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DISTRIBUTION OF MOLLUSCS IN MANGROVES AT SIX SITES IN THE UPPER GULF OF THAILAND

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***ABSTRACT.* –** Molluscs were studied in mangroves at six sites in the upper Gulf of Thailand from March to June 2004. At each site, density, diversity, and biomass of molluscs were measured in replicate samples made in four habitats: *Avicennia* and *Rhizophora* tree zones, and the unvegetated mudflat and channel. There is no *Rhizophora* zone at the site at Ang Sila. A moderate diversity of 47 species (31 gastropods and 16 bivalves) was collected. There was considerable variation in population characteristics between sites and between habitats at a site. Mangrove tree habitats tended to have greater diversity than unvegetated habitats. Mean density varied from 9.4/m^2 at Ban Num Chieo to 841.5/m^2 at Bangpoo, a difference of almost two orders of magnitude. There was no clear pattern of density in the different habitats. Three habitats (mudflat, *Avicennia* and *Rhizophora* tree zones) each had one site where there were no molluscs found. The greatest densities were recorded in three different habitats: 1,120.6/m^2 in the channel at Laem Chabang; 1,235.8/m^2 in *Rhizophora* at Khlong Khon; and 3,289.6/m^2 in *Avicennia* at Bangpoo. The high densities in these three habitats were contributed entirely by three different species, one at each of the habitats. The greatest biomass was found at different sites from the greatest density. A single species of bivalve was responsible for the high biomass at the three sites with the greatest biomass; the dominant species differed at the three habitats. Three assemblage groupings were found. The largest comprised molluscs from all *Avicennia* and *Rhizophora* habitats and the channel habitats at Bangpoo and Bang Ya Phreak. All five mudflat and two channel habitats formed a second group, and the Leam Chabang channel formed an isolated group. Gastropods were mostly epifaunal (24 species) or arboreal (7 species); most bivalves were infaunal. All 16 bivalves were filter feeders, and 23 gastropods were herbivores. In general, filter feeders and detritivores dominated density and biomass. This is consistent with the ecological role of molluscs being intermediate between the mangroves as primary producers and the higher trophic levels in the food web. Marine species dominated the salinity preference.

***KEYWORDS.* –** Trophic levels, habitat, salinity, density, diversity, biomass.

INTRODUCTION

Mangrove forests are comprised of taxonomically diverse, salt-tolerant species of trees and shrubs that thrive in intertidal zones of sheltered tropical and warm-temperate shores and estuaries throughout the world (Macnae, 1968; Tomlinson, 1986; Yamada, 1998). Mangroves are key contributors of primary production to coastal marine ecosystems, either within the mangrove community itself or through export of trunks, branches, and leaves of the mangroves to other areas by waves and currents. Few animal species feed directly on living mangroves. Instead, dead and decaying parts of the plants are broken down into progressively smaller pieces by a combination of physical, chemical and biological actions to form a rich detritus-based foodweb (Hutchings & Saenger, 1987). The Indo-West Pacific region has both the highest

diversity of mangrove plant species and the largest areas of mangroves (Duke, 1992, Duke et al., 1998; Ellison, 1999). Southeast Asian mangroves comprise a third of the world's total (Macnae, 1968; Yamada, 1998), with Thailand having some of the most diverse mangrove forests in Southeast Asia. Mangrove areas of 120,536 km^2 and 328,093 km^2 are reported in the central and eastern parts of the Gulf of Thailand, respectively (UNEP, 2005). Mangroves are valuable resources for Thailand. The forests have both ecological and economic functions, providing both physical environment and a source of nutrients (Tomlinson, 1986; Field, 1996; Ng & Sivasothi, 1999). The forests are nursery grounds or habitat for a wide variety of commercial species, including fish, prawns, crabs, oysters and other shellfish (Sasekumar & Chong, 1998; Hogarth, 1999; Ng & Sivasothi, 1999). Despite their importance, mangroves in Thailand have been substantially reduced in area because the trees have been cut down to provide firewood and the land has been reclaimed for use for shrimp farms, etc., or damaged by pollution. Although they have provided different figures, Aksornkoae et al. (1993), Khemnark (1995), Menasveta (1997) and many others have reported substantial declines in the areas covered by Thai mangroves. The threat is continuing (Aksornkoae & Tokrisna, 2004), although there have been some areas of active replanting (Macintosh et al., 2002). Because of their importance, it is critical that more investigations are undertaken to understand the functioning of Thai mangrove ecosystems.

Mangrove invertebrates are important links in energy flow between the initial detritus at the bottom of food webs to higher-order predators such as birds and fish (Berry, 1963). Molluscs are one of the dominant invertebrate groups in the mangrove community and are thought to play a significant ecological role in the structure and function of mangrove systems (Lee, 1999; Ng & Sivasothi, 1999; Tan & Chou, 2000; Macintosh et al., 2002; Ashton et al., 2003). Despite their importance, there are few quantitative data on the diversity, density, and biomass of molluscs in mangroves (Wells, 1983, 1984, 1986a), and little is known of the molluscs in Thai mangroves (Brandt, 1974; Frith et al., 1976; Tantanasiriwong, 1978, 1979; Macintosh et al., 2002; Wells et al., 2001; Sanpanich et al., 2004, 2006). To help fill this gap in our knowledge, the present paper investigates the molluscs found in six mangrove systems in the upper Gulf of Thailand.

MATERIALS AND METHODS

Molluscs were studied in mangroves at six sites in the upper Gulf of Thailand from March to June 2004 (Fig. 1): Khlong Khon (13º38'50.8"N 100º35'63.3"E), Bang Ya Phreak (13º30'15.7"N 100º16'22.8"E), Bangpoo Industrial Estate (13º31'08.7"N 100º38'72.7"E), Ang Sila (13º20'79.8"N 100º57'32.1"E), Leam Chabang Industrial Estate (13º04'98.4"N 100º52'84.6"E) and Ban Nam Chieo (12º12'25.7"N 102º33'50.7"E). Four habitats were examined at each sampling site: unvegetated seaward mudflat, unvegetated channel, and *Avicennia* and *Rhizophora* tree zones (except that no *Rhizophora* zone was present at Ang Sila). In each habitat, six replicate stations were sampled within a randomly chosen 10 × 10 m^2 quadrat. In each replicate, three sampling strategies were employed and the data pooled. Visible molluscs were collected by hand within a 0.5 m^2 steel ring randomly placed on the sediment. A 0.1 m^2 cylinder was then placed in the center of the ring. The sediment was removed to a depth of 20 cm and sieved through a 1-mm mesh. Living molluscs remaining on the sieve were collected. Arboreal species in each quadrat were hand picked from six trees closest to the ring. All collected molluscs were placed separately in labeled plastic bags.

In the laboratory, molluscs were sorted to species, counted and identified using Brandt (1974), Reid (1986), Lamprell & Whitehead (1992), Lamprell & Healy (1998) and Swennen et al. (2001) as references. Specimens of uncertain identification were compared with specimens in the Western Australian Museum. Voucher specimens are deposited in the Malacology Laboratory and Museum of Mahidol University, Thailand. The feeding strategy and salinity preferences of each species were determined using information from Beesley et al. (1998). Dry weight, shell-free biomass was determined using the techniques of Wells (1983). The dendrogram, based on species presence and absence, was constