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Original Article

Biodiversity of benthic fauna in the seagrass ecosystem of Kung Krabaen Bay, Chantaburi Province, Thailand

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Abstract

Biodiversity of benthic fauna was high in the seagrass ecosystem in Kung Krabaen Bay even though the bay's coast had many intensive shrimp farms. *Halodule pinifolia* and *Enhalus acoroides* were two species of seagrasses distributed widely in the bay. Their biomass was higher in summer than in the rainy season. 27 families of polychaetes and 10 species of gastropods were predominantly distributed in the seagrass beds and their biodiversity indices were not different among transects (North, East, South). At the same time, 18 species of bivalves were distributed among seagrass beds, but they had a greater diversity index in the north and east than in the south. The abundance of gastropods, bivalves and polychaetes were significantly correlated with the biomass of *H. pinifolia* (65%, 39% and 27%, respectively); whereas only bivalves correlated significantly with the biomass of *E. acoroides* (36%). Treated wastewater effluents from shrimp farms did not affect the seagrass ecosystem. Water quality in the bay was suitable for natural resources preservation.

Keywords: biodiversity, seagrass, benthic fauna, shrimp farming, Kung Krabaen Bay

1. Introduction

Seagrasses are marine angiosperms (Phillips and Menez, 1988), widely distributed in shallow coastal areas. They play several significant ecological roles including being highly productive, a nursery and feeding ground for associated marine fauna, and a nutrient and detritus cycling source, stabilizing and enriching sediments, and improving coastal water quality (Bostrom & Bondsdorff, 1997; Hemminga & Duarte, 2000; Spalding *et al.*, 2003; Kwak & Klumpp, 2004). Twelve species of seagrass are found in 19 provinces of Thailand i.e. along the coastlines of the Gulf of Thailand and Andaman Sea (UNEP, 2004). *Enhalus acoroides*, *Halodule pinifolia*, *Halaphila minor*, *H. decipiens* and *H. minor* were found in the seagreass beds of Kung Krabaen Bay; the first two species were recorded as the most dominant species (Sudara *et al.*, 1991; Ayuttaka *et al.*, 1994).

Seagrasses are declining according to natural and anthropogenic impacts (UNEP, 2004). In Thailand, seagrasses have been subjected to a number of threats including fishing with trawl and push nets, wastewater discharge from coastal industries and urban development, in particular from shrimp farms, and siltation from coastal land development (Satumanatpan, 2008; Satumanatpan and Plathong, 2003).

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Sangrungruang *et al*. (1999) reported that Kung Krabaen Bay has been disturbed by shrimp farming. High nutrients from the shrimp farms accumulated continuously within the sediment along the bay resulting in deteriorated sea-shore communities. To address this problem, the Fishery Department constructed a sea irrigation system for shrimp farming in this area. The system was designed to treat wastewater from shrimp farms before it drained into the bay. Even though this system was developed thoughtfully, treated wastewater may have some other influences on seagrass ecosystems after drainage into the bay.

This study focuses on the biodiversity of benthic fauna, which include polychaetes, gastropods, and bivalves in the seagrass ecosystem and their relationship with the biomass of seagrasses. A parallel study assesses the quality of treated wastewater from shrimp farms, which may alter the biomass of seagrasses.

2. Methodology

Seagrasses and benthic fauna were sampled along transect lines located in the north, east, and south of Kung Krabaen Bay during the rainy season in October 2005 and the summer in April 2006 (Figure 1). Distances of sampling depended on the presence of seagrasses distributed along each transect line. GPS was used to indicate sampling stations along the transect lines. Random sampling was done with a quadrat of 0.25 m^2, twice at each station. All samples were preserved in plastic bags with 10% formalin. Water samples were also collected at the drainage canals around the shrimp farms (October 2005 and April 2006) and at each transect in the bay (April 2006), into which the canals ran (Figure 1).

Biomass of seagrasses was determined by washing the preserved seagrasses with fresh water and then soaking them in 5% phosphoric acid for about 10–15 minutes. The pre-treated seagrasses were then dried at 25°C followed by oven drying at a temperature range of 40–60 °C for 1–2 days after which they were weighed.

