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MACROBENTHIC FAUNA ASSOCIATED WITH MANGROVE PLANTATION AND ABANDONED SHRIMP PONDS IN PAK POON ESTUARY, NAKHON SI THAMMARAT, THAILAND.

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ABSTRACT

The colonization of macrobenthic fauna associated with mangrove plantation in abandoned shrimp ponds and a newly formed mudflat in Nakhon Si Thammarat coast was studied from 1997 to 2000. Polychaetes, *Neanthes* sp. and *Prionospio* sp., were predominant in the abandoned shrimp ponds and newly formed mudflat before mangrove plantation. After two years of plantation, the density of these polychaetes decreased, while crustacean density and diversity tended to increase. Except in the closed, abandoned shrimp pond with occasional seawater intrusion, a stable community did not become established. The rehabilitation of abandoned shrimp ponds by mangrove replanting should be considered.

Key words: benthic fauna, Crustacea, estuary, invertebrates, mangrove plantation, polychaetes, shrimp ponds

INTRODUCTION

The importance of mangroves to coastal fishery resources is well known, as nursery and feeding grounds among other functions. However, for over 25 years now the mangrove forests of Thailand have been increasingly encroached upon, primarily by shrimp farming operations. According to SAHAVACHARIN (1995) as much as 34 percent of the decrease in mangrove forests in Thailand is directly attributable to shrimp farms. A similar figure was given by CHARUPPAT & CHARUPPAT (1997), who took their data from the LANDSAT-5^{TM}, geocoded at a scale of 1:500,000 for classification of land use types in mangrove forest zoning. They calculated that in 1996, 33 percent of mangrove forests in Thailand had been converted to shrimp farms.

Shrimp farming infringement on the coastal mangrove zones is a serious problem from both the economic and ecological aspects of the fisheries (FEGAN 1996; MACINTOSH 1996; PAPHAVASIT *ET AL.*, 1997) and nature conservation (ANGSUPANICH & AKSORNKOAE, 1996; PAPHAVASIT *ET AL.*, 1997). For various reasons, but mostly related to unsustainable farming practices, up to 70 percent of former shrimp ponds now lie unused, although accurate assessments of the precise area are hard to find (STEVENSON, 1997). In Nakhon Si Thammarat Province in southern Thailand, most shrimp ponds at Pak Poon were abandoned due to a

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variety of diseases which led to the failure of the shrimp crop (personal observation). However, the environmental conditions remaining in the shrimp farm areas after the failure of the shrimp crop may prove to be a larger problem than the failure of the crop itself, as the changes to the land associated with the shrimp pond construction, shrimp production, and pond abandonment lead to physical and chemical changes in the soil, hydrology, and local flora and fauna (STEVENSON, 1997). Reclamation of these lands may be difficult. Acid-sulfate soils may persist for many years following abandonment (STEVENSON, 1997). Abandoned ponds can also deteriorate and be unstable, thus representing a risk to nearby habitats. Unless managed, they may become progressively more difficult to restore.

For these reasons, the Research Association for Global Mangroves (REAGMAN) and the Thailand Union for Mangrove Rehabilitation and Conservation (TUMREC) have initiated the Green Carpet Project in association with the Thai Forestry Department and local shrimp farmers. Attempts to restore the abandoned shrimp ponds at Pak Poon Estuary, Nakhon Si Thammarat, by replanting mangroves such as *Rhizophora mucronata* and *R. apiculata* have been undertaken. Although the costs may prove to be quite high, it is believed the reclamation is a worthwhile goal. For proper evaluation of the project, the benthic ecology must be studied and understood on an ongoing basis, for evaluation of the conditions and progress. The present paper provides some baseline data on macrobenthic faunal colonisation in three selected, related habitats in this area from 1997–2000.

MATERIALS AND METHODS

Study Site and Sampling Periods

Sampling of macrobenthic fauna was carried out at four study sites at the Pak Poon estuary, Nakhon Si Thammarat (Fig. 1). The areas were intertidal zones which were exposed to the sun in some seasons. Stations 1–3 were affected by daily seawater intrusion.

