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Ecological Assessment on the Success of Mangrove Restoration in Pak Phanang Bay, Nakhon Si Thammarat, Southern Thailand

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Abstract: Mangrove forests in Pak Phanang estuary have been through three important phases as others in Thailand. Before 1961, the mangrove forests in Pak Phanang Estuary were pristine and rich in diversity. The transition phase commenced from 1962 onward to 1996, where mangrove reclamation and utilization activities in particular the expansion of shrimp farming and urbanization, have diminished 87.97% of the total mangrove area. Mangrove restoration and afforestation efforts began since 1960 but not until 1982 that the mangrove reforestation and afforestation in the bay have been planned and implemented. Ecological assessment on the success of mangrove restoration were carried out in selected mangrove plantations of different ages on the eastern coastline. Assessment on ecosystem integrity was carried out in order to determine whether the existing diversity and biological productivity should sustain the ecosystem indicators with emphasis on fishery resources. Forest productivity assessed from different age mangrove plantations revealed that these mangrove plantations were productive and in the developing and climax conditions. Forest production and natural regenerations were in the category of productive forests. High primary production were recorded in the mangrove forests. Zooplankton compositions of copepods, copepod nauplii, bivalves larvae, gastropod larvae and polychaetes larvae were dominant. The ratio of meroplankton in the plankton communities could indicate the ecosystem health. Benthic communities in the area also indicated the environmental quality and fishery productivity. Change in the fish community in forests confirmed the role of mangrove reforestation supported the availability of habitat and food sources. Based on the food web analysis in these mangrove plantations indicated that the system in balanced due to the productivity and complexity in the food webs.

Keywords: Mangrove restoration, Ecological assessment, Ecosystem integrity, Ecological indicators

Introduction

Pak Phanang Bay system is a small, shallow estuary in the Gulf of Thailand in Nakhon Si Thammarat Provinces, Southern Thailand. It receives discharges, sediment and nutrients from Pak Phanang River and tributaries. Pak Phanang Bay system is one of the richest and most diversed in term of fishery resources. The estuary was once lined with rich dense mangrove forests due to mangrove reforestation programs launched by the Royal Department of Forestry. Unplanned urban expansion and intensive shrimp farming in the Pak Phanang watershaded in the past 25 years has resulted in the deteriorating environment quality and degraded mangrove forests. Conflicts of interests in land use and saline water intrusion in the upland agricultural area has led to the Royal-initiated Pak Phanang Basin Area Development Project with the construction of the Uthokvibhajaprasid Dam. The dam was designed to prevent the intrusion of saline water and retain freshwater in the water course for people daily use for agriculture and consumption. However the operation of the dam has disrupted the circulation and water exchange processes. This in turn has affected the water quality in term of salinity changes and nutrient loading These environmental changes have shown pronounced impact on the biodiversity and fishery resources.

Mangrove forests in Pak Phanang estuary have been through three important phases as others in Thailand. Before 1961, the mangrove forests in Pak Phanang estuary were pristine and rich in diversity of more than 20 species. The forests dominated by *Avicennia marina, A. alba, A. officinalis, Soneratia caseolaris, S. alba, Rhizophora apiculata, R. mucronata, Xylocarpus granatum, Bruguiera* spp. and *Lumnitzera* spp. The transition phase commenced from 1962 onward to 1996, where mangrove reclamation and utilization activities in particular the expansion of the shrimp farming and urbanization, have diminished 87.97% of the total mangrove area. Mangrove reforestation and afforestion effort began since 1960 due to high sedimentation rate. Siltation in the bay is rapid due to high suspended sediment from the rivers. Major pioneer species were *Avicennia* spp. and *Sonneratia* spp.. These pioneer species were replaced by *Rhizophora* spp.,

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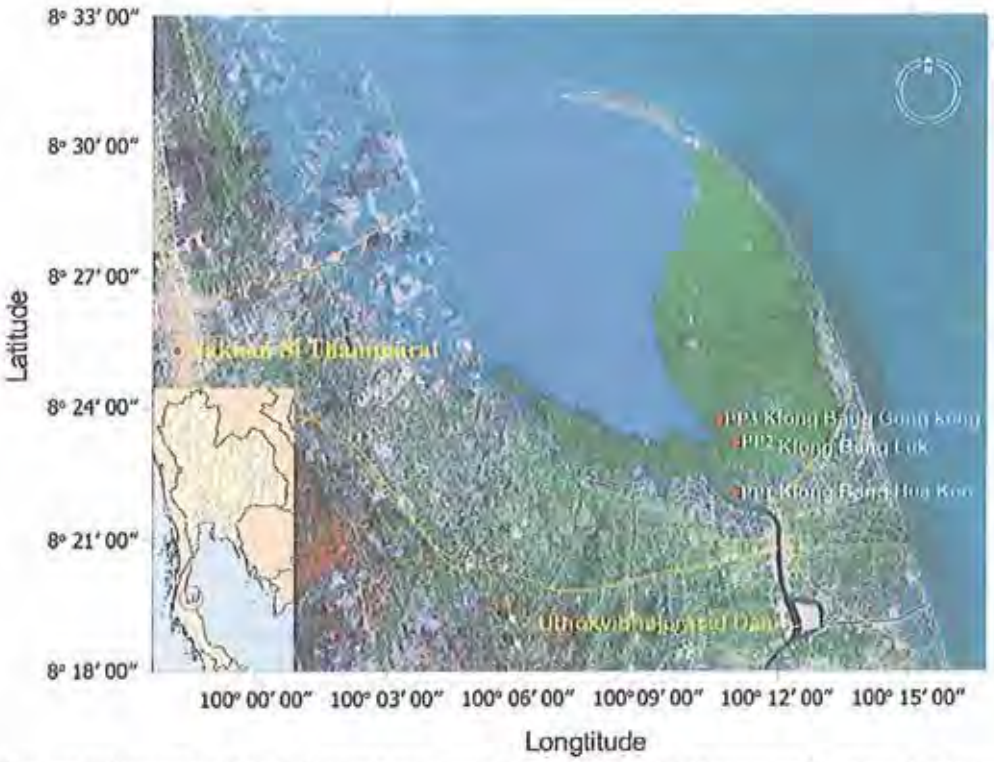

Figure. 1 Study sites in Pak Phanang mangrove forest, Nakhon Si Thammarat Province, Southern Thailand

Xylocarpus spp., *Brugiera* spp., *Ceriops* and *Lumnitzera* spp.. It was not until 1982 that the mangrove reforestation and afforestation in the bay had been planned and implacemented by the Royal Department of Forestry with emphasis on the economic species only, *R. apiculata* and *R. mucronata*. Later from 1985 onward the department has put efforts on the mangrove planting in the abandoned shrimp farms with *R. mucronata* and *R. apiculata*, the major species. As the results of these efforts, mangrove plantations of different ages dominated the bay. These mangrove forests served as nursery grounds, permanent habitats and breeding grounds as well as feeding grounds for fishery resouces.

The assessment of the success of mangrove restoration/ reforestation efforts is necessary. The assessment should served to document effects of mangrove restoration that are of ecological and social important secondly the assessment is to ensure that the restoration process is conducted to minimize any impacts to the coastal resources. Lastly the restoration evaluation/assessment should provide information served a database for the management of restored mangrove forests and for wise use of its resource.(Paphavasit, *et al.*, 2008b) It is important to select the indicators that best represent ecological responses to restoration effort and also meaningful relative to societal values. Forest production and litter production as forest productivity was usually used as the indicator of mangrove restoration. Development of ecological indicators as the assessment of mangrove restoration should be based on linkage of ecosystem components in order to demonstrate the whole picture not as a fraction. The assessment should be designed to measure the success of the mangrove restoration/reforestation programme in reestablishing ecosystem integrity which implies balanced, healthy and productive characteristics of the ecosystem. Ecological assessment on the success of mangrove restoration were carried out in selected mangrove plantations to different ages on the eastern coastline of Pak Phanang Bay. Assessment on ecosystem integrity in holistic approaches based on the status of biological productivity mainly the mangrove forest and fishery productivity were carried out.

Materials and Methods

Pak Phanang mangrove forest was divided into two parts, western and eastern coastline by Pak Phanang Bay.

The study area were located on the eastern coastline; mangrove plantation of 40 years (PP1) – Klong Bang Hua Koo dominated by *A. alba* and *R. apiculata*, mangrove plantation of 30 years (PP2) – Klong Bang Luk dominated by *R. apiculata* and *R. mucronata* and mangrove plantation of 20 years (PP3) – Klong Bang Gong Kong also dominated by *R. apiculata* and *R. mucronata* as shown in Figure 1.

Forest structure and productivity

Forest structures were determined from transect lines from the seaward margin of the forest at right angles to the edges of the mangrove forest. Species composition density and height in each subsequent 10 m × 10 m plots along the belt transect were recorded. Seedlings (girth less than 4 cm and height less than 1.30 m) identified and counted individually in the 1 m × 1 m subplot. Sampling (girth less than 4 cm and height over 1.30 m) also identified and counted in the 5m × 5m subplot. Tree density and forest production in volume were also calculated. Litter fall production were also carried out monthly at each site. The details of forestry study will not be discussed in this paper.

Biological productivity

Field studies were conducted during the dry season in May 2007 and wet season in October 2007. For quantitative sampling of phytoplankton, a depth integrated 10 - 20 liters of water sample was collected in duplication for each station. Sample was filtered onto a 20 µm meshed net. Aliquots were preserved in 2 percent neutral formalin for analyse diversity and abundance of microphytoplankton. Zooplankton samples were collected by plankton nets of 100 and 300 µm mesh size equipped with flow meter (General Oceanics medel 2030R) Duplicate horizontal tows from 1 m near bottom depth to surface were taken. Samples were preserved in 4 -5 percent neutralized formalin solution for identification and enumeration.

As for the quantitative sampling of benthic communities, 3 replicate samples of macrofauna per station were collected using 0.5 m × 0.5 m quadrats and core sampler (diameter of 0.15 m and 0.5 m in length). Samples were sieved through percent neutralized formalin for identification to the lowest same quadrats as the macrofauna using a corer with 3 cm in diameter pushed to a depth of 10 cm in sediment. Core with Rose Bengal dye for identification and enumeration. The environmental parameter of porewater in the sediment were measured in situ namely temperature, salinity, pH and EC. Sediment samples were also collected for soil texture analysis using a hydrometer method and for organic content by Walkley Black Wet Oxidation Technique.

Fish larvae and juveniles were collected by using a modified push net as the fry – sweeper comprised of V – shaped bamboo frame with Velon wing net and a pouch of fine mesh net. The net was operated during low tides by moving back and forth along the shoreline in waist – to – chest deep water during day time. Gill net with 3 mm mesh size was employed for fish larvae and juveniles collection. Samples of adult fish population were collected using local fisherman gill nets of approximately 1 cm mesh size. Sampling period was approximately 30 min. at each station. Samples were preserved in 10 percent neutralized formalin for identification and enumeration.

Results and Discussion

Forest structure and productivity

Low species diversity were observed of only half of the previous recorded (Terathanathorn and Panichchart, 2002) of 30 species in 20 genera and 16 families of mangrove plants recorded in the area. The mangrove plantations of different ages dominanted by *R. apiculata*, *R. mucronata* and *A. alba*. These were resulted from the mangrove restoration/reforestation efforts. As the mangrove plantations aged, the natural succession also taken place thus the forest conditions in some areas are similared to the natural forests.

Transect line at mangrove plantation of 40 yrs-Klong Bang Hua Koo extended 410 m. consisting of 10 species of mangrove. Dominant plants found in the area were *R. apiculata, A. alba, R. mucronata, Nypa fruticans, Lumnitzera racemosa, Sapium indicum, S. ovata, S. caseolaris, B. sexangula* and *Hibiscus biliaceous*. Tree density recorded was 2,612 trees/hectare with the tree height in the range of 3-21 m. When compared with the previous work by Terathanathorn *et al* (2007) *Xylocarpus moluccensis, Acrostichum aureum* and *Derris trifoliate* can not be found due to the inundation of the area.

The species composition in the mangrove plantation of 30 yrs- Klong Bang Luk similared to those reported by Terathanathorn *et al* (2007). The transect line of 340 m. was dominanted by *R. apiculata, R. mucronata, B. sexangula, Nypa fruficans, X. moluccensis, X. granatum, S. caseolaris, A. alba, A. officinalis* and *Acanthus ilicifolius*. Tree density recorded was 4,468 trees/hectare with tree height in the range of 5-24 m.

The long transect of 500 m. was conducted at the mangrove plantation of 20 yrs-Klong Bang Gong Kong. Total of 11 mangrove species were recorded namely

Table. 1 Forest structure and productivity in the mangrove plantations of different age in Pak Phanang Bay, Nakhon Si Thammarat, southern Thailand

Indicators	Mangrove Plantation of 40 yrs- Klong Bang Hua Koo	Mangrove Plantation of 30 yrs- Klong Bang Luk	Mangrove Plantation of 20 yrs- Klong Gong Kong
1. Forest structure			
1.1 Species diversity (no. of species)	10	10	11
1.2 Species zonation	zonation not apparent	zonation not apparent	zonation not apparent
1.3 Tree density (trees/hectare)	2,612	4,468	5,575
- Tree height (m)	3-21	5-24	4-25
1.4 Forest production in volume (cu.m./hectare)	110.37	265.44	223.75
1.5 Percent coverage (%)	80-90	80-90	80-90
2. Natural regeneration			
2.1 Samplings and seedling density (stems/hectare)	48,475	24,319	18,787
3. Litter fall production (kg/hectare/yr)	28,810	35,016	27,216

Table. 2 Indicators used for the classification of mangrove forest condition based on the data from mangrove forest in Thailand

Indicators	Degraded	Developing	Healthy/Matured
1. Forest structure			
1.2 Species diversity (no. of species)	less than 5	5 - 20	more than 30
1.2 Species zonation	no zonation	zonation no apparent	clear zonation
1.3 Tree density (trees/hectare)	less than 125	125 - 625	more than 625
1.4 Forest production in volume	less than 31.25	31.25 - 125	more than 125
1.5 Percent coverage	less than 50%	50 - 80%	more than 80%
2. Natural regeneration			
2.1 Samplings and seedling density (stems/hectare)	625 - 18,750	more than 18,750	less than 18,750

R. apiculata, R. mucronata, B. saxangula, B. cylindrical, N. fruticans, Excoecaria agallocha, S. alba, A. alba, X. granatum, L. racemosa and *Aegiceras corniculatum*. Tree density recorded in the area was 5,575 trees/hectare with the tree height of 4-25 m. Table 1 showed the forest structure and productivity of the three mangrove plantations.

When compared the forest structure and productivity in the mangrove plantations of the different age in the Pak Phanang estuary with the criteria for classification of mangrove forest condition based on the data from mangrove forest in Thailand as in table 2 (Paphavasit,*et al.*, 2008a), these mangrove plantations were productive

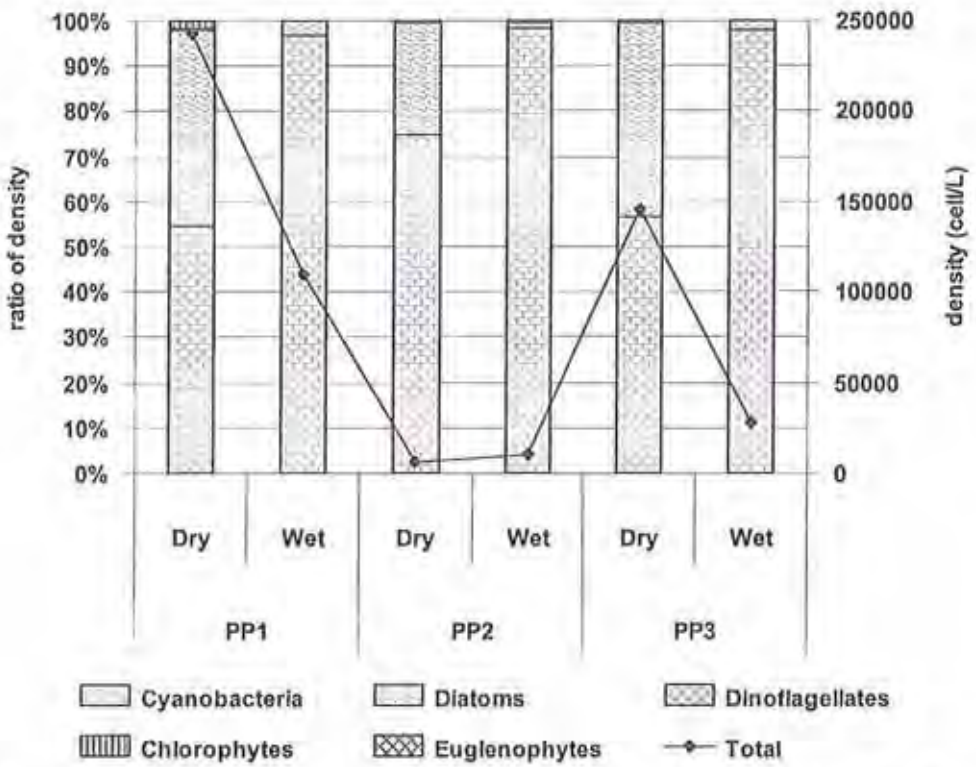

Figure. 2 Composition of microphytoplankton in the mangrove plantations of different age in the Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

and in the developing and matured conditions. Tree density recorded were higher than those recorded from the Inner Gulf of Thailand (Paphavasit,*et al.*, 2007). Forest production were in the range of productive forests. Natural regenerations, as revealed from numbers of seedling and saplings, are in excellent condition. The percent coverage were in the range of 80-90%. The litter fall production also indicated the productive forests.

Biological productivity

Several studies of mangrove associated with fish communities in Pak Phanang Bay provided evidences that these mangrove forests were used by fish as nursery grounds, permanent habitats, breeding and feeding grounds (Sirimontarpon, 1998; Somkleeb *et al*, 2001; Sri thakon *et al*, 2003; Paphavasit *et al*, 2004; Tongnunui *et al*, 2007; Wongchinawit *et al*). The mangrove forests provide a greater abundance of food. Food sources are the major factors inducing fish into mangrove forest. Plankton, mainly microphytoplankton and dominant zooplankton such as copepod, crustaccan larvae and bivalve larvae are important food source. High diversity and abundance of phytoplankton indicating the productivity of the system in supporting the higher trophic levels in the grazing food webs. High phytoplankton diversity observed in the mangrove plantations on the eastern coastline of Pak Phanang Bay were in the range of 21 - 67 genera. Phytoplankton density were in the range of 6.66×10^3 - 2.64×10^5 cells/litre in the dry season and 9.93×10^3 - 1.09×10^5 cells/litre in wet season. These phytoplankton density of 10^3 to 10^5 cells/litre are normally observed in the mangrove forests in the Inner Gulf of Thailand and Andaman coastline. Cyanobacteria diatom and dinoflagellates were the three dominant groups as in Figure 2. There was the shift from diatom dominated phytoplankton communities to cyanobacteria in the mangrove plantations (Piumsomboon *et al*, 2004) indicating the organic enrichment in the area. The calculated primary production were in the range of 15.76 - 54.49 and 4.60 - 121.91 g C/m^2/yr. in the dry and wet season respectively. High primary production recorded in the productive mangrove forests (Paphavasit *et al*, 2002; Paphavasit *et al*, 2007). However the values recorded are lower than previously recorded in the dry season of the year 2001 and 2002 in the range of 93 - 326 g C/m^2/yr. by Piumsomboon *et al* (2004).

