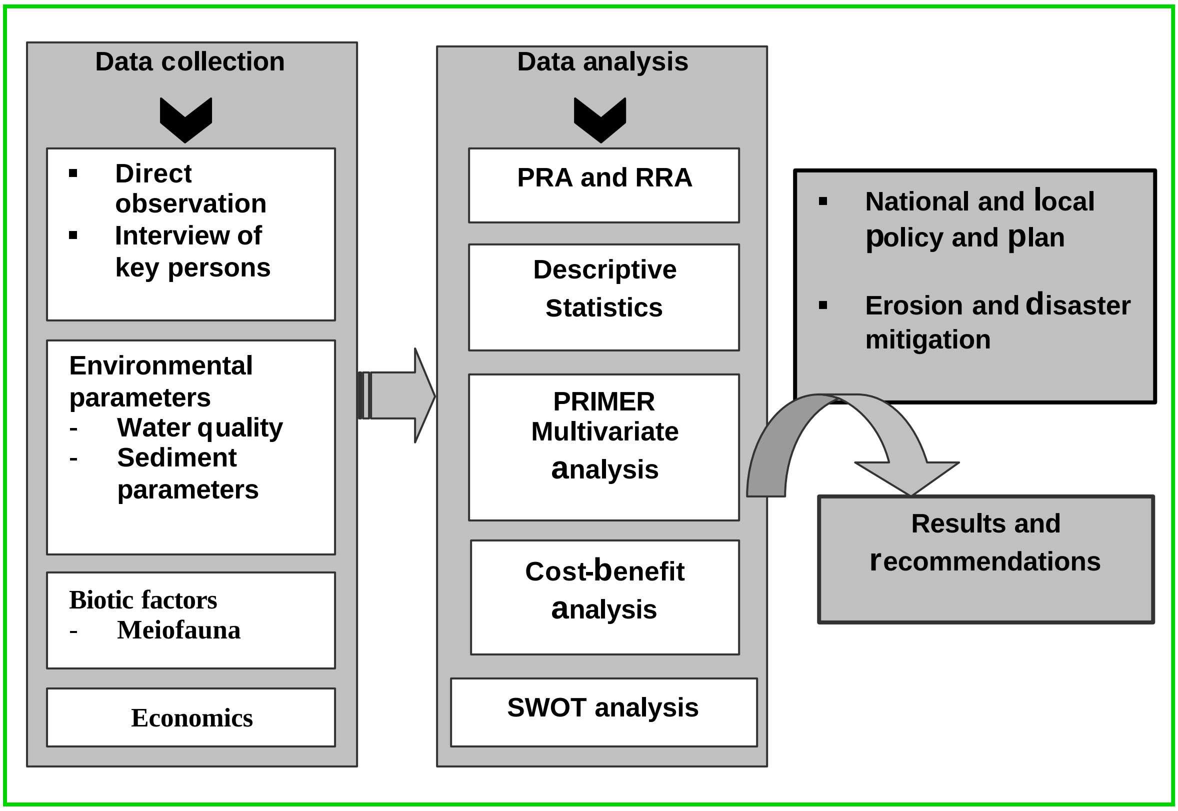


Figure 6. Schematic presentation of the research methodology

Results and discussion

Re-use of abandoned shrimp farms with different options

The causes of failure of shrimp farming and the resulting conditions in the abandoned shrimp farms are the most important concerns that must be taken into account for the rehabilitation or re-use of abandoned farms. The reasons behind failure and eventual abandonment with the concomitant economic and environmental pitfalls have been described by many scientists in Thailand and also within the region (Briggs and Funge-Smith, 1994; Hambrey, 1996; Phillips, 1992; Sammut and Mohan, 1996; Yap, 1997; Jayasinghe, 1995; Stevenson, 1997; Stevenson, et al., 1999; Tuan, 1996; Lin, 1989; Sreng, 1996; Lewis, 1998; Fegan, 1996; Flaherty and Karnjananakesorn, 1995; Pataros 1995). The most common problems that might be associated with abandoned shrimp farms are hard substrate unsuitable for other agricultural activities, acidification of soil and water, and high organic load. However, despite these potential obstacles there are also examples of re-use of abandoned shrimp farms, some of which may be regarded as successful. But it is important to examine sustainable conversions and identification of "best-use" scenarios for abandoned farms.