Station 1 (an opened, abandoned shrimp pond) was examined in November 1997 (before mangrove replanting), and then in February 1999 (14 months after plantation), in July 1999 (20 months after plantation) and in February 2000 (26 months after plantation).

Station 2 (18 year old mangrove plantation) was examined in February and July 1999, and February 2000, to compare species richness and density between new and old plantation areas. Station 2 was selected as a reference station (intact mangrove) because of its well-balanced community maintained over 18 years of mangrove plantation.

Station 3 (a newly formed mudflat) was examined in November 1997 (before mangrove plantation), in February 1999 (12 months after plantation), in July 1999 (18 months after plantation) and in February 2000 (24 months after plantation).

Station 4 (a closed, abandoned shrimp pond with occasional seawater intrusion) was examined in February 1999 (6 months after plantation), in July 1999 (12 months after plantation), and in February 2000 (18 months after plantation). The sediment was still mainly consolidated clay which was different from the other stations.

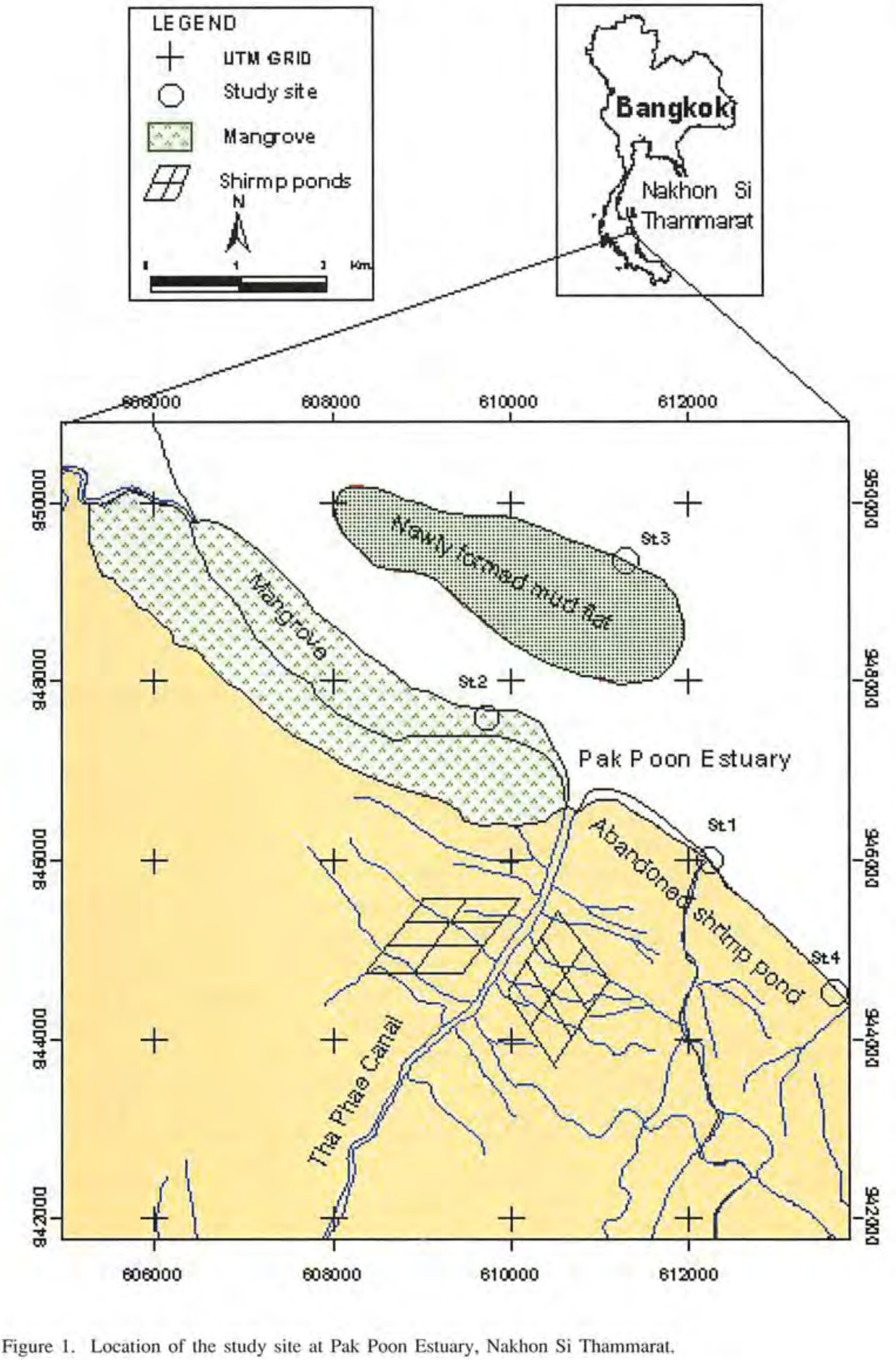

Figure 1. Location of the study site at Pak Poon Estuary, Nakhon Si Thammarat.

Table 1. Water temperature (°C) and salinity (psu) (—, no data)

		St.1	St.2	St.3	St.4
Nov. 1997	Temperature Salinity	31±1 29±0	– –	31±1 30±0	– –
Feb. 1999	Temperature Salinity	30±0 14±0	28±0 12±1	29±0 17±1	29±0 16±1
Jul. 1999	Temperature Salinity	29±0 29±1	28±0 24±1	29±1 21±0	29±0 27±0
Feb. 2000	Temperature Salinity	29±0 20±1	28±0 21±0	28±1 21±1	31±0 20±0

St. 1 = opened, abandoned shrimp pond St. 2 = 18 year old mangrove forest
St. 3 = newly formed mudflat St. 4 = closed, abandoned shrimp pond

Table 2. Percentages of total nitrogen (TN) and organic matter (OM) in sediment (–, no data) stations are described in Table 1.

