MANGROVE-FRIENDLY MARINE SHRIMP AQUACULTURE TECHNOLOGY: THAILAND EXPERIENCE

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I. Introduction

The intensive marine shrimp farming has just developed in the past decade. Since 1991, Thailand has become the leading country for exporting marine shrimp product from aquaculture in the world market. In 1998, the yield was around 234,000 mt and the average production rate was 3324 kg/ha. Thailand has developed technologies for mangrove-friendly marine shrimp culture including the zero water discharge during culture period and water recycle system which have been adopted by the shrimp farmers. The research on biotechnology for shrimp farm effluent treatment processes has also been conducted both by the concerned government agencies and private shrimp farms. Mangrove reforestation in suitable coastal areas has also been carried out.

Thailand has had the experience on coastal aquaculture for a long time. It has a huge flood plain, long riverine stretch, natural lagoon, estuarine, and brackishwater areas along the coastal line, on the Gulf of Thailand and Andaman Sea with approximately 2600 km of shoreline. Shrimp farming has been practiced on traditional or extensive methods in the coastal land area for nearly three quarters of a century. Shrimp fry were accidentally trapped in salt beds and paddy fields near estuarine areas. Originally, wild shrimp fry either enter during tidal water exchange or are intentionally gathered from the wild and stocked directly in ponds. Production depends on the seasonal abundance of wild fry which fluctuates widely year by year.

In 1973, Thailand successfully spawned and partially reared larvae of *Penaeus* spp., such as *P. monodon* and *P. merguiensis* (Tookwinas, 1993). This was in response to the efforts of the Department of Fisheries (DOF) which encouraged the production of additional seedstock from hatcheries for stocking in extensive ponds. Later, the semi-intensive marine shrimp farming system was adopted with the addition of supplemental feeds.

In the past decade, intensive farming technology for *P. monodon* has been developed and practiced in Thailand, making the area for marine shrimp farm expand tremendously to 74,942 ha in 1995. At present, shrimp farming in Thailand can be classified into three categories: intensive, semi-intensive, and traditional or extensive. As a result, the shrimp production reached 234,000 mt in 1998 (Table 1).

II. Farming Method

Marine shrimp farming system can be classified into three or four categories depending on the intensity (Tookwinas, 1993): extensive (traditional), semi-intensive, intensive, and super-intensive shrimp farming systems. Each type is classified in terms of the area and stocking density.

Extensive shrimp farming system or the traditional method is characterized by irregular shapes and size of ponds from 5 to 10 ha. Semi-intensive shrimp farming system is improved over the extensive farming system, where ponds are normally rectangular in shape of about 1-6 ha, and the stocking density is about 5-10 PL/m^2. On the other hand, the pond size for intensive farming system varies from 0.16-1.0 ha and the depth is approximately 1.5-2.0 m. The pond shape can be either rectangular or round with stocking densities ranging from 20 to 50 PL/m^2 and requires high financial and technical inputs. Artificial aerator used may be the paddlewheel which is either electric or diesel motor-driven, while another common practice makes use of oxygen injection.

In this system, shrimps are fed nutritionally complete artificial diet. Cropping is 2x/yr with an average survival rate of about 60-90%, and production can be as high as 12,500 kg/crop. However, problems on disease and environmental pollution occurring with this system are much greater than the other two farming systems.

Super-intensive shrimp farming system is the most organized system of shrimp farming. In Thailand, few farms are operated by converting the semi-intensive farm and/or intensive farm to super-intensive farm. However, this system would require very high financial and technical inputs. Although the pond construction scheme is the same as that of intensive system, the stocking rate is much higher at about 100 PL/m^2, but production is about 20,000 kg/ha/crop.

According to the survey of NACA/ADB (Tookwinas, 1995), it was estimated that most of marine shrimp farms in Thailand are either intensive or extensive farms. There are no semi-intensive marine shrimp farm at present, while most of the extensive farms are located at the inner areas of the Gulf of Thailand, Chanthaburi, Eastern Thailand, and Nakon Sri Thammaraj in Southern Thailand.

III. Culture and Production

The suitable coastal area for intensive marine shrimp farming depends on many factors and criteria, including water salinity and source, soil quality, and socio-political factors. The suitable average water salinity the whole year should range from 10 to 32 ppt. The texture of soil should be mud or muddy sand in order to reduce water seepage and prevent water losses in the ponds. The soil pH should be around 7-8 (Tookwinas, 1993).

Due to the development of the technology of intensive farming since 1985, the culture area of marine shrimp in Thailand has expanded very rapidly from 4939 farms in 1985 covering about 40,769 ha to 26,145 farms in 1995 with a total area of 74,942 ha as can be seen in Table 1 and Fig. 1.

