VERIFICATION AND REFINEMENT OF INTENSIVE SHRIMP CULTURE TECHNIQUES: THAILAND

Evaluation of Seawater Irrigation for Intensive Marine Shrimp Farming

Chanin Sangrungruang
Kung Krabaen Bay Fisheries Development Study Centre
Office of Coastal Fisheries Research and Development Bureau
Department of Fisheries
Thamis District, Chantaburi 22120, Thailand

Project Site: Kung Krabaen Bay Fisheries Development Study Centre, Chanthaburi. Thailand

BACKGROUND

Kung Krabaen Bay Royal Development Study Centre

In Kung Krabaen Bay, located in Chantaburi Province east of Thailand, His Majesty the King Bhumibol Adulyadej initiated the establishment of the Royal Development Study Centre in 1981 in order to develop a harmonized system among fisheries, mangroves and other agriculture activities in the coastal area of the Province. The main purpose of the Centre is to promote sound shrimp culture practices for the farmers situated in the deteriorated forest reserve areas around the Bay, known to have caused various problems to the environment and other agricultural activities around the Bay.

Kung Krabaen Bay still has plenty of aquatic animals and its extremely complex mangrove forests provide a good spawning and nursing ground for many fishes and shellfishes. The Bay is also a source of livelihood for fishermen and serves as site for the Province' shrimp culture zone.

The black tiger shrimp culture at the Bay area had increased the income and improved the standard of living of the shrimp farmers. His Majesty the King Bhumibol Adulyadej in his address on the 4th of December 1994, stressed that:

"Some say that shrimp farming produces pollution; that is true if it is not properly done or if done in a primitive way; the sea will be polluted. But now, there are techniques to produce substantial quantity of shrimps without creating pollution. On the contrary, Thailand will be able to export shrimp of high quality in great quantity."

Kung Krabaen Bay is 230 km from Bangkok, with an area of 4000 rai (640 ha). The mouth of the Bay is 650 m and 2600 m wide, 4600 m long and a maximum depth of 8.0 m. There are seven (7) short local canals around the Bay, surrounded by mangrove forests 5.0 km long and 30-200 m wide. The major problems in the Bay are mangrove destruction, decline of coastal fish stocks and saline water intrusion into the surrounding agricultural area, which not only cause environmental deterioration but also adversely affected the way of life of the local fishermen and farmers.

In order to develop and study the potential benefits of the coastal areas in the eastern region of Thailand, the Royal Development Study Centre was created for the development and promotion of shrimp aquaculture around Kung Krabaen Bay. The Royal Development Study Centre was instrumental in the establishment of the Kung Krabaen Bay Royal Development Study Centre (KKBRDSC), with a total area of 5760 ha, lying along the shoreline and adjacent to the inner land.

Objectives of the Centre

1. To promote the effective management of coastal fishery, as well as agricultural and occupational development in the eastern coastline of Thailand;
2. To provide an effective program on environmental conservation, examine the problems and find solutions related to mangrove destruction in the coastal environment using an integrated approach;
3. To increase the income of the surrounding villagers and farmers as well as improve their standard of living; and
4. To promote the dissemination of knowledge, skills and appropriate techniques on aquaculture, coastal environmental protection and conservation, agriculture and animal husbandry through the use of *"demonstration projects"* and provision of training-base study, research and experimentation work conducted at the Centre.

Activities of the Centre

There are several activities conducted at the Kung Krabaen Bay Royal Development Study Centre, the main focus of which is the preservation of natural resources and the ecosystem. The activities are integrated and coordinated among the twenty-two participating agencies with the understanding that these activities are geared towards creating awareness of the local people on the sustainable use of their resources and improve their living conditions.

Shrimp Culture in Kung Krabaen Bay

Since the request of the Kung Krabaen Bay Royal Development Study Centre to use the 1650 rai (264 ha) of deteriorated forest reserve area around the Kung Krabaen Bay for the implementation of a shrimp culture project was approved, the area was divided into three portions:

1. Shrimp culture area. The Kung Krabaen Committee divided the area of 728 rai (116.5 ha) into 104 plots (1.12 ha each), which were provided to 113 families for them to operate a shrimp culture farm, in particular the culture of the black tiger shrimp. Each plot comprised two parts: (1) shrimp pond covering 0.84 ha for 2-3 rearing ponds and a sludge pond; and (2) housing part covering 0.28 ha.

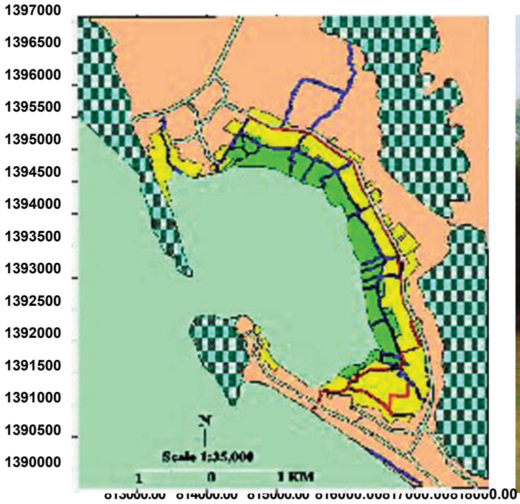
2. Mangrove area. Covering an area of 610 rai (97.6 ha), this area was designated as the mangrove forest conservation zone.

3. Demonstration area. The remaining 312 rai (49.9 ha) was allocated for demonstration of shrimp culture, reforestation of mangroves and various types of public utility.

Open-system Shrimp Culture

The shrimp culture around Kung Krabaen Bay has been carried out since 1986 adopting the semi-intensive culture system. The farmers, who were trained at the Centre, started using the open-water system where the seawater was supplied from the seven natural canals around the Bay during high tide. Effluents were discharged from the shrimp ponds into the same canals during the low tide. Sasaki and Inoue (1985) reported that the circulation pattern in the Bay is generally counter-clockwise at ebb tide and the motion of seawater in the Bay was almost entirely controlled by the inflow from the mouth of the Bay since inflows from the local canals were quite small. This investigation showed that 86% in volume of the Bay water at low level is replaced with open seawater, in one tide cycle.

The Kung Krabaen Bay Royal Development Study Centre, Chantaburi, Thailand



The Kung Krabaen Bay (left) and the Centre Facilities (right)

The shrimp ponds in Kung Krabaen Bay (above left) adopting the open system were devastated by diseases in 1990 (above right), but recovered few years later after using the closed-system (right)

The Bay has been the receiving area for the discharged water from the shrimp culture ponds with stocking densities of 15-20 postlarvae/m^2. In the beginning the incomes of the shrimp farmers appreciated compared to those from other activities. Big size black tiger shrimp was achieved (20-30 pc/kg) within three months of culture. The average production attained by the farmers operating around the Bay was 4000-5000 kg/ha. However, many problems occurred much later in the area.

Outbreak of Yellow-Head Disease and While Spot Syndrome Disease

In 1990, the first serious outbreak of the yellow-head virus (YHV) in black tiger shrimp *(Penaeus monodon)* occurred in the central and eastern parts of Thailand (Boonyaratpalin et al., 1994). This disease rapidly resulted in high mortality of the shrimps. It was observed at 50-70 days post stocking (Chanratchakool, et al., 1994), when the infected shrimps exhibited pale bodies and swollen cephalothorax with light yellow hepatopancreas and gills (Boonyaratpalin et al, 1994). Cumulative mortalities could reach 100% of the affected population within 3-5 days from the onset of the disease. In most cases, emergency harvest has to be undertaken regardless of the stage of production (Boonyaratpalin et al., 1994; Chanratchakool, et at, 1994).

From October 1994 to 1995, the black tiger shrimp was subsequently affected by a systemic ectodermal and mesodermal baculovirus (SEMBV) (Flegel et al., 1996), the later was referred to as white spot syndrome virus (WSSV). Shrimps, 40-75 days old were most susceptible and mass mortality reached 100% within 7-10 days from the onset of the disease. For YHV and WSSV disease outbreaks, the recommended procedures for their elimination are similar. Since both viruses can be spread by infected water and by non-cultivated crustacean carriers, current preventative measures emphasize good water management and the exclusion of carrier species. However, there are several cases of mixed infections of YHV and WSSV in Thailand and elsewhere (Flegel, et al., 1996). Although many shrimp farmers have changed from open to closed or semi-closed culture systems, the viral diseases remain a problem. It is particularly serious among the post larvae during the low temperature period from late October to January in the central and eastern parts of Thailand (Limsuwan, 1997).

Shrimp farms in Thailand, which suffered from these major diseases, also encountered serious losses as what happened in the shrimps cultured in Kung Krabaen Bay. Some farmers tried to increase the post larvae stocking densities to at least 80 pc/m^2, but unfortunately, the shrimp production was still lower. From the beginning of the project until at present, the Department of Fisheries tried to solve the problems by educating the farmers; monitoring the water qualities in their culture ponds, the canals, the bay and surrounding shoreline; seminars; demonstration of the shrimp culture system, service for shrimp health monitoring and disease diagnosis, taking note of the conservation systems. The culture system at the Centre has now been changed from open to closed-system or low water exchange system in order to avoid disease outbreaks. In addition, every farm must have sludge plots and following the regulations to treat the wastes from culture ponds, after harvesting the wastes should be piled in the sludge plots without flushing them into the canals. The Kung Krabaen Bay Royal Development Study Centre has been collecting sludge from the sludge-ponds for conversion to fertilizers that can be used in agriculture.

Closed-system

The closed-system for shrimp culture around Kung Krabaen Bay was adopted by treating the incoming water for the ponds, either by chemical, biological, or physical treatment. Farmers are made to understand that if they continue using water without improving its quality, the incidence of diseases could increase. To reduce the risk of disease contamination, a new technique has been adopted in which water exchange is limited (Chanratchakool. 1996).

During longer culture period of 4-5 months, organic matters accumulate in the ponds, causing phytoplankton to over bloom sometimes even dinoflagellates also over bloom, depleting the dissolved oxygen resulting in poor water quality. During summer, water evaporation causes extreme high salinity above 40-45 ppt and high temperature while the pH fluctuates. These factors led to shrimp stress inducing the opportunity of pathogen infection resulting in low survival and poor growth rate. This system is suitable only in the rainy season because rain promotes exchange of water in the culture ponds automatically. Under such circumstance, farmers could conduct shrimp culture only one crop per year.

Some Obstacles of Shrimp Culture around Kung Krabaen Bay

1. Lack of good water supply because Kung Krabaen Bay has a natural feature of a closed bay. Therefore, seawater from shrimp culture, which contains high nutrients (nitrogen and phosphate), remained circulated within the Bay, especially in the canals.
2. The discharged water from the shrimp culture ponds and drained into the Bay contain sediments and if not been treated, some parts of the water which cannot be completely treated by nature, flow back into the canals and finally into the farmer's shrimp ponds, creating problems.
3. The problem of deteriorating of seawater quality at the Kung Krabaen Bay has affected the coastal resources of the Bay environment.
4. The epidemic of diseases in shrimps particularly those that stemmed from uncontrolled viruses, has costly damaged the shrimp production because the seawater system supplying shrimp culture ponds is already contaminated from the water inflows and outflows.

Seawater Irrigation System for Shrimp Culture at Kung Krabaen Bay

The Seawater Irrigation Project, which was established to support shrimp culture activities at Kung Krabaen Bay, has the following objectives:

1. To separate the direction of inlet and outlet water canals of the culture areas;
2. To increase the capacity of shrimp production around Kung Krabaen Bay;
3. To develop sustainable shrimp culture around the Kung Krabaen Bay;
4. To maintain proper environmental condition, in order to establish a balanced ecological system at Kung Krabaen Bay; and
5. To create a model of seawater irrigation system for shrimp culture for demonstration in other areas of the country.

Project Description

The seawater irrigation system for shrimp culture at Kung Krabaen Bay is aimed at ensuring proper water quality required for shrimp culture. This system also serves as a rest canal for rearing water released from the shrimp ponds, by undergoing water treatment before being further released into the Kung Krabaen Bay.

Seawater Delivery System

Seawater Conduit

The facility has six rows of high-pressure HPDE conduits, each having a diameter of 1.0 m, and buried under the sea at a distance of about 350 m offshore. These conduits deliver seawater to the pumping station onshore.

Water Pumping Station

The Water Pumping Station, constructed using reinforced concrete, is used to pump seawater from the storage located underground at a level of about 11.50 m deep. This station can store water up to 4650 m^3 and can continuously drain water using eight 200-HP pumps, each having a drainage capacity of 1.25 m^3 of water/sec. Water flows in through two HPDE conduits 1.0 m in diameter, into a stocking pond which can hold up to 3000 m^3 of water.

Water Inlet Canal

Running a distance of about 8820 m, this canal delivers seawater to the shrimp culture areas around the Kung Krabaen Bay. The concrete canal stores seawater from the stocking pond, before the water is further released into the shrimp ponds by force of gravity. The canal comprises:

- *Main Water Inlet Canal (M Route),* 12 m wide and approximately 6620 m long, is used for receiving and distributing seawater to farmers in the upper area of the project.
- *Central Water Inlet Canal (R Route,* 8 m wide and approximately 1620 m long, is used for receiving and distributing seawater to farmers in the central area of the project.
- *Sub-distributory Canal (R Route),* 5 m wide and approximately 580 m long, is used for receiving and distributing seawater to farmers in the lower area.
- *Secondary Canals,* which are separated from the main canal, are necessary for delivering water to shrimp ponds since the shrimp culture area is rather large. Each farmer handles the construction of his own secondary canals.

Waste Water Treatment System

The potentials of nature have been relied upon in the wastewater treatment system of this project, enhancing the water quality for aquatic organisms. The wastewater treatment system consists of:

1. *Sludge-ponds*

   In the sludge-ponds, suspended solids settle down so that the clear water flows into the water treatment canal.

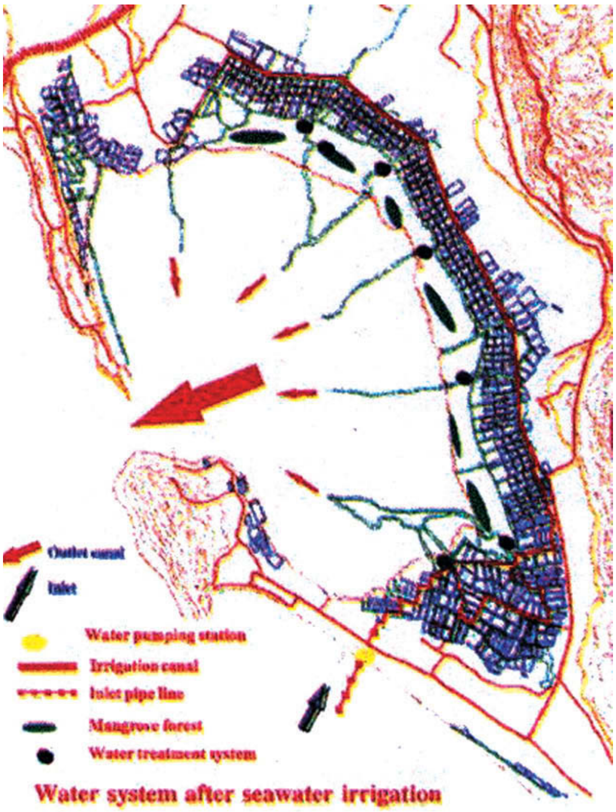
2. *Water treatment canals*

   The water treatment canals, are supplemented with physical and biological treatment system, with an aeration system consisting of 24 5-HP mechanical aerators along the canals. Oysters are cultured by hanging method in the treatment canals in order to enhance the efficiency of the wastewater treatment and achieve a standard level before passing the water to the sedimentation canals.

3. *Sedimentation canals*

   The sedimentation canals comprises seven local canals, where both sides of the canals lay along the mangrove forest areas. The canals receive discharged water from the treatment canals and with biological treatment the water passes through the Bay where seagrass and seaweeds are abundant.

The construction of this project started on 1 November 1996 and was completed and made operational since 3 May 1999. Its main purpose is to allow an effective administration system for shrimp culture at Kung Krabaen Bay.



The main objective of the seawater irrigation facility is to separate the direction of the inlet and outlet canals in the shrimp culture areas

The Kung Krabaen Bay Royal Development Study Centre enlisted 192 farmers under the Project and from nearby areas as members who utilize the water from the system. Now the Project covers 351 shrimp ponds with total area of 1064 rai (170.24 h) divided into 860 rai (137.6 h) for shrimp culture and 204 rai (32.64 h) for ditches, canals, roads as well as infrastructures for various activities.

The Kung Krabaen Bay Fisheries Development Study Centre is being handled by the Department of Fisheries under the Kung Krabaen Bay Royal Development Study Centre, which takes charge and supports the project in its various aspects. After two years of operation, the members took charge of the project administration from the Kung Krabaen Bay Fisheries Development Study Centre. However, the Centre still provides support in terms of technical aspects and recommendations for achieving the goal of promoting sustainable shrimp culture

Benefits

1. The project is promoted in order to increase shrimp production, the annual black tiger shrimp production of the Kung Krabaen Bay is expected to achieve a minimum of 800 mt/year
2. Shrimp culture should remain sustainable
3. This project serves as a model on the development of seawater irrigation system to support shrimp culture in other areas of the country
4. Farmers can expect to earn reasonable income, allowing them to have better quality of life, thus fulfilling the Royal intention of His Majesty the King in the establishment of the Kung Krabaen Bay Royal Development Study Centre.

THE MANGROVE-FRIENDLY SHRIMP CULTURE PROJECT

Four research activities are conducted in the Kung Krabaen Bay Royal Development Study Centre under the Mangrove-Friendly Shrimp Culture Project. Results from these activities indicated a low impact assessment on water and soil qualities as well as the mangrove area around KKB, while shrimp production has increased. These findings show that activities under the seawater irrigation system could control the impact from shrimp culture, supporting the objective of the seawater irrigation system.

Impact assessment of the intensive shrimp farming under seawater irrigation facility on sediment and water qualities in Kung Krabaen Bay (KKB)

The nutrients of the effluents from shrimp farming around KKB have shown limited impacts during the study period 2000-2002. There were also no significant differences before and after the operation of the seawater irrigation system (Table 1 and 2). Small amount of sediments were found accumulated only in the inner part of KKB such as in the canals and shoreline than in the outer part (middle area of KKB). The water quality data of the treatment canals in 2001-2002 have not shown any impacts from the effluents of the shrimp farms. Water quality parameters found within acceptable standard for coastal aquaculture have been monitored (Table 3).

Variation of sediment and water qualities in intensive marine shrimp farm drainage canals

In 2001, the analysis of samples of soil and water qualities in five stations in water treatment canals (drainage canals) showed that:

1. The thickness of settled sediment was higher than during the year 2000 (Table 4).
2. Hydrogen sulfide was detected in high amount. The quantities of hydrogen sulfide found in water treatment canals could affect some meiofauna, microfauna, benthos and aquatic animals on the bottom surface (Table 5) of the canals.

Based on these data, every after 2-3 years, the water treatment canals or drainage canals must be managed such as renovation the bottom soil surface of the canals.

Study on the possibility using mangrove forest as a wetland treatment unit for shrimp farm effluent

Shrimp farm's effluents had some effects on the mangrove trees. Some mangrove trees have shown some benefits such as the *Avicennia alba* which had the highest growth rate among the mangrove species (Table 6) used in the study on the efficiency of mangrove forest on water treatment:

1. Treatment of low nutrient waste from shrimp farm (BOD= 2-3 mg/l) using four mangrove species (Table 7)

   Water discharged from shrimp farms kept in the pond for 3 days then water qualities were checked. Results are recorded as follows:

   BOD, TN, TOC and SS before treatment were 3.8 mg/l, 3.05 mg/l, 11.65 mgO/l and 26.80 mg/l, respectively, while the BOD, TN, TOC and SS after 3 days treatment were 2.6 mgO/l, 2.56 mgN/l, 11.19 mgC/l and 9.64mg/l, respectively in *Ceriops tagal*; 2.1 mgO/1, 2.72 mgN/l, 10.86 mgC/1 and 6.24 mg/l, respectively in *Rhizophora apiculata;* 1.4 mgO/l, 2.57 mgN/l, 9.51 mgC/l and *5.39* mg/l, respectively in *Avicennia a/ba;* 0.8 mgO/l, 2.51 mgN/l, 8.91 mgC/1 and 4.93 mg/l, respectively in *Bruguiera gymnorrhiza;* and 1.7 mgO/l, 2.55 mgN/l, 9.52 mgC/I and 5.29 mg/l, respectively in the control. *Bruguiera gymnorrhiza* showed the highest efficiency on water treatment as shown by the BOD of 78.94 %, TN of 17.70 %, TOC of 23.52 % and SS of 81.60 %, while in the control the parameters were: BOD 55.26%, TN 16.39%, TOC 18.28 % and SS 80.26%.

2. Treatment of high nutrient waste from shrimp farm (BOD 20-30 mg/l) using four mangrove species (Table 8)

   BOD, TN, TOC and SS before treatment were 51.4 mgO/l, 1 l.05 mgN/l, 106.93 mgO/l and 48.13 mg/l, respectively, while the BOD, TN, TOC and SS after 3 days treatment were 31.22 mgO/1, 14.84 mgN/l, 48.43 mgO/l and 58.48 mg/l, respectively in *Ceriops tagal;* 20.67 mgO/l, 12.60 mgN/l, 47.12 mgC/l and 43.68 mg/l, respectively in *Rhizophora apicu/ata;* 18.8 mgO/l, 12.53 mgN/l, 44.57 mgO/l and 34.34 mg/l, respectively in *Avicennia alba;* 24.33 mgO/l, 14.59 mgN/1, 47.62 mgC/l and 47.54 mg/l, respectively in *Bruguiera gymnorrhiza;* and 25.8 mgO/1, 13.76 tngN/l, 51.94 mgC/1 and 55.67 mg/l respectively in the control. *Avicennia alba* showed the highest efficiency on water treatment as shown by the BOD of 63.42 *%,* TN of -13.30 *%,* TOC of 58.32 % and Ssof 28.65 %, while in the control: BOD was 49.80%, TN -24.52 %, TOC 51.43 % and SS -15.67 *%.*

There was little difference between the control and treatment in low and high nutrient loading system. *Avicennia a/ba* and *Bruguiera gymnorrhiza* showed the best performance among four (4) mangrove species in both experiments. Mangrove species required low nutrients from the soil, as they are able to use CO_2 form the air for photosynthesis process.

Study on the variation of mangrove forest at Kung Krabaen Bay

The number of natural mangrove trees around the Kung Krabaen is still the same as in the previous years. The trees are still in good growth condition. In conclusion the wastewater from shrimp farm has no negative effect on the natural mangrove area (Table 9 and 10).

CONCLUSION

The seawater irrigation system has benefited the intensive marine shrimp culture making shrimp culture sustainable and increasing shrimp production. The results obtained from this research study indicated that the adverse effects of shrimp farms on mangrove and costal environments around the irrigation system could be controlled and minimizedThere are three main critical control points identified in this study that need to be considered:

1. Supply canals in the system should be cleaned and renovated every 2-3 years.
2. Wastewater treatment system should be monitored to avoid the accumulation of solid wastes while the solid wastes should be properly managed.

3. The seawater irrigation system can minimize shrimp pathogens from entering the culture ponds, however for disease prevention, farmers should adopt good aquaculture practices including pond preparation, seed quality, and prevention of disease carriers.

Managing the seawater irrigation system needs a systematic teamwork. The above critical control points of the system should be monitored regularly and managed properly. The pond manager should assess the system regularly to prevent the adverse effects to the shrimp farms and to the environment.

Table 1. Water qualities in Kung Krabaen Bay, culture ponds, harvest ponds and production before and after using the seawater irrigation system (1995-2002)

Parameters	Before (95-99)	After (99—02)
Transparency (cm)	108.97±60.84**	123.26±55.07**
Salinity (ppt)	29.66±7.43 ns	28.99±5.34 ns
Temperature (ºC)	2918±0.21**	28.52±2.4 1
SS (mg/l)	17.14±20.92**	13.87±13.67**
pH	8.18±0.21**	8.13±0.23**
Alkalinity (mg/l)	113.54±19.99**	111.02±13.73**
DO (mg/l)	5.68±2.61 ns	5.67±0.9 1 ns
NO_2 (mg/l)	0.0057±0.0376 ns	0.0034±0.0198 ns
NO_3 (mg/l)	0.0074±0.0198**	0.0 139±0.0286**
NH_3 (mg/l)	0.0295±0.1161 ns	0.0261±0.1715 ns
TN (mg/l)	1.294±1.042 ns	1.380±00966 ns
PO_4 (mg/l)	0.0041±0.0106**	0.0021±0.0039**
TP (mg/l)	0.0295±0.1161 ns	0.026I±0.0715 ns
SiO_2 (mg/l)	0.438±0.379**	0.519±0.355**
BOD (mg/l)	0.91±0.58 ns	0.92±0.73 ns
COD (mg/l)	89.38±32.51**	116.93±57.16**
TOC (mg/l)	4.01±2.07 ns	4.12±1.977 ns
Chlorophyll a (mg/rn³)	3.89±7.37 ns	3.53±4.38 ns
Culture ponds (ponds/month)	73.61±31.10**	117.60±47.22**
Harvest ponds (ponds/month)	21.39±14.18**	32.09±21.94**
Production (tons/month)	26.63±21.82**	32.82±24.45**

Table 2. Soil qualities in Kung Krabaeb Bay before and after using the seawater irrigation system (1997-2002)

Soil parameters	Before	After
pH	7.81±0.64**	7.41±0.59**
Organic Matter (%)	2.22±1.77 ns	2.45±2.35 ns
Organic Carbon (%)	1.29±1.03 ns	1.43±1.37 ns
Total Nitrogen (%)	0.059±0.043 ns	0.066±0.065 ns
Available Phosphorus (mg/kg)	63.57±24.57**	56.42±15.27**
BOD (mg/g soil)	1.56±1.10**	0.85±1.0**
Sand (%)	72.15±11.83 ns	70.29±14.93 ns
Silt (%)	21.83±10.39 ns	22.82±11.61 ns
Clay (%)	6.01±3.52 ns	6.88±5.96 ns
Harvest ponds (ponds/year)	229	328
Production (tons/year)	256	345

Table 3. Water qualities in the treatment canals before and after the using the seawater irrigation system

Year	Salinity (ppt)	DO (mg/l)	pH	Alkalinity (mg/l as $CaCO_3$)	Total ammonia (mg/l)	NO_2^-N (mg/l)	TN (mg/l)	TOC (mg/l)	Chlorophyll a (mg/l)
Before									
1997	30.2	5.5	8.2	112.3	0.0268	0.0067	1.4296	4.5200	5.48
1998	30.3	5.3	8.3	109.2	0.0092	0.0004	1.7991	3.1619	2.39
1999	29.2	5.6	8.1	110.7	0.011	0.0056	1.1911	3.8642	2.71
After									
2000	26.9	5.5	8.1	111.0	0.0621	0.0054	1.4809	4.1944	4.10
2001	29.2	5.4	8.2	112.1	0.0255	0.0019	1.7742	5.5791	4.76
2002	31.0	5.2	8.1	112.8	0.0236	0.0030	1.3410	4.8467	4.63

Table 4. Sediment quantity (thick, cm) in treatment canals around KKB

Station	Mar-01	Jun-01	Sep-01	Dec-01
1	2.33±1.2	-0.33±1.7	8.00±2.8	1.33±0.5
2	-1.00±1.6	-1.00±1.4	0.00±0.0	1.00±1.1
3	2.33±1.7	5.33±5.4	9.00±5.7	1.67±0.9
4	1.33±1.9	3.33±1.2	5.33±2.5	1.33±0.2
5	3.00±1.6	3.00±1.6	19.33±2.4	2.17±0.6

Table 5. H_2S of sediment in treatment canals around KKB (mgH_2S/soil 1g)

Station	Mar-01	Jun-01	Sep-01	Dec-01
1	0.01546	0.00166	0.01910	0.02794
2	0.00454	0.00022	0.00842	0.03508
3	0.01042	0.00004	0.02020	0.02490
4	0.00682	0.00008	0.02338	0.02332
5	0.00414	0.00076	0.01542	0.01636

Table 6. Average Girth, Ave Height and percentage of survival of mangrove trees in the experiment tanks (June - October 2001 and March 2002)

Date	Plot	Species (Treatments)	Ave Girth h (mm)	Ave Height (cm)	% survival
Jun-01	1	Ceriops tagal	15.31	90.06	93.98
	2	*Rhizophora apiculata*	21.55	70.99	100.00
	3	*Avicennia alba*	22.26	114.80	100.00
	5	*Bruguiera gymnorrhiza*	19.22	67.45	94.44
Oct-01	1	Ceriops tagal	16.54	92.48	81.94
	2	*Rhizophora apiculata*	19.93	73.65	100.00
	3	*Avicennia alba*	22.46	131.21	100.00
	5	*Bruguiera gymnorrhiza*	20.84	74.48	95.83
Mar-02	1	Ceriops tagal	18.52	96.62	81.94
	2	*Rhizophora apiculata*	21.39	78.31	100.00
	3	*Avicennia alba*	24.07	137.98	100.00
	5	*Bruguiera gymnorrhiza*	22.31	80.84	95.83

Table 7. Water quality before and after treatment by the mangrove trees (low nutrient loading)

Treatment	Mangrove Species	BOD (mg O/l)	TN (mg N/l)	TOC (ppm)	SS (mg/l)
before treatment		3.8±0.1	3.0514±0.0738	11.6551±1.6173	26.80±3.83
after treatment	*Ceriops tagal*	2.6±0.4	2.5686±0.2367	11.1965±0.7177	9.46±1.46
after treatment	*Rhizophora apiculata*	2.1±0.4	2.7283±0.1094	10.8679±1.9975	6.24±0.37
after treatment	*Avicennia alba*	1.4±0.1	2.5793±0.1934	9.5162±2.0475	5.39±0.38
after treatment	*Bruguiera gymnorrhiza*	0.8±0.3	2.5128±0.1665	8.9125±2.4990	4.93±1.40
after treatment	Control	1.7±0.5	2.5559±0.0714	9.5262±2.3042	5.29±0.18

Table 8. Water quality before and after treatment by the mangrove trees (high nutrient loading)

Treatment	Mangrove Species	BOD (mgO/l)	TN (mg N/l)	TOC (ppm)	SS (mg/l)
before treatment		51.42+9.68	11.0591+5.3169	106.9388+54.6440	48.13+14.53
after treatment	*Ceriops tagal*	31.22+4.22	14.8449+2.8898	48.4348+5.8309	58.48+17.34
after treatment	*Rhizophora apiculata*	20.67+7.55	12.6003+3.5077	47.1235+4.8425	43.68+14.51
after treatment	*Avicennia alba*	18.89+6.19	12.5359+2.3828	44.5716+5.4892	34.34+7.82
after treatment	*Bruguiera gymnorrhiza*	24.33+4.71	14.5991+2.4012	47.6201+4.8076	47.54+8.79
after treatment	Control	25.89+3.45	13.7623+3.0734	51.9442+6.6175	55.67+6.92

Table 9. Diameter at breast height and height of trees in permanent plot (Natural Area)

Species	Tree		Sapling	
	Ave DBH Ave (cm)	Height (cm)	Ave DBH (cm)	Ave Height (cm)
1. *Rhizophora apiculata*	12.80	13.06	3.30	3.92
2. *Rhizophora mucronata*	7.67	10.17	-	-
3. *Bruguiera gymnorrhiza*	7.93	10.15	2.07	2.51
4. *Ceriops taga*	8.76	6.73	2.74	2.71
5. *Xylocarpus moluccensis*	12.46	9.60	2.99	6.02
6. *Xylocarpus granatum*	9.11	8.50	-	-
7. *Lumnitzera racemosa*	7.14	5.71	2.50	4.26
8. *Lumnitzera liltorea*	6.75	6.22	3.10	3.49

Table 10. Average density of trees, sapling and seedling in permanent plot (Natural Area)

Species	Density (Tree/rai)			
	Tree	Sapling	Seedling	Total (Tree/rai)
1. *Rhizophora apiculata*	224	329	1,600	2,173
2.*Rhizophora mucronata*	1	-	-	1
3. *Bruguiera gymnorrhiza*	3	5	34	43
4. *Ceriops tagal*	8	16	1,239	1,144
5. *Xylocarpus moluccensis*	4	3	155	162
6. *Xylocarpus granatum*	1	1	17	19
7. *Lumnitzera racemosa*	9	94	1,376	1,479
8. *Lumnitzera liltorea*	8	40	378	426
Total	227	640	4,800	5,717




Results of research studies in Kung Krabaen Bay (above) indicated that the nutrients of effluents from shrimp farms using the seawater irrigation facility have limited impacts. *Avicennia alba* and *Bruguiera gymnorrhiza* (below) had the best performance among mangrove species tried as treatment for shrimp farm effluents

Results of the studies in Kung Krabaen Bay also suggested that every 2-3 years, the water treatment pond and drainage canals should be managed, e.g., excavation of the bottom soil surface, etc.


REFERENCES

Boonyaratpalin, S., K. Supamattaya, J. Kasornchantra, S. Direlcbusaracom, U. Aekpanithanpong and C. Chantanaehooklin. 1994. Yellow-head disease of black tiger prawn *(Penaeus monodon)* AAHRI Newsletter 3(l):6.

Boonyaratpalin, M., C. Sangrungruang, S. Tantisaowaphap and A. Lanwapong. 2002. The Study of Impacts of Seawater Irrigation on Kung Krabaen Bay Vicinity. Technical Paper No. 8/2002. Office of Fisheries Technical Advisor. Department of Fisheries. 101 pp.

Chanratcbakool, P., J. F. Turnbull and C. Limsuwan. 1994. Health Management in Shrimp Ponds. Aquatic

Animal Health Research Institute Department of Fisheries, Kasetsart University Campus, Bangkok. 91 pp.

KKBRDSC. 2000. 2000 Annual Reports of Kung Krabaen Bay Royal Development Study Center. 122 pp.

FIegeI, T. W. S. Boonyaratpalin and B. Withyachumnamkul. 1996. Current status of research on yellow-head virus and white-spot virus in Thailand. *In:* Thailand Department of Fisheries and the Chulabhorn Research Institute (eds.). The 1996 Annual Meeting of the World Aquaculture Society, Jan. 29- Feb. 2, 1996, Queen Sirikit National Convention Center, Bangkok, Thailand. p. 126.

Flegel, T. W. 2000. An overview of PCR probes for shrimp diseases *of Penaeus monodon* inn Asia, with emphasis on Thailand. Molecular Epidemiology and Diagnostics of shrimp Viruses in the Asian Region, Workshop II. ACIAR-NSTD (BIOTEC)-Crawford Fund-Mahidol University-CSIRO.L211 -19.

Kasornchandra, J., It. Khongpradit, V. Srikaew, J. Sbahagaroo, J. Ponngkaew and S. Boonyaratpalin. 1996. Rapid diagnosis of systemic ectodermal and mesodermal baculovirus in *Penaeus monodon* postlarva using polymerase chain reaction. AAI-IRl Newsletter 5(2):7.

Kasornchandra, J., S. Boonyaratpalin, It. Khongpradit and U. Aekpanithanpong. 1996. Mass mortality caused by systemic bacilliform virus in cultured penaeid shrimp, *Penaeus monodon,* in Thailand. *In.* Thailand Department of Fisheries and the Chulabhom Research Institute (eds.). The 1996 Annual Meeting of the World

Aquaculture Society, Jan. 29- Feb. 2, 1996, Queen Sirikit National Convention Center, Bangkok, Thailand. p. 193.

Sangrungruang, C., W. Sakares, M. Anongponyoskun and B. Damrak. 1999. The environment impact of shrimp culture on physical characteristics, soil qualities and seawater qualities of Kung Krabaen Bay before seawater irrigation construction. *In* KKBRDSC(eds.) A Decade researches of the KKBRDSC, 1999; p47- 117.

Sangrungruang, K. 2001. Shrimp culture in Kung Krabaen Bay, the Royal Project. *In* Proceedings of the JSPSNRCT International Symposium on Sustainable Shrimp Culture and Health Management Diseases and Environment. P.157-166

Sasaki, T. and H. Inoue. *1985.* Studies on fundamental environments in the Kung Kraben Bay, Eastern Thailand: Hydraulic environments. *In:* Mangrove Estuarine Ecology in Thailand, p. 77-98. Thai-Japanese Cooperative Research Project on Mangrove Productivity and Development, 1983-1984.