Date		St. 1	St.2	St.3	St.4
Nov. 1997	TN OM	0.16±0.04 3.94±0.27	– –	0.08±0.01 1.76±0.16	– –
Feb. 1999	TN OM	0.09±0.01 1.63±0.09	0.15±0.02 1.81±0.08	0.08±0.01 1.81±0.07	0.09±0.01 0.99±0.01
Jul. 1999	TN OM	0.12±0.02 1.62±0.13	0.15±0.02 2.37±0.15	0.13±0.02 1.89±0.11	0.12±0.02 1.93±0.04
Feb. 2000	TN OM	0.11±0.01 1.71±0.06	0.14±0.02 1.77±0.09	0.09±0.01 1.80±0.10	0.09±0.00 1.84±0.05

Collection of Macrobenthic Fauna

Macrobenthic fauna samples were collected in 5 replications by a 0.05-m^2 Tamura's grab with a depth of 10–15 cm. The samples were sieved consecutively through 3 orders of screens of 5 mm, 1 mm and 0.5 mm mesh; the macrobenthic fauna was removed from the screen by washing in a seawater container, and filtered through a net of 300 µm mesh size. Finally the samples were fixed in 10% rose bengal buffer formalin. Data for all replicates per location were pooled, and converted to square meters. Besides using the numerous taxonomic keys, some benthic fauna were identified by comparison with the materials at the Natural History Museum, London, in consultation with Dr. Gordon Paterson and Dr. Alexander Ian Muir for polychaetes, and at Grigore Antipa, Museum National D'Histoire Naturelle, Romania, in consultation with Dr. Modest Gutu for tanaidaceans.

Water and Sediment Analyses

At the same time as the benthic fauna samples were collected (1000–1400 h at time between high and low tide), environmental parameters were also carried out in tripicate. Subsurface water temperature and salinity (30–50 cm) were measured using a bucket thermometer and a refractometer. Subsurface sediments (about 1–5 cm depth) were analysed for total nitrogen by the Kjeldal method (BREMNER & MULVANEY, 1982), organic matter by the Walkley and Black method (NELSON & SOMMER, 1982) and grain size by the hydrometer method (GEE & BAUDER, 1986).

RESULTS

Water Temperature and Salinity

Water temperature varied slightly among stations (Table 1). Salinity varied among sampling periods. The highest salinity range was recorded in November 1997 and July 1999 while the lowest salinity range was recorded in February 1999.

Organic Contents and Particle Size of Sediments

The organic content of all stations varied among seasons but the organic matter of Stations 1 and 2 in particular changed markedly (Table 2). The organic matter of Station 1 was reduced by about 2.4 times after 14 months of mangrove plantation (February 1999) and seemed to be stable at the range 1.6–1.7%. The organic matter of Station 4 increased from 0.99% (February 1999) to 1.93% (July 1999) and 1.84% (February 2000), and the sediment became less solid than in February 1999. Nitrogen content ranged from 0.08 to 0.16%. In general, most particle sizes and textures of sediments in all stations were 40–50% clay.

Macrobenthic Fauna

The densities of total benthic fauna at almost all stations were much higher during the northeast monsoon season (November–February) than during the southwest monsoon season (July). The full list of macrobenthic species is given in Table 3. Although polychaetes, crustaceans and molluscs were commonly found in the study stations, the species richness and densities of each taxon varied among areas and periods of time (Fig. 2).

Station 1: opened, abandoned shrimp pond.—Before mangrove plantation in November 1997, most macrobenthic fauna were polychaetes, with *Neanthes* and *Prionospio* the predominant species. About 94% of the total benthic fauna in November were *Neanthes* (47%) and *Prionospio* (47%). Crustaceans and molluscs were fewer than polychaetes in both species richness and density. The mollusc population tended to increase after 14 months of mangrove plantation (February 1999), while the polychaete density seemed to decrease, with the number of species reduced slightly. The total density of benthic fauna in July decreased markedly but the species number slightly increased. Moreover, the total density of benthic fauna in February 2000 was less than in February 1999, but the species richness was higher.

Station 2: mangrove forest (18 years old).—As in St.1, polychaetes and crustaceans were also found, but the relative densities of these taxa were not much different. There were no polychaete species showing marked dominance. In July, although the total macrobenthic fauna decreased, some crustaceans such as *Pagurapseudopsis, Upogebia,* and some crabs were also found. But species richness of polychaetes was about 50% less. The total density of fauna was higher in February 1999 than in February 2000. This may have been caused by the decrease in the crustacean population. However, the diversity of crustaceans slightly increased.

Station 3: newly formed mudflat.—Polychaetes were abundant, with *Neanthes* markedly dominant (98%) in November. After 12 months of plantation (February 1999) the species composition of macrobenthic fauna changed. The number of molluscs (55%) markedly increased but the polychaetes (44%) decreased, while crustaceans were still rare. In July (after 18 months plantation), the macrobenthic fauna decreased in both density and species. *Solen* was the major bivalve. It is noted that the total faunal density was also less in February 2000 than in February 1999 but the species richness was not changed. Moreover, the crustaceans tended to increase in both density and species number, while the polychaetes decreased in both aspects.

Station 4: closed, abandoned shrimp pond (with occasional seawater intrusion).—After 6 months of mangrove plantation (February 1999) macrobenthic fauna were still very rare. After 12 months of mangrove plantation, they increased slightly. The tanaid crustacean, *Pagurapseudopsis* sp., was predominant. In February 2000, although the colonization of the fauna was not markedly different from February 1999, the mollusc density seemed to increase.

