WISE-USE TECHNOLOGIES IN MANGROVE-FRIENDLY AQUACULTURE: VIETNAM EXPERIENCE

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I. Introduction

Vietnam has more than 3260 km of coastline, 112 estuaries, 12 large lagoons, bays, lagoon pools, river systems, ponds, water reservoirs, and inland hydroelectric reservoirs, which provide a great potential for aquaculture development. The potential surface water area is about 1,700,000 ha which includes small ponds and lakes (120,000 ha); water reservoirs and large water areas (340,000 ha); paddy fields for aquaculture (580,000 ha); and littoral areas (660,000 ha). In, addition, 300,000 ha of bays and lagoons in coastal areas are also suitable for aquaculture activities.

A. *Aquatic resources*

1. Freshwater fishes

About 581 species freshwater fishes are recorded, 240 of which are in the Red River Delta region, with 35 species having high economic value. In the Mekong River Delta region, 341 are recorded with 57 high-value species.

B. *Biological resources in coastal areas*

1. Fish

There are about 186 fish species, some are high-value such as grouper (*Epinephelus* spp.), amberjack (*Seriola* spp.), black kingfish (*Rachycentron canadum*), sea bass (*Lates calcarifer*), snapper (*Lutjanus* spp.), milkfish (*Chanos chanos*), striped mullet (*Mugil cephalus*). Some of these species are presently cultured such as grouper (*Epinephelus* spp.), amberjack (*Seriola* spp.), sea bass (*Lates calcarifer*), etc.

2. Shrimp

About 16 main species with high value are recorded and many of these are cultured such as the tiger shrimp (*Penaeus monodon*), white shrimp (*P. merguiensis*), Indian shrimp (*P. indicus*), taisho shrimp (*P. orientalis*), greasy-back shrimp (*Metapenaeus ensis*), yellow ringspiny lobster (*Panulirus ornatus*), and giant freshwater prawn (*Macrobrachium rosenbergii*).

3. Molluscs

According to some statistical data, there are about 690 species of molluscs found in the coastal areas. Some high-value species are cultured such as the pearl oyster (*Pteria martensii*), ark shell (*Anadara granosa*), blood cockle (*Arca granosa*), clam (*Meretrix* spp.), and oyster (*Ostrea rivularis*).

4. Seaweeds

About 90 high-value species have been identified, of which *Gracilaria* and *Sargassum* with high natural production, are being cultivated. The *Gracilaria* genus includes 13 species, the most important of which are *Gracilaria asiatica* and *G. blodgetti* which are used in the production of agar. On the other hand, *Sargassum* is used to extract alginate.

5. Mangroves

Mangrove forests are diverse ecosystem and abundant in estuaries and coastal areas. Mangroves provide not only forestry products but also habitats for marine species of high value and serve as nursery grounds for larvae of shrimps, crabs and fishes. An example of the role of mangroves in the aquatic ecosystem is illustrated in Figure 1.

The destruction and conversion of mangroves into large area extensive shrimp and fish ponds usually provide high profit only during the early years of operation. Afterwards however, the productivity usually decrease because the destruction leads to some serious effects to the natural resources and the environment. In order to solve this problem, the State recommended measures to rehabilitate the mangroves, improve farming technologies, and develop suitable and effective aquaculture systems in the mangroves areas.

This report refers to the status of aquaculture technologies in coastal areas in general. Some mangrove-friendly aquaculture systems in Vietnam are also discussed including several measures to develop aquaculture in mangroves suitably and sustainably.

II. Aquaculture in Vietnam

A. *General situation*

In almost 10 decades, aquaculture in Vietnam has developed rapidly in all three types of surface waters, namely, freshwater, brackishwater and marine water. From 1995 to 1998, aquaculture area increased at an average of 4-5%/year (597,000 ha in 1995 to 626,330 ha in 1998). In 1998, about 290,440 ha was used for brackishwater and marine water aquaculture or 46% of national total exploited area of which 225,000 ha was utilized for shrimp farming or 88% of exploited brackishwater area (Tables 1,2).

Aquaculture contributes around 30% to the national fish production as well as to the country's exports, particularly the shrimp export. In 1998, aquaculture output was 550,000 mt with total export revenue of about 400 million US Dollars or about 50% of the total export from fisheries (Table 3), accounting for 35-40% of the total export products.

The growth in aquaculture production from 1990 to 1998 is shown in Table 4, increasing from 300,850 mt in 1990 to 537,870 mt in 1998. The Mekong River Delta region is the main contributor to the national aquatic production with about 364,139 mt (1998) or 68% of total aquaculture output, followed by the Red River Delta region with its production of 69,242 mt or 13% of the total fisheries production. The products from aquaculture are mainly shrimps and freshwater fishes. For many years, finfish (mostly freshwater species) and shrimps (mainly marine species) contributed around 75% and 15%, respectively to the country's total fish production. The remaining 10% is shared by molluscs, mud crab, and seaweeds. The aquaculture of the species using various methods employs a big number of labor force. In 1998, approximately 550,00 people were employed in aquaculture which is about 15% of total labor force in fisheries. Tables 5 and 6 list the important species cultured in three types of habitats, namely, freshwater, brackishwater, and marine water.

However, the yield of the marine species is still considerably low due to the fact that Vietnam has not been successful in artificial seed production. The culture is entirely dependent on juveniles caught from the wild. On the other hand, production from freshwater aquaculture is rather high, specifically the production output from carps and tilapia culture, which is mainly for domestic consumption. Meanwhile, shrimp, crab and mollusc farming in brackishwater areas currently provide important production for export (especially the culture of shrimp, *Penaeus monodon*).

B. *Freshwater aquaculture*

Freshwater fish farming in ponds and small lakes is a traditional family farming in Vietnam which is widely practiced at the national scale. The VAC (Garden-Ponds-Livestock) farming system, integrating gardening with fish culture and animal husbandry has been developed. This system promotes the development of aquaculture in ponds and small lakes. Although freshwater fish farming area accounts for only 10% of the total aquaculture area, the yield comprises 60% of total aquaculture production.

The main freshwater species cultured in North Vietnam are the grass carp (*Ctenopharyngodon idella*), silver carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), Nile tilapia (*Tilapia niloticus*), rohu (*Labeo rohita*), and mrigal (*Cirrhina mrigal*). Recently, the culture of special high-value species such as soft shell turtle (*Palea steindachneri*), swamp eel (*Fluta alba*) and frog (*Rana sp.*) has been disseminated widely in North Vietnam, while the farming of sand goby (*Oxyeleotris marmorratus*) and giant prawn (*Macrobrachium rosenbergii*) has been developed in the South.

Fish and prawn farming in low-lying rice fields are also practiced in various provinces. In 1998, the low-lying fields area used for shrimp and fish farming was about 154,200 ha or 24.6% of the total aquaculture area. The Mekong River Delta provinces and Red River Delta region are the main areas where fish and prawn culture are integrated with rice farming.

1. Farming methods

Alternate farming of prawn + rice or rice + Nile tilapia is practiced in the Mekong River Delta where the prawn productivity was 200-300 kg/ha/yr and rice output was around 506 mt/ha/yr. Moreover, integrating fish culture with rice or rice with giant prawn is also practiced in North Vietnam where the main fish species are the common carps (*Cyprinus carpio*), Nile tilapia (*Tilapia niloticus*), mud carps (*Cirrhina molitorella*), rohu (*Labeo rohita*), etc. On the other hand, the main species cultured in the South are the silver carp, snake head, kissing gourami, and giant prawn.

Fishes are also cultured in floating cages in rivers and water reservoirs. According to the 1998 statistics, Vietnam has about 16,000 freshwater floating cages of which about 12,000 cages are installed in rivers. There are also industrial aquaculture models in large surface water areas such as in lakes and reservoirs with productivity of around 60-100 kg/ha/m^3. In the Southern provinces, the main species cultured are yellow catfish, sand goby and snakehead. Yellow catfish (*Panggasius* spp.), a high-value fish for export, is exclusively cultured in the Mekong River Delta, particularly in An Giang province where floating cage culture has been practiced for years. The cages are of varying sizes, between 100 to 150 m^3/cage. In the Northern and Central provinces, the dominant species are grass carps and common carps which are cultured in small-sized cages, about 20-30 m^3/cage. Grass carp cage culture is practiced in rivers and water reservoirs, near water inlets or outlets where water exchange in the cages is good.

In 1998, about 335,890 ha of freshwater area was used for inland freshwater aquaculture, and the total freshwater fish production was estimated at 359,000 mt (Table 3) or about 68% of total aquaculture production. Of this total, 70% were grass carps, common carps, and rohu. The Ministry of Fisheries (MoF) in 1998 estimated around 353 freshwater hatcheries in Vietnam, producing more than 6 billion fish fry/year, sufficient enough to supply the demand from freshwater aquaculture.

C. *Coastal aquaculture*

1. Production systems

Coastal aquaculture in ponds uses more than 2 ha to over 100 ha, where most of the large ponds are in intertidal areas and are used for intensive culture. Whether small or large area, each pond has only one or two gates for tidal water exchange, entry for seeds, and water level adjustment. On the other hand, aquaculture in estuaries and tidal flats is also practiced by fishermen using fish-nets or bamboo fence to round up the tidal flats for the culture of mollusc species such as clam, blood cockle, and ark shell.

Fish and mollusc cage culture in coastal areas is a relatively new activity in Vietnam. Fish cages are installed mainly in estuaries and bays where there is least impact by strong winds. Each cage is from 27 m^3 (3m x 3m x 3m) to 64 m^3 (4m x 4m x 4m), of which 6-8 cages are combined in one raft. The cages however, can be separated and moved to a safer place during the onset of typhoons.