The possibilities for rehabilitation of abandoned shrimp farms include (Study Area Survey and Stevenson, 1997):

- Extensive shrimp farming
- Aquaculture (seabass or grouper farming, crab culture)
- Integrated mollusk-shrimp-fish farming
- Aquasilviculture
- Mangrove plantation
- Salt production and Artemia culture
- Polychaete culture
- Coconut plantation
- Industry and housing development
- Topsoil sale

Soon after abandonment most of the farms in Samut Sakhon Province were converted into extensive shrimp farms (3 306 ha in 1989 to 5 835 ha in 1995) and salt pans (1 312 ha in 1992 to 5 546 ha in 1994). Since the government had a policy for mangrove rehabilitation, many farms along the seashore and riverside were replanted with mangrove (from 0 ha in 1989 to 1 696 ha in 1993) (Anon, 2000). A survey in the study area showed that 30 percent of abandoned shrimp farms were replanted with mangrove and 30 percent were converted into salt pans. The remaining 40 percent was used for extensive shrimp farming with a few cases of integrated mollusk-shrimp-fish farming (Figure 7).

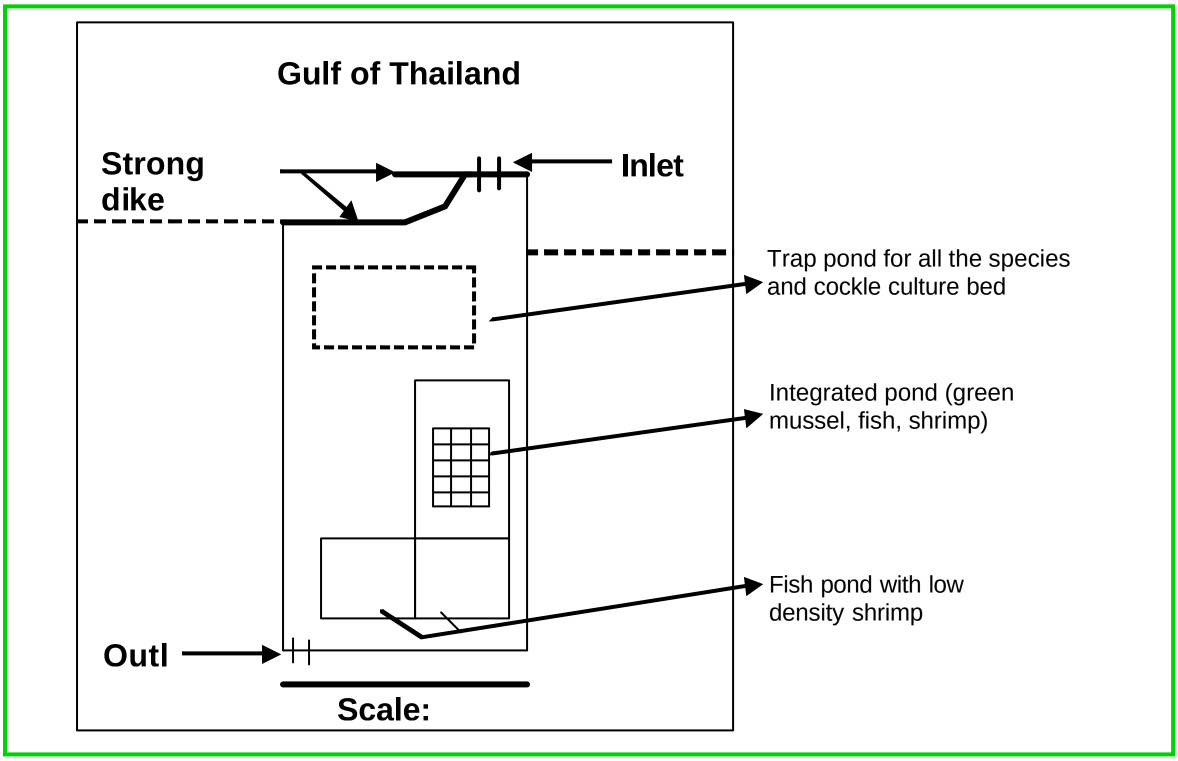


Figure 7. Integrated mollusk-shrimp-fish farm developed in an abandoned shrimp farm