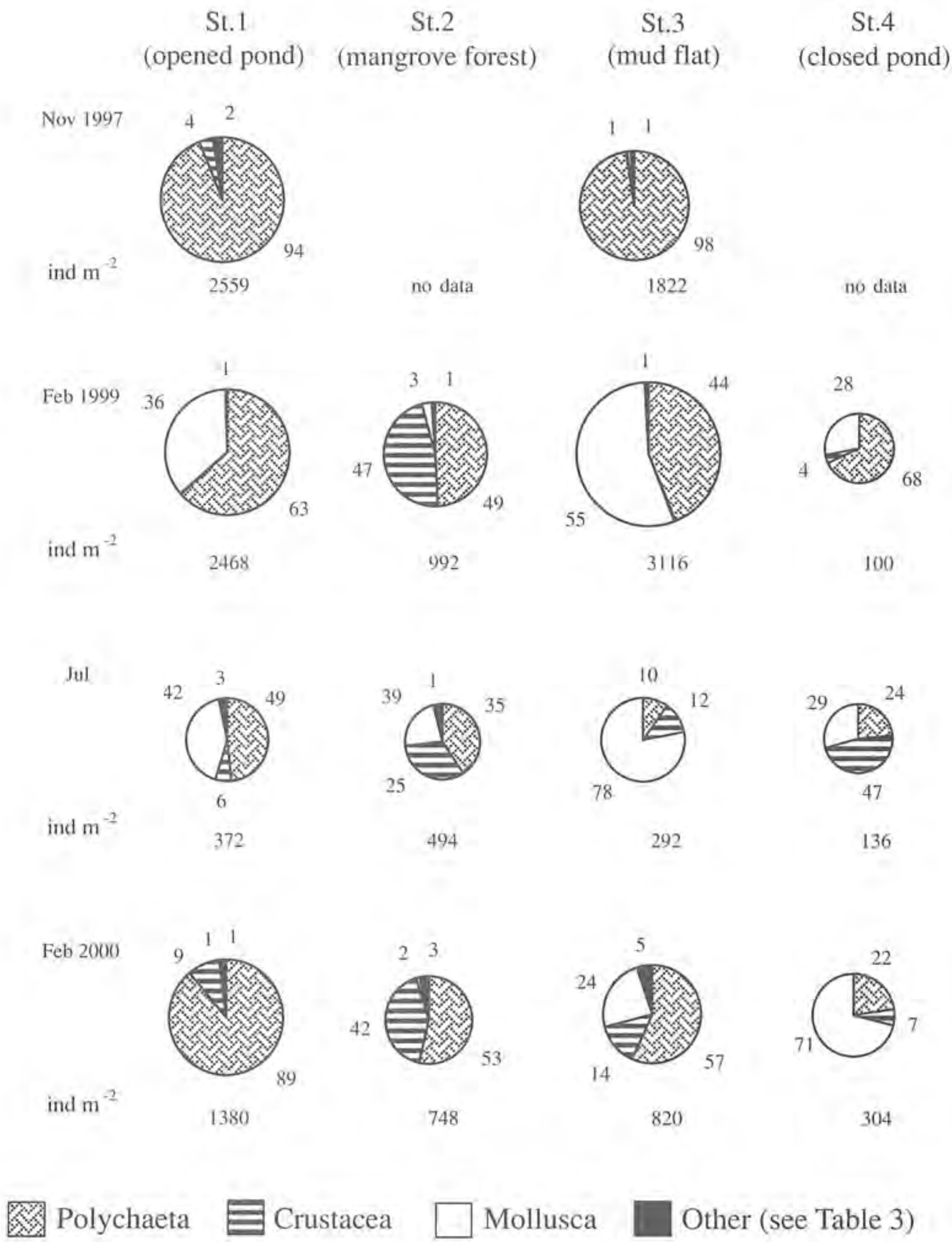

Figure 2. Percentages of macrobenthic faunal groups obtained from four stations. Circled areas express mean numbers of individuals · m^{-2}.

Table 3. Macrobenthic fauna (ind. m^{-2}) at Pak Poon estuary, Nakorn Si Thammarat coast.

Station	1				2				3				4			
Date	N 97	F 99	J 99	F 00	N 97	F 99	J 99	F 00	N 97	F 99	J 99	F 00	N 97	F 99	J 99	F 00
Cnidaria																
Sea anemone	56	12	4	8	-	0	0	0	2	4	0	12	-	0	0	0
Plathyhelmintes																
Unidentified sp.	0	0	4	4	-	0	4	0	0	4	0	0	-	0	0	0
Nemertea																
Unidentified sp.	0	4	0	0	-	12	0	0	0	16	0	0	-	0	0	0
Sipunculida																
Unidentified sp.	0	0	0	0	-	0	0	0	18	0	0	12	-	0	0	0
Annelida																
Polychaeta																
Pilargiidae																
Sigambra sp.	4	16	0	24	-	84	0	60	10	4	0	0	-	0	0	0
Lysarelidae ?																
Unidentified sp.	0	0	0	0	-	4	0	0	0	0	0	0	-	0	0	0
Nereidae																
Dendronereis sp.	42	0	0	0	-	0	0	4	70	4	0	20	-	0	0	0
Leonnates sp.	0	444	24	72	-	4	0	8	0	0	0	0	-	4	0	4
Paraleonnates sp.	0	0	0	0	-	0	0	0	0	0	0	0	-	0	4	0
Neanthes sp.	1129	648	8	468	-	24	4	40	1498	804	8	196	-	0	0	0
Platynereis sp.	0	0	40	44	-	0	0	0	0	0	0	0	-	0	0	0
Ceratonereis sp.	0	440	4	200	-	24	0	36	0	480	8	160	-	44	0	36
Nereis sp.	0	0	0	0	-	0	4	0	0	0	0	0	-	0	0	0
Nereidae larvae	0	0	76	0	-	0	0	0	0	0	0	0	-	0	0	0
Nephtyidae																
Nephtys sp.	10	0	0	48	-	84	0	72	12	8	0	28	-	12	0	12
Aglaophamus sp.	0	0	0	0	-	8	0	8	0	4	0	0	-	0	0	0
Nephtyidae larvae	0	0	0	0	-	0	0	0	0	0	0	0	-	0	4	0
Goniadidae																
Glycinde sp.	0	8	0	0	-	8	0	8	0	8	0	0	-	0	0	0
Goniada sp.	0	0	0	0	-	0	0	0	0	8	0	0	-	0	0	0
Spionidae																
Polydora sp.	0	0	0	0	-	0	4	12	0	0	0	0	-	0	0	0
Minuspio sp.	0	0	0	0	-	4	72	60	0	0	0	0	-	0	0	0
Prionospio sp.	1122	0	0	360	-	0	0	0	160	0	0	32	-	0	0	0
Poecilochaetidae																
Poecilochaetus sp.	0	0	0	0	-	132	40	68	0	28	4	0	-	0	0	0
Cossuridae																
Cossura sp.	12	0	0	0	-	4	0	0	0	0	0	0	-	4	0	0
Sternaspidae																
Sternaspis sp.	0	0	0	0	-	32	0	0	0	0	0	0	-	0	0	0
Capitellidae																
Mediomastus sp.	8	4	4	12	-	76	40	24	4	20	8	20	-	0	24	8
Unidentified sp.	0	0	0	0	-	0	12	0	0	0	0	0	-	0	0	0
Capitellidae larvae	70	0	20	0	-	0	0	0	16	0	0	0	-	0	0	0
Sabellidae																
Branchioma sp.	0	4	4	0	-	0	0	0	0	0	0	0	-	0	0	0
Laonome sp.	0	0	0	0	-	0	0	0	0	0	0	0	-	4	0	8
Glyceridae																
Unidentified sp.	0	0	0	0	-	0	0	0	6	0	0	8	-	0	0	0

Table 3 (continued).