The production per culture area has also increased from 388.7 kg/ha in 1985 to 3596.7 kg/ha in 1994. However, the yield, culture area and number of farms have decreased in 1996 and 1998. The shrimp farm areas which are located along coastal provinces of the country has shifted from the Inner Gulf of the Thailand and Eastern part to the Southern part both west coast of the Gulf and the Andaman Sea, due to the pollution in the Inner Gulf area. Most of shrimp farmers are small operators with farming area categorized into four scales: 0.16-1.6 ha. (78.7%), 1.6-8.0 ha. (18.8%), 8.0-32.0 ha. (2.20%), and more than 32.0 ha (0.3%) (CP Aquaculture, 1994).

Table 1. Marine shrimp farming in Thailand Area Number of farms and production (1985 - 1998)

Year	Number of farm	Area (ha)	Yield (mt)	Production (kg/ha)
1985	4,939	40,769	15,840.56	388.7
1986	5,534	45,368	17,885.83	394.2
1987	5,899	44,770	23,566.47	526.4
1988	10,246	54,778	55,632.84	1015.6
1989	12,545	71,165	93,494.50	1313.7
1990	15,072	64,060	118,227.05	1830.0
1991	18,998	75,332	162,069.69	2151.4
1992	19,303	72,796	184,884.32	2539.8
1993	20,027	71,887	225,514.30	3137.1
1994	22,198	73,247	263,445.96	3596.7
1995	26,145	74,942	259,540.54	3463.2
1996	22,913	69,463	229,000.00	3296.7
1997	21,000	69,120	219,000.00	3168.4
1998	22,500	70,400	234,000.00	3323.9

Source : Fisheries Statistics (1998)
Data in 1998 is estimated.

Farmed shrimp is the third largest export commodity of Thailand (Export Production Department, 1997). In 1996, the total export was 161,461 mt (Table 2) valued at 43. 4021 million Baht. Thailand exports shrimps to many countries, especially to Japan, U.S.A., EU, Singapore, Hong Kong, and Australia.

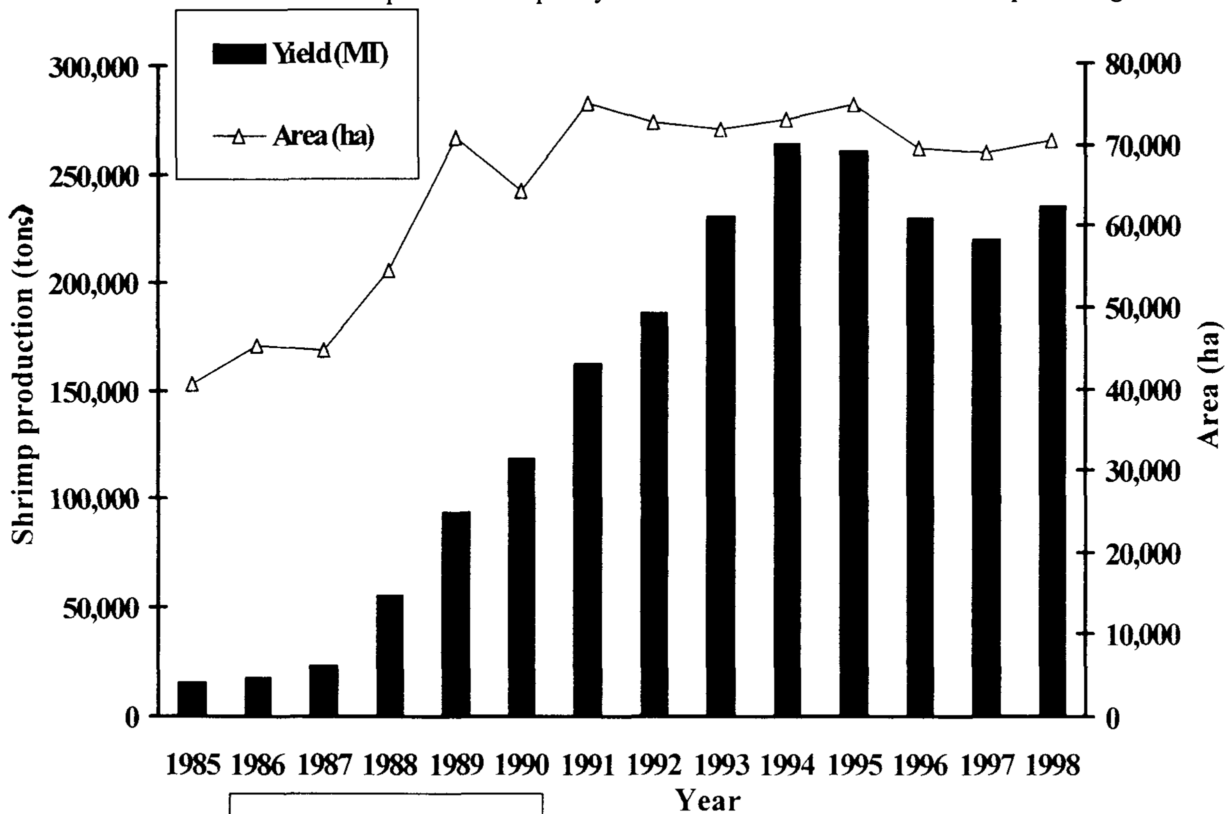
IV. Success Factors and Impacts of Shrimp Farming in Thailand

A. *The success factors*

The expansion of culture area and increase in production occurred very rapidly since 1985. Thailand has become the leading country in marine shrimp production from farming since 1991. Kongkeo (1994) and Tookwinas (1996) stated that the key factors for the success of marine shrimp farming in Thailand are attributed to the following factors:

1. Suitable sites

Thailand is in the tropics and has plenty of coastal areas suitable for shrimp farming.



