Diversified Uses of Abandoned Shrimp Ponds

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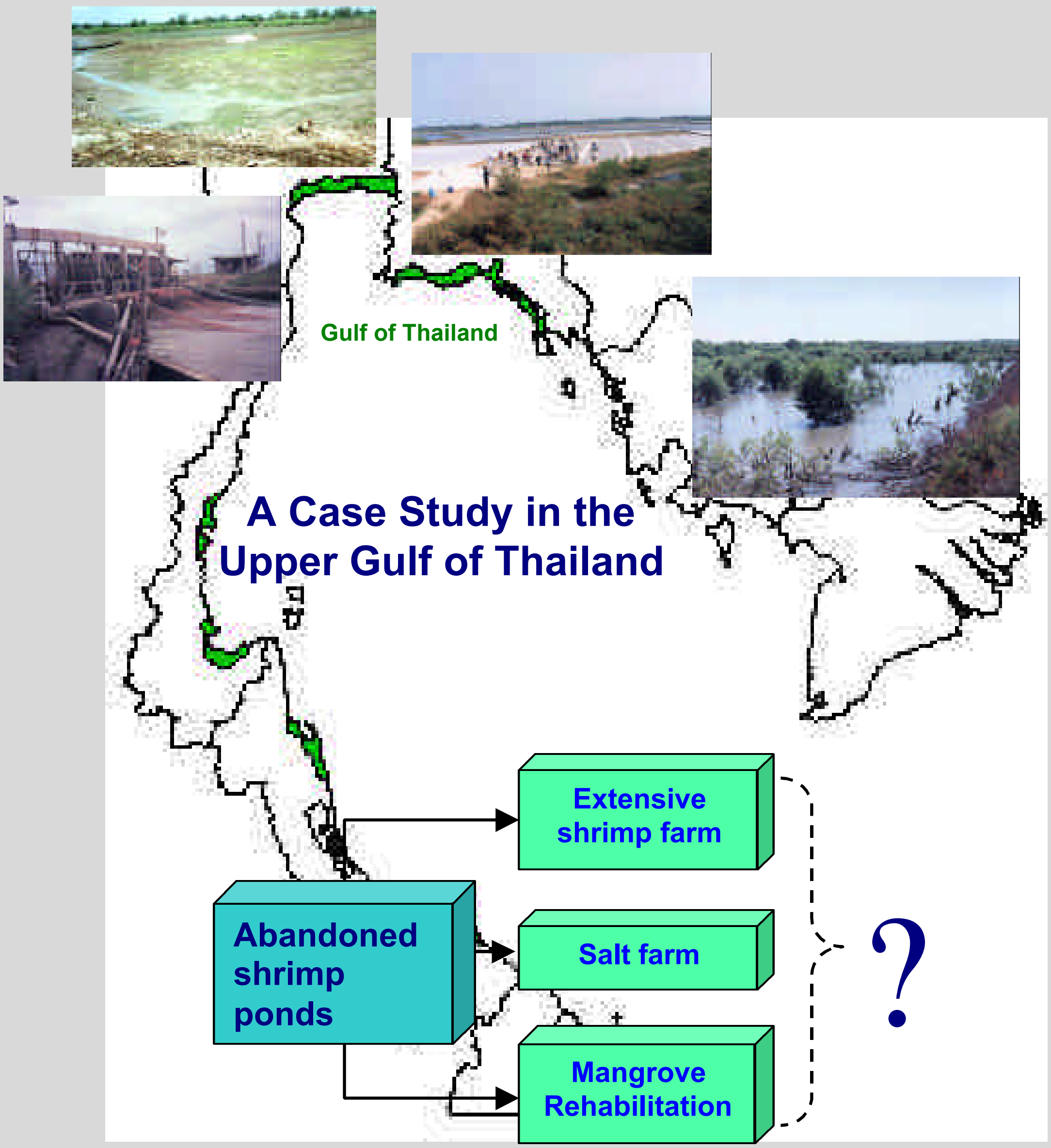

Diversified Uses of Abandoned Shrimp Ponds

A Case Study in the Upper Gulf of Thailand

Md. Zakir Hossain and C. Kwei Lin

The Integrated Tropical Coastal Zone Management at AIT is an area of specialization under the Schools of Environment, Resources and Development and Civil Engineering. This interdisciplinary field aims to develop human resources for coastal zone management in the Asia and the Pacific regions where the coastal areas encompass a diverse array of resources and ecosystems with intense human activities.

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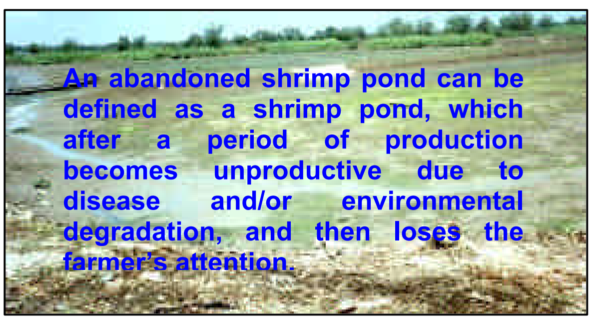
Contents

Abandoned Shrimp Ponds - A Disaster in the Coastal Areas

The history of shrimp farming in Thailand is about 75 years beginning in the 1920s with traditional type of farming mainly in the stocking ponds of salt farms. Large-scale intensive shrimp farming began to accelerate

- Large-scale intensive shrimp farming accelerated in Thailand after 1985.
- Rapid expansion occurred during 1986 and 1989 that made Thailand the world largest shrimp producer since 1995.

in Thailand after 1985 with the adoption of an aquaculture promotion policy and the first area to be intensively developed was the Upper Gulf region. Particularly rapid expansion occurred during 1986 and 1989, when the production in the major prawn producing countries was affected by environmental degradation. Thailand had become the world's largest shrimp producer by 1995. This rapid development of marine shrimp farming was not smooth and there has been a large-scale



conversion of mangroves and other land uses into shrimp ponds. Many of these conversions have proven non-sustainable with the result that a large number of ponds have been left abandoned after a period of shrimp production. The accurate estimation of pond abandonment is difficult either in terms of total extent or number of ponds and, with the exception of Thailand, there is little quantification of pond abandonment reported in the literature. However, unofficially it can be as high as 70% after a period of shrimp production and in 1996 there were 20,800 ha of abandoned shrimp ponds in Thailand with an economic loss of about THB 5,000 million [1].

- Unofficial quantification of pond abandonment says that it can be as high as 70% after a period of shrimp production.
- In 1996 Thailand saw 20,800 ha of abandoned shrimp ponds with an economic loss of about THB 5,000 million.

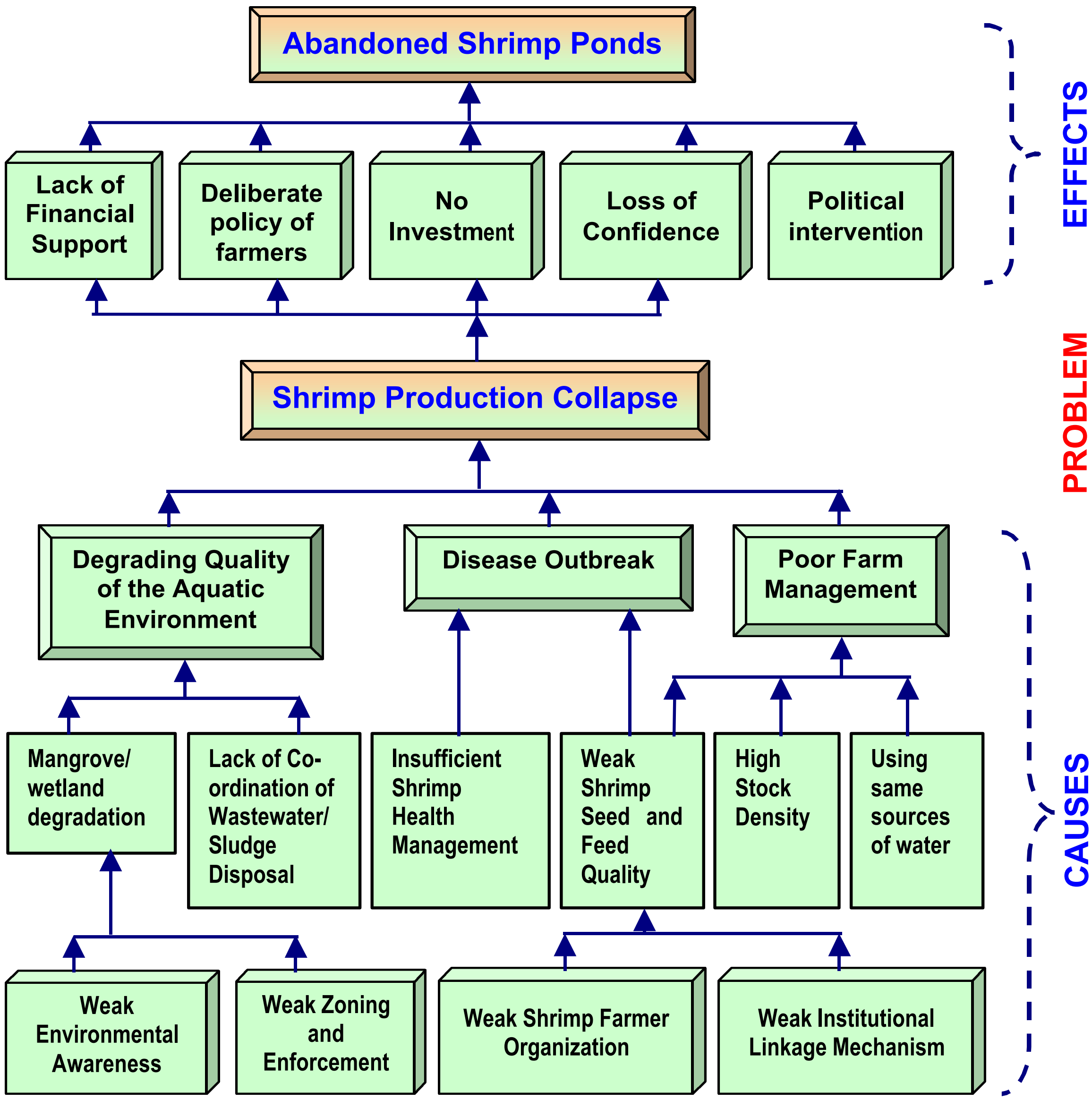
What Lies Behind?

The main reason behind this crash was improper planning and management, which has resulted, *inter alia,* in some specific problems, *i.e.,* acidification of soils, shrimp diseases, poor water quality and self-pollution. Another reason was the introduction of new farmers with little knowledge of aqaculture into marine shrimp farming because it was highly profitable.

From many studies it has been found that the declining environmental suitability, weak institutional arrangement, weak environmental awareness and deliberate policy of the shrimp farmers were the main causes for the appearance of abandoned shrimp ponds in Thailand. Abandoned shrimp ponds are the ultimate effect of the failure of shrimp production.

Some of the direct causes of shrimp pond abandonment in Thailand have been identified as :

- Diseases outbreaks
- Environmental degradation and self-pollution
- Shrimp farming development through mangrove destruction and consequences like acidification.



Problem Tree of Shrimp Farms Abandonment in Thailand

Why This Study?

A few years back most of these abandoned areas were converted back into extensive shrimp farms, salt farms and rehabilitated mangrove. These conversions had an economic impact that put many farms out of business. In 1995 the production from extensive shrimp farms was only 93.75 kg/ha/crop with an average income 509.17 USD/ha/crop or 1,018.34 USD/ha/year in comparison to 504.72 USD/ha/year from salt farm. In contrast the income from intensive shrimp farming in 1989 was 5,078.88 USD/ha/crop or 10,157.76 USD/ha/yr. The mangrove replanting was an investment with long term direct monetary return. So there was a need to find alternative options with quick and reasonable income for the farmers facing difficulty with abandoned shrimp farms. However, sometimes rehabilitation or reuse of abandoned shrimp farms becomes difficult because of the prevailing environmental conditions in the ponds. It is also predictable that until sustainability is achieved in marine shrimp farming, countries will continue to see the appearance of abandoned and unproductive ponds, and continue to see degradation of the resource base on which the coastal communities, particularly the local poor depend.

Therefore a reconnaissance survey and consulting with internationally recognized resource persons resulted in the objectives to compare an integrated mollusk-shrimp-fish farm model, that is practiced also in an abandoned shrimp farm in Samut Skahon Province, with two other common options (mangrove replanting and salt farming) practiced by the farmers. It was attempted to compare these three options considering existing economic and environmental conditions.

Since the abandonment of shrimp ponds appeared, the coastal zone management issue of what to do and how to deal with the extensive abandoned lands became a major challenge for the country. Until 1995 the existence of abandoned shrimp ponds was largely denied but just one year later the rehabilitation and management of abandoned shrimp ponds was identified as a "priority research" area.

Remaining part of a farmhouse of an abandoned shrimp farm

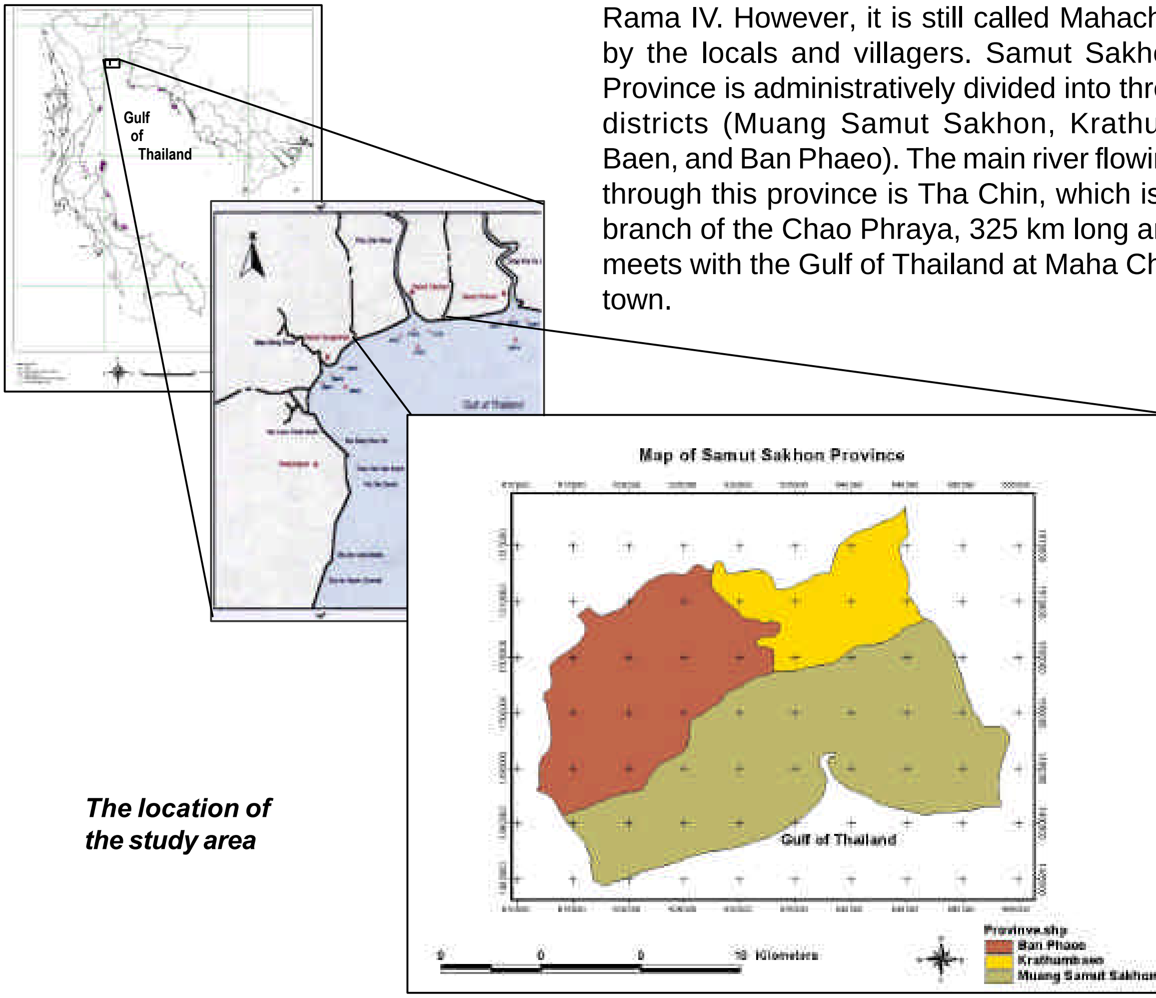
Study Area - A Profile with Major Land Use Changes

Location

Samut Sakhon Province, located at Latitude 13°12'N-13°40'N and Longitude 100°20'E-100°30'E, is one of the Upper Gulf Provinces of Thailand where rapid development of intensive shrimp farming started soon after 1985 and that saw a huge number of abandoned shrimp ponds after just 5 years. Samut Sakhon is 28 km from Bangkok and has an area of 872 km^2.