Station	1				2				3				4			
Date	N 97	F 99	J 99	F 00	N 97	F 99	J 99	F 00	N 97	F 99	J 99	F 00	N 97	F 99	J 99	F 00
Ophelidae																
Unidentified sp.	4	0	0	0	-	0	0	0	2	0	0	0	-	0	0	0
Crustacea																
Ctenapseudes sp.	0	0	0	0	-	220	0	52	0	0	0	0	-	0	0	0
Pagurapseudopsis sp.	0	0	0	0	-	88	12	8	0	0	8	12	-	0	52	4
Amphipoda																
Melita sp.	80	0	0	32	-	12	0	84	0	0	0	0	-	0	0	0
Vitoriopisa sp.	0	0	0	28	-	136	0	112	0	8	0	24	-	4	4	12
Isaeidae	8	4	0	8	-	0	0	0	0	0	0	0	-	0	0	0
Decapoda																
Penaeus sp.	2	0	4	4	-	4	2	8	0	0	8	20	-	0	0	0
Alpheus sp.	0	0	0	0	-	4	0	0	0	0	0	0	-	0	0	0
Upogebia sp.	0	0	0	20	-	0	36	12	0	0	0	0	-	0	0	0
Ocypodidae																
Uca lecteaperplaxa	0	0	20	32	-	0	72	36	0	4	20	40	-	0	8	4
Macrophthalmus sp.	4	0	0	0	-	0	0	0	4	0	0	20	-	0	0	0
Mollusca																
Bivalve																
Circinae	0	16	112	0	-	0	4	0	0	1596	4	32	-	0	0	0
Macoma sp.	0	40	8	8	-	0	20	0	0	44	0	8	-	8	8	28
Solen sp.	0	0	36	0	-	0	0	0	4	0	224	160	-	0	0	0
Corbula sp.	0	0	0	0	-	0	0	0	0	0	0	0	-	0	4	20
Gari sp.	0	0	0	0	-	4	0	0	0	0	0	0	-	0	0	0
Unidentified sp.	0	0	0	0	-	0	0	0	16	0	0	0	-	0	0	0
Gastropoda																
Cerithiidae (dead)	6	0	0	0	-	0	0	0	0	0	0	0	-	0	0	0
Unidentified sp.	2	0	0	0	-	0	0	0	0	0	0	0	-	0	0	0
Littorina sp.	0	0	0	0	-	0	160	0	0	0	0	0	-	0	0	0
Cerithiopsis sp. (?)	0	828	0	0	-	24	4	12	0	72	0	0	-	20	16	160
Stenothyra sp.	0	0	0	0	-	0	4	0	0	0	0	0	-	0	0	0
Alvania sp.	0	0	0	0	-	0	0	0	0	0	0	0	-	0	8	8
Hydrobiidae	0	0	0	0	-	0	0	0	0	0	0	0	-	0	4	0
Chordata																
Periophinalmidae	0	0	4	0	-	0	0	0	0	0	0	0	-	0	0	0
Fish larva	0	0	0	8	-	0	0	24	0	0	0	16	-	0	0	0
Total	2559	2468	372	1380	-	992	494	748	1822	3116	292	820	-	100	136	304

DISCUSSION

The value of replanting mangroves in abandoned shrimp farms cannot, at this time, be thoroughly assessed. Data must be assembled over a multi-year and comparable period, dating to pre-shrimp pond establishment if possible, and this study provides only preliminary data. Several points are worth noting, however, particularly, the changes in the benthic faunal community investigated in mangrove forest (Station 2) in comparison with the abandoned shrimp ponds (Stations 1, 4) and newly formed mudflat (Station 3).

In February 1999 polychaete density was much higher than crustacean density in the opened shrimp pond and newly formed mudflat, while they were similar in mangrove forest. Moreover, the density of each benthic species in the mangrove forest was not markedly different, in contrast to the opened shrimp pond and newly formed mudflat where some species of polychaetes, gastropods or bivalves were markedly dominant over other species. Season and water salinity were probably not factors, as these results were all from the February sampling. It is also unlikely that the organic content was a special factor, as the highest organic content (3.9%) was similar to that of the intact mangrove forests (FRITH *ET AL.*, 1976; SHIKANO *ET AL.*, 1997). However, the ratio of polychaetes to crustaceans was similar to sites having a much higher organic content. Such a phenomenon has been previously noted; i.e. (BROWN *ET AL.*, 1987) noted that at a distance of 3 m from some fish cages there was a zone of rich carbon content (9.4%) with low species diversity dominated by the opportunistic polychaetes *Capitella capitata* and *Scalelepis fuliginosa*. In Hiuchi-nada, Seto Inland Sea (Japan), KIKUCHI (1991) found that in an area of high organic matter (10–14% ignition loss of dry mud) in the surface sediment, all crustaceans and echinoderms disappeared, and only a small number of species of minute bivalves (*Theora lubrica*) and polychaetes (*Paraprionospio* sp. B, *Prionospio cirrifera* and *Sigambra tentaculata*) become dominant. In polluted or stressed environments, other studies have reported more polychaetes and fewer crustaceans than usual (AMIO, 1979). GEE & WARWICK (1985) showed that at high levels of organic enrichment harpacticoid copepods decreased in both abundance and diversity of species.