The benthic fauna was collected by removing the sediment in each of the biomass quadrat, and sieving through a 1–2 mm sieve to separate macrofauna. The fauna sample collected was thoroughly washed with fresh water and the species present were identified based on the taxonomic classifications of Kira (1965), Habe (1968), Abbott and Dance (1991), Carpenter and Niem (1998), Day (1967a, b) and Fauchald (1977). Each group was preserved in 70% alcohol. The biodiversity index of benthic fauna was calculated using the Shannon-Weiner diversity index, whereas the relationship between biomass of seagrasses and each group of benthic fauna was analyzed with Spearman's rho correlation and a curvilinear regression.

Water quality was analyzed following standard methods (Pollution Control Department, 2006). Twelve parameters were considered: pH, temperature (°C), salinity, dissolved oxygen (DO), transparency, alkalinity, suspended sediment, nitrate (NO_3^-), ammonia (NH_4^+), orthophosphate ($OrPO_4^{3-}$) , biological oxygen demand (BOD), and chlorophyll A.

3. Results

3.1 Seagrasses

Two species of seagrasses, *Halodule pinifolia* and *Enhalus acoroides*, were dominant in Kung Krabaen Bay. Both species were present in the north and east. In contrast,

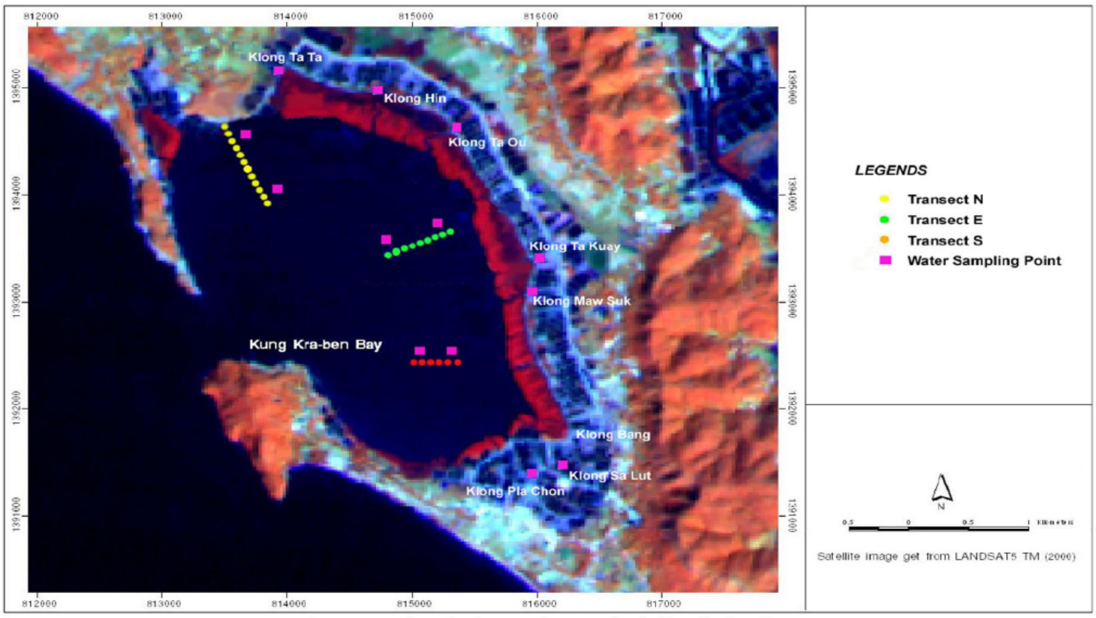

Figure 1. Transect lines in the north, the east, and the south to sample seagrasses, benthic fauna, and water quality.

only *Enhalus acoroides*, was found in the south. The biomass in summer (April) was higher than in the rainy season (October) as shown in Table 1.

3.2 Benthic fauna

The abundance of benthic fauna in Kung Krabaen Bay was analyzed at family and species level. Twenty seven families of polychaetes were found across all transects; 25, 20, and 19 families were found in the north, east, and south, respectively (Table 2). There were more polychaetes in the north and the east than in the south. Abundance of gastropods was considered at the species level and a total of 10 species were found. In the north, nine species were found whereas there were five species in the south (Table 3). *Clithon oualaniensis* was the dominant species. *Cerithium coralium*, *Cerithidia cingulata*, and *Nassarius spp* were present in relatively lower proportions. Abundance of bivalves was also considered at the species level, and 18 species were found throughout the study area. Sixteen species of bivalves

Table 1. Average biomass of seagrasses in Kung Krabaen Bay (g/m^2)