2. Culture species

Table 6 lists the main species cultured, the culture methods and the scale of operation. The most important species cultured in marine waters are groupers (*Epinephelus* spp.), amberjack (*Seriola* spp), black kingfish (*Rachycentron canadum*), yellow ringspiny lobsters (*Panulirus ornatus),* and pearl oyster (*Pteria martensii*). Up to now, Vietnam produces only pearl oyster seeds, while marine aquaculture in general is still entirely dependent on the juveniles caught from the wild.

For brackishwater aquaculture, the dominant species are tiger shrimps (*Penaeus monodon*), white prawn (*P. merguiensis*), greasy-black shrimp (*Metapenaeus ensis*), serrated mud crab (*Scylla serrata*), clam (*Meretrix* spp.), and seaweeds (*Gracilaria* spp.). At present, only shrimp and seaweed seeds are produced in the hatcheries, but for some other species, culture is still dependent on juveniles caught from the wild.

3. Shrimp farming in brackishwater ponds

Shrimp culture is the most important industry in the coastal zones of Vietnam. Although shrimp extensive farming was recently started, it became one of the most important aquaculture practices in the early 80s in terms of area under culture, production, employment, and export volume. In 1998, shrimp farming in littoral area used about 255,000 ha or 39% of the estimated potential area in coastal zone with a production of around 80,000 mt. In Minh Hai province, shrimp farming area accounted for 50% of the total national shrimp culture area (Table 2 and Figure 3). Today, there are 1358 shrimp hatcheries in Vietnam, mostly located in the Central provinces with an annual production of about 2.5 billion PL_{15}. In general, the shrimp culture methods used are the extensive and intensive systems, utilizing small areas but low in productivity. According to the statistics of the coastal provinces, in 1998 the area for semi-intensive and intensive culture was around 30,000 - 40,000 ha.

a. Traditional extensive culture

(i) Suitable pond sites

Ponds are usually constructed in the middle zone of the tidal areas where water can be changed easily by tidal movements. The ponds are near the river mouths, mangrove areas and canals where there is abundant supply of shrimp seeds and natural food. The sites usually have favorable salinity (≥ 5% in rainy season), clean water source and far from inland pollution, and the pond bottom soil is sandy-muddy.

(ii) Pond construction

Ponds are large with areas ranging from > 2.0 ha or 10-30 ha or even up to 100 ha or more. Each pond has one or two gates (the width of gates depends on the pond area) for water exchange, seed supply entry and water level adjustment. Canal systems in the ponds help water exchange, especially since the ponds are located outside the National Dike system. The pond edges are built strong enough to protect the ponds from typhoons and floods.

(iii) Management

Water exchange rely on the tidal movement and the natural seeds, food and nutrients that enter the ponds with the incoming water. Culture is for 9-10 months in the north or two months in the Mekong River Delta region (Minh Hai province). In some areas, farmers stock tiger shrimp seeds at 0.2-0.4 pc PL_{45}/m^2) in extensive ponds. Since natural food is available in the ponds, supplementary food is no longer introduced.

(iv) Harvesting

Harvesting is usually done before the onset of the new moon, because it is believed that at this time the shrimps' carapace is hard. Farmers use bamboo fish-traps to harvest the shrimps and the ponds are later dried to gather extra fishes, crabs, and seaweeds.

In 1980s, mangrove areas were converted into extensive shrimp ponds in the coastal provinces, particularly in Mekong River Delta. The model introduced is known as the shrimp-cum-forest which however, negatively affected the environment and the mangrove ecosystems. Although the productivity from such model was stable, it is largely dependent on the site of the ponds, the availability of wild shrimp seeds and the efficient water exchange in the ponds. The average production recorded was 70-250 kg/ha/yr, the maximum of which was 400 kg/ha/yr attained by some farms in Minh Hai province.

b) Improved extensive culture

This model is usually carried out in ponds about 2-10 ha and protected from predators. The farmers add more shrimps into extensive culture shrimp ponds at 1-3 pc/m^2 (2-3 cm/pc). Therefore, there are two shrimp seed sources used, from natural source and from the hatcheries.

After stocking the seeds in the large ponds, artificial food is given on the first month. During the second month, minced molluscs, trash fish, small shrimps or artificial food are given in the areas where shrimps are seen to be dense. Water in the ponds is changed more often to avail of the nutrients supply from nature. When changing water through the gates, nets and bamboo traps are installed near the gates to avoid shrimps from getting out from the ponds and to prevent predators from coming into the ponds.

The survival rate in this system is 30-60% for a culture period of 3-5 months depending on the cultured species and the natural conditions. Shrimps are harvested using bamboo traps installed in the ponds. Productivity is about 50-400 kg/ha/yr but in the Mekong River Delta, productivity has been at 500 kg/ha/yr or more. This model is now rapidly transferred to the other coastal provinces.

c) Semi-intensive culture

(i) Site selection and pond construction

Ponds may be rectangular or square, with an area of 0.5-1.0 ha. The pond bottom is flat with 0.5% drainage gates. The depth is from 1.0 to 1.4 m. In areas near river mouths, the ponds are surrounded with mud. The pond bottom is mud-sand or sand-clay and salinity is 25‰ (not lower than 5‰ during the rainy season). Seawater change is by high tide and freshwater is supplied using water pumps.

The procedure for shrimp semi-intensive culture follows:

Pond preparation ➡ Stocking of seeds ➡ Management ➡ Harvesting

(ii) Pond preparation

This includes killing the predators, draining dry the pond bottom (for 5-7 days), liming (1000-2000 kg/ha), and applying inorganic fertilizer (Urea: 20-25 kg/ha and phosphate: 10-15 kg/ha).

(iii) Management

Shrimps are fed twice a day, once in the morning and afternoon. Food may consist of minced mollusc, trash fish, small shrimps or artificial food, and rice bran. Quantity of food for each stage of shrimp in the culture pond are calculated as follows:

Stages of culture shrimp	Survival rate	Rate (%) of quantity of food based on total biomass of shrimp in the culture ponds
From PL_{15} to 5 g/pc	Estimate at 90%	30%
From 6-10 g/pc	Estimated at 80%	20%
From 11-15 g/pc	Recalculated	10%
From 16-20g/pc	Recalculated	7%
From 21g/pc or more	Recalculated	4-5%

The food in feeding trays should be regularly monitored to regulate the feeding regime for the succeeding days. From the third month, shrimp should be fed four times/day: at 6, 11,17 and 21 Hr. Water change must take advantage of high tide, changing at least 200% of the water volume of the pond during each tidal cycle. In areas where water pumps are used, water should be supplied opposite the drainage gates. During heavy rains, the surface layer of the pond water should be changed. The culture duration is three months for *P. merguiensis* and 4-5 months for *P monodon*.

(iv) Harvesting

This is done before the onset of the new moon because it is believed that at that time the carapace of the shrimps is hard. Harvesting may make use of bamboo traps within 3-4 days before drying the pond for total harvesting. The shrimp productivity in the North is from 700-1000 kg/ha/crop, in the South (Mekong River Delta) from 1500-2000 kg/ha/crop. The North is characterized by seasonal variation in temperature which allow only one or two crops/yr. In the first season, tiger shrimp (*Penaeus monodon*) is cultured from April to August. During the next season, white prawn or taisho prawn is cultured from September to November and from February to May.

The South has favorable conditions throughout the year where 2 to 3 cropping can be made. However, in poorly planned ponds, the use of waste water which is supplied to other ponds and raw food as feed, could cause pollution and diseases outbreak. This has very serious consequence to aquaculture.

d) Shrimp semi-intensive in closed systems

In order to prevent environmental pollution and the spread of diseases, the Research Institute of Marine Products developed new techniques of shrimp culture in closed system, where water is processed before this is supplied to the ponds. This model was found to be effective especially in the coastal provinces where shrimp culture is practiced.

In the semi-intensive closed system, the waste water of the shrimp ponds is poured into the mollusc or seaweed culture ponds (biological treatment) and after some time released to sediment ponds for chemical treatment. The water in the treatment ponds is used to fill up the shrimp ponds. The area for seaweeds culture and water treatment is about 50-80% of the shrimp culture pond area (Fig 4). For this system, artificial feeds should be used.

Results from this model showed that the shrimp productivity was from 1,500 2,000 kg/ha/crop in the north and 2,000-3,000 kg/ha/crop in the south. This model eliminates environmental changes and the spread of diseases

e) Intensive culture

Intensive culture requires high technical management, high investment for seeds and artificial food, pumping, and aeration. This model has been experimented by VATECH in Da Nang City in 1989 and in Thai Binh province in 1994 by a Taiwan company. The results from their projects were not stable, although the maximum yield was 4 /ha/crop in some ponds. Since the model was found not effective, both companies stopped their operations.

f) Integrated culture

This is an improved model in large ponds, from 2 to 10 ha. In addition to the number of shrimps and fish caught from the wild through the gates, farmers add tiger shrimp seeds at 02-0.5 pc/m^2 (3-4 cm/pc), crabs at 0.1-0.2 pc/m^2 (20-25 g/pc), and *Gracilaria asiatica* at 0.2 kg/m^2. In some ponds, supplemental food is added such as trash fish and small shrimps. The main food is the nutrients available in the ponds. Shrimp productivity is from 150-200 kg/ha/crop (including natural seed and stocked seeds); crabs: 100-150 kg/ha/yr; *Gracilaria asiatica*: 800-1000 dry kg/ha/yr; and fishes. Other combination adopted is integrating the culture of tiger shrimp, Nile tilapia and *Gracilaria asiatica,* a common practice in the North.