Samut Sakhon, formerly called Muang Tha Chin and later Muang Maha Chai after digging the Mahachai canal, received its present name of "Samut Sakhon" during the reign of King

Rama IV. However, it is still called Mahachai by the locals and villagers. Samut Sakhon Province is administratively divided into three districts (Muang Samut Sakhon, Krathum Baen, and Ban Phaeo). The main river flowing through this province is Tha Chin, which is a branch of the Chao Phraya, 325 km long and meets with the Gulf of Thailand at Maha Chai town.

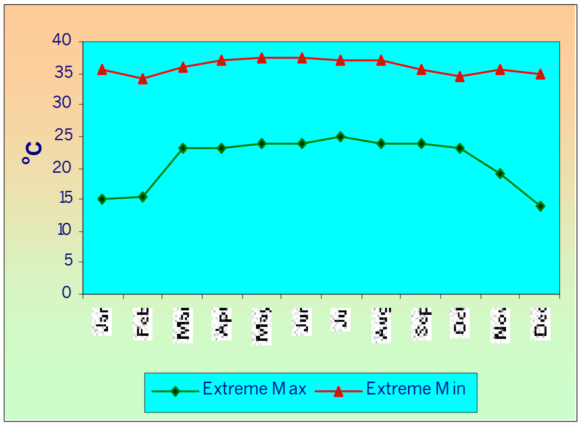


The location of the study area

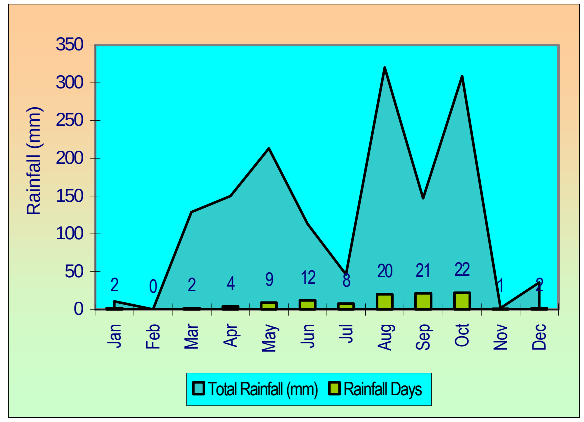
Coastal Environment, Oceanography and Climatic Conditions

Samut Sakhon is generally a low elevation of coastal plain with the Tha Chin River running from north to south. In addition there are a number of natural and man made canals throughout the province. The southern part of the province is primarily low-lying land parallel to the coastal area and used for salt making and shrimp farming. The province has approximately 42 km of coastline. The coastal bed is a muddy flat with a slope of about 1%. The tidal period is mixed between a semidiurnal and a diurnal tide producing two low tides and one high tide per day. The data from Royal Thai NAVI shows that the tidal range near the Tha Chin river mouth varies from 0.9 m to 3.19 m above the lowest low water level. The average high tide near Tamboon Maha Chai is

- The province has a 42-km long coastline.
- Tidal range varies from 0.9 m to 3.19 m.
- Average temperature is 21-36^{o}C.
- The relative humidity varies from 63-80%.
- The average yearly rainfall is 1400mm.
- Three seasons: summer from February to April, a rainy season from May to October and winter from November to January.



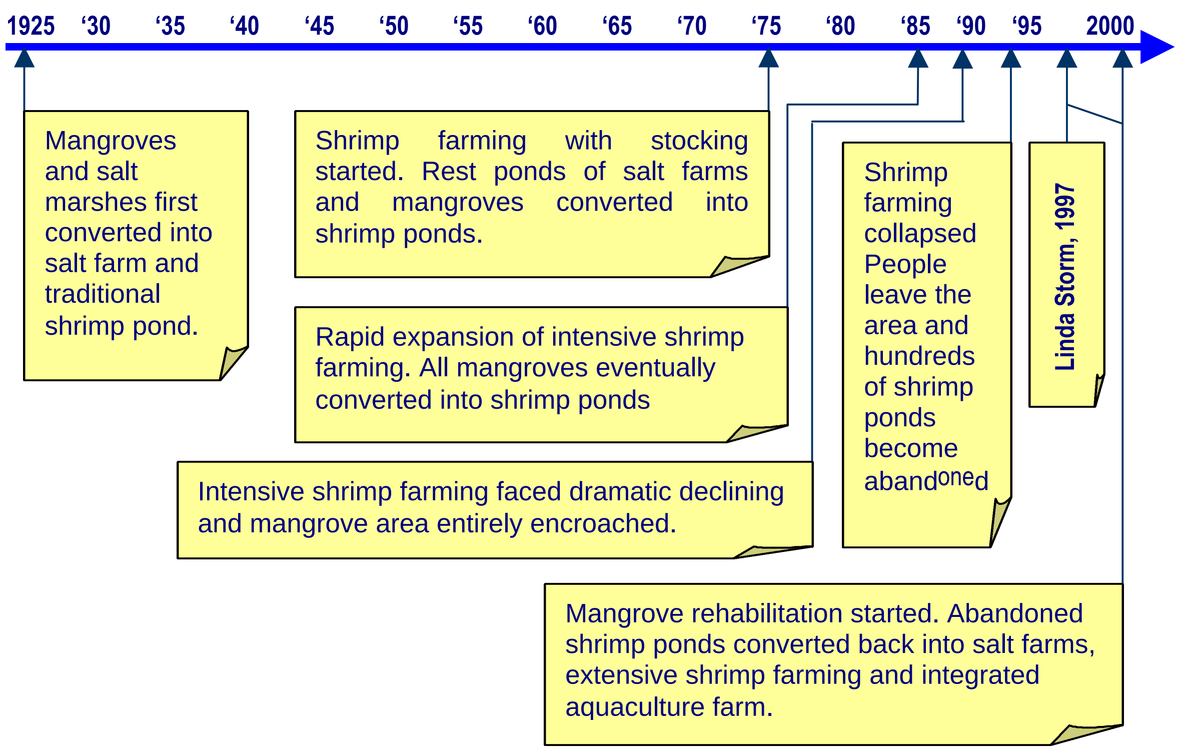
Monthly maximum and minimum temperature



Average monthly rainfall with rainfall days

1.11m, whereas the low tide reaches –0.36 m from the mean sea level. The current flows northwards during high tide and southwards during low tide at a flow rate ranging from 2.70 to 3.70 km/hr. The inshore wind ranges from 8.88 km/hr to 82.5 km/hr creating surface waves ranges from 0.22 to 2.10 m in height.

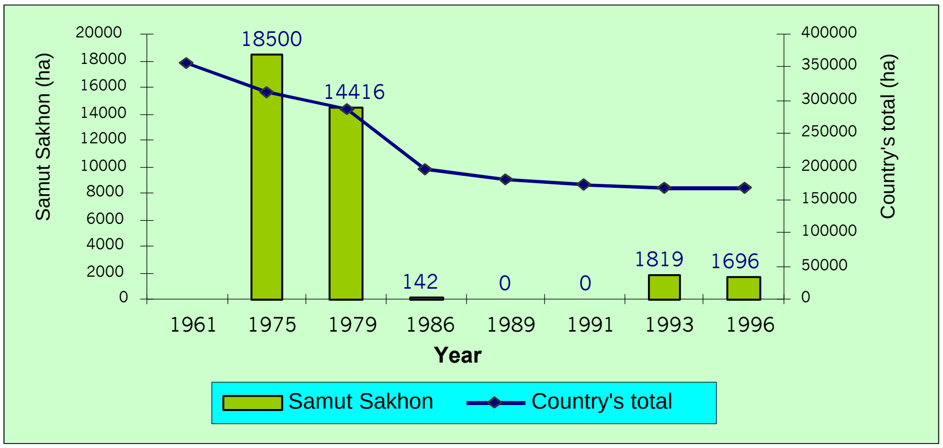
Timeline of Major Land Use Changes



Timeline of land use changes in the study area (1925-2000).

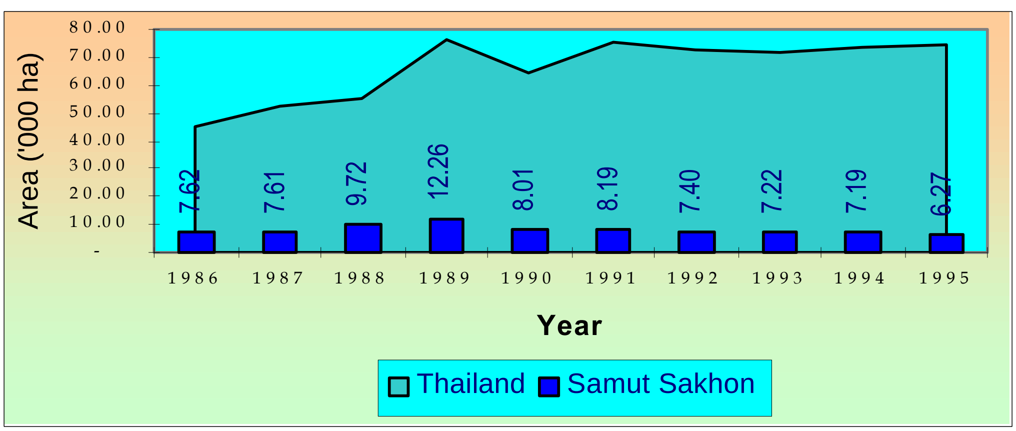
Changes in Mangrove Forest and Shrimp Farming Area

Mangrove forest distribution data are available for the entire country since 1961 and for Samut Sakhon Province since 1975. The data interpreted from aerial photos in 1961 and later on from Satellite Images (Landsat-1 to Landsat-5) by NRCO (National Research Council Office) and RFD (Royal Forestry Department) clearly show that the mangrove forest cover in Thailand has continuously decreased. In 1961 the mangrove forest covered some 368,000 ha of the entire country while, as in 1996 it was 168,000 ha.



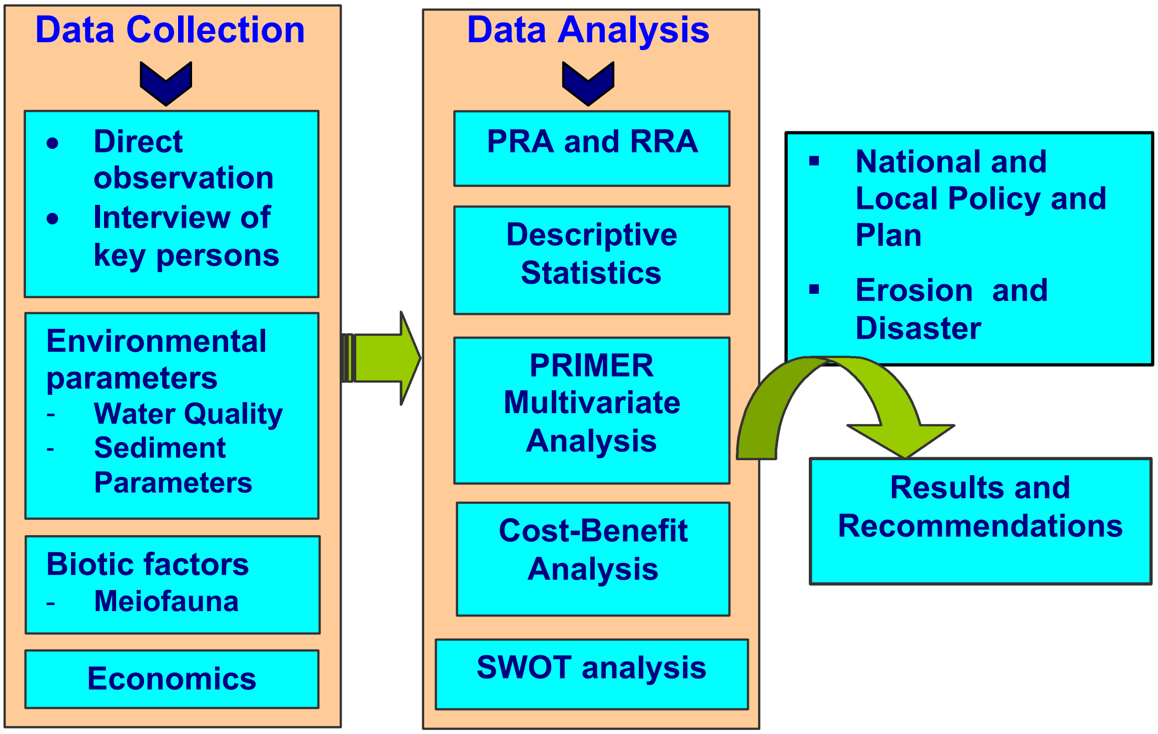
Changes in mangrove forest cover in Samut Sakhon Province and Thailand

In the last 35 years 200,000 ha (54%) of mangrove forest cover have been destroyed at an average rate of 5,723 ha per year. The data also show that in 1989 Samut Sakhon Province had virtually lost its entire mangrove forest from 18,500ha in 1975. At this time the shrimp farming area also had been increased to its highest level of 12,259.52 ha [2].



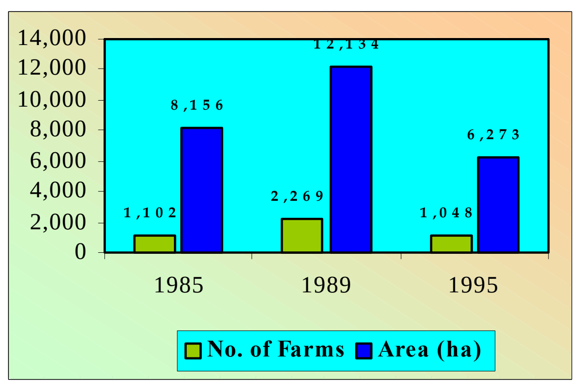
Changes in shrimp farming area in Samut Sakhon Province and Thailand

Methodology of the Study at a Glance

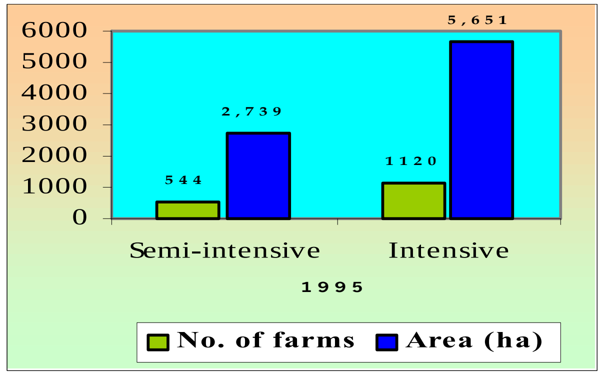


Extent of Severity: A Decade of Change in Marine Shrimp Farming

The traditional shrimp farming in Samut Sakhon Province started more than 75 years ago. With a sudden fall in salt prices in 1947 the number of farms started to increase, until it reached 1,102 farms in 1985. Until 1985 the farms were classified into "With Stocking" and "Without Stocking" distributed as 37 farms with an area of 21.6ha and 1,065 farms with an area of 7,940 ha respectively. The number of shrimp farms steadily increased after 1985 and reached 2,269 farms (11.9% of country's total shrimp farms) in 1989 with an area of 12,134.24 ha (16.1% of country's total shrimp farming area). The provincial shrimp farming area was 8,156.48 ha in 1985, which had been raised 48.77% in 1989. This had happened with the establishment of new farms and the development of old farming areas. In 1989 there were 413 farms (3,305.92 ha) with extensive farming, 584 farms (2,963.36 ha) with semi-intensive farming and 1,272 farms (5,864.96 ha) with intensive farming. Within four years (1985-1989) the number of shrimp farms



The changes in shrimp farms (1985-1995) increased 105.90% in Samut Sakhon Province. After 1990 the number of shrimp farms began to decrease steadily with environmental problems and the spread of diseases. A report, published on the state of the environment of Thailand [2], says that around 40,000 ha of shrimp farming area in the Upper Gulf of Thailand became abandoned, which forced 90% of the farmers out of business. In this connection 53.81% of the shrimp farms stopped their activities in Samut Sakhon Province in 1995, which had accounted for 48.30% of the total shrimp farming area in 1989. Whereas the number of extensive shrimp farms during this time increased dramatically from 413 farms in 1989 to 856 farms in 1995.