	Transects	North		East		South	
		H. pinifolia	*E. acoroides*	*H. pinifolia*	*E. acoroides*	*H. pinifolia*	*E. acoroides*
Biomass	October	20.19±6.87	140.66±42.09	19.20±4.18	74.68±53.06	-	244.53±30.53
(g/m^2)	April	84.15±28.46	823.79±184.39	115.41±30.49	354.57±110.93	-	616.29±63.29

Table 2. Abundance of polychaetes (number /m^2)

No.	Families	North				East				South			
		Oct.	%	Apr.	%	Oct.	%	Apr.	%	Oct.	%	Apr.	%
1	*Aphroditidae*	0	0	0	0	0	0	0	0	0	0	8	0.69
2	*Amphinomidae*	0	0	185	8.65	0	0	56	3.35	0	0	32	2.78
3	*Phyllodocidae*	26	1.12	0	0	6	0.57	0	0	0	0	32	2.78
4	*Lacydoniidae*	4	0.17	24	1.04	0	0	0	0	0	0	0	0
5	*Hesionidae*	2	0.09	24	1.04	2	0.19	24	1.44	0	0	0	0
6	*Pilargidae*	6	0.26	16	0.69	0	0	0	0	0	0	0	0
7	*Syllidae*	8	0.34	16	0.69	0	0	16	0.96	0	0	0	0
8	*Nereididae*	20	0.86	224	9.69	6	0.57	240	14.35	2	0.74	112	9.72
9	*Nephtyidae*	6	0.26	0	0	14	1.33	8	0.48	0	0	0	0
10	*Glyceridae*	14	0.60	16	0.69	28	2.65	8	0.48	8	2.94	0	0
11	*Goniadidae*	82	3.53	40	1.73	42	3.98	72	4.31	4	1.47	56	4.86
12	*Eunicidae*	46	1.98	96	4.15	28	2.65	40	2.39	28	10.29	72	6.25
13	*Lumbrineridae*	62	2.67	104	4.50	56	5.30	8	0.48	10	3.68	0	0
14	*Oenomidae*	8	0.34	0	0	0	0	0	0	4	1.47	0	0
15	*Onuphidae*	0	0	0	0	0	0	0	0	0	0	8	0.69
16	*Orbiniidae*	776	33.36	120	5.19	286	27.08	216	12.92	72	26.47	112	9.72
17	*Paraonidae*	238	10.23	120	5.19	122	11.55	8	0.48	52	19.12	8	0.69
18	*Spionidae*	60	2.58	120	5.19	48	4.55	112	6.70	16	5.88	16	1.39
19	*Magelonidae*	6	0.26	0	0	0	0	0	0	0	0	0	0
20	*Cirratilidae*	2	0.09	8	0.35	2	0.19	0	0	2	0.74	0	0
21	*Opheliidae*	2	0.09	824	35.64	2	0.19	600	35.89	6	2.21	352	30.56
22	*Capitellidae*	392	16.86	248	10.73	340	32.20	72	4.31	54	19.85	40	3.47
23	*Maldanidae*	456	19.60	72	3.11	36	3.41	48	2.87	6	2.21	72	6.25
24	*Oweniidae*	0	0	16	0.69	0	0	32	1.91	0	0	0	0
25	*Ampharetidae*	32	1.38	0	0	0	0	32	1.91	0	0	0	0
26	*Sabellidae*	76	3.27	8	0.35	22	2.08	0	0	2	0.74	0	0
27	*Terebellidae*	2	0.09	16	0.69	16	1.52	80	4.78	6	2.21	232	20.14
	Total	2,326	100	2,297	100	1,056	100	1,672	100	272	100	1,056	100
	Families	23		19		17		18		15		14	

Table 3. Abundance of gastropods (number/m^2)