Environmental characteristics of abandoned shrimp farms re-used with different options

An attempt was made to compare the environmental characteristics (Table 1) of abandoned shrimp farms that had been converted into integrated mollusk-shrimp-fish farms, mangrove plantations, and salt pans (Figure 8). This showed that the temperature, pH, and salinity of integrated mollusk-shrimp-fish farms were the same as areas planted with *Avicennia* and *Rhizophora* forest and under the accepted limit of standard coastal water quality set by the Pollution Control Department (PCD) of Thailand. The dissolved oxygen (DO) was slightly lower but NH_3-N and PO_4-P were slightly higher than the natural condition.

Table 1. Water quality parameters of three land-use systems showing means and standard deviations

Station	Temp. (oC)		Salinity (ppt)		pH		DO (mg/L)		Turbidity (NTU)		NH_3-N (mg/L)		TKN (mg/L)		SRP (mg/L)		TP (mg/L)	
	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)	Mean	Std. Dev.(±)
IP	29.52	1.56	25.00	2.52	7.43	0.06	3.69	0.68	10.48	2.09	0.28	0.16	3.02	0.95	0.24	0.05	0.32	0.07
MN	29.95	1.08	24.88	1.75	7.57	0.09	4.34	0.21	88.50	46.21	0.21	0.09	3.13	0.40	0.22	0.11	0.32	0.12
SA	34.75	1.76	56.25	24.06	8.11	0.30	3.31	0.68	11.58	2.38	0.05	0.02	4.32	0.99	0.06	0.02	0.15	0.05

IP = integrated pond of mollusk-shrimp-fish farm, MN = mangrove replantation area, SA = pond of a salt pan

Figure 8. Diverse uses of abandoned shrimp farms

Table 2. Sediment characteristics of integrated mollusk-shrimp-fish farm, replanted mangrove, and the condenser pond of a salt pan

Systems	Soil pH	OM (%)	Organic carbon (%)	% clay	% silt	% sand	Texture class
IP	7.48-7.92	3.85-4.27	2.23-2.48	31.48-32.67	52.31-54.01	14.44-15.51	Silty clay loam
MN	7.39-7.70	4.55-6.25	2.64-3.62	35.77-38.91	53.81-56.38	6.42-9.35	Silty clay loam
SA	7.55-7.63	3.49-4.17	2.02-2.42	44.83-48.76	42.40-45.98	8.30-10.09	Silty clay

IP = integrated pond of mollusk-shrimp-fish farm, MN = mangrove replantation area, SA = pond of a salt pan.

Table 2 shows the organic matter (OM) content, the soil pH, and the soil texture classes of the integrated mollusk-shrimp-fish farm, the mangrove area, and the salt pond. The hard and highly acidic nature of the soil, juxtaposed by low OM content are major problems for the rehabilitation of abandoned shrimp farms. According to Anon (1995) the soil pH of abandoned shrimp farms in Samut Sakhon Province ranged from 6.23 to 8.16 at a depth of 0 to 30 cm. At the same depth, OM content varied between 0.85 and 1.64 percent.

Biological characteristics of abandoned shrimp farms re-used with different options

We identified 14 meiofaunal taxa (including one undetermined) from three different groups of stations (13 in the integrated mollusk-shrimp-fish pond, nine in the shrimp pond replanted with mangrove, eight in the pond of a salt pan) and took 36 samples (12 from each station). The most abundant taxa were the nematodes for the integrated mollusk-shrimp-fish pond and the shrimp pond replanted with mangrove followed by copepods in the pond of the salt pan. In the integrated mollusk-shrimp-fish pond other abundant taxa were copepods, polychaetes, sarcomastigophora, and tunicata (tens of specimens in most of the samples). Sarcomastigophora was the most abundant taxon after nematodes in the shrimp pond replanted with mangrove, whereas in the pond of the salt pan ostracoda and bivalve mollusks were most abundant after copepods.