Number and area of abandoned shrimp farms in 1995

- About 73% of the shrimp farms and 60% of the shrimp farming area became abandoned during 1989 to 1995.
- The estimation shows that a total of 1,664 shrimp farms had been abandoned in 1995 with an area of 8,390.24 ha.

Environmental Constraints for Further Rehabilitation

The environmental conditions remaining after abandonment may be more important than the causes of failure. They may be unrelated. For instance, in Karnataka, India many hundred ponds had been abandoned as a result of white spot disease but the major obstacle to the re-development of these ponds was not the presence of disease, but the remediation of acid sulphate soils which may persist for many years after abandonment [3].

In addition the effects of mangrove clearance and consequent abandonment may accelerate soil erosion due to increased surface runoff and subsurface flow, decrease in soil water storage capacity, reduction in soil fauna biodiversity and transport of sediments. It may also accelerate the dissolution of inorganic and organic constituents and principal nutrients and the depletion of soil organic matter through leaching and mineralisation. As a result the environmental conditions that once fostered the growth of mangrove forest might have been removed or severely altered, which can cause complications for the rehabilitation of those abandoned areas. The likelihood of mangrove rehabilitation might be severely limited by the reduction in the soil quality through increased erosion, activation of acid sulphate soil and addition of chemicals.

The remediation of acid sulphate soils of abandoned shrimp ponds is time as well as cost intensive. Continuous flushing with fresh or brackish water can enhance the oxidation of acid producing materials and washing out of the acids. The number of flushings, as high as 150, may be reduced by drying and tilling the ponds in between flushing. However this flushing method would not be advisable if the area shows poor tidal flushing and has an ecological problem of acid leachate [3].

Rehabilitation or Reuse of Abandoned Shrimp Ponds

Rehabilitation Options

The causes of failure of shrimp farming and the resulting conditions in the abandoned shrimp ponds are the most important concerns that must be taken into account for the rehabilitation or reuse of abandoned ponds. The most common problems that might occur in abandoned shrimp ponds are hard substrate unsuitable for other agriculture activities, acidification of soil and water and high organic load. However, despite these potential obstacles there are also examples of reuse 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 ponds.

The information regarding rehabilitation of abandoned shrimp farms are not rich at all. The only information available is about mangrove replantation in an abandoned shrimp farm in Thailand. All others are possibilities and suggestions. In 1992 a replantation was done in an abandoned shirmp pond at Ranong Province, Thailand. After assessing the growth it was recommended that the abandoned shrimp ponds similar to the study site in nature can be rehabilitated with the species *Rhizophora mucronata, Rhizophora apiculata, Bruguiera cylindrica* as those species grow well and lead quickly to the recovery of the mangrove ecosystems [4]. The use of three species was also recommended because it mimics the structural complexity of natural multi-species forest with only slightly slower growth rate.

The possibilities for rehabilitation of abandoned shrimp ponds include (present study and [3]):

- Extensive shrimp farming
- Fish farming (Seabass farming, Crab culture, Grouper farming)
- Integrated aquaculture
- Aquasilviculture
- Mangrove plantation
- Salt production and *Artemia* culture
- Polychaete culture
- Coconut plantation
- Industry and housing development
- Top soil sale

Among the other possibilities and suggestions aquasilviculture might have a significant potential. In the Philippines particularly the abandoned shrimp ponds that have been left due to acid sulphate soil are suggested as being suitable for the development of aquasilviculture, which promotes a harmonious co-existence between fishery species and mangrove tree species while also providing coastal protection and maintenance of the ecosystem.

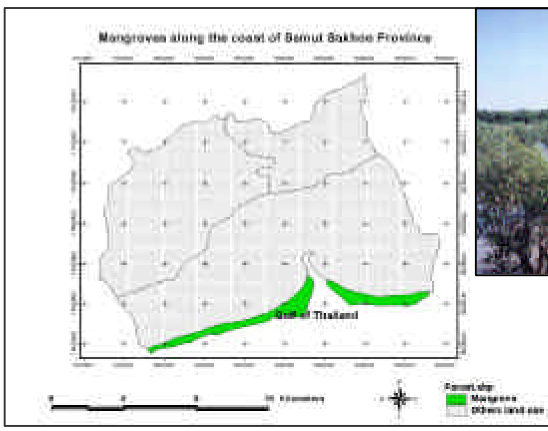
Existing Reuses of Abandoned Shrimp Farming Area

In Samut Sakhon Province a total of 8,390.24 ha area has been abandoned from shrimp farming during 1989 to 1995. Very soon most of the farms were converted into extensive shrimp farms. Since the Government had a policy of mangrove rehabilitation, many farms along the seashore and river were replanted with mangrove trees. The extensive shrimp farming area in Samut Sakhon Province was increased from 3,305.92 ha in 1989 to 5,835.2 ha in 1995. The provincial salt farming area changed from 1,312 ha in 1992 to 5,546.24 ha in 1994 [1]. The rehabilitated mangrove area also increased from 0 ha in 1989 to 1,819.04ha in 1993 [2]. Most of these conversions happened from the abandoned shrimp farms.

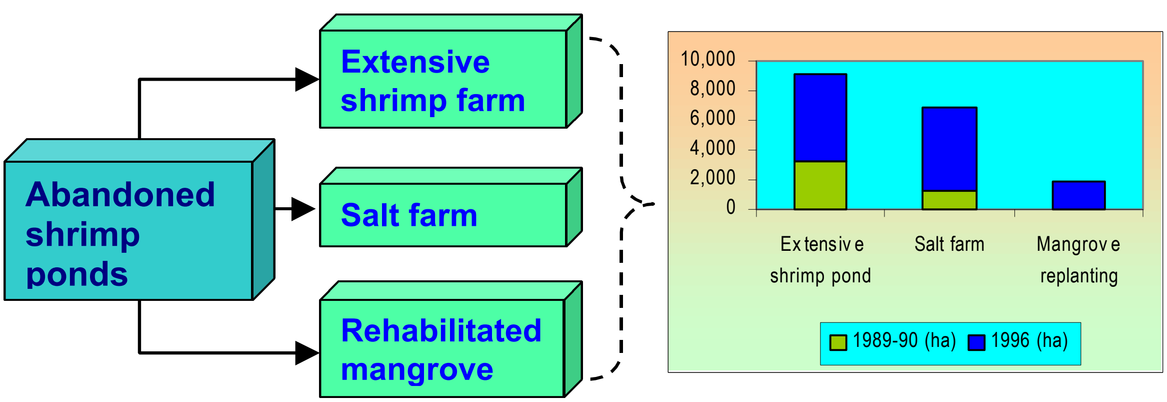
Preparation of salt pans or crystallizer

Harvesting of salt

A survey in Moo Hok, Tamboon Bang Ya Phreak, Muang Samut Sakhon shows that 30% of the abandoned shrimp farms were replanted by mangrove and 30% were converted into salt farms. The remaining 40% have been used for extensive aquaculture (shrimp, shrimp and fish, shrimp and mussels) and reservoir of salt farms. In Bang Ya Phraek sub-district, there were no salt farms in 1992. However, in 1994, there were salt farms existing which covered 463.04 ha. The area covered by mangroves increased from 50.08 ha in1992 to 110.08 ha in 1994 (Anon, 1995b and current survey). However, data may be inaccurate as the statistics is only available from productive farms.



Mangrove replantation in abandoned shrimp pond and the mangrove area in Samut Sakhon province

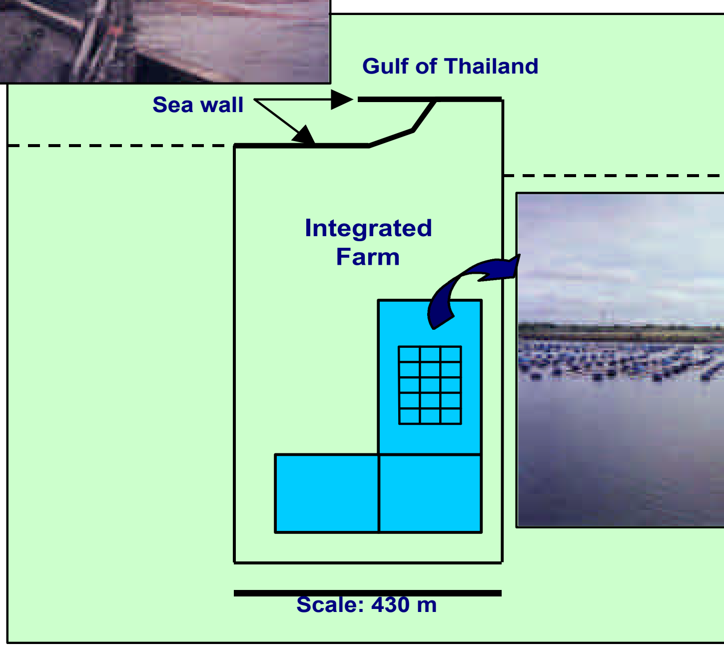


Conversion of abandoned shrimp farming area into three main land use systems.