No.	Species	North				East				South			
		Oct.	%	Apr.	%	Oct.	%	Apr.	%	Oct.	%	Apr.	%
1	*Clithon oualaniensis*	1,560	93.53	552	57.98	1726	95.46	592	56.92	358	92.33	88	33.33
2	*Cerithidea cingulata*	14	0.84	120	12.61	16	0.88	304	29.23	2	0.52	48	18.18
3	*Cerithium coralium*	38	2.28	152	15.97	8	0.44	128	12.31	6	1.53	16	6.06
4	*Epitonium* sp.	0	0	16	1.68	0	0	0	0	0	0	0	0
5	*Nassarius livescens*	0	0	16	1.68	18	1.00	0	0	0	0	0	0
6	*Nassarius* sp.	6	0.36	0	0	20	1.11	16	1.54	0	0	0	0
7	*Mitra* sp.	50	3.00	64	6.72	10	0.55	0	0	26	6.63	104	39.39
8	*Pyramidella* sp.	0	0	8	0.84	4	0.22	0	0	0	0	8	3.03
9	*Thiara* sp.	0	0	24	2.52	0	0	0	0	0	0	0	0
10	*Umbonium* sp.	0	0	0	0	6	0.33	0	0	0	0	0	0
	Total	1,668	100.0	952	100.0	1,808	100.0	1,040	100.0	392	100.0	264	100.0
	species	5		8		8		4		4		5	

Table 4. Abundance of bivalves (number/m^2)

No.	Species	North				East				South			
		Oct.	%	Apr.	%	Oct.	%	Apr.	%	Oct.	%	Apr.	%
1	*Anadara troscheli*	8	1.69	0	0	18	7.14	0	0	8	12.90	0	0
2	*Anadara tricenicosta*	10	2.12	88	7.75	10	3.97	152	15.08	0	0	32	1.39
3	*Barbatia foliata*	0	0	0	0	0	0	8	0.79	0	0	8	0.35
4	*Striarca* sp.	2	0.42	56	4.93	0	0	8	0.79	0	0	0	0
5	*Musculista senhausia*	0	0	88	7.75	0	0	120	11.90	0	0	2064	89.58
6	*Pteria* sp.	0	0	40	3.52	0	0	8	0.79	0	0	0	0
7	*Pelecyora gouldi*	4	0.85	24	2.11	2	0.79	0	0	0	0	0	0
8	*Anomalocardia squamosa*	180	38.14	128	11.27	64	25.40	232	23.02	26	41.94	48	2.08
9	*Placamen tiara*	14	2.97	136	11.97	2	0.79	32	3.17	6	9.68	0	0
10	*Katelysia hiantina*	8	1.69	16	1.41	4	1.59	0	0	0	0	8	0.35
11	*Dosinia* sp.	120	25.42	120	10.56	82	32.54	112	11.11	0	0	8	0.35
12	*Circe scripta*	12	2.54	16	1.41	2	0.79	24	2.38	0	0	0	0
13	*Gafrarium tumidum*	32	6.78	192	16.90	14	5.56	112	11.11	14	22.58	80	3.47
14	*Tellina* sp.	46	9.75	160	14.08	46	18.25	104	10.32	6	9.68	48	2.08
15	*Acropagia* sp.	10	2.12	32	2.82	6	2.38	48	4.76	0	0	0	0
16	*Solen* sp.	10	2.12	8	0.70	0	0	0	0	0	0	0	0
17	*Corbula crassa*	16	3.39	32	2.82	2	0.79	48	4.76	2	3.23	0	0
18	*Laternula* sp.	0	0	0	0	0	0	0	0	0	0	8	0.35
	Total	472	100.0	1136	100.0	252	100.0	1,008	100.0	62	100.0	2304	100.0
	species	14		15		12		13		6		9	

were found in the north and east, which was more than in the south (12 species) (Table 4). *Anomalocardia squamosa* was the dominant species in the north and east followed by *Dosinia sp.* and *Gafrarium tumidum*, respectively. In the south, *Musculista senhausia* was the dominant species.

Biodiversity indices of polychaetes and gastropods across each transect were not different whereas bivalves had a higher index in the north and east compared to the south (Table 5).

Abundance of polychaetes, gastropods and bivalves was correlated with the biomass of *H. pinifolia* (27%, 65%, and 39% respectively). Curvilinear regression analysis showed the relation between gastropods and *H. pinifolia* to be: $Y = 48.64-4.98X-0.029X^2+0.00004X^3$ (where Y = abundance of gastropod, X=biomass of *H. pinifolia*). On the other hand, the number of bivalves correlated with *E. acoroides* (36%).

3.3 Water quality

Water quality in the bay and in the drainage canals (Tables 6 and 7) was comparable even though there were many intensive shrimp farms draining into the canals. The measured parameters complied with the national coastal water quality for natural preservation or type 1 water (Pollution Control Department, 2006). Nevertheless BOD, nitrate, and phosphate in those drainage canals were higher than in the bay.