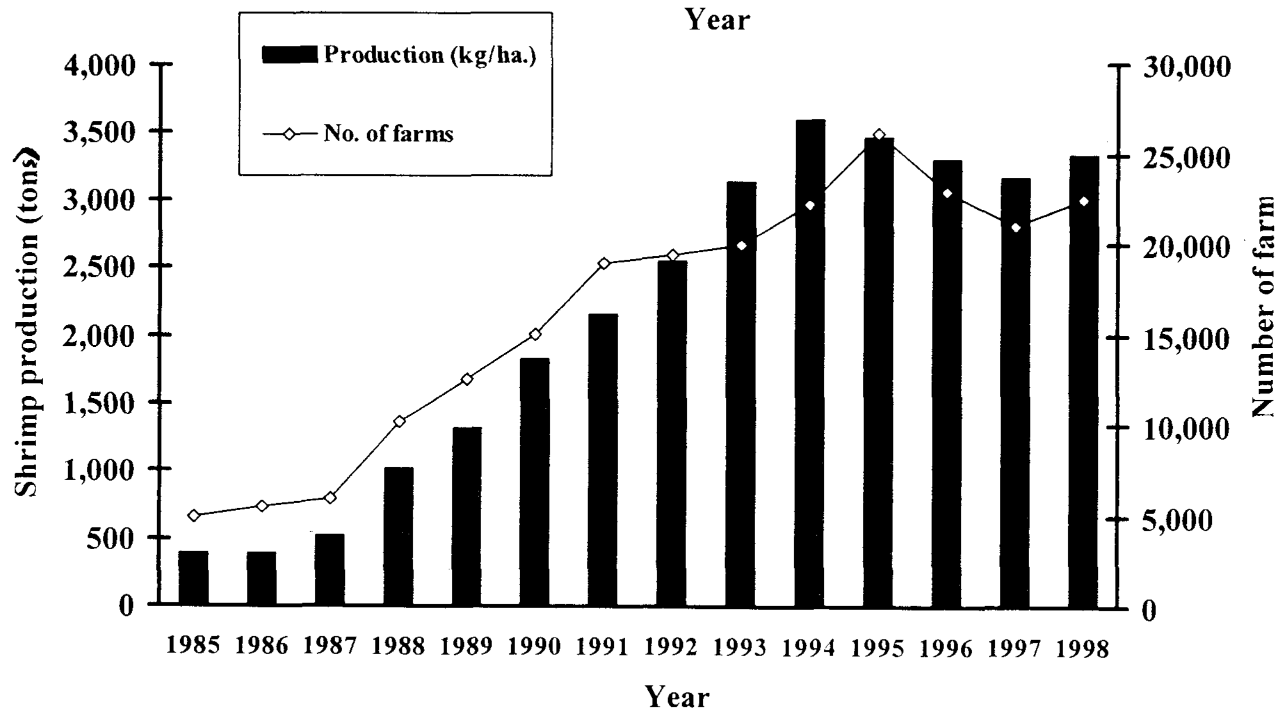


Fig 1. Shrimp production, culture area, annual yield and number of farms in 1985-1998.

Table 2. Export quantity of fresh and frozen farm shrimps by country 1989 - 1996
Quantity: tons

Country/ Year	1989		1990		1991		1992	
Total	74,294	100%	84,724	100%	121,240	100%	130,516	100%
JAPAN	40,258	54.19	43,486	51.33	56,194	46.35	51,166	39.20
U.S.A.	14,620	19.68	14,941	17.64	31,037	25.60	37,150	28.46
EU	6,184	8.32	11,837	13.97	15,351	12.66	16,790	12.86
ASEAN	7,585	10.21	7,307	8.62	8,139	6.71	10,176	7.80
TAIWAN	138	0.19	232	0.27	557	0.46	1,690	1.30
EFTA	0	0	597	0.71	687	0.57	1,793	1.37
OTHERS	5,509	7.41	6,324	7.46	9,275	7.65	11,751	9.00

Country/ Year	1993		1994		1995		1996	
Total	148,886	100%	187,072	100%	175,091	100%	161,462	100%
JAPAN	53,873	36.18	66,082	35.32	50,738	28.98	41,812	25.90
U.S.A.	46,034	30.92	53,332	28.51	44,385	23.35	35,575	22.03
EU	15,027	10.09	17,377	9.29	20,712	11.83	18,195	11.27
ASEAN	10,731	7.21	11,854	6.34	13,996	7.99	14,644	9.07
TAIWAN	8,338	5.60	11,649	6.23	11,743	6.71	10,034	6.21
EFTA	1,788	1.20	1,697	0.91	1,983	1.13	1,257	0.78
OTHERS	13,095	8.79	25,081	13.41	31,534	18.01	39,945	24.74

Source: Department of Custom (1988) cited by Fisheries Economic Division (1998)

2. Availability of wild broodstock

Tiger shrimp (*P. monodon*) is a local shrimp species in Southeast Asia and its wild broodstock is readily available in Thailand for the hatchery production of fry. The Department of Fisheries has implemented a conservation program for the restocking of shrimp fry in coastal waters at around 400-500 million fry every year. Some farmers in cooperation with the Department of Fisheries also restock portions of their shrimp production after harvesting in order to maintain or supplement the natural population of the tiger shrimp.

3. Long experience in aquaculture

The shrimp farmers in Thailand have a long experience in aquaculture and are also enthusiastic to learn and practice advanced technologies and new ideas for development or modification. The farmers are also eager to run experiments by themselves. The present success of Thailand in this industry is a testimony to the persistence and ingenuity of the Thai people in utilizing applied science to its utmost potential (CP Aquaculture, 1994).

4. Well developed infrastructure and support industries

Marine shrimp industry requires infrastructures and support services such as transportation, electricity and telephone communications that are most important for its fast development. Luckily, these are very well developed to support the industry in Thailand. There are also enough support and line business such as construction materials, heavy machines, feed mill, shrimp fry hatcheries, and food processing plants which help the development of the country's shrimp industry.

5. Small-scale industry

Marine shrimp farming in Thailand is still a small-scale industry where most of grow-out farm area is small at approximately 0.16-1.6 ha, and run by family members with intensive care and attention. This system is quite convenient for pond construction and operation, and the cost of investment is much lower. Thailand also uses techniques for backyard hatcheries, which can be managed with simple but efficient technology by farmers with little education, but producing more than 80% of the national shrimp fry production.

6. Control of environmental impact

Thailand has a coastal line of about 2600 km where the marine shrimp farming has expanded and scattered in every coastal province. Since the effluents from shrimp farms can be easily dispersed. the farmers adopt a low water exchange system which can reduce effluent release to the coastal areas. Previously, mangroves were converted to shrimp farms because of its convenience to get water supply.

Thus, vast mangrove areas were destroyed for the construction of aquaculture ponds. However, it has been accepted that the destruction of mangroves also destroys not only fish and crustacean nursery grounds but also natural flood and storm protection barriers (Sakthivel, 1985). The area now considered best suitable for shrimp farming are the rice fields in the coastal areas. These are the rice fields with very low production because of very high clay silt content of the soil, conditions suitable for pond construction and prevention of seepage. Government agencies such as the Department of Fisheries and Office of Environmental Policy and Planning have had many mitigation measure programs for aquaculture and other agriculture activities, as well.

7. Government support

The Thai government policy strongly supports the shrimp culture industry. The Government has provided investments in terms of infrastructure, research, training and extension, and other activities to support sustainable shrimp farming. This institutional support is a crucial factor in the development of the shrimp farming industry in Thailand.

8. Adaptability

The government and the private sector have been able to adopt management practices, policy, and institutional support responding to the changes in shrimp farming which have occurred over the past 10-15 years. For example, shrimp disease problem, marketing conditions, and other changes have been responded to quickly by government and the private sector.

B. *Impact of marine shrimp farming*

The growth of shrimp production from culture brings not only national income but at the same time, it also results in various impacts to the culture areas and the environment.

1. Impacts of mangrove removal

Mangroves are in the coastal areas close to the sea. In shrimp culture which made use of the extensive method, the shrimp seeds and sea water are pumped into the ponds during high tide. Therefore, the ponds are conveniently located in the mangroves or in areas near the sea. Although it is a known fact that mangrove areas are not really ideal for shrimp farm construction because the subsoil contains pyrite which can make the soil very acidic or low in pH when exposed to air. Secondly, mangrove soil is very soft and contains plenty of plant roots and stumps, not suitable for pond construction.

The satellite survey (Landsat TM5, 1:50,000) in 1993 showed that only 17.25% of the total area of the mangroves has been converted into marine shrimp farms (National Research Council of Thailand, 1989; Charuppat and Ongsomwang, 1995). Therefore, the main areas destroyed may have been used for other purposes. A Cabinet Resolution of 15 December 1989, resulted in the division of mangroves into three zones with the total area of 3724.48 km^2 (Budget Bureau, 1990; Kongsangchai, 1993).