Development of an Integrated Mollusk-Shrimp-Fish Farm in Abandoned Shrimp Ponds

> **Culture species in different ponds**
>
> There are six important species for this nature dependent farm, which are also commercially feasible in the local as well as in the international market (especially the two shrimp species). Besides the six main commercial species there are several shrimp, fish and mollusk species which can also be found as a bycatch. The important species are:
>
> - Fish
>   - Seabass (*Lates calcarifer)*
>   - Mullet (*Liza valamugil)*
> - Shrimp
>   - Banana Shrimp (*Penaeus merguiensis)*
>   - Tiger Shrimp (*Penaeus monodon)*
> - Mollusk
>   - Green Mussel (*Perna viridis)*
>   - Blood Cockle (*Anadara granosa)*

Around 1975, the farm *"Wang Koong Maneerat"* had been established as an extensive shrimp farm (Stage 1) by digging out 5 ponds in a total area of 38.4ha (240 rai). The input was only the high tidal water; there was no application of feed or seed from outside. The production was not so good. So the system lasted only a few years. After a few years the owner had converted his five ponds into one pond (Stage 2) by digging out the dyke soil. It was an improved extensive type of shrimp farm with feed application but also lasted only a few years due to poor production and benefits. Around 1985, when intensive shrimp farming was booming in Thailand especially in the Upper Gulf Provinces, the farm owner had changed his farm into intensive shrimp farm and dug out 10 ponds (Stage 3), each of which had a water body of 10 rai (1.6 ha). The shrimp species *Penaeus merguiensis* was being farmed in one pond and the other 9 ponds were for *Penaeus monodon.* Around 1995 because of the disease, environmental degradation and low price, which had worked synergistically, the



Integrated mollusk-shrimp-fish farm

farm became abandoned. Two years later the farm owner dug out all the dykes and made 3 different sizes of ponds and developed the present integrated system (Present stage or stage 4).

Today in the 4th stage system pond no. 2, which has an area of 6.8 ha is being used for green mussel farming with raft culture system. But this pond also has fish and low density of shrimps. Shrimp culture is practiced in the pond no. 1 in an extensive way of farming. This pond has an area of 24 ha, which has also been used as a trap pond for all the farmed species and a culture bed of blood cockle. Ponds 3 and 4 have the same area of 1.6 ha each, where mainly fish and low densities of shrimps are raised.

Important Mananagement Aspects and Issues of Three Land Use Systems

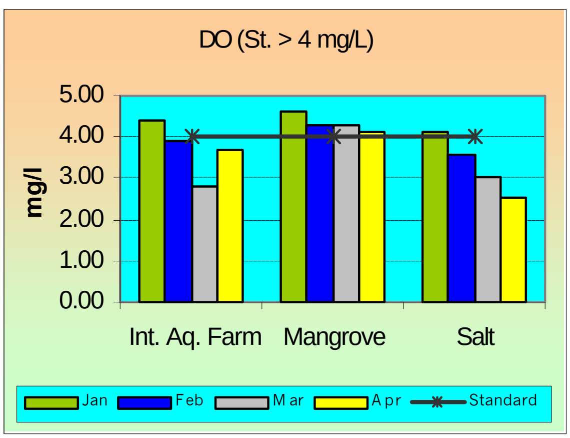
Systems	Integrated mollusk-shrimp-fish farm	Mangrove replanting	Salt farming
Management aspects	▪ Water quality and water management ▪ Stocking ▪ Feed input ▪ Harvesting	▪ Sediment trapping ▪ Pond preparation before plantation ▪ Seedlings (nursery produced potted seedlings had better survival). ▪ Plantation time ▪ Protection	▪ Season ▪ Preparation of stocking ponds and pans ▪ Stocking of seawater ▪ Complex technical method of salt precipitation
Issues	▪ Erosion and farm protection ▪ Industrial pollution and pesticides ▪ Likelihood of frequent storm ▪ Poaching	▪ People's perception and interest ▪ Periodic erosion and accretion ▪ Barnacle infestation ▪ Sesarmid crab (Sesarma taeniolatum) ▪ Sometimes monkeys	▪ Seasonality and low production ▪ Price fluctuation ▪ Quality and Government policy ▪ Marketing of brine

Erosion of mangrove and shrimp farm (left), stocking pond for selling of high salinity water (right)

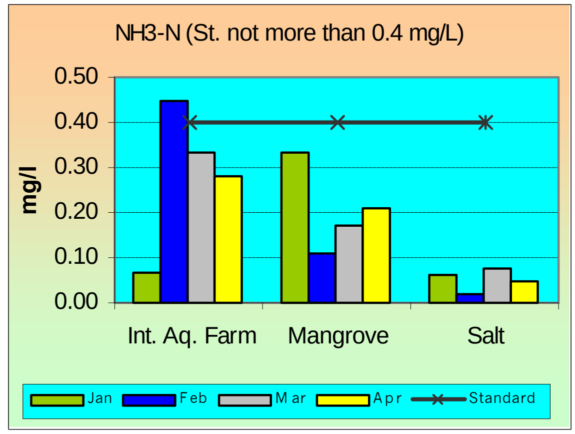
Environmental and Biotic Characteristics of Three Land Use Systems

Water and Sediment Quality

The environmental condition of the integrated mollusk-shrimp-fish farm is similar to the replanted mangrove in terms of water quality parameters, soil texture and organic matter of sediment. Whereas the environmental condition of the salt farm is entirely different from the integrated mollusk-shrimp-fish farm and replanted mangrove in terms of water quality (temperature, salinity, pH, NH_3-N and inorganic phosphate) and sediment parameters (soil texture and organic matter). This is naturally expected due to characteristics of the salt production process that results in an extreme saline environment.

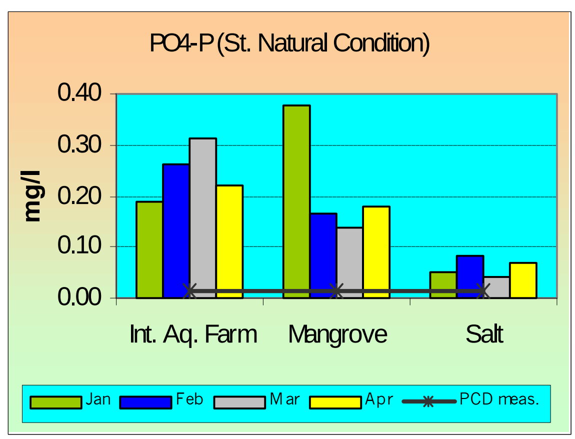


The environmental study also shows that the temperature, pH and salinity of integrated mollusk-shrimp-fish farming are same as with planted *Avicennia* and *Rhizophora* forest and below the accepted limit of standard coastal water quality set by the Pollution Control Department (PCD) of Thailand. Dissolved oxygen is important in supporting life of aquatic fauna and for the bacterial degradation of organic matter. If the DO level is reduced



below 0.7 mg/l, many aquatic organisms along with most important commercial species of shrimps would normally die. The study shows that the DO is slightly lower but NH_3-N and PO_4-P are slightly higher than natural conditions.

High ammonia concentrations decrease the growth rate of many aquatic organisms. Usually it affects the oxygen transportation capacity of blood. Phosphorus is an important plant nutrient for the growth of phytoplankton. The form of phosphorous that phytoplankton is able to utilize is inorganic orthophosphate, which has a solubility of less than 0.1 mg/L in saline water. Orthophosphate is usually precipitated and absorbed between the clay particles at acidic pH and reacts with calcium at basic pH.



The soil texture of the integrated mollusk-shrimp-fish farm and mangrove is silty-clay-loam, whereas it is silty clay in the salt farm. One of the major problems of abandoned shrimp farms regarding their rehabilitation is the soil quality which becomes hard, highly acidic and with low organic matter.