4. Discussion and Conclusion

H. pinifolia and *E. acoroides* were the dominant species in Kung Krabaen Bay. Other studies have reported similar findings (Sudara *et al.*, 1991; Ayuttaka *et al.*, 1994). Biomass of both species was higher in summer than during the rainy season. This may be due to changes in seagrass beds caused by tidal fluctuations. Particularly, during the rainy season, which was influenced by the southwestern monsoon, much sediment covered seagrass beds. Consequently, seagrasses were not able to photosynthesize and then declined. Siltation has been indicated as the primary cause of deterioration for seagrass in the South China Sea (Terrados *et al.*, 1998; UNEP, 2004; Satumanatpan and Sanwong, 2006; Satumanatpan, 2008). Moreover, in the rainy season, fishermen prefer to catch fish, especially economic groups such as mullet, snapper, grouper, and *Acetes* spp., on the seagrass bed by using a push net which may destroy seagrasses. Therefore, biomass during this season was lower than in summer (Ayuttaka *et al.*, 1994; Chatananthawej, 2002).

Overall, the biodiversity indexes of polychaetes and gastropods was not much different among the three transects

Table 5. Biodiversity indexes of polychaetes, gastropods, and bivalves along each transect line

Transects	Biodiversity indexes (H′)		
	Polychaetes	Gastropods	Bivalves
North	1.0583	0.7894	2.2317
East	1.0574	0.6878	2.2258
South	1.0138	0.9301	0.6175

Table 6. Water quality in the bay

Transects	Standard for natural resources preservation [1]	North (Start point)	North (End point)	East (Start point)	East (End point)	South (Start point)	South (End point)
pH	7.5-8.0	8.0	8.0	8.0	8.0	8.0	8.0
Temp (C°)	$\leq$ 1°C from natural condition	30	30	30	30	30	30
Salinity (ppt)	$\leq$ 10% of the lowest salinity[2]	30	30	30	30	30	30
DO (mg/l)	$\geq$4.0	4.8	4.8	5.2	4.6	4.2	5.6
Transparency (cm)	Decrease $\leq$ 10% from the lowest transparency [3]	120	120	120	120	120	80
Alk (mg/l)	-	110	109	108	109	108	108
SS (mg/l)	Increasing change $\leq$ average concentration of SS (±SD)[4]	4.27	4.03	1.86	2.66	3.20	4.90
NO_3^- (mg/l)	<0.02	0.0016	0.0011	0.0010	0.0011	0.0032	0.0015
NH_4+ (mg/l)	<0.07	0.0006	0.0010	0.0000	0.0009	0.0028	0.0000
$OrPO_4^{3-}$ (mg/l)	<0.015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BOD (mg/l)	-	0.27	0.27	0.70	0.30	1.00	0.57
ChloroA (mg/m³)	-	4.86	3.28	3.80	3.83	4.60	3.93

Remarks: From Pollution Control Department (2006)

[1] Water quality for natural resources preservation: Coastal water that are not for any purpose usage, but are places for reproductive, nursery grounds, food sources or habitat for fauna and flora (such as seagrasses).

[2] Salinity: Lowest salinity of seawater from the same station in the previous year, with the same tide and season

[3] Transparency: Lowest transparency means transparency which was measured from the same station in the previous year, at the same tide time

[4] Suspended solid (SS): Three categories can be done as follows

Average 1 day: measures of SS every single hour or at least 5 times of equal period in one day

Average 1 month: measures of SS at least 4 times of equal period in a month

Average 1 year: measures of SS every month at the same time

Table 7. Water quality in the drainage canals around Kung Krabaen Bay, Chantaburi Province