In the present study, however, organic concentrations were not very large. Therefore, it is likely that colonization of the abandoned shrimp ponds or newly formed mudflats was undertaken by opportunistic species that can quickly establish a presence in a newly available area rather than by species responding to high organic content alone (PEARSON & ROSENBERG, 1978).

In July 1999, the total density of benthic fauna decreased drastically at almost all stations, with the exception of the closed shrimp pond (Station 4), which was basically poor. This may have been due to the change of season from dry (March–May) to the southwest monsoon (July–October) which was accompanied by strong wave action, disturbing the habitats of benthic fauna. The degree of benthic community changes varied among stations. The highest impact was in the newly formed mudflat, which was most exposed to the waves, and resulted in the highest decline of species richness and density. At the shoreline, as at the opened shrimp pond, the total density decreased but not the number of species. In addition, crustaceans were still low in number compared to polychaetes or molluscs. The community structure in the young plantation stations (Stations 1, 3 and 4) was not stable yet, unlike that in the mature mangrove forest (Station 2) in which the benthic fauna density decreased but the species richness and proportions of most taxa were relatively low and stable. This tendency was seen in the mangrove swamp of Samut Songkhram, Thailand (SUZUKI *ET AL.* 1997). ROSENBERG (1976), who studied benthic faunal dynamics during succession following pollution abatement in the Saltkallefjord Estuary in Sweden, found that polychaetes dominated at some stations in the first years following pollution abatement, but that at non-polluted stations echinoderms dominated the biomass, with polychaetes and molluscs making up a smaller but almost equal share.

The closed shrimp pond seemed to be little affected by the onset of the strong waves because of unbroken dikes around the pond. In fact, with a bottom substratum of consolidated clay, the area was poor in both benthic fauna and organic content. The combination of these two physical factors may have delayed the colonization of benthic infauna such as polychaetes which are often found in the coastal benthos communities. It is notable, however, that the tanaid crustacean, *Pagurapseudopsis* sp., was predominant in July in the closed shrimp pond. This species was found in mangrove forest but not in the opened shrimp pond and newly formed mudflat. SUZUKI *ET AL.* (1997) suggested that the tanaid, *Apseudes* sp., needed the habitat created by young *Avicennia* colonizing the plantation area 1 to 5 years after planting.

In February 2000, the sediment and water quality in each study site were similar to the previous February. However, the benthic fauna communities clearly changed in the opened shrimp pond and newly formed mudflat. The dominant polychaete species tended to decrease while the crustaceans increased in both density and species diversity, indicating better recolonization.

The abundance of benthic fauna at the study area was not much different from that found in Kradae Chae Canal, Ban don Bay (ANGSUPANICH & AKSORNKOAE, 1996), but the species richness was comparatively high. The latter was affected by deforestation along the canal (ANGSUPANICH & AKSORNKOAE, 1996). However, the present study shows lower density and species richness than at Samut Songkhram mangrove swamp (SUZUKI *ET AL.* 1997). The different sampling methodology should also be noted, as the sampling of benthic fauna by grab may be unrepresentative for the larger epifauna, and more mobile fauna (e.g. crabs) may escape.

The community structure of intact mangrove swamps and abandoned shrimp ponds needs to be monitored continuously for at least 5 years. This would provide important baseline data for the conservation of mangrove ecosystems. In addition, abandoned shrimp ponds which are often flooded by tide seem to be better colonized by macrobenthic fauna. Although the colonization and succession of the macrobenthic community in the study area has not yet been fully traced, some trends seem evident. Mangrove replanting may be the most effective method for rehabilitation of abandoned shrimp ponds. Although this will involve expenditure of some time and money it can effectively restore this important natural ecosystem and reduce the pollution of coastal waters.

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