Conservation zone is only for preservation purposes, Economic zone A is for timber and charcoal businesses, while Economic zone B which are unproductive areas that can be leased for any purpose from the government. In 1993, the remaining mangrove is only 45.29% or 168,682.5 ha. The area of shrimp farms in mangrove area is around 17.25% or 64,991.7 ha.

The shrimp farms in economic zone B (37,580.20 ha; 10.10%) have been leased to the farmers. Therefore, only shrimp farms in Conservation zone (4471.76 ha; 1.20%) and economic zone A (22,939.67 ha; 6.16%) totaling 27,441.44 ha or 7.36% may have been constructed from illegally destroyed mangroves. The mangrove areas may have also been used for land settlement (1.33% or 4,972.3 ha), and destroyed for other purposes (35.92% or 133,812.5 ha).

Table 3 showed that the decrease of the mangrove areas has no relation to the increase of shrimp farming areas. The data from satellite in 1996 which was done by Charuppat (1998) showed the same results, confirming that mangroves were not significantly destroyed for shrimp farms starting in 1993.

Table 3. Comparison between the decrease in mangrove areas and the increase in shrimp production areas

Unit: ha

Year	Mangrove area	Decrease in Mangrove	Shrimp Production Area	Increase in Shrimp Production Area
1961	356,700	-	-	-
1975	321,700	44,000	12,868	-
1979	387,308	25,392	24,675	11,807
1986	196,427	90,881	44,770	20,095
1989	180,560	15,867	64,606	19,836
1991	173,820	6,738	75,332	10,717
1993	168,682	5,138	71,880	-3,443
1996	167,582	1,100	69,464	-2,416

Source : Budget Bureau (1990), Kongsangchai (1993), Tookwinas (1996), and Charuppat (1998)

2. Effects on ground water and salinity intrusion

The abstraction of freshwater from underground aquifers for intensive shrimp farming in Thailand has resulted in saltwater intrusion and salinisation of freshwater aquifers (Liao, 1992 and Primavera, 1991). The problems and conflicts with local farmers and residents in Songkhla and Nakornsrithammarat provinces about salinity intrusion in freshwater consumption and agricultural water supplies occurred a few years ago. At present, shrimp farmers in many areas prefer to use full strength seawater directly from the open sea. Therefore, the farmers has stopped using the freshwater from aquifers for mixing with seawater for the ponds. The main effect was actually due to salinity drained out during water exchange and after harvesting the shrimps. However, the government has enforced a regulation not allowing farmers from pumping freshwater from agricultural areas.

3. <u>Effects on coastal environment and resources</u>

The effluents and sludge from marine shrimp farms have effects on the coastal environment. Macintosh and Phillips (1992) compared the quality of shrimp farm effluents to the wastes from other potential sources of pollution (Table 4) and their analysis showed that the pollution potential of shrimp farm effluents is considerably less than that of domestic or industrial wastewater. However, the waste from intensive shrimp farm has contributed many effects because of excess feeds, fertilizers, chemicals, and antibiotics (Table 5).

Table 4. Shrimp farm effluent during operation compared with other types of wastewater (Macintosh and Phillips, 1992)

Unit: mg/l

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

Table 5. Problems associated with effluents (Macintosh and Phillips, 1992)

Waste material	Primary effect	Secondary effect
1. Uneaten food, feces and dissolved excreta	Increased nutrient Loadings and reduced oxygen in ponds, water supplies, increased sedimentation	Environmental changes, reduced carrying capacity
2. Chemicals and drugs	Ecotoxicological impacts	Mortality and sublethal water quality changes
3. Antibiotics	Increased antibiotic resistance among micro-organism	Increased problem in treating, bacterial disease, residues in marketed shrimp

4. <u>Chemicals and drugs</u>

Chemicals and drugs are widely used in marine shrimp culture for the prevention or treatment of diseases or as disinfectants, pesticides or for soil or water treatment. Several compounds used pose potential treats to shrimp health and product quality (Macintosh and Phillips, 1992). For example, the widespread use of oxytetracyclin and oxolinic acid in Southeast Asian countries resulted in the development of resistant strains of *Vibrio* making the treatment of V*ibrio* infections extremely difficult (Nash, 1990). Improper use of antibiotics and some other chemicals leave residues in shrimp flesh, which may lead to the rejection of products in the export markets.