Transects	Month	Tata Canal	Hin Canal	Ta-Uoo Canal	Ta Guai Canal	Morsuk Canal	Pla chon Canal	Slut Canal
pH	Oct	7.9	7.9	7.9	8.0	8.0	8.0	8.0
	Apr	8.0	7.8	7.7	8.0	8.0	8.0	7.9
Temperature (C°)	Oct	31	30	28	31	30	30	30
	Apr	32	30	30	32	32	31	31
Salinity (ppt)	Oct	20	10	15	25	30	29	25
	Apr	35	34	35	34	35	30	30
DO (mg/l)	Oct	5.4	3.4	1.6	4.8	4.8	3.0	4.2
	Apr	6.4	3.8	3.6	6.2	4.6	4.4	4.6
Transparency (cm)	Oct	60	30	40	40	50	30	40
	Apr	40	60	40	50	60	40	40
Alk (mg/l)	Oct	134	110	178	154	128	124	126
	Apr	132	130	154	176	114	112	114
SS (mg/l)	Oct	24.5	24.7	11.0	27.8	31.5	22.3	22.4
	Apr	36.2	12.4	21.3	29.1	12.0	8.9	25.1
NO_3^- (mg/l)	Oct	0.4306	0.6590	1.1513	0.4921	0.0277	0.1601	0.0499
	Apr	0.1294	0.0402	0.0633	0.1124	0.0540	0.0598	0.0368
NH_4^+ (mg/l)	Oct	0.1203	0.0644	0.1142	0.0690	0.0188	0.0569	0.1815
	Apr	0.2327	0.0608	0.1886	0.6488	0.1306	0.0761	0.0860
$OrPO_4^{3-}$ (mg/l)	Oct	0.0040	0.0038	0.0598	0.0026	0.0000	0.0035	0.0032
	Apr	0.0000	0.0000	0.0003	0.0054	0.0000	0.0043	0.0000
BOD (mg/l)	Oct	3.5	3.3	3.3	6.2	2.0	2.2	2.5
	Apr	3.5	1.6	3.5	5.5	0.2	2.5	2.1
Chlorophyll A (mg/m^3)	Oct	36.54	44.67	24.47	65.38	21.34	29.52	24.52
	Apr	35.41	14.11	23.96	44.96	11.53	24.56	6.94

as compared to the bivalves. The number of species for each group of fauna was clearly higher in the north and east than the south transects. This could be explained by the complicated structure of the seagrass ecosystem. In the north and east transects, there were *H. pinifolia* and *E. acoroides* communities whereas in the south only one community of *E. acoroides* was present. (Nateekanjanalarp and Sudara, 1992).

Although sediment type and organic content were considered important factors to control diversity and abundance of benthic fauna (Rhoads, 1974), no obvious indication revealed that those two factors explained the high diversity and abundance of benthic fauna in the north and east compared with the southern transects from this study. Many studies (Ayuttaka *et al.*, 1994; Sangrungruang *et al.*, 1999) reported that Kung Krabaen Bay basin was formed with a slightly heterogeneous sediment pattern, mainly mud (silt-clay) in the north and south and fine to very fine sand in the middle part of the bay. Similarly, the organic content was higher in the drainage canals and the shoreline gradually reducing towards the bay (Sangrungruang *et al.*, 1999). It appeared that a greater sediment organic content was found in the north than in the other two transects (Kanogdate, 2006). This might explain the high diversity and abundance of polychaetes in the northern transect, as organic matter was essentially food sources for polychaetes (Rhoads, 1974; Bianchi, 1988). The higher organic content of the sediments and the seagrass itself compared with the adjacent bare sand area (Kakai, 2004) may explain the high abundance and diversity of benthic fauna in the seagrass bed (Kirkman *et al.*, 1991; Satumanatpan *et al.*, 2006).

Clithon oualaniensis was the dominant species of gastropod found in the bay, because they are herbivorous and presumably fed by scraping seagrass leaves for algae and diatoms (CSIRO, 2007). In the southern transect there was a higher abundance of the bivalve *Musculista senhausia* than in the other two transects. There were two likely reasons for this: first, *M. senhausia* is an opportunistic species which can be found from intertidal to subtidal habitats and on soft or hard substrata. Second, it is likely that juveniles of *M. senhausia* preferred to settle on the seagrass structure; preferably on the large blades of *E. acorodides* than on the smaller blades of *H. pinifolia.* Juveniles of this species have been reported to settle on eelgrass at densities of 28,650 ind./m^2 on tropical coasts (Global Invasive Species Database, 2006).