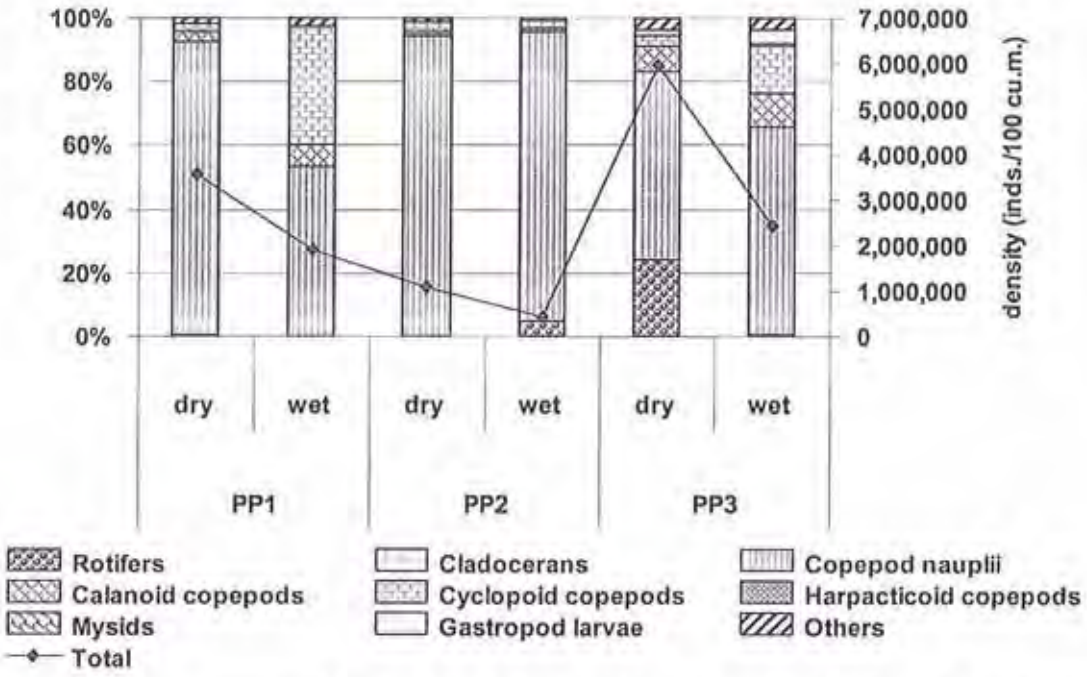

Figure. 3 Composition and total density of zooplankton in mangrove plantations of different age in the Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

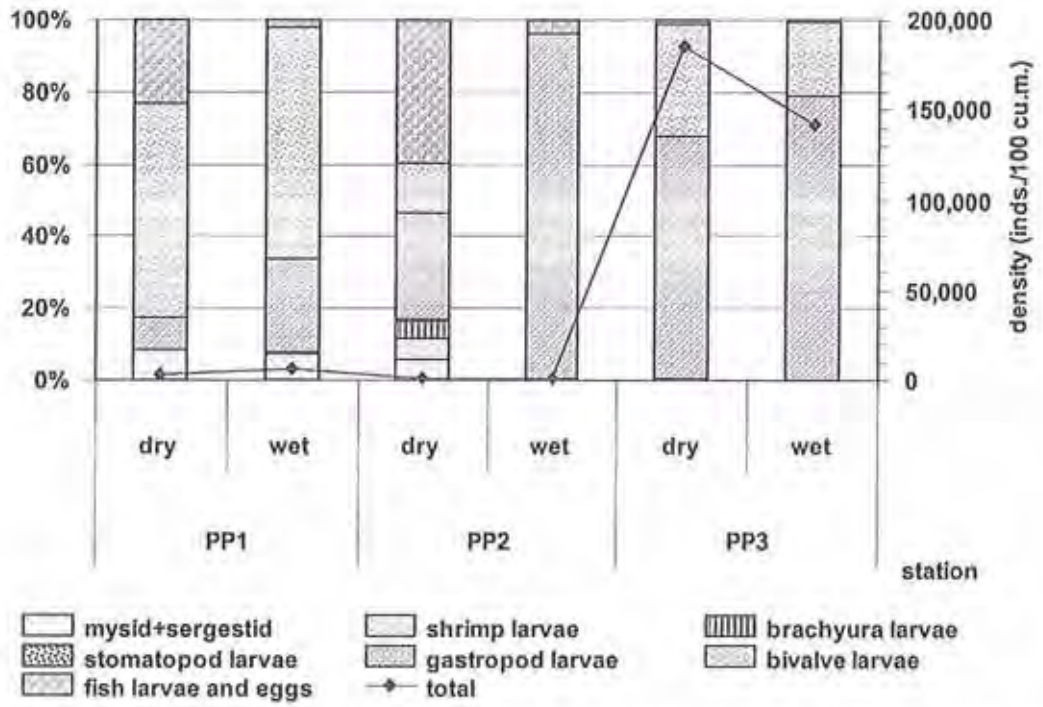

Figure. 4 Composition and total density of meroplankton with emphasis on economically important species in mangrove plantations of different age in the Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

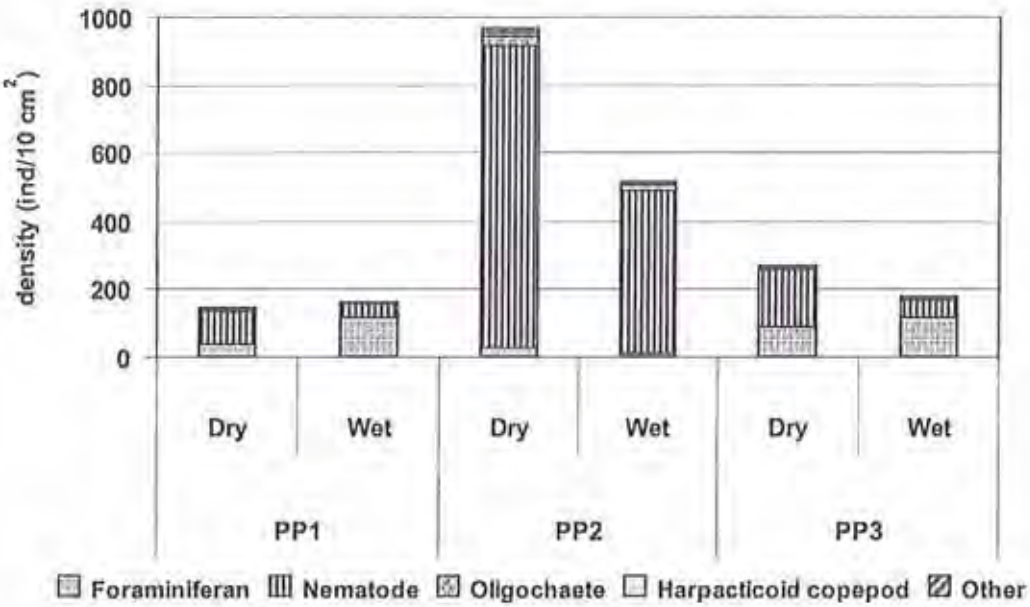

Figure. 5 Composition and total density of meiofauna in mangrove forest plantations of different age in the Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand.

Zooplankton communities in the mangrove plantations in the Pak Phanang estuary as in Figure 3 were dominated by copepods, copepod nauplii, bivalve larvae and gastropod larvae similar to previous studies . Zooplankton density was in the range of 10^3 of 10^7 individuals/100 cu.m. which was in the same range as reported by Piumsomboon *et al* (2000) and Piumsomboon *et al* (2004). The density of zooplankton in the wet season was higher than the dry season. Cladocerans and rotifers were abundant in the low salinity period. The ratio of meroplankton in particular the economically important zooplankton as in Figure 4 indicated the important roles of mangrove forest as food sources and nursery for fisher resources such as mysids, sergestid, shrimps gastropod and bivalve larvae apart from fish larvae.

Benthic communites can be used as the indicators of environmental quality and fishery productivity. The meiofauna diversity in the dry and wet season of total 11 taxagroup dominated by nematode and foraminiferans. The high density was recorded in the dry season as in Figure 5. Nematode was the dominant group in the mangrove area as reported by Paphavasit *et al.* (2004) in the Pak Phanang mangrove forest and Chalermwudhisak (2002) in the Samut songkram mangrove forest in the Inner Gulf of Thailand . Nematodes can be widely distributed due to their high tolerance of environmental changes in particular in the hypoxia and anoxic condition. They are mainly deposit feeders (Riemann, 1988) When compared the meiofauna density in the same area as reported by Paphavasit *et al* (2004), the density increased from 41-239 ind/10 cm^2 to 6-966 ind/10 cm^2 in the present study. The increase in organic detritus in term of forest biomass as the mangrove plantation aged provided the food sources for these meiofauna.

Mangrove benthos namely nematodes, gastropods, polychaetes, crustaceans and crabs are also major food sources for fishery resources. The total of 50 species of macrofauna were recorded in the mangrove plantations in the Pak Phanang estuary. The composition of macrobenthos in orders of dominance were polychaetes crustaceans and mollusks as in Figure 6 indicating species assemblages associated with a disturbed forest, as polychaetes were the dominant group (Paphavasit *et al*, 2003) The ratio of these three major groups for the mangrove plantation of 40 yrs., mangrove plantation of 30 yrs. and mangrove plantation 20 yrs. were 37 : 26 : 19, 30 :22 : 22 and 32 : 32 : 18 respectively. In the natural productive mangrove forest were high diversity of macrofauna were recorded, the ratio for polychaete, mollusks and crustaceans was usually 15 : 30 : 40. However the disturbed forest and abandoned shrimp farm the ratio for polychaetes increased.

The macrofaunal density in the dry season were higher than those in the wet season. The dominant

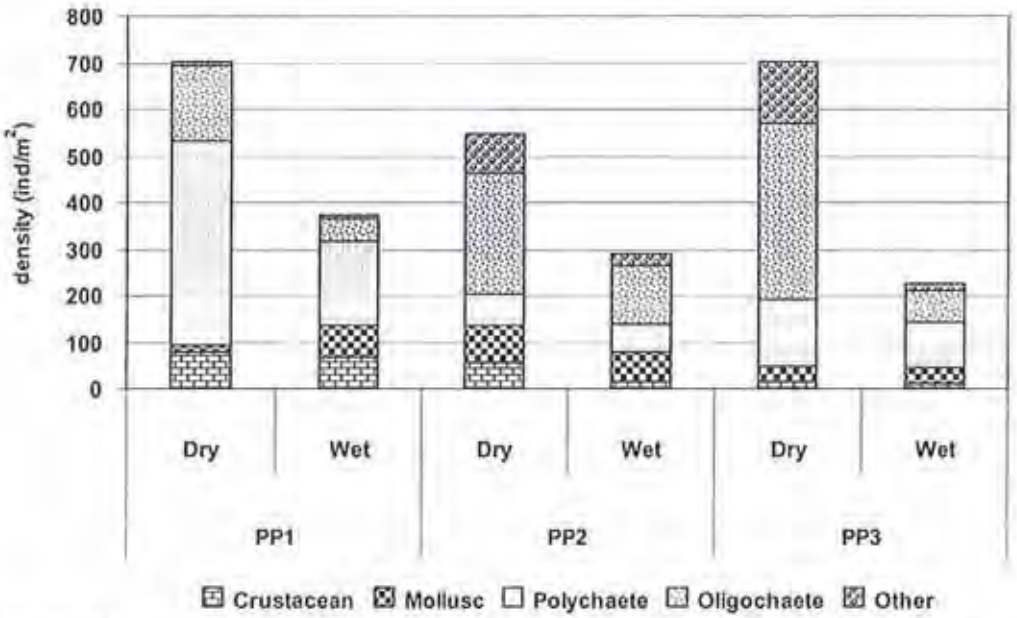

Figure. 6 Composition of dominant macrofaunal groups in mangrove plantations of different age in Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

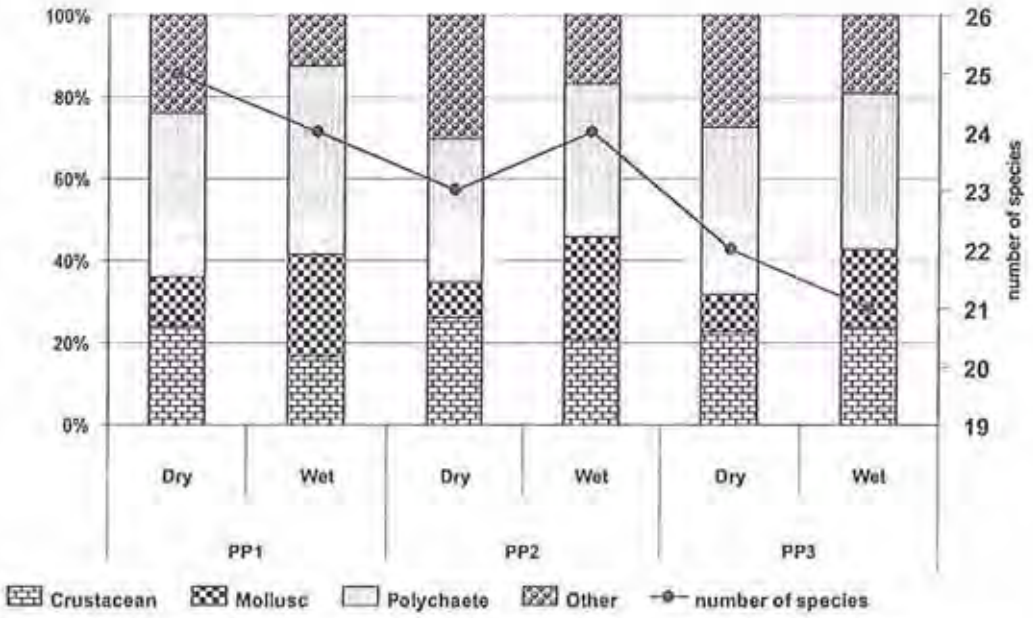

Figure. 7 Macrofaunal density in the mangrove plantations of different age in Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

macrofauna were oligochaete, polychaetes in the families Nereidae, Capitellidae, Spionidae and Sabellidae and red snail, *Assiminea brevicula* found in the eastern coastline mangrove forest as in figure 7

Although the three mangrove plantations were productive in term of forest productivity, the benthic invertebrate communities should best represent food source and spawning ground for fishery resources. However in this study, we find that low benthic density as compared to those previously reported from other mangrove forest in the Gulf of Thailand (To-on, 1999 and Wichitworakhun, 2001). High polychaete density

Table. 3 Dominant macrofaunal communities in the mangrove plantations of different age in Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

Station	Dominant species	Habitat	Dominant Mangrove species
Mangrove plantation 40 years (PP1)	Oligochaete Polychaete: *Ceratonereis* cf. *burmensis*, *Heteromastus* sp., *Namalycastis* cf. *indica* , *Prionospio (Minuspio) japonica*, Ampharetidae Isopod: *Cyathura* sp. Gastropod: *Assiminea brevicula*	Temperature: 25.9 – 28.8 ° C Salinity: 7.2 – 11.3 psu pH: 6.70 – 7.11 Redox potential: -122 to -115 mv Organic matter: 4.05 – 5.91% Sediment type: loam (dry) clay loam (wet)	*Rhizophora apiculata*, *Nypa fruticans*, *Avicennia alba*
Mangrove plantation 30 years (PP2)	Oligochaete Gastropod: *Assiminea brevicula* Insect larvae: Diptera Polychaete: *Namalycastis* cf. *indica*, Sabellidae, *Heteromastus* sp. Isopod: *Cyathura* sp.	Temperature: 25.8 - 28.5 ° C Salinity: 6.3 – 7.3 psu pH: 6.93 – 7.00 Redox potential: -108 to -81 mv Organic matter: 4.46 – 4.71% Sediment type: sandy clay loam (dry) clay loam (wet)	*Rhizophora apiculata*, *Rhizophora mucronata*
Mangrove plantation 20 years (PP3)	Oligochaete Insect larvae: Diptera Polychaete: *Namalycastis* cf. *indica*, *Neomediomastus* sp., *Neoheteromastus* sp., *Prionospio (Minuspio) japonica* Gastropod: *Assiminea brevicula*	Temperature: 25.7 - 26.5 ° C Salinity: 6.3 – 12.8 psu pH: 6.99 – 7.16 Redox potential: -231 to -172 mv Organic matter: 9.28 – 11.08% Sediment type: sandy loam (dry) clay loam (wet)	*Rhizophora apiculata*, *Rhizophora mucronata*

correlated to high organic content in the mangrove forest. Several macrobenthos found as in Table 3 were the indicators of eutrophic and hypoxia conditions. Polychaetes in the family Capitellidae, *Neomediomastus* sp., *Neoheteromastus* sp. And *Prionospio (Minuspio) japonica* in the family Spionidae. Other indicator of organic enrichment were *Namalycastis* cf. *indica*, Nereid polychaete and polychaete in the family Ampharetidae.

Figure 8 showed the density of fish larvae in the mangrove plantations in the eastern coastline of Pak Phanang estuary. Mangrove forest support fisheries production by providing nursery grounds for larval and juvenile marine fish. Juvenile survival may be enhanced in shallow mangrove habitats where structural complexity, shading and turbidity are relatively high providing a predation refuge. Moreover the habitat complexity resulting from prop roots pneumatophores and mangrove debris as well as the soft mud substate also provide protection from predators (Laegdsgaard and Johnson, 2001; Ellis and Bell, 2004). Fish larvae in the families Gobiidae and Phallostethidae dominated the area. Fish larvae in the families Engraulidae, Leiongathidae, Ambassidae, Scatophatidae, Sciaenidae and Clupeidae were common. High diversity of fish larvae were recored in the wet season.

Fish composition and diversity is often the good ecological indicator representing the universal and meaningful language to all stakeholders, scientists, coastal communities and policy administrators. The role of mangrove plantations in Pak Phanang estuary supported the availability of habitat and food sources. Total of 22 species from 14 families were recorded during the dry season with fishes in the family Gobiidae were the most diversed group in the western mangrove forest. Gobiid fishes, Mud sleeper, *Butis koilomatodon* and Burrowing goby, *Trypauchen vagina* were dominant in the wet season while Perchet, *Ambassis vachelii* and *Butis koilamattodon* common in the dry season. During the wet season, total of 23 species from 17 families were recorded. Tade mullet, *Chelon tade* and *Platycephalus indiscus* also common during this season. Several economically important species were recorded from the area such as Scat, *Scatophagus*

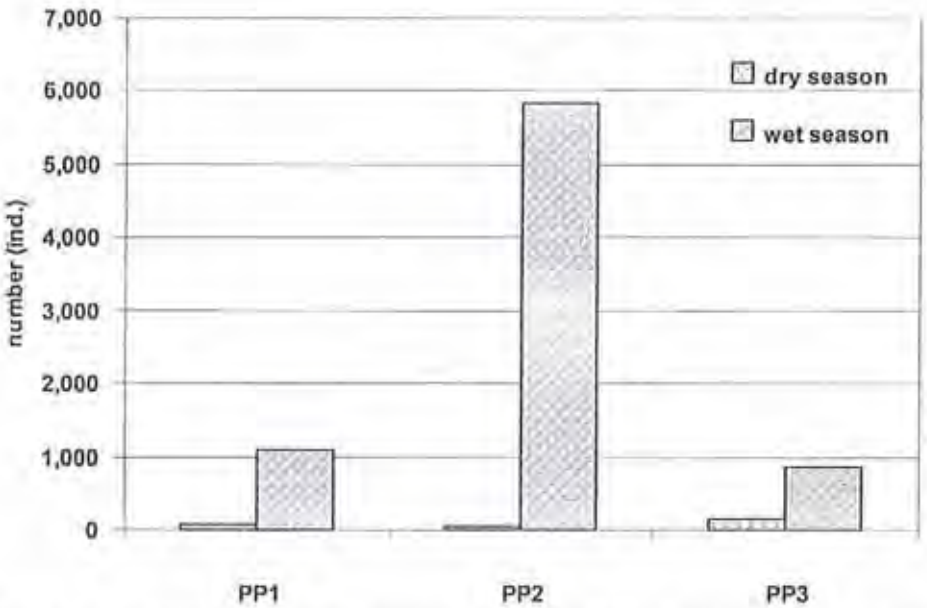

Figure. 8 Fish larval density in the mangrove plantations of different age in Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

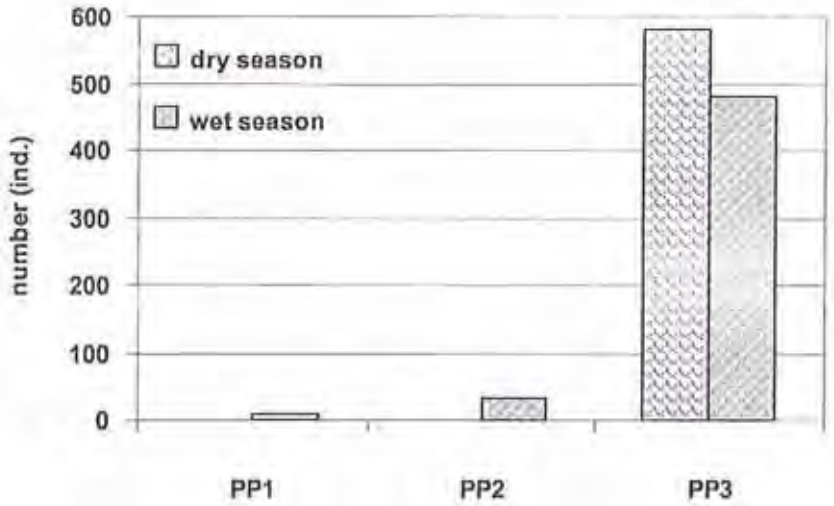

Figure. 9 Fish density in the mangrove plantations of different age in Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand

argus, Java rabbitfish, *Siganus javus*, Fourfinger threadfin, *Eleutheronema tetradactylum*, Burrowing goby Trypauchen vagina, Yellow spotted rabbit fish, *Siganus guttatus* and Tade mullet, *Chelon tade*.

Fish composition and diversity reflected the health of the mangrove forests (Shinnaka *et al*, 2007; Tongnunui *et al*, 2007 and Wongchinavit *et al*, 2007). Several fish families, true residents in the mangrove forest, spent their complete life cycle by reproducing and feeding within mangrove habitats. Fish in the families Gobiidae, Mugilidae, Syngmathidae, Ambassidae, Plotosidae, Ariidae and Scatophagidae can be used as the indicators. Shinnada *et al* (2007) suggested that Scat, *Scatophagus argus*, Scalloped perchet, *Ambassis malua*, Mullet, *Chelon subviridis* and Spotted green puffer, *Tetradon nigroviridis* indicated mangrove recovery. The diversity of fish in the family Gobiidae decreased in the disturbed mangrove forest in comparison with natural healthy forest. (Ikejima *et al*, 2006; Shinnaka *et al*, 2007; Tongnunui *et al* 2007).

Ecosystem integrity in this study, implies balanced,

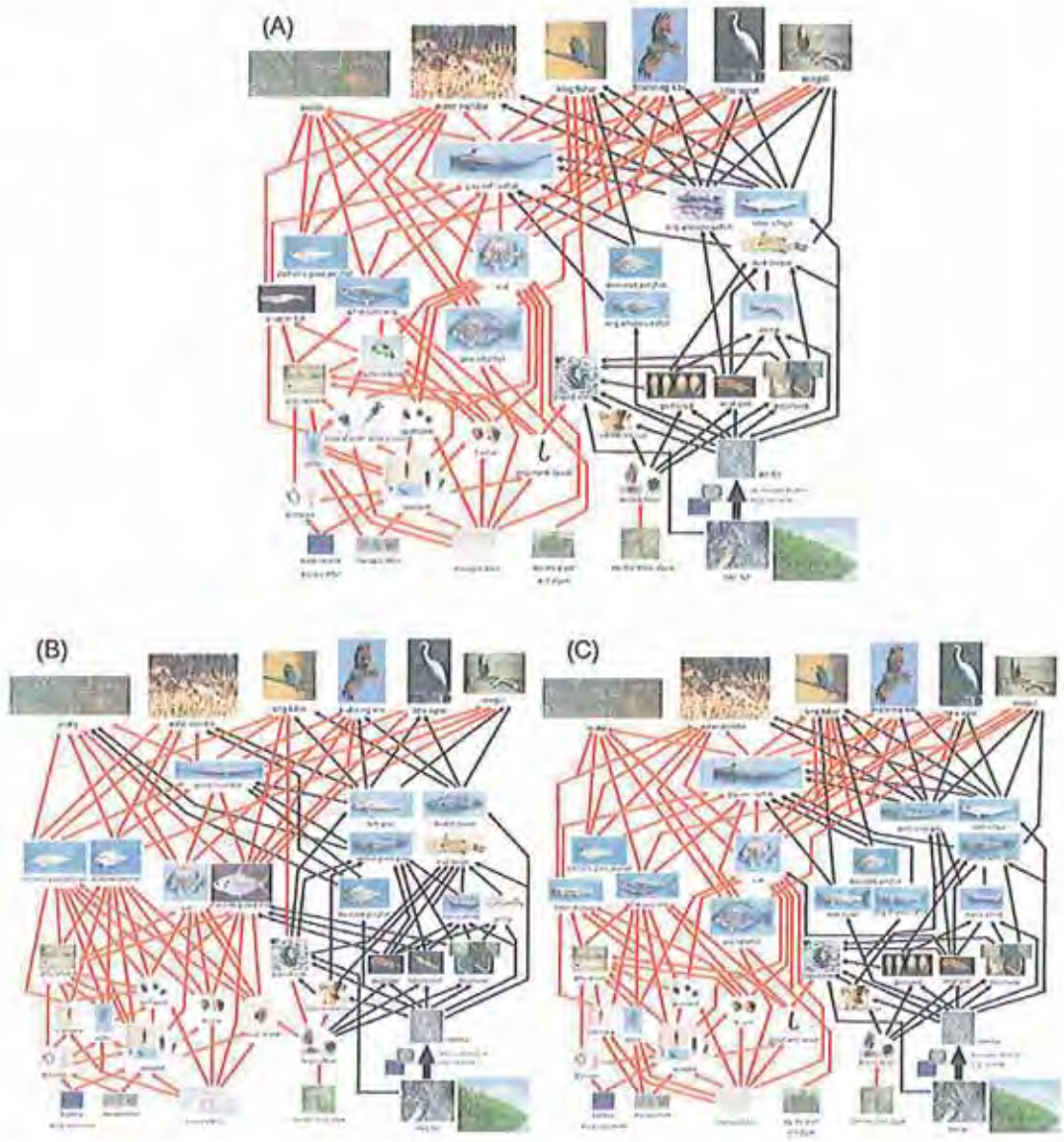

Figure. 10 Food web complexity in the mangrove plantations of different age in Pak Phanang estuary, Nakhon Si Thammarat, southern Thailand
(A) In 2002-2004 (B) Dry season in 2007 (C) Wet season in 2007

healthy and productive characteristics of the ecosystem. Based on the food web analysis in the mangrove plantations on the eastern coastline, the system in balanced due to the productivity and complexity in the food webs as compared to those in the past as in Figure 10. The detrital food webs in the mangrove forests showed high complexity. The food webs in both seasons were similar to those in the past. This was due to the composition of the benthos. Fish diversity mainly herbivores, zooplankton feeders and benthic feeders were lower in the dry season as compared to the previous reports. Carnivorous fish species were also on declining trend. The forage carnivorous ratio in fish calculated to 15:1 was indicating the balanced condition.

Conclusion

Ecological assessment on the success of mangrove restoration/reforestation in the mangrove plantations of different age in the Pak Phanang eatuary, Nakhon Si Thammarat, southern Thailand revealed that mangrove restoration had restored the mangrove structure and function in enhancing coastal productivity and fisheries.

Assessment on ecosystem integrity showed that the system in balanced due to the productivity and complexity in the food webs. Due to reforestation and afforestation techniques in the mangrove plantations, the mangrove diversity decreased to only 2 – 3 selected species and others from the natural succession process. Forest productivity assessed from the mangrove plantations revealed that these mangrove forests were productive and in the developing and matured condition. Forest production were in the range of productive forests. Natural regenerations are in excellent conditions. High litter fall production served as the base in the complex detrital food webs in the forest. However several biological indicators demonstrated the deteriorating health in term of organic enrichment in the mangrove forest such as the increase of cyanobacteria. Several meiofauna and macrofauna were the indicators of eutrophic and hypoxia concitions such as nematodes, foraminiferans, polychaete in the families Nereidae, Spionidae, Capitellidae and Ampharetidae. Low diversity of benthos recorded in the mangrove plantations was due to hypoxia condition of the mangrove floors. Paphavasit *et al* (2008a) observed low dissolved oxygen concentration or hypoxia condition in the mangrove forests. High organic contents were indicating the eutrophic condition found in the mangrove sediment. Although the mangrove reforestation has been carried out since 1982, the mangrove plantations were not maintained in the silviculture technique to promote production. Thinning and pruning have not carried out. Dense tree canopy in the mangrove plantations contributed to high organic detritus in term of forest biomass as the mangrove plantation aged. In the long term, even with high forest biomass as the mangrove plantations aged, but these hypoxia condition provide the unsuitable habitats for benthos and fish. The availability of habitats and food sources provided by these forests will soon be lost.

This study showed that the mangrove restoration/ reforestation programme has reestablished the ecosystem integrity. However re-introducing different mangrove species as the key to re-establishing the forest as viable ecosystem should be considered. Selection of suitable mangrove species and mangrove rehabilitation scheme should enhance the natural recovery process leading to ecosystem integrity. Several studies on the stability assessment of mangrove reforestation in Thailand demonstrated that the ecological recovery required longer period of time depending on the degree of disturbances in the sediment, availability of natural seedlings in the area and degree of human interference on natural plant succession (Paphavasit *et al.*,2008b). Different selected mangrove species required different time frame allowed for the mangrove stability to be reached such as *Avicennia*, *Sonneratia* and *Rhizophora*. The assessment on the multispecies/ mixed plantations on abandoned shrimp farms in Nakhon Si Thammarat showed similar results as the natural succession forest without human intervention reaching stability within 5 years.

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