V. Technologies for Mangrove-Friendly Marine Shrimp Culture

A. *Water quality criteria for intensive marine shrimp culture*

Predalumpabuart and Chaiyakam (1994) and OECF (1991) have reviewed the water quality criteria for intensive marine shrimp culture. Results of their studies indicated that the criteria should include: water salinity ranging from 5 to 32 ppt; pH at about 6.5 – 8.5; transparency greater than 40 cm; BOD_5^{20} in the range of 0 – 3.0 mg/l; ammonia-nitrogen around 0 – 0.4 mg/l; total coliform bacteria less than 1,000 MPN/100 ml; total organochloride pesticide less than 0.05 microgram/L; sulfide less than 0.01 mg/L; cyanide less than 0.01 mg/L; and lead less than 0.05 mg/L

B. *Zero water discharge culture technique*

1. Pond preparation

The ponds to be used in the shrimp culture should be cleaned and maintained and the sludge or bottom mud sediment in the ponds should be cleaned after harvesting. Treatment is therefore necessary. The water in ponds is maintained at a depth of 5 – 30 cm. The water and sludge are pumped and sprayed over the pond bottom in order to have some air mixed with the water and the sludge. This is done twice in 3-5 days for the oxidation process in the sludge, and for the evaporation of the toxic gases such as ammonia and hydrogen sulfide. After three days, lime is sprayed over the pond bottom at the rate of 60-100 kg/rai or 375-625 kg/ha. The water and sludge are pumped and sprayed over the pond bottom again then the water is drained out.

The pond bottom will be left for air drying about one week then ploughed using a small tractor. This will facilitate oxidation in the bottom soil as well as evaporation of the toxic gases. Lime will be applied using the same rate as in the earlier process.

2. Sea water preparation

The sea water or the discharge water from shrimp farm is retained in reservoirs for about six weeks to allow suspended solids and other organic matters to settle down in the sedimentation pond. Then the sea water is pumped into the second pond which is stocked with sea grass, sea weeds and herbivorous fish. These organisms would neutralize the sea water quality making it suitable for marine shrimp culture.

3. Shrimp culture

The water salinity in culture ponds are adjusted to be the same as that in the hatchery. Thus, the aerators in culture ponds are operated for about one day before the shrimp larvae are stocked in order to increase the dissolved oxygen in the pond and the water temperature is also adjusted before stocking at a recommended rate density of around 30-40 PL/m^2, PL_{15} shrimp fry. The expected survival rate would be around 60-80%.

Commercial feed is given at the usual rate while the feed and consumption rates are regularly checked by cast nets. Then some small herbivores and omnivorous fish 0.5-3.0 cm in length are stocked in the culture ponds in order to get rid of some planktons, excess feeds and shrimp feces. One or two aerators per rai (6.25 rai = ha) are operated in order to increase dissolved oxygen and maintain the water circulation in the ponds. Lime is added to maintain the suitable pH range at 5-30 kg/rai. The sea water is not be changed, instead it is being refilled to compensate for the water lost due to evaporation.

4. Data collection

Data on shrimp growth, feeding rate, and survival rate should be checked every two weeks.

C. *Biotechnology for Shrimp Effluent Treatment*

1. Effluent treatment study

Treatment of shrimp pond effluents offers considerable potential for reducing the impacts on the water quality in the external environment (Macintosh and Philips, 1992). One major problem is the diluted but high volume of aquaculture effluents compared with traditional forms of wastewater (Muir, 1982). Thus, the treatment system is divided into physical, chemical and biological methods.

Physical methods include filtration or settlement treatment. In one study, a one ha settling pond was required to handle 900 m^3 of shrimp pond effluents per day (Rubeland Hager, 1979). The authors concluded that filtration was the best treatment process to remove suspended solids of concentration less than 10 mg/l. However, the cost of filtration is likely to be high and prohibitive.

Many experiments for shrimp farm effluent treatment have been conducted. Tookwinas (1995) conducted chemical treatment trials in the laboratory. The results showed that calcium oxide (CaO) at 0.3 mg/l or zeolite at 10 mg/l with aeration can reduce the effluent concentrations down to acceptable level in 24 hr. The efficiencies were about 89% and 94% for CaO and Zeolite, respectively.

An experiment on seaweed cultivation in the effluents from shrimp ponds was conducted at Chanthaburi and Songkhla provinces (Daroonchoo, 1991; and Chaiyakam and Tunvilai, 1992). Results indicated that ammonia-nitrogen and BOD were absorbed by seaweeds in 24 hr at 100% and 39% efficiency, respectively. Experiments using *Artemia* and green mussel were also conducted (Tunvilai and Tookwinas, 1991; and Chaiyakam and Tunvilai, 1992). The results showed that the green mussel could decrease ammonia-nitrogen and BOD in the effluent with an efficiency of 67% and 77% in 24 hr, respectively. Using such biological treatments, the closed system and recycle system of marine shrimp culture may be possible.

Herbivorous fish such as mullet, together with *Gracilaria* and mussel cultured in drainage ponds can be used in a biological treatment system. In this way, the sea water could be purified and recycled back to the culture pond (Tunsutapanich et al, 1994). Results of chemical and biological processes are shown in Table 6. More research on this subject is recommended to study the details for further development and improvement of the system.