Gastropod abundance showed a significant correlation with the biomass of *H. pinifolia* (65%), followed by bivalves (39%) and polychaetes (27%), whereas only bivalves significantly correlated with the biomass of *E. acoroides* (36%). The high correlation of gastropods with *H. pinifolia* may be because of the high surface area of leaves compared with that of *E. acoroides* which has wider leaves but much fewer. The gastropods were feeding on food sources living on the seagrass blades and using them for protection. This was further supported by a study of Doropoulos *et al.* (2009), who found two species of gastropods (*Pyrene bidentata* and *Cantharidus lepidus*) displayed a preference for food sources over seagrass leaves. Similarly, the gastropod (*C. oualaniensis)* presumably chosen to feed on algae and diatom on seagrass leaves and the bivalve (*M. senhausia)* selected to settle on the seagrass blade of *E. acorodides,* such preferences were likely to answer the mollusks' abundance as mentioned in the previous paragraph. A decline in *H. pinifolia* could result in a decrease in gastropod population. On the other hand, when the community recovers, the gastropod population will also develop (Lauhajinda, 2003).

Water quality in the seagrass beds complied with the standard of water quality for nature preservation (Pollution Control Department, 2006). This indicated that Kung Krabaen Bay was a healthy area for reproduction, nursery grounds, food sources or habitat for marine fauna and flora. The reason for this may be that shrimp farm effluent was treated by physical (aeration system) and adjacent biological (mangrove) systems around the bay. Moreover, the tidal system in the bay flushed approximately 86% of it every day (Sasaki and Inoue, 1985). These might be the reasons that there was good water quality in the undisturbed seagrass ecosystem, and why it was able to support a highly diverse and abundant benthic fauna.

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References

Abbott, R.T. and Dance, S.P. 1991. Compendium of seashells. Charles Hetts & Co.Ltd., London. 412 pp.

Ayuttaka, J., Sungthong, S. and Awaivanonth K. 1994. Seagrass beds in Kung Krabaen Bay, Chantaburi Province. In: Department of Fisheries Seminar Report, 16–18 September 1993. Department of Fisheries.

Bianchi, T.S. 1988. Feeding ecology of surface deposit-feeder *Leitoscoloplos fragilis* Verrill. I. Mechanism affecting particle availability on intertidal sandflat. Journal of Experimental Marine Biology and Ecology. 115, 79-97.

Bostrom, C. and Bonsdorff, E. 1997. Community structure and spatial variation of benthic invertebrates associated with *Zostera marina* (L.) beds in the northern Baltic Sea. Journal of Sea Research. 37, 153-166.

Carpenter, K.E. and Niem, V.H. 1998. The Living Marine Resources of the Western Central Pacific. Vol 1. FAO, Rome. 686 pp.

Chatananthawej, B. 2002. Seagrasses of Kung Krabaen Bay, Chantaburi Province. Royal Development Center for Kung Krabaen Bay, Department of Fisheries. Ministry of Agricultural and Cooperative. Bangkok.

CSIRO. 2007. Cycloneritomorpha Neritidae. Available from http://www.mdfrc.org.au/bugguide/display.asp?class=21&subclass=&order=46&Couplet=0&Type=3 [Accessed 27 June 2011].

Day, J.H. 1967a. A monograph on the Polychaeta of Southern Africa, Part I. Errantia, Trustees of the British Museum (Natural History), London.

Day, J.H. 1967b. A monograph on the Polychaeta of Southern Africa, Part II. Serdentaria, Trustees of the British Museum (Natural History), London. 10

Doropoulos, C., Hyndes, G.A., Lavery, P.S., and Tuya F. 2009. Dietary preferences of two seagrass inhabiting gastropods: Allochthonous vs autochthonous resources. Estuarine, Coastal and Shelf Science. 83, 13-18.

Faunchald, K. 1977. The Polychaete worms: definitions and keys to the Order Families and Genera. Natural History Museum of Los Angeles County, Science Series; 28: 1–190.

Global Invasive Species Database. 2006. *Musculista senhousia*. Available from: http://www.issg.org/database/species/ecology.asp?si=1031&fr=1&sts [Accessed 27 June 2011].

Habe, T. 1968. Shells of Western Pacific in Color. Vol 2. Hoikusha Publishing Co. Ltd., Osaka.

Hemminga, M.A. and Duarte, C.M. 2000. Seagrass ecology. Cambridge University Press, Cambridge, United Kingdom, pp. 199-247.

Kakai, N. 2004. Structure of macro-benthic in seagrass beds, Kung Krabaen Bay, Chantaburi Province. (Master thesis in Aquatic Science). Burapha University.