Meiofauna, dominant metazoans in most coastal and estuarine habitats, can generally be defined as animals that pass through a 0.5-mm mesh sieve but are retained on a 63-mm mesh sieve. Nematodes and copepods constitute over 90 percent of the hard-bodied components of these fauna and play an important role in decomposition. They also form the prey for commercially important fish and shrimp species and serve as food for higher trophic levels. Meiofauna are sensitive indicators of environmental perturbation because of their large numbers, relatively stationary life habits, short generation times, benthic larvae, and intimate association with sediments known to accumulate various contaminants.

The pairwise test of One-way ANOSIM (PRIMER-multivariate tool) showed that the abundance of meiofaunal taxa in the three systems was significantly different (P=<0.05%) from one another and the difference in abundance between three samplings within each station was not significant. The SIMPER test showed that the dissimilarity percentages of meiofaunal abundance in the integrated mollusk-shrimp-fish farm compared with the mangrove area and the salt pan were 30.20 and 39.79 percent respectively. The dissimilarity between the mangrove area and the salt pan was 28.98 percent (Table 3). The cumulative abundance of the first three taxa was 36.64 percent for integrated mollusk-shrimp-fish farm, 50.09 percent for the mangrove area, and 56.44 percent for the salt pan (Table 4). This means that the 14 identified taxa in the integrated mollusk-shrimp-fish farm were more highly diversified than the nine identified taxa for the mangrove area and the eight taxa for the salt pan. The BIOENV result showed that the most significant parameters were NH_3-N and organic carbon.

Table 3. The average dissimilarity of meiofaunal taxa in three stations at three samplings

Station groups	Dissimilarity (%)
St.M, St.A	30.20
St.S, St.A	39.79
St.S, St.M	28.98

St.A = integrated mollusk-shrimp-fish farm, St.M = mangrove, St.S = salt pan

Table 4. Results of the SIMPER test showing the similarity of all the taxa identified from three stations

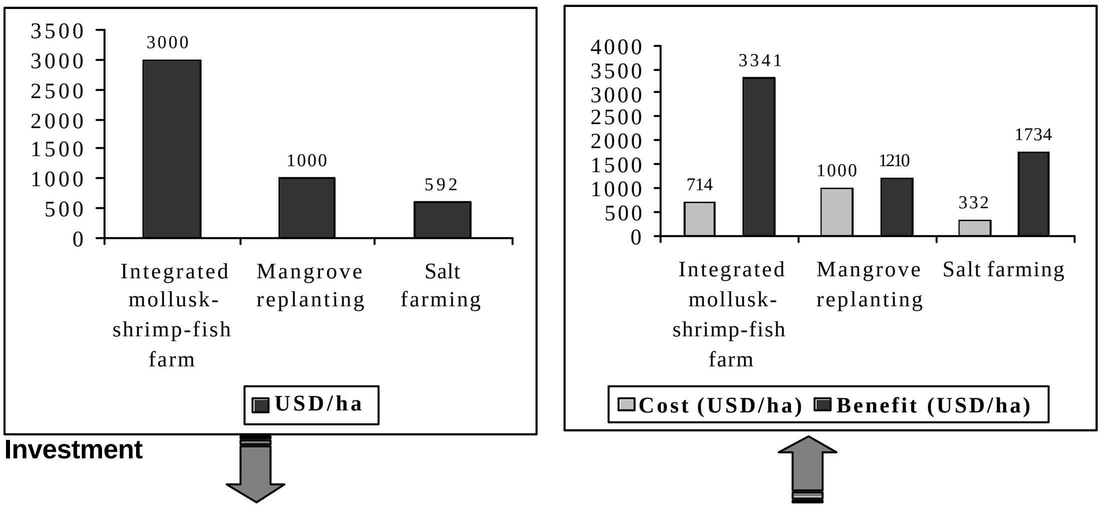
Stations	Average similarity (%)	First 3 taxa and their cumulative abundance in each station	
		Taxa	Cumulative abundance of 3 taxa (%)
Integrated mollusk-shrimp-fish farm	90.49	Nematodes, copepods, and polychaetes	36.64
Mangrove rehabilitation	89.85	Nematodes, sarcomastigophora, and ostracoda	50.09
Salt pan	87.29	Copepods, ostracoda, and Bivalve mollusks	56.44

Sample size = 12

Cost-benefit and economic return from re-uses of abandoned shrimp farms with different options

For the economic study of the integrated mollusk-shrimp-fish farm, mangrove area, and salt pan a cost-benefit analysis of each system was conducted. The investment, products, and cost-benefits of each of the three systems were calculated and compared (Figure 9). The economic valuation of mangrove plantation can be done in many ways using different benefits from the mangrove. However for this study only the potential wood resources were taken into consideration due to the local people's interest and perceptions. The local people are only interested in wood resources from which they can earn direct benefits; they do not consider other benefits from the mangroves.