Table 6. Potential treatment methods (Modified from Macintosh and Phillips, 1992)

Method	Benefits
1. Mussel and oyster	Removal of particulate organic matter and phytoplankton from water column
2. Brackish water fish (Mullet and tilapia)	Removal of particulate organic matter
3. Red algae	Removal of dissolved nutrients (N and P)
4. Sedimentation pond plus adding CaO and Zeolite	Removal of particulate organic matter
5. Mangroves	Wetland to absorb nutrient and increase the sedimentation rate by mangrove trees.

2. Design for biotechnology of shrimp farms effluent treatment

Tookwinas (1995) reviewed the possibilities and proposed the recycling of discharge water from marine shrimp farms and the biotechnology for shrimp farms effluent treatment. The discharge water or effluents would be treated using biological and physical processes before recycling. The conceptual design, drawn up from some technical information (Fig. 2), involves the following processes:

a. Water improvement process

After draining the water from intensive marine shrimp ponds, the water improvement process is as follows:

Step 1. Use mussel culture pond, since mussel can reduce toxic gases, organic matter as well as suspended solids in the discharge water or shrimp farm effluents. The stocking rate should be around 1400 pcs/rai (or 1600 m^2) and the residence time should be between 2 to 7 days.

Step 2: Use sedimentation ponds with physical treatment processes. The residence time may be 1 to 4 days. Aeration, as a physical process, should be applied.

Step 3: Use biological filtration pond or maturation pond to receive the water from the sedimentation pond. Sea weeds, sea grass and herbivorous fish such as mullet should be stocked to clear the water until its suitable quality then pumped to the culture ponds or released into coastal waters. The retention time should be 5-10 days.

b. Water recycle

After the biological filtration process, the water quality should be good enough for releasing into the coastal waters or for recycling back to shrimp culture ponds.

c. Treatment area

The area for the three ponds may be 60% of the culture pond area. However, it is important that the farmers should pay more attention to this aspect to ensure sustainability of marine shrimp culture.