Kirkman, H., Humphries, P. and Manning, R. 1991. The epibenthic fauna of seagrass beds and bare sand in Princess Royal Harbour and King George Sound, south-western Australia. Proc. of Third International Marine Ecological Workshop: The Marine Flora and Fauna of Albany, Western Australia. Eds. Wells, F.E., Walker, D.I., Kirkman, H. and Lethbridge, R. Western Australian Museum, Perth. 553-563

Kira, T. 1965. Shells of the Western Pacific in Color. Vol 1. Hoikusha Publishing Co. Ltd., Osaka. 224 p.

Kanongdate, K. 2005. Influence of physical and chemical characteristics of sediment on the distribution and biomass of seagrasses: Kung Krabaen Bay, Chanthaburi Province. (Master thesis in Technology of Environmental Management). Mahidol University.

Kwak, S. and Klumpp, D.W. 2004. Temporal variation in species composition and abundance of fish and decapods of a tropical seagrass bed in Cockle Bay, north Queensland, Australia. Aquatic Botany. 78, 119-134.

Lauhajinda, N. 2003. Ecology: basic environmental education. Kasetsart University Press. Bangkok. (In Thai).

Nateekanjanalarp, S. and Sudara, S. 1992. Species composition and distribution of seagrasses at Koh Samui, Thailand. In Proceeding of the 3rd ASEAN-Science and Technology Week Conference, L.M. Chou and C.R. Wilkinson, editors. Singapore, 1992, 251-260.

Phillips, R.C. and Menez, E.G. 1988. Seagrasses. Smithsonian Institution Press. Washington, D.C. 104p.

Pollution Control Department. 2006. Marine water quality standard. Ministry of Natural Resources and Environment. Bangkok.

Rhoads, D.C. 1974. Organism-sediment relations on the muddy sea floor. Oceanography and Marine Biology: An Annual Review. 12, 263-300.

Sasaki, T. and Inoue, H. 1985. Studies on fundamental environments in the Kung Krabaen Bay, eastern Thailand, hydraulic environments: In: Mangrove estuarine ecology in Thailand.

Thai-Japanese Cooperative Research Project on Mangrove Productivity and Development 1983-1984, 77-98

Sangrungruang, C., Sakares, V., Anongpornyosakul, M. and Dumluk, B. 1999. Impact assessment of shrimp farming to the physical structure of soil and water, Kung Krabaen Bay before using seawater irrigation system. Kung Krabaen Royal Development Center, Chantaburi Province. (In Thai)

Satumanatpan, S. (eds.). 2008. National strategic and action plan for management seagrasses and dugong. Department of marine and coastal resources, No.34.

Satumanatpan, S. and Plathong, S. 2003. Causal chain analysis and management intervention for seagrass resources in The Gulf of Thailand. 6th International Conference on the Environmental Management of Enclosed Coastal Seas (EMECS 2003) "Comprehensive and Responsible Coastal Zone Management for Sustainable and Friendly Coexistence between Nature and People", Bangkok, Thailand, November 18-21, 2003.

Satumanatpan S., and Sanwong V. 2006. Effect of suspended sediment quantity on the survival rate of seagrass: *Halodule pinifolia.* Songklanakarin Journal of Science and Technology. 28(4), 877-885

Satumanatpan, S. Thummikkapong, S. and Kanongdate, K. 2006. Impact of coastal activities on seagrass ecosystem in the Gulf of Thailand. Mahidol University.

Spalding, M., Taylor, M., Ravilious, C., Short, F. and Green, E. 2003. Global overview the distribution and status of seagrsses. University of California Press, Los Angeles, U.S.A, pp 5-26.

Terrados, J., Duarte, C.M., Fortes, M.D., Borum, J., Agawin, N.S.R., Bach, S., Thampanya, U., Kamp-Nielsen, L., Kenworthy, W.J., Greetz-Hansen, O. and Vermatt, J. 1998. Changes in community structure and biomass of seagrass communities along gradients of siltation in SE Asia. Estuarine, Coastal and Shelf Science. 46, 757-768.

Sudara, S., Nateekanjanalarp, S., Thamrongnawasawat, T., Satumanatpan S. and Chindonniral, W. 1991. Survey of fauna associated with the seagrass community in Aow Khung Krabaen Chantaburi, Thailand. Proceedings of the Regional Symposium on Living Resources in Coastal Areas. Manila, Philippines, October 16-20, 1991, 347-352.

UNEP. 2004. Seagrass in the South China Sea. UNEP/GEF/SCS Technical Publication No. 3