The economic study showed that the financial return of the integrated mollusk-shrimp-fish farm *per annum* varied from US$1 877.55 to US$3 341.44/ha, whereas the returns from the salt pan ranged from US$500.63 to US$1 733.97/ha/year. The economic return of mangrove (from wood resources only) varied from US$4 689.67 to US$14 519.22/ha, achievable after 12 years. Here the economic return from the mangrove has been calculated using the discounted value of potential wood resources at a 6 percent discount rate as the benefit can be achieved after 12 years. However considering wood resources alone is not an exact valuation of mangrove as there are several other benefits. In this connection the results of a case study (Sathirathai, 1998) were used to compare all other benefits that can be achieved from one hectare of mangrove. According to this case study the economic return from one hectare of productive mangrove is in the range of US$3 207.73 to US$4 090.45 per year. Here the term "productive" is used because a planted forest can become a productive forest after 15 years of plantation (Sathirathai, 1998). The case study considered direct use value, offshore fisheries' linkage, and coastline protection using the selling of locally exploited products, surrogate prices of subsistence products, and cost to build a seawall. The high economic return from the mangrove obviously comes from the overestimation in terms of coastline protection (US$2 991.35/ha).



Main products from one hectare of three different systems

Systems	Products	Amount/ha
Integrated mollusk-shrimp-fish farm	Shrimp	0.094-0.375 MT
	Fish	0.615-0.633 MT
	Mussel	2.604-3.125 MT
	Cockle	1.953-2.604 MT
Mangrove plantation	Wood for charcoal	1 700-2 000 plants (21.25-39.00 m^3)
Salt farm	Salt	40-48 MT

Figure 9. Investment, products, and cost-benefit of three different systems

The economic study also showed that the cost-benefit ratios of the integrated mollusk-shrimp-fish farm and salt pan were in the range of 0.38 to 0.21 and 0.66 to 0.19 respectively. The cost-benefit ratio of mangrove was higher than the aforesaid two systems, being in the range of 0.21 to 0.07.

Sensitivity analysis of different rehabilitation options

All three systems had some sensitive relation with the environment in terms of viability and profitability. The most sensitive venture was salt production because of its dependence on seasons and price fluctuation. In years with a longer wet season or higher total rainfall, production can fall by more than 30 percent. The worst-case scenario is if the price per tonne decreases drastically. The sustainability of mangroves mostly hinges on the erosion problems that the area is facing. If there is no severe erosion in the area the mangrove area will be sustained, as plantation seems to be successful in many abandoned shrimp farms. But if the part of the planted area suffers from erosion then the profit that has been computed from the wood resources may not be achieved along with the other benefits from mangroves. The integrated mollusk-shrimp-fish farm is more sensitive to pollution than to other problems facing the salt pan and mangrove plantation. One of the major concerns regarding pollution of the integrated mollusk-shrimp-fish farm is location next to an industrial estate and near the mouth of a river. Many farm owners also blamed pollution for hindering the growth of green mussels.

Conclusion

Many studies have already shown that without sound management of water quality, feed, and seed input the shelf-life of a shrimp farm could be only five years. Many efforts (closed system, zero water exchange, biological filtration etc.) are currently underway to improve the sustainability of shrimp farming in Thailand and other countries. However, until sustainability is achieved, it is obvious that countries will continue to face the issue of farm abandonment. Thus it is worthwhile to have some alternatives in store for the potential abandonment of shrimp farms. From the present study, the integrated mollusk-shrimp-fish farm can be recommended as having the greatest commercial potential for the reclamation of abandoned shrimp farms. Other important issues to be taken into account are coastal processes, the impact of previous land-use changes, local and national needs as well as ongoing government policy and strategy.

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