Meiofaunal Importance, Abundance and Diversity in Three Land Use Systems

We identified 14 meiofaunal taxa (including one undetermined) from 3 different groups of stations (13 in integrated mollusk-shrimp-fish pond, 9 in the shrimp pond replanted with mangrove, 8 in the pond of a salt farm) and 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 copepod in the pond of a salt farm. 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 a salt farm ostracoda and bivalve mollusks were most abundant after copepods.

Meiofauna can generally be defined as animals that pass through a 0.5-mm mesh sieve but are retained on a 63-µm mesh sieve. They are the dominant metazoans in most coastal and estuarine habitats [5]. Nematodes and copepods constitute over 90% of the hard-bodied components of this fauna and play an important role in decomposition process. They also form the prey for commercially important fish and shrimp species and serve as food for higher trophic levels. Meiofauna are known to be sensitive indicators of environmental perturbations because of their large numbers, relatively stationary life habits, short generation times, benthic larvae and intimate association with sediments known to accumulate various contaminants.

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 farm.

Sediment characteristics of integrated mollusk-shrimp-fish farm, replanted mangrove and

Systems	Soil pH	OM (%)	Organic Carbon (%)	% Clay	% Silt	% Sand	Texture class
Integrated farm	7.48-7.92	3.85-4.27	2.23-2.48	31.48-32.57	52.31-54.01	14.44-15.51	Silty Clay Loam
Mangrove	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
Salt	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

The pairwise test of One-way ANOSIM (PRIMER-multivariate tool) shows that the abundance of meiofaunal taxa in three systems were significantly different (P=<0.05%) from one another and the difference in abundance between 3 sampling occasions within each station were not significant. The SIMPER test shows that the dissimilarity percentages of meiofaunal abundance in integrated mollusk-shrimp-fish farm versus mangrove and salt farm are 30.20% and 39.79% respectively. Whereas the dissimilarity percentage of mangrove versus salt farm is 28.98%. The cumulative abundance of the first three taxa is 36.64% for integrated mollusk-shrimp-fish farm, whereas for mangrove it is 50.09% and for salt farm 56.44%. This means that the 14 identified taxa in integrated mollusk-shrimp-fish farm were more highly diversified than the 9 identified taxa for mangrove and 8 taxa for salt farm. Finally BIOENV result shows that the most significant parameters are NH_3-N and organic carbon.

- The abundance of meiofaunal taxa in each system was significantly different from one another.
- The diversity of abundance of different taxa in integrated mollusk-shrimp-fish farm was higher than in the other two systems.
- The most significant parameters are ammonia nitrogen and organic

The average dissimilarity of meiofaunal taxa in 3 stations in 3 sampling occasions

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 farm

Results of SIMPER test showing the similarity of all the taxa identified from 3 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%	Nematode, Copepods and Polychaetes	36.64%
Mangrove rehabilitation	89.85%	Nematode, Sarcomastigophora and Ostracoda	50.09%
Salt farm	87.29%	Copepods, Ostracoda and Bivalve mollusks	56.44%

Sample size = 12

Economics of Three Land Use Systems

Cost-Benefit and Economic Return

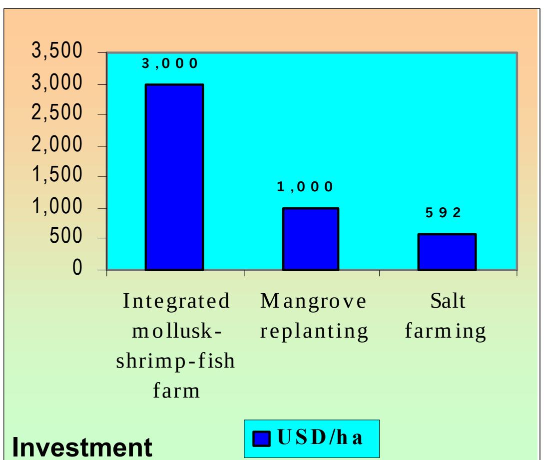
For the economic study of the integrated mollusk-shrimp-fish farm, mangrove and salt farm a cost-benefit analysis of each system has been done. The economic valuation of mangrove can be done in many ways using different benefits from mangrove. However for this study only the potential wood resources are taken into consideration due to the local people's interest and perception. This is because the local people care about the wood resources rather than other benefits of mangroves.

The economic study shows that the financial return of the integrated mollusk-shrimp-fish farm per year varies from USD 1,877.55 to USD 3,341.44 per hectare, whereas the returns from the salt farm varies from USD 500.63 to USD 1,733.97 per hectare per year. The economic return of mangrove only from wood resources varies from 4,689.67 USD to USD 14,519.22 per hectare that can be achieved after 12 years. Here the economic return from the mangrove has been calculated using the discounted value of potential wood resources at 6% discount rate as the benefit can be achieved after 12 years. But considering only the wood resources is not the exact valuation of mangrove as it has several other benefits. In this connection the results of a case study has been used to compare all other benefits that can be achieved from one ha of mangrove. According to this case study the economic return from 1 ha of productive mangrove is in the range of USD 3207.73 to USD 4,090.45 per year. Here the word productive is used because a planted forest can become a productive forest after 15 years of plantation (Sathirathai, 1998). The case study has considered direct use value, offshore fisheries linkage and coastline protection using selling of locally exploited products, surrogate prices of subsistence products and cost to build a seawall. Here the high economic return from the mangrove obviously comes from the over estimation in terms of coastline protection (2,991.35 USD/ha).

Economic Potential of Sensitive Relation of the Three Land Use Systems

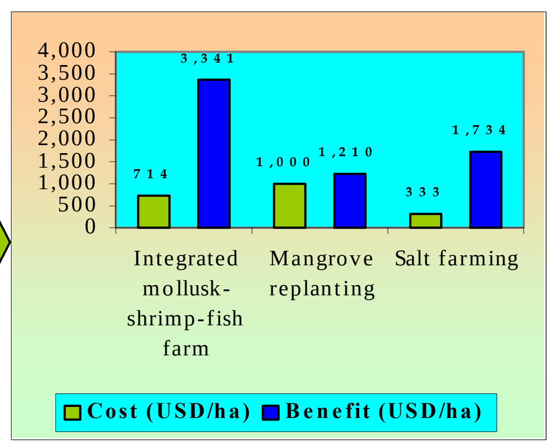
The economic study shows that the cost benefit ratio of the integrated mollusk-shrimp-fish farm and salt farm are in the range of 0.38 to 0.21 and 0.66 to 0.19 respectively. The cost benefit ratio of mangrove is higher than the above-mentioned two systems, namely are in the range of 0.21 to 0.07.

From this study it has been found that all those three systems have some sensitive relation with the environment in terms of viability and profitability. The most sensitive venture among these three systems is salt farming because



Main Products from 1 ha of three different resources uses systems

Systems	Products	Amount/ha
Integrated Aquaculture 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	1700 – 2000 plants (21.25 – 39.00 m^3)
Salt Farm	Salt	40 – 48 MT



Investment, products and cost-benefit of three different systems of its dependence on season, government policy and price fluctuation. In years with longer wet season or higher total rainfall production can be decreased more than 30%. The average yearly production and income per hectare decreased from 40-48 MT with a benefit USD 500.63-1,733.97 to 26.67-32.00 MT with a benefit USD 222.86-1,045.08. But the worst thing that can happen is if the price per MT decreases from USD 20.83-43.06 to USD 6.94. In this case the yearly benefit may decrease from USD 500.63-1,733.97 per hectare for the average farm production to USD 0.34-(-78.67) for the wet season case.

The sustainability of mangroves is mostly dependent 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 the plantation seems to be successful. But if part of the planted area erodes the profit that has been computed from the wood resources will not be obtained along with the other benefits for mangroves.

The integrated mollusk-shrimp-fish farm is more sensitive to pollution than to other problems facing the salt farm and mangrove plantation. One of the major concerns regarding pollution of this farm is that it is situated near the Maha Chai industrial estate and near the mouth of Tha Chin River. According to the farm owner the shrimp and fish harvest decreases because of the polluted water. He has observed many times like October 2000 when the dead fish, shrimp and other aquatic fauna were floating on the water surface. The highest shrimp production he can get is 0.094-0.375 MT per hectare with an income of USD 362.50-1,450.00 but due to pollution the production can be stopped at 0.094-0.11 MT per hectare with the income of USD 362.50-428.13. The farm owner also blamed pollution for hindering the growth of the green mussels as his daughter is facing this problem.