Conceptual design for sustainability

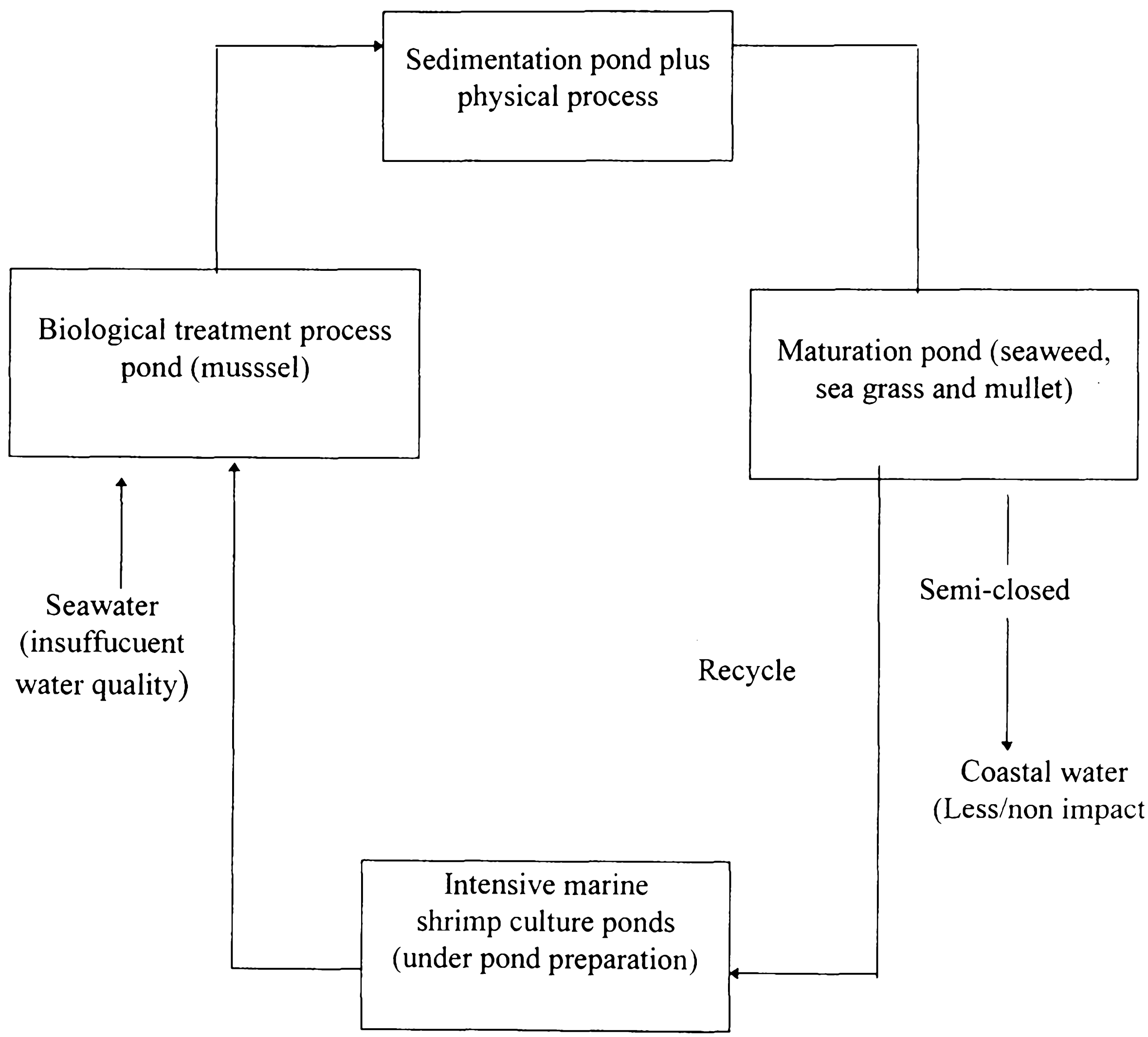


Fig 2. Conceptual design for biotechnology of marine shrimp farms effluent treatment

VI. Mangrove Reforestation Policy and Action Plan

A. Mangrove rehabilitation project

The National Mangrove Rehabilitation Project has been funded by the Royal Thai Government for the past years. Seedlings are raised in large nurseries run by government staff using seeds bought from villagers. Coastal communities are directly involved in raising the seedlings and are apparently involved in the extension of the program.

The local people could now initiate and run their own rehabilitation projects. The project has set a target of planting 50,000 rai (8,000 ha) per year. The program record is shown in Table 7.

Table 7. Progress of mangrove replanting record in February 1995

Unit : ha

Province	1992	1993	1994	Total
Rayong	12.8	15.36	64.00	92.18
Chanthaburi	25.60	28.16	-	53.76
Trat	25.60	33.28	38.40	97.28
Petchburi	23.04	30.72	25.60	79.36
Prachup Khiri Khan	2.56	7.68	15.36	25.60
Chumphon	25.60	-	46.08	71.36
Surat Thani	51.20	-	51.20	102.40
Nakhan Sri Thammarat	16.64	51.20	76.80	144.64
Pattani	-	5.12	-	5.12
Ranong	-	25.60	38.40	64.00
Krabi	17.54	29.44	38.40	85.38
Phangnga	68.2	11.52	12.80	34.56
Phuket	-	21.76	12.80	34.56
Trang	42.75	33.28	40.96	116.99
Satun	46.85	43.52	61.44	151.81
Total	358.40	336.60	560.64	1,255.70

Source : Royal Forestry Department (1995)

A number of mangrove rehabilitation projects have also been undertaken by NGOs and local communities (MIDAS, 1995). One project was in Klong Khone sub-district in Samut Songkhram province. The project had originally been the idea of the provincial government and in the first two years, planting was done by volunteer laborers from the local community, the province and NGOs from Bangkok. In these two years, areas of around 500 rai (80 ha) were planted in a comparatively short time.

In the first year, planting of exclusively *Rhizophora* was made but this was almost 100% failure due to barnacle spat settling on the seedlings which later broke under the weight of the developing barnacles, and some seedlings being eaten by crabs. In the second year, planting of *Rhizophora* and *Avicennia* at a 1:1 ratio was made.

During the third year (1994) around 1000 rai (160 ha) were planted with *Avicennia* from seedlings that were raised and planted by local people. Planting in 1995 availed of a neighboring sub-district which agreed to join in the planting program. Another mangrove rehabilitation project was at Khao Sam Roi Yod National Park. Mangrove seedlings are obtained from nurseries growing *Rhizophora* sp. and *Ceriops* sp from seed stocks collected locally. Community groups, particularly school groups visiting the Park are encouraged to plant the mangrove trees. Several hectares have been planted during the past two years.

B. *Reforestation program under the Royal project.*

Some mangrove reforestation projects have been done under the Royal Project. The mangrove replanting at Kung Krabean Bay has been actively done under The Kung Krabean Bay Royal Development Study Center since 1987. Around 264 ha of productive mangrove area has been strongly reserved and approximately 166.4 ha was replanted.

Another mangrove reforestation project was also done under the Royal Princess Sirinthorn Project since 1995 in Petchburi province about 160 km south of Bangkok, where an area of around 17 ha was reforested. Scientists have also carried out a research program under this Royal Reforestation Project.

C. *Research for replantation in abandoned shrimp farms*

Some research activities were conducted to rehabilitate abandoned shrimp farms which were formerly mangrove areas. Macintosh (1996) mentioned the result of an experiment in Ranong province, Southern Thailand under the joint research project of Stirling University, U.K.; Aarhus University, Denmark; and Royal Forestry Department of the Royal Thai Government, that mangroves can be planted successfully in shrimp waste sediments. The growth of young mangrove was four times faster than the growth in the natural habitat.

The same observation has also been made in Chanthaburi province, Eastern Thailand. It was found that the abandoned shrimp farms in Tha Mai District, Chanthaburi can be naturally planted with wild mangrove trees where the growth rate is also comparable to the growth rate in the natural habitat.

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