4. Crab semi-intensive culture in ponds

a. Pond construction

Ponds for crab culture, 1000-10,000 m^2 are built like the shrimp ponds but the dike's crown is fenced to prevent the crabs from escaping.

b. Stocking

Crablets are collected from the wild and stocked at 0.5-1.0 pc/m^2 or 2-3 pc/m^2 (40-50g/pc) depending on the culture season. In the North, crabs can be cultured in two seasons, the first season is from March to August while the second is from October to February. In the South, crabs are cultured all year round, but the main season is from October to February.

c. Feeding

Food for the cultured crabs are small bivalves, snails, and trash fish. The quantity of food given daily is 7-10% of the total biomass of the crabs in the ponds (if the food consists of small shrimp or trash fish) and up to 30% (for molluscs). The food is broadcast all over the pond twice a day, once in the morning and late in the afternoon.

d. Management

The quality of water in the ponds should be regularly monitored. In the rainy season if the pH decreases, lime is spread on the pond dikes at 5-10 kg/m^2. Water should be changed as often as possible.

e. Culture duration

The culture duration depends on the size of the crablets, feeding regime and culture models. If stocking is 40-500 g/pc crablets, the crabs can be harvested after 4-5 months. If the crablets intended for semi-intensive culture are smaller, the pond area can be used for extensive or improved extensive culture combined with tiger shrimp.

5. Seaweeds culture

Gracilaria culture in ponds has rapidly developed in the Northern and Central coastal provinces, particularly, from Hai Phong City to Thanh Hoa and Thua Thien Hue province. According to some algologists, 13 species of Rhodophyta are identified in the coastal zones of Vietnam, of which three are of economic value, namely, *Gracilaria asiatica, G. blodgetti* (cultured mainly in the North) and *G. tenuistipitata* (in Central) which are used to produce agar. About 3000-3500 ha of brackishwater ponds is used for *Gracilaria* spp. culture with an annual production of about 2000 dry tons/yr. *Gracilaria asiatica* is cultured in brackishwater using two models: improved extensive culture combined with brackishwater shrimp, crab and fish culture in large ponds, 2-10 ha or more producing about 500-1000 kg/ha/yr; and intensive culture in small ponds, 0.5-2.0 ha. The culture system includes many small ponds having main canal systems and separate water supply, and drainage systems which guarantee maximum water change.

In pond preparation, all harmful seaweeds and tree roots are taken out, and a layer of soft mud on the pond bottom is formed. Lime is spread on the pond bottom (2-3 mt/ha) fertilized with organic manure (8-10 mt/ha) and phosphate fertilizers (0.8-1 mt/ha). Stocking density is 500 - 600 g/m^2, spread carefully over the pond bottom. The water depth is kept at 35-40 cm in winter and 40-50 cm in summer. After 35-35 days, the stock is harvested leaving some 500-600 g/m^2. After every harvesting, supplemental fertilizers are added using the following scheme: organic manure (3-4 mt/ha) or inorganic manure (Urea: 20-30 kg/ha and phosphate: 10-15 kg/ha). Using this system, production has been recorded to increase by 2-4 mt/ha/yr.

On the other hand, from 1993, Vietnam started to develop *Eucheuma* culture in the Central coastal zone. The main species cultured are: *Kappaphycus alvarezii, Eucheuma gelatinae* and *E. denticulatus,* using either fixed culture method on mono line near sea bottom; floating frame culture method; or bottom culture in calm bays or pond with high salinity.

6. Mollusc in estuaries and tidal flats

In recent years, *Meretrix* spp. and *Arca* culture have rapidly developed in the northern and southern provinces. Fishermen use fish nets or bamboo fence to round up the sheltered areas in the estuaries or tidal flats where the ground bottom is flat, to culture *Meretrix* spp. and *Arca.* The area of each farm is about 1.0 ha. *Meretrix* and *Arca* spat are collected from the wild with a diameter of about 0.5 cm or more. The spat is spread equally at 2000-3000 pc/m^2. The bottom of the cockle culture ground should be flat, muddy and sandy; the depth at high tide 2-3 m. On the other hand, *Meretrix* spp. ground culture areas are near the estuaries with a salinity range of 10-25‰, while *Arca* culture ground have higher salinity at 20-30‰.

The natural food for the *Meretrix* spp. and *Arca* is phytoplankton and after 4-6 months of culture, partial harvesting may be done followed by total harvesting. The productivity from this method is over 10 mt/ha/crop. Vietnam's total production of *Meretrix* and *Arca* in 1998 was about 115,00-120,000 mt.

7. Pearl oyster cage culture

In Vietnam, pearl oyster is cultured in coastlines to produce pearl. All over the country, 21 companies mainly located in Quang Ninh and Khanh Hoa province, are engaged in this industry. In the North, *Pteria martensii* is the dominant species while in Central Vietnam, *Pinctada maxima* is cultured. The pearl oyster seeds are produced in hatcheries and at the same time spat are also collected from the wild.

Raft culture is a typical method used in pearl oyster farming in sheltered bays. The pearl oyster raft is about 30-50 m^2, with water depth of 4-6 m. Generally, pearl oyster farms are located in the calm bays or straits with clean water and high salinity (20-30‰). Pearl oyster cages are rectangular or square shaped (40x 60x 15 cm) or a frustum of a cone (bottom and upper diameter: 30 and 25 cm; height: 15 cm). Each cage can contain 20-25 pc pearl oysters which are suspended from rafts or long line using synthetic ropes. In producing the pearl, a mantle piece from a donor oyster is grafted into the gonad of the recipient oyster, along with a spherical nucleus.

8. Marine cage culture

Marine fish cage culture in Vietnam has been developed in recent years. Based on the statistics in 1998, there was a total of 2,590 floating cages. Generally, cages are rectangular or cubic with volume from 8 to 75 m^3, cage size is 2 x 2 x 2 m or 3 x 3 x 3 m. Cage is made of synthetic net (mesh size: 2a=1 cm) and tied to wood frame with a buoy system as floats. The shape of the cage bottom is fixed by a square frame. The position of the cage bottom is at least 1.0 m from the sea bottom. The size of cage for commercial culture is 3 x 3 x 3 m or 4 x 4 x 4m (mesh size: 2a=3 cm), water current: 0.2-0.5 m/s, and salinity at 18-35‰.

The main species cultured are grouper (*Epinephelus* spp.), snapper (*Lutjanus* spp.), black kingfish (*Rachycentron canadum*), seabream (*Sparus latus*), yellow ringspiny lobster (*Panulirus* spp.). However, seed supply is still dependent from the wild. Fingerlings (50 g/pc) are stocked at 40-60 pc/m^3. Minced trash fish is given twice a day (morning and afternoon) at about 10% of the weight of cultured fish. After 2-3 months of culture, the weight of fish should be more than 150 g/pc.

Grouper fry, 150-180 g/pc is stocked in cages at 20-25 pc/m^3. The main food is trash fish and minced mollusc, feed once a day at 1700 Hr at 5% of the weight of the cultured fish. Culture facilities are checked and cleaned regularly to avoid the accumulation of harmful organisms. Harvest can be done after 5-8 months when the weight of the fish reaches 600-1500 g/pc.

III. Consequence of Shrimp Extensive Ponds to the Mangrove Ecosystem

Before 1990, the conversion of mangroves to shrimp extensive ponds took place only in the coastal provinces, particularly in the Red River Delta and the Mekong River Delta. This activity had caused serious problems to the natural resources and the environment.

A. *Reduction of biodiversity resources*

Resource reduction has taken place mainly in extensive ponds because of the deforestation and conversion of mangroves to large shrimp pond areas. Due to the absence of gates, the water in the ponds could not be easily changed making the environment heavily polluted and reducing the number of species in the ponds. Researchers P.N. Hong and L.D. An (1992) showed that the quantity of phytoplankton and benthos, used as food by shrimps, had also reduced relatively two years after the construction of shrimp ponds specifically in the western derelict land of Ca Mau. This has been brought about by the rapid growth of *Oscillatoria* and when the plant dies covering the pond bottom., this is accumulated as H_2S and NH_4 through some chemical processes, which are toxic to the cultured species. Research results of the Research Institute of Aquaculture II showed that the degradation of the environment and the reduction of organisms content, are common in shrimp ponds in Ben Tre province.

B. *Increase in the area of barren land*

Deforestation and conversion of mangroves to shrimp ponds or agricultural production farms led to the increased area of waste and barren land. Shrimp extensive ponds may be profitable in the early years but afterwards the productivity may decrease and make the area less productive. Moreover, large ponds are difficult to manage especially the change of water by tide, thus, in many cases, the environment becomes deteriorated. According to the statistics of Minh Hai Forestry Department, from 1993 about 86,037 ha of mangroves was destroyed of which 20,000 ha was converted to farms for agriculture production. Due to shortage of freshwater, the land has degraded and become unusable for farming, an example of a barren waste land.

C. *Speed up siltation and erosion*

Mangroves act as fence protecting the coastal dike systems. Due to the destruction of mangroves, typhoons and big waves had caused erosion and flood over a vast areas. This is a critical problem for many provinces, including those in the coastal areas such as Nam Dinh, Tra Vinh Tre and Tien Giang province.

D. *Land and water pollution*

Due to the large area of the ponds which makes it difficult to change water, H_2S and NH_3 contents derived from tree leaves, roots, and other poisoning matters, also increased. The ratio of Fe_2O_3/FeO also increases as well as the SO_4^{2-} content, due to the drying of the pond and oxidization (N.V. Cu, 1990). This can be expressed using the following reaction:

$$FeS_2 + O_2 + H_2O \rightarrow Fe^{2} + SO_4^{2-} + H^{+} + OH^{-2} \text{ or}$$

$$Fe^{2} + SO_4^{2-} + O_2 + H_2O + K^{+} \rightarrow KFe_3(SO_4)_2(OH)_6 + H^{+} + SO_4^{2-}$$

As a result, the once natural and nutrient laden land becomes a sulfate waste land, which is not suitable for the culture of aquatic species.

E. *Spread of diseases*

In some culture ponds, water could be affected with diseases due to microorganisms and fungi. It should be noted that the shrimp diseases outbreak in recent years have not been completely solved. Measures to prevent diseases were not applied thoroughly, thus, adversely affecting the productivity. Diseases had spread widely in shrimp extensive culture ponds in Ho Chi Minh City, Ben Tre and Minh Hai province, posing danger to the other pond areas in the country.

IV. Mangrove-Friendly Aquaculture

Mangrove-friendly aquaculture is an integrated mangrove tree culture with aquaculture. It is an approach of conserving and utilizing the mangrove ecosystem, while maintaining the economic benefits. Over the past ten years, many aquaculture models under silvo-fisheries received financial support from various sources, in order to protect the mangrove forests. In this report, some models applied in Vietnam, are briefly introduced for reference.

A. *Mangrove-friendly aquaculture models*

1. Mollusc culture

Carithides eingulata culture started in 1995 using a simple culture technique where mangrove area of about several thousands m^2 is fenced and stocked with hundreds of the mollusc seeds. After 4-6 months without feeding, when the weight of the stock is more than three times the stocking weight, the molluscs are harvested.

Cockle and clam culture is done in flat ground bottom which is muddy and sandy near the mangroves. The culture is simple but could give high benefits. Cockle and *Meretrix* culture are now developing rapidly in the Mekong River Delta provinces and the Red River Delta region.

2. Crab cage culture (*Scylla serrata*)

A model developed in 1990 involves cages made of bamboo or wooden frames 1.2m x 2m x 5m, with buoys all around to make the cages float, making sure that about 4/5 of the cage is under water. The stocking rate is 40-50 pc/m^3 and fresh food consisting of trash fish and small shrimps, is given. After 20-25 days, the stocks may be harvested.

3. Yellow ringspiny lobster (*Panulirus ornatus*) cage culture

This model adopted in Can Gio (Ho Chi Minh City), is similar to the crab cage culture with stocking density of 50 pc/cage and food is dependent on the sea organisms. The lobsters are cultured from July to February in cages which are mainly located at the edge of the mangroves near the sea.

4. Greasy grouper (*Epinephelus tauvina*) culture in ponds

Groupers are cultured in small ponds with an average area of 200 m^2 and stocked with 30-40 pc/pond. When the weight is about 200-300 g/pc, fresh food such as trash fish and small shrimps are given. After 5-6 culture months, the fish weighing about 600-700 g/pc, are harvested.

5. Shrimp (*P. monodon*) culture in ponds

Shrimp is cultured in small ponds, from 500 to 2000 m^2 at 5 pc/m^2. In the Mekong River Delta, shrimp can be cultured in two crops per year. Average productivity is 800-1200 kg/ha/crop. This is the shrimp culture model under the mangrove forests, which if properly planned will not affect the mangroves.

Aquaculture under mangrove forests is unavoidable, but the established aqua-silvi-culture principles must be followed. The need for proper techniques in seed production for each species and proper planning of the mangrove areas, should therefore be considered.

B. *Silvo-fisheries model*

1. Culture ponds consisting of mangroves

Many regions in the Mekong River Delta, such as Ngoc Hien, Minh Hai and some areas in Ben Tre province invested in silvo-fisheries specifically in *Rhizophora apiculata* and *Bruguiera* spp. forests. A model has been developed to control water and ensure the natural condition of the mangrove areas using gates and canal systems. Gates were constructed in such as way that during the high tide there is enough water for the mangroves and at the lowest tide, water level must be 50 cm in the canal system. It is necessary that a separate water supply and drainage systems be provided (Figure 5 and Figure 6). The ratio of culture pond and mangrove area is 1:4 and in any case, the farming pond area should not be over 30% while the mangrove area is 70%. The main culture species of this model is tiger shrimp (*Penaeus monodon*) and white prawn (*P. merguiensis*), using the improved extensive culture system.

2. Mangroves including culture pond

A model of a 10 ha mangrove including a culture pond which can be managed by a family, makes use of a suitable area where small-scale shrimp ponds and seaweed culture farms (Fig 7) can be constructed. The total farm area is 10 ha to be managed by one family, which can be divided into shrimp culture pond, 4 or 2 ponds = 2 ha; seaweed and fish culture pond combine with waste water treatment pond 7000 m^2; water treatment pond 3000 m^2; and mangrove area with crab culture by net or cage 7 ha. This model could also be adopted in the culture of shrimp in closed-system in mangrove areas with a ratio of 3:7 ha culture area to mangrove area. Tiger shrimp is stocked at 10-12 pc/m^2 (3-4 cm/pc). After four culture months (in the North from March to July), shrimp production is from 1000 to 1500 kg/ha/crop and *Gracilaria* production is 2500-3000 dry kg/ha/year. Additional produce may consist of fishes, crabs and molluscs.

3. Shrimp culture in closed-system in high tide areas

To ensure the existence and maintain a renewable mangrove ecosystem, and prevent environment pollution and the spread of shrimp diseases, this model has been adopted in high tide areas near mangroves or in the National Dike system. The total area utilized is 2.0 ha, 1.0 ha of which is for shrimp culture pond, 0.5 ha for *Gracilaria* spp. culture, and 0.3 ha. to 0.5 ha for water treatment (Fig. 8).

The depth of shrimp culture pond is 1.2 m, the main species stocked is tiger shrimp at 10-12 pc/m^2 (3-4 cm/pc), and cultured for four months. In this model, shrimp production was about 1000-1500 kg/ha/season while *Gracilaria* production was 3000 dry kg/ha/yr. This model which was implemented at the Research Institute of Marine Products has been transferred to some coastal provinces in the North.

V. Aquaculture Development in Mangrove Areas

A. *Seed production*

Except for the shrimp seeds, other species seeds are caught from the wild, causing some difficulty for aquaculture development in mangrove areas. There is therefore a need to carry out a study on artificial seed production of marine fishes (e.g. groupers, sea bass, seabream), crabs and molluscs (*Meretrix, Arca*). Moreover, there is also a need to improve the quality of shrimp seeds for culture. The State is also encouraged to grant some capital through loans to help improve the techniques in seed production for aquaculture development and management at the national or local level.

B. *Improved culture techniques in mangroves*

Mangrove environment has some advantages and disadvantages for shrimp culture. In order to get high productivity, suitable sites for ponds should be targeted where change of water volume by tidal movement is possible. Farmers must be provided with capital and taught the proper techniques to convert the areas once used for extensive culture into improved extensive and semi-extensive culture areas.

A separate water supply canal and drainage system must be constructed to minimize pollution. The shrimp culture pond system should also have a water storage pond while siltation and treatment ponds should form part of the waste treatment system. Moreover, crab and fish cage culture can also be located in the canal systems of the mangrove area.

The ratio of aquaculture area to mangrove area must be kept at 1:3. Arrangement for technical training course on silvo-fisheries should be made for the fishermen. The training may be aimed at attaining high productivity, and at developing environmentally sound and sustainable aquaculture in mangrove areas.

C. *Socio-economic and population management in mangrove area*

Mangrove as a vital resource serves as sanctuary for fishes and other marine animals. However, mangroves have long been exploited by people from the localities and other places who deforest and convert mangroves to shrimp culture ponds. In many cases, the local people even give up their traditional jobs to do extensive shrimp farming. If this continues, the mangroves will also be continuously destroyed including the marine resources. Some solutions to the outstanding problems were therefore identified to include the following:

1. Equal policy of handing land, forest and surface water to farmers for culturing marine products in order to recover the mangroves;

2. Provision of capital and promotion of technical culture using silvo-fisheries model in small areas;

3. Establishment of an education program on mangroves and mangrove resources protection in schools; and

4. Improving the methods of population control and community management plan to formulate suitable socio-economic models.

Table 1. Estimated aquaculture resources in Vietnam (in ha)

STT	Regional Resources	Esti. Potential (EP)	Esti. usable Areas	Estimated area exploited		
		(ha)	(ha)	1985	1994	1998
	North Mount/Midland					
1	Freshwater area	149,626	116,250	50,200	55,620	59,088
	Brackishwater area	28,000	20,135	2,500	12,055	12,565
	Total	165,624	136,380	52,700	67,675	71,653
	Red River Delta					
2	Freshwater area	83,062	77,866	42,700	51,229	52,977
	Brackishwater area	72,652	43,420	4,200	11,218	18,115
	Total	155,714	121,286	46,900	62,447	71,092
	North and South central coast					
3	Freshwater area	123,000	54,607	24,500	28,839	33,079
	Brackishwater area	70,430	55,632	8,100	19,972	21,481
	Total	193,430	110,234	32,600	48,811	54,560
	Central Highlands					
4	Freshwater area	85,000	38,000	2,500	4,235	9,612
	Total	85,000	38,000	2,500	4,235	9,612
	South-East Area					
5	Freshwater areas	105,565	60,500	25,000	53,880	40,145
	Brackishwater area	28,510	13,230	3,500	7,593	5,455
	Total	134,075	73,730	28,500	61,473	45,600
	Mekong River Delta					
6	Freshwater area	504,000	270,000	139,600	63,613	142,989
	Brackishwater area	460,410	282,000	48,700	237,739	232,824
	Total	964,410	552,000	188,300	301,352	373,813
	Total					
	Freshwater area	1,041,253	617,223	284,500	257,416	335,890
	Brackishwater area	660,002	414,417	67,000	288,577	290,440
	Grand Total	**1,700,178**	**1,031,630**	**351,500**	**545,993**	**626,330**

Table 2. Potential and status of freshwater, brackishwater and marine area for aquaculture (As of 1998)

Regions	Freshwater												Brackishwater and marine area		
	Total Freshwater area			Small ponds and lakes			Water Reservoirs			Low-Lying fields			Coastal areas, Bays, Lagoons		
	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)	Potential (ha)	Esti. usable (ha)	Exploited area (ha)
North mount. Midland	149,626	116,250	59,088	30,000	30,000	18,000	80,315	65,482	30,825	31,314	20,765	10,236	28,000	20,135	12,565
Red River Delta	83,062	77,866	52,977	42,000	42,000	32,897	15,631	15,631	9,740	25,431	20,235	10,340	72,652	43,420	18,115
North and South Central Coast	123,000	54,607	33,079	13,000	10,000	9,765	110,000	42,107	21,235	7,000	2,500	2,079	70,430	55,632	21,481
Central Highlands	85,000	38,000	9,612	5,000	3,000	1,210	70,000	35,000	8,402	—	—	—	—	—	—
South-East Area	105,565	60,500	40,145	10,000	8,000	4,850	65,000	40,000	28,540	32,000	12,500	6,755	28,510	13,230	5,455
Mekong River Delta	504,000	270,000	192,989	20,000	20,000	15,974	—	—	208	484,225	250,000	124,837	460,410	282,000	232,824
Grand Total	1,041,253	617,223	335,890	120,000	113,000	82,696	340,946	198,220	98,977	579,970	306,000	154,217	660,002	414,417	290,440

Table 3. Main results of aquaculture, Vietnam (1995-1998)

Order	Items	Units	Annual Results				Note
			1995	1996	1997	1998	
I	Aquaculture areas	Ha	597,000	600,000	606,000	626,330	
1	Freshwater area		380,000	370,000	346,000	335,890	
2	Brackishwater area		217,000	270,000	270,000	290,440	
II	Aquatic Productivities	Ton	459,950	411,000	509,000	537,870	
1	Freshwater productivities		370,128	348,649	342,622	359,000	
2	Brackishwater productivities		89,820	92,351	166,378	178,870	
III	Export	Million USD	200	250	300	400	
IV	Employment	Person	422,500	457,634	500,000	550,000	

Table 4. Total aquaculture production (Unit: mt)				
	1986	**1990**	**1994**	**1998**
North Mount./Midland				
Total	14,336	20,919	24,115	32,375
% of Grand Total	6.16	6.95	6.08	6.04
Red River Delta				
Total	31,090	37,810	44,200	69,242
% of Grand Total	13.21	12.57	11.15	12.92
North and South Central Coast				
Total	14,630	21,250	27,237	37,710
% of Grand Total	6.23	7.06	6.87	7.04
Central Highland				
Total	1,330	2,550	6,280	4,624
% of Grand Total	0.57	0.85	1.58	0.86
South-East Area				
Total	10,930	22,610	17,430	27,780
% of Grand Total	4.65	7.51	4.39	5.18
Mekong River Delta				
Total	162,520	195,711	277,057	364,139
% of Grand Total	69.21	65.04	69.90	67.96
Grand Total	**234,836**	**300,850**	**396,319**	**535,870**

Table 5. Main freshwater aquaculture species, Vietnam

Scientific Name	English Name	Vietnamese Name	Culture Method	Culture Volume
Anabas testudineus	Climbing perch	Ro dong	RF, NS	Low
Aristichthys nobilis	Bighead carp	Me hoa	P, R, HS	Low
Catla catla	Catla	Catla	P, HS	Low
Cirrhina mrigal	Mrigal	Mrigan	P, HS	High
Cirrhina molitorella	Mud carp	Troi ta	P,R, HS	Medium
Clarias macrocephalus	Walking catfish	Tre vang	P,T, NS, HS	Low
Clarias gariepinus	African catfish	Tre phi	T, HS	Low
Clarias hybris	Catfish hybrid	Tre vang lai	P.T. HS	Low
Ctenopharyngodon piceus	Grass carp	Tram co	P, R, FC, HS	High
Cyprinus carpio	Common carp	Chep	P, HS	High
Helostoma tenmincki	Kissing gourami	Mui	P, HS	Low
Hipophthapleichth molitrix	Silver carp	Me trang	P, R, HS	High
Milopharyngodon piceus	Snail carp	Tram den	P, R, HS	Low
Labeo rohita	Rohu	Rohu, Troi an do	P, R, HS	Low
Leptobarbus hoeveni	Slender carp	Chai	P, RF, NS	Low
Fluta alba	Swamp eel	Luon dong	T, NS	Low
Notopterus notopterus	Featherback	That lat	RF, NS	Low
Ophiocephalus striatus	Snake head	Loc	P, RF, NS	Medium
Ophiocephalus micropeltes	Snake head	Loc bong	FC, NS	Medium
Oreochromis niloticus	Nile tilapia	Ro phi	P, RF, HS	High
Osphronemus gourami	Giant gourami	Tai tuong	FC, P, HS	Low
Oxyeleotris marmorratus	Sand goby	Bong tuong	FC, P, NS, HS	Medium
Panggasius bocourti	Yellow catfish	Basa	FC, NS, HS	High
Panggasius hypophthalmus	Catfish	Tra nuoi	P, NS, HS	High
Barbus gonionotus	Silver carp	Me vinh	P, FC, RF, HS	High
Puntius altus	Tinfoil carp	He vang	P,FC,RF,NS,HS	Low
Trichogaster pectoralis	Snakeskin gourami	Sac ran	RF, NS	Medium
Pelodiscus sinensis	Soft-shell turtle	Baba tron	T, P, NS	Low
Palea steindachneri	Soft-shell turtle	Ba ba gai	T, P, NS	Low
Rana spp	Frog	Ech dong	T,P, NS	Low
Macrobranchium rosenbergii	Giant prawn	Tom cang xanh	P, RF, NS, HS	High

P: Pond; **RF**: Rice field; **T**: Tank; **FC**: Floating cages; **R**: Reservoirs; **NS**: Natural Seed; **HS**: Hatchery Seed

Table 6. Main marine and brackishwater aquaculture species in Vietnam

Scientific name	English Name	Vietnamese Name	Culture Method	Culture Volume
Marine aquaculture				
Epinephelus spp.	Grouper	Mu, Song	FC, NS	Low
Lutjanus spp.	Snapper	Hong	FC, NS	Low
Seriola sp.	Amberjack	Cam, Bo bien	FC, NS	Low
Rachycentron sp.	Crab eater	Bop, Gio	FC, NS, HS	Low
Hippocampus spp.	Sea horse	Ca ngua, Hai ma	T, P, NS,HS	Low
Pteria sp.	Pearl oyster	Trai ngoc	P, NS	Low
Haliotis sp.	Abalone	Bao ngu	Intertidal rock	Low
Holothuria sp.	Sea cucmber	Hai sam	Infra-littoral	Low
Panulirus sp.	Lobster	Tom hum	P, NS	Low
Brackishwater aquaculture				
Penaeus monodon	Tiger shrimp	Tom su	P, HS	High
Penaeus merguiensis	Banana shrimp	Tom bac the	P, NS, HS	Medium
Penaeus indicus	White shrimp	Tom the do duoi	P, NS	Low
Penaeus semisulcatus	Green shrimp	The ran	P, NS	Low
Penaeus japonicus	Kuruma shrimp	Tom he nhat	P, NS	Low
Penaeus orientalis	Taisho shrimp	Tom nuong	P, NS	Low
Metapenaeus bevicornis	Yellow shrimp	Bac nghe	P, NS	Low
Metapenaeus ensis	Endeavour	Dat, Rao	P, NS	Medium
Scylla serrata	Mud crab	Cua xanh, Cuabien	P, BC, NS	Medium
Pisoodonophis boro	Brackishwater eel	Lich su	BC, NS	Medium
Lates calcarifer	Sea bass	Chem, Vouc	P, FC, BC,NS	Low
Bostrichthys sinensis	Grobia	Ca bop	T, P, NS	Medium
Sparus latus	Sea bream	Ca trap	T, P, NS	Low
Siganus guttatus	Spine foot	Dia	FC, NS	Low
Arca granosa	Blood cockle	So huyet	Tidal flats, NS	Medium
Anadara antiquata	Ark shell	So long	Tidal flats, NS	Medium
Meretrix spp.	Clam	Ngao, Ngheu	Tidal flats, NS	High
Ostrea rivularis	Oyster	Hau cua song	Estuaries, NS	Medium
Artemia	Artemia	Artemia	SP	Medium
Gracilaria spp.	Seaweed	Rong cau chi vang	Lagoon, P, NS	Medium
Kappaphycus alvarezii	Seaweed	Rong sun	Bays, NS	Low

FC: Floating Cages; **T**: Tank; **BC**: Bottom Cages; **NS**: Natural Seed; **HS**: Hatchery Seed; **SP**: Salt Pan

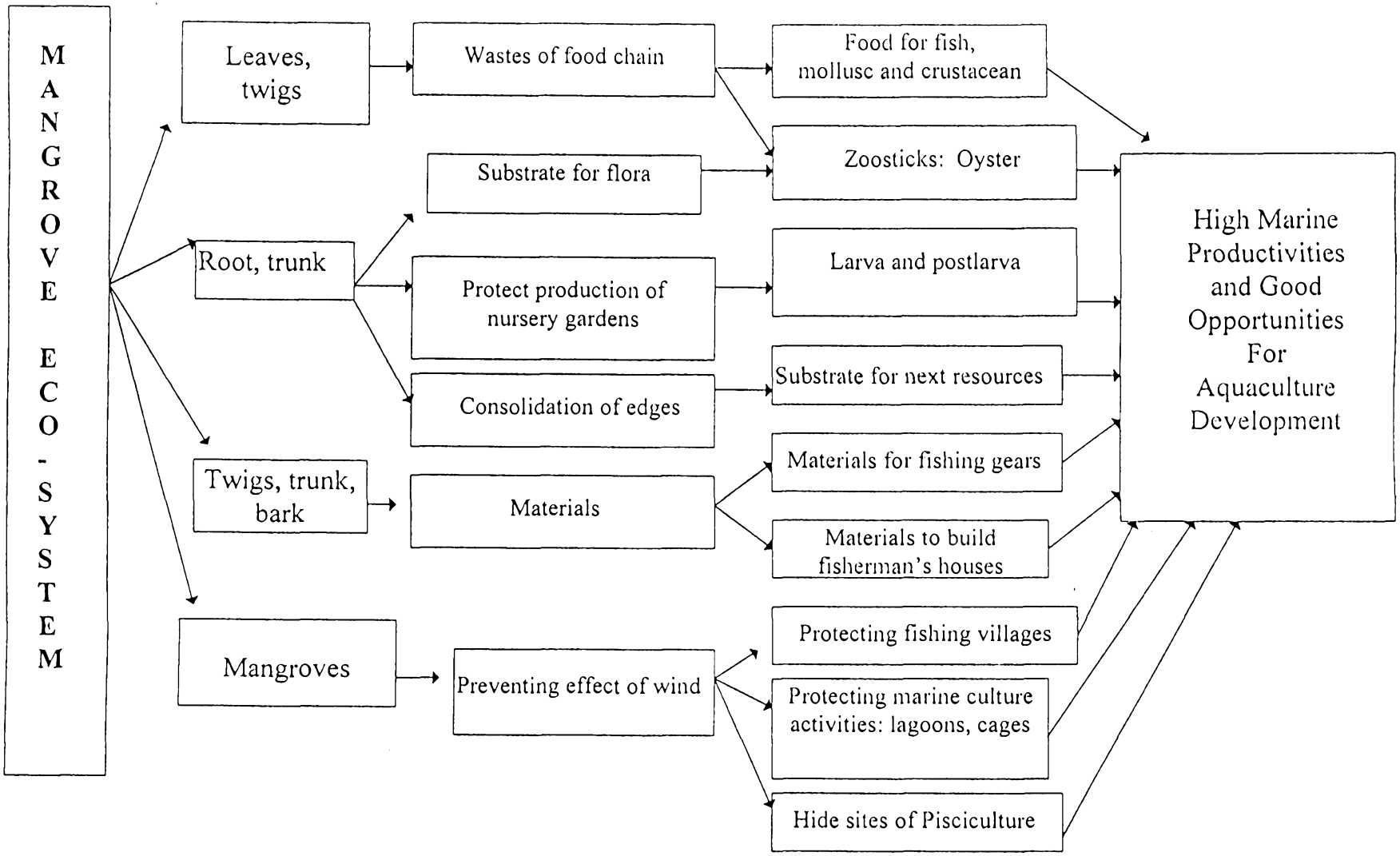

Fig 1: Functions of mangrove in relation to aquatic resources (Kapetsky, 1996)

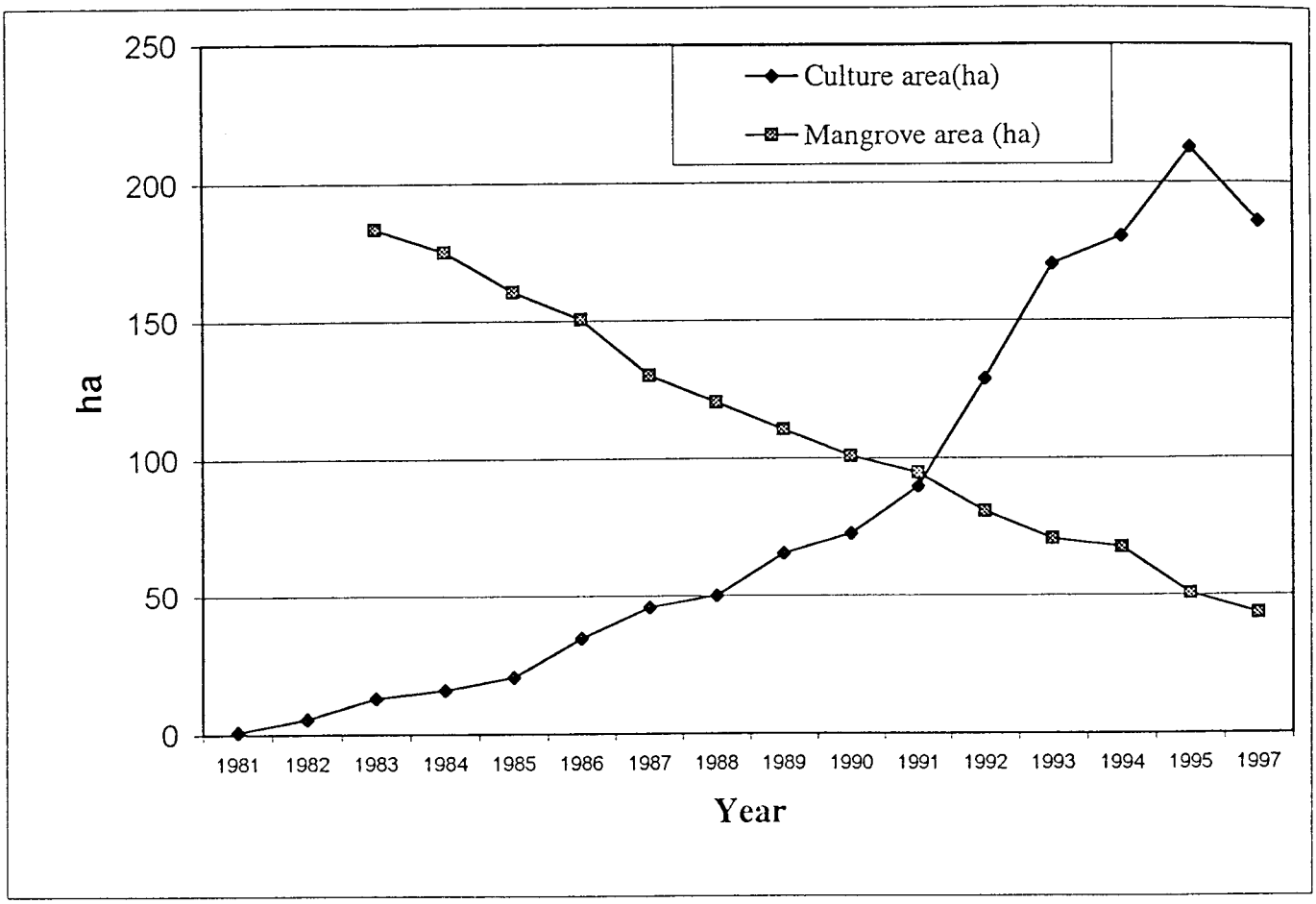

Fig 2. Interactive relationship between shrimp expansion and mangrove reduction (Mekong River Delta, in ha)

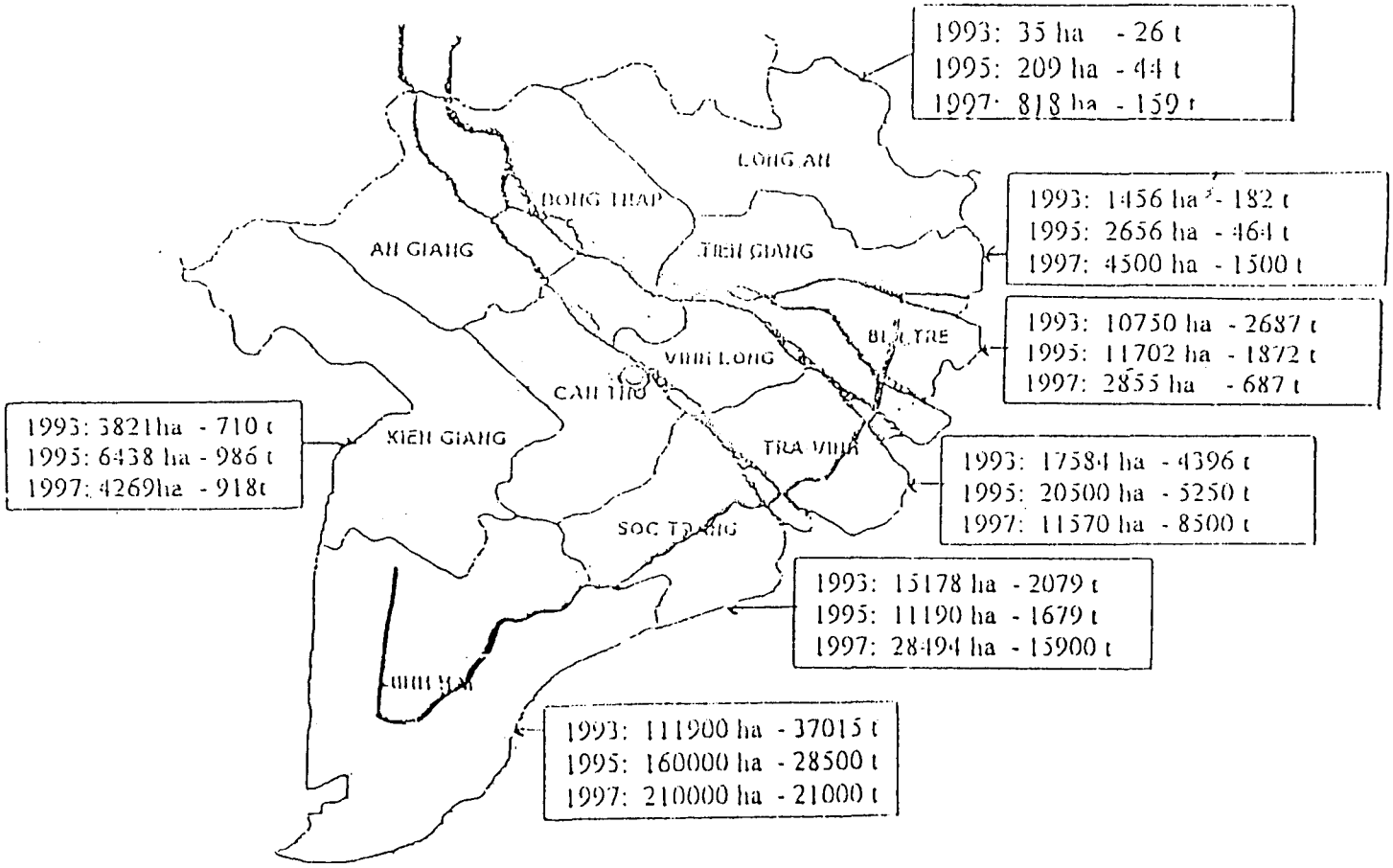

Fig 3. Evolution of shrimp farming in the Mekong River Delta, Vietnam (1993-1997)

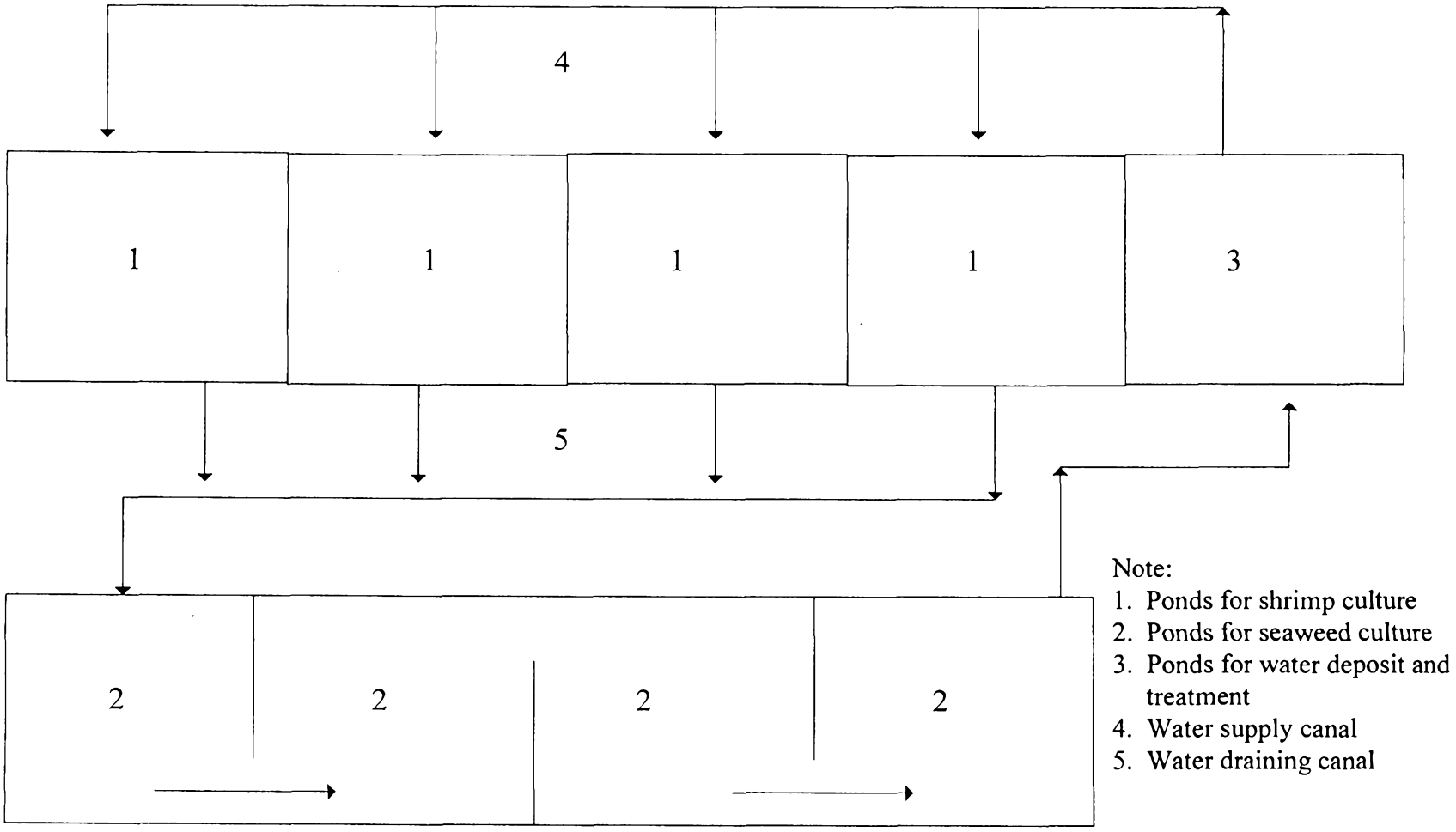

Fig 4. Model of shrimp culture ponds in a closed system

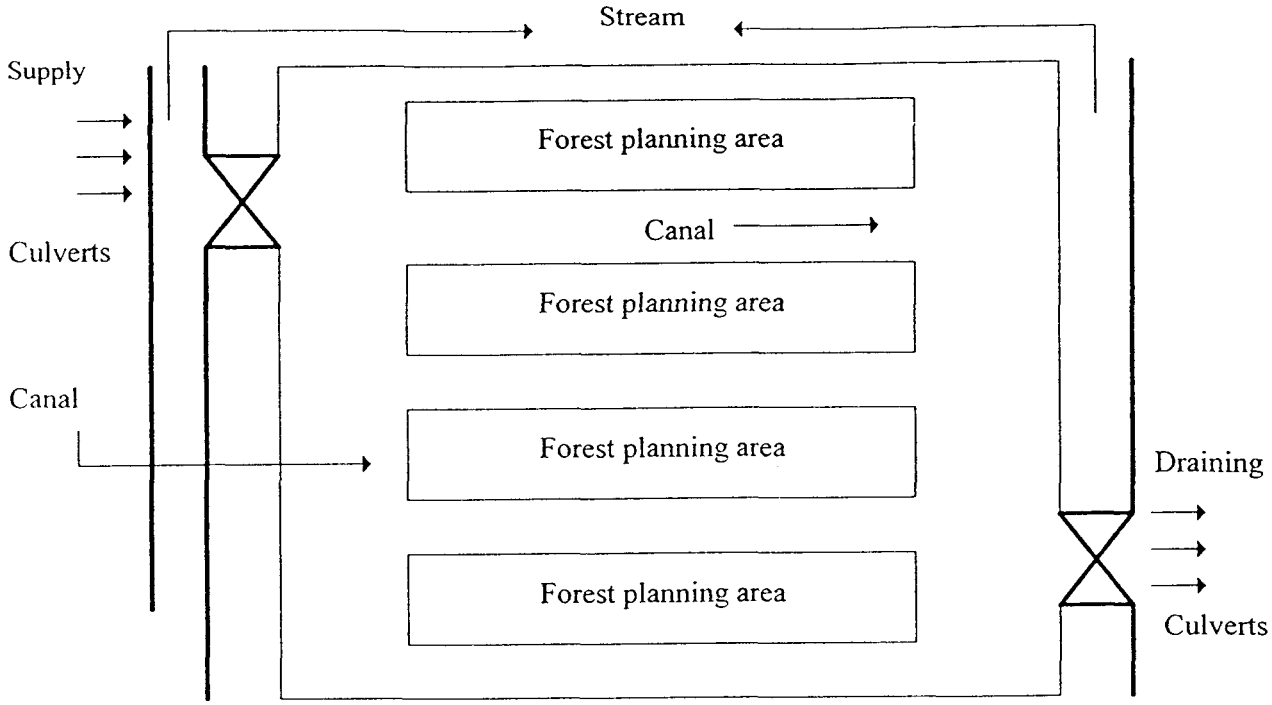

Fig 5. Model of a shrimp culture system with canals for shrimp culture (improved extensive) between mangrove forests in Minh Hai Province

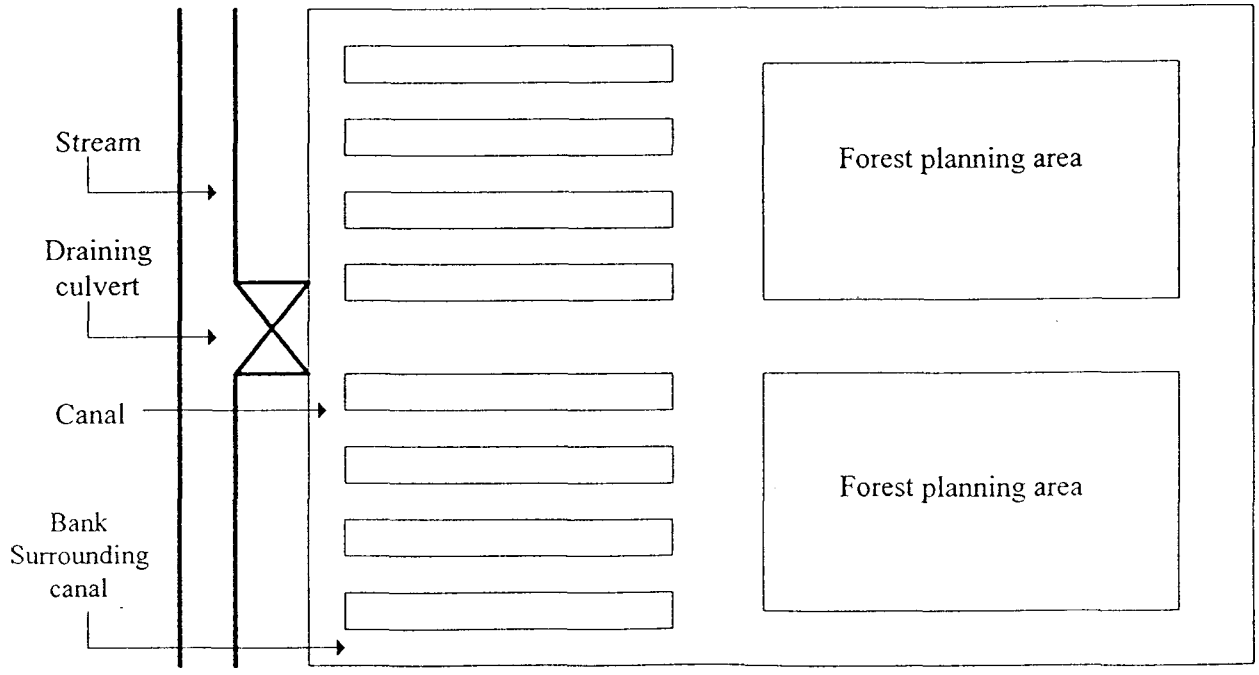

Fig 6. Model of a fishery-forestry area in Minh Hai Province

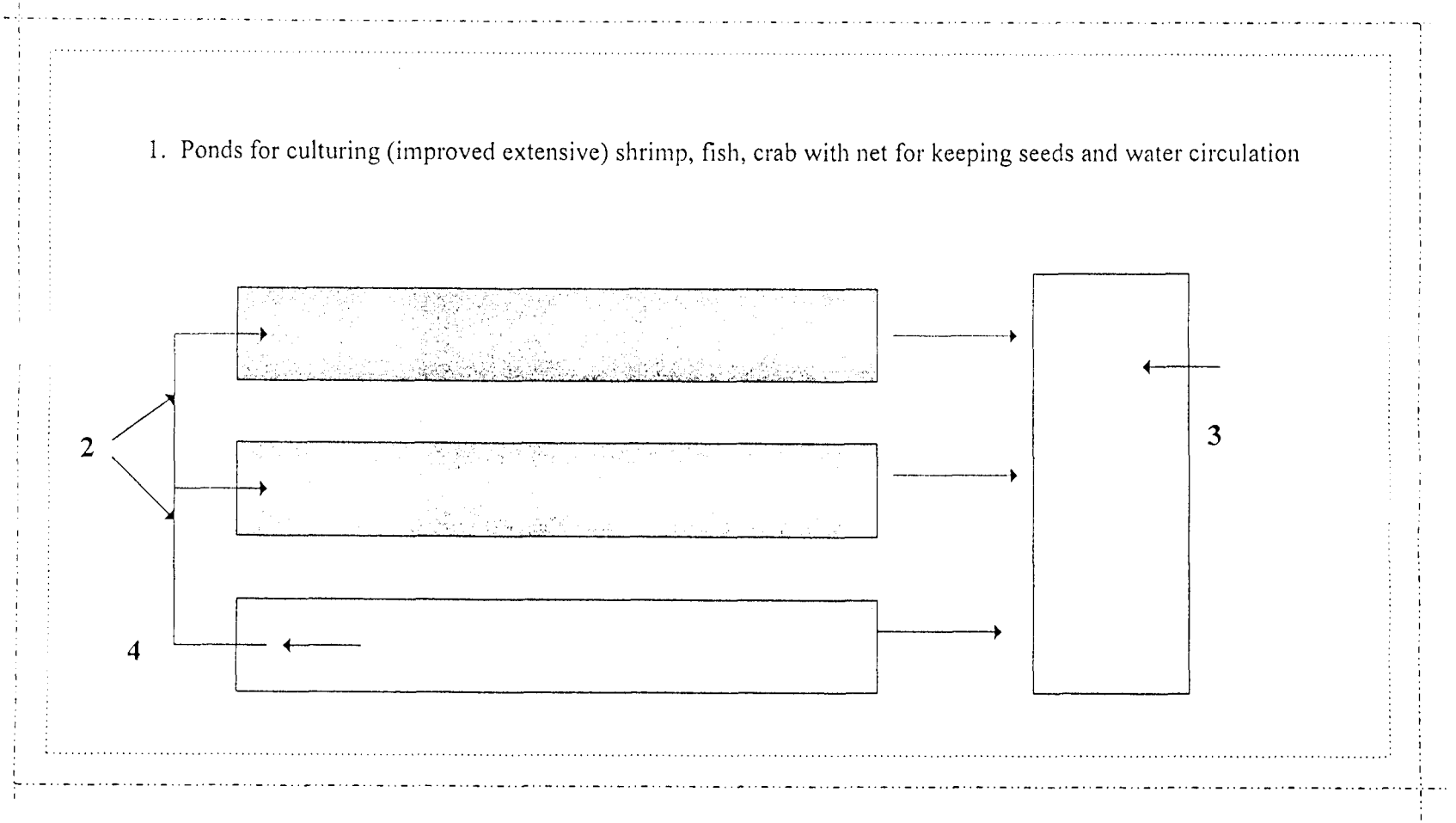

Fig 7. Model of mangrove-friendly aquaculture

Total area: 10 ha, including (**1**) ponds for culturing (improved extensive) shrimp, fish, crab with net for keeping seeds and water circulation; (**2**) shrimp semi-intensive culturing ponds, 4 ponds with 5,000 m^2 per pond; (**3**) ponds for culturing molluscs or fish for biological water treatment; and (**4**) ponds for water treatment about 3,000 m^2

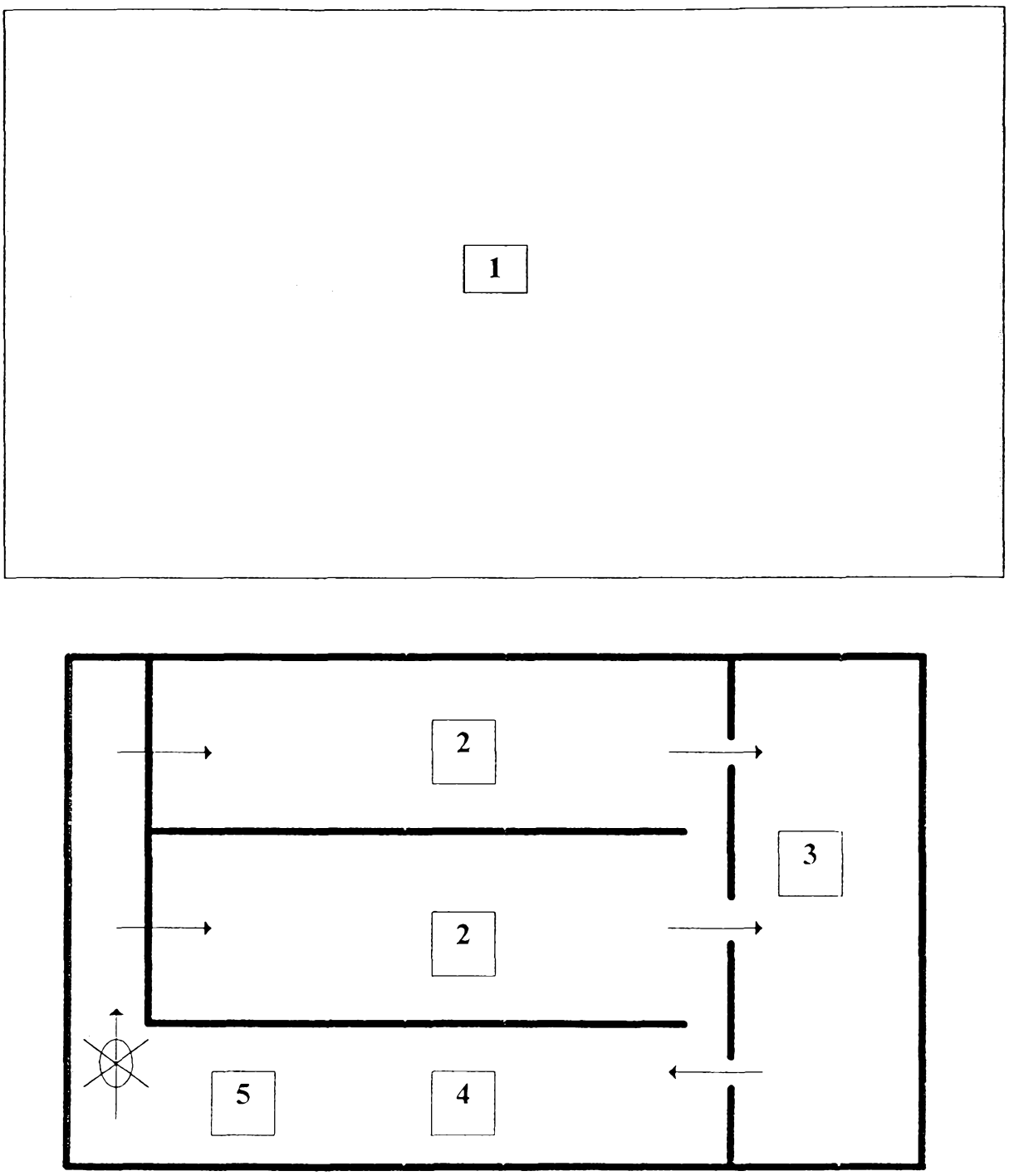

Fig 8. Model of shrimp culture in closed system with water treatment

Note: (1) Mangrove forest; (2) Ponds for shrimp culture; (3) Ponds for seaweed culture, (4) Treatment ponds using chemical; (5) Water pump