Legislative Administration, Policies and Regulations for the Utilization of Coastal Lands in Thailand

The Thai government agencies responsible for coastal area administration and coastal resource management can be grouped in three categories (Jenkins et al., 1999 and Anon, 1995): Policy agencies, planning agencies and implementing agencies. Besides many agencies there are also some national committees and provincial sub-committees that develop policies and give advice to the planning and implementing agencies (Figure 17). As many agencies, as authorized by laws, have been working in the coastal areas without proper coordination, the duplication of work and conflicts have occurred owing to the job description by laws (Anon, 1995). Even though several committees have been established to resolve these problems, they have not been successful, as those committees had no authority to control the activities of other agencies.

Besides, the Department of Fisheries (DOF) has a strong policy of relocating the shrimp farms that have been sited inside the coastal mangrove fringe, facing abandonment problems and running with low production. Other important policies regarding shrimp farming are the conversion of extensive and semi-intensive farms into intensive farms, registration of shrimp farms, enforcement of effluent treatment before discharging into the recipient waters and implementation of seawater irrigation systems.

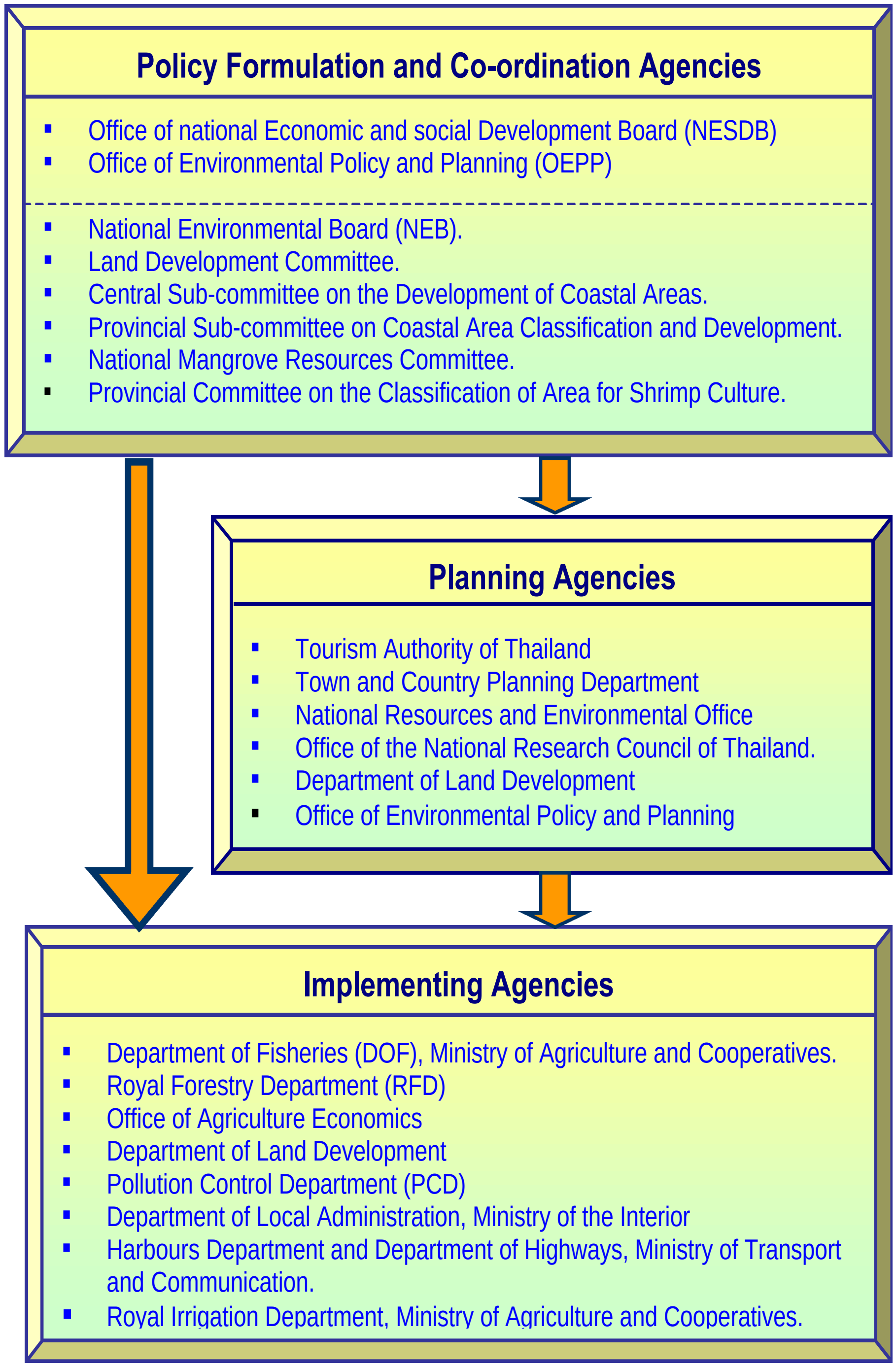
In 1987, using satellite technology as a base line information, the Royal Forestry Department (RFD) had done a land use zoning of mangrove areas in three principal zones:

- Conservation Zone (427sq.kilometers): mangrove forests in this zone are strongly protected from any impacts on natural environmental values. No exploitative uses are permitted.

- Economic zone A (1,997 sq. kilometers): This zone can be used for the exploitation of forest products, e.g. charcoal production and local uses, on a sustainable yield basis.

- Economic zone B (1,300 sq. kilometers): This zone can be used for other activities besides forest product exploitation, with consideration given to the the impacts to the environment.

The Department of Land Development under the direction of the National Committee on Land Development, which was created by the Land Development Act-1983, has an integrated development project for the efficient use of coastal land, taking into consideration the impact on ecological balance.



The heirarchy of Thai government agencies responsible for the formulation and implementation of policy and planning on utilization of coastal areas

Recommendations

Since the rehabilitation of abandoned shrimp ponds was identified as a priority research area in late 1996, most of the research has been carried out on mangrove rehabilitation. However, certain innovations are necessary to ensure an even better utilization of abandoned shrimp ponds, aiming at the provision of sustainable coastal resource utilization and management and creation of sound natural environment. Based on the results from detailed environmental and economic analysis with special reference to integrated mollusk-shrimp-fish farming, mangrove replanting and salt farming, the recommendations have been identified for the rehabilitation of abandoned shrimp ponds in the Upper Gulf coast of Thailand. With some spatial analysis and modification these recommendations can also be applied to other coastal areas in Thailand and other countries facing abandonment of shrimp farming area.

- Clear identification and marking of three mangrove zones (conservation zone, economic zone A and economic zone B), which is the prerequisite for the further development of the coastal zone, should immediately be carried out by the Royal Forestry Department (RFD) and demonstrated to the local people, before further development of the coastal zone.

- The integrated mollusk-shrimp-fish farm is recommended as having the greatest commercial potential for the use of abandoned shrimp ponds subject to RFD's mangrove zoning.

- Abandoned shrimp ponds in the conservation zone should be rehabilitated with mangrove.

- Conversion of abandoned shrimp ponds into salt farm should be the last option after other alternatives (including crab fattening and aquasilviculture) subject to local people's perception and needs. In addition one dry season salt production and wet season culture of shrimp or fish or both can be an attractive option for the salt farmers, as the season for salt production is short due to the rainy season.

- The further rehabilitation of abandoned shrimp ponds into intensive shrimp farms must be within a *closed system framework.* In closed systems, recycling of water using integrated farming of green mussels, blood cockle, seabass and mullet as a bio-filter should be taken into consideration.

- Considering mangrove zoning of RFD, the Department of Fisheries (DOF) should also develop aquaculture zoning with specific regulations for further development of coastal aquaculture.

- Strict regulations or ban on the introduction of outsiders in shrimp farming and the provision of polluter pays principle should be introduced.

- An Integrated Coastal Zone Management (ICZM) framework and working body is recommended to develop from the national level to the provincial level. Only the primary stakeholders (locals and the most involved government agencies and departments) should be involved with policy, planning and implementation of coastal resources utilization following a top down and bottom up approach. The expected outcome would be the integrated coastal resources management policy and plan that ensures the sustainable utilization of coastal resources upon which the local poor depend.

Further Reading

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Integrated mollusk-shrimp-fish farm model developed in abandoned shrimp pond in Samut Sakhon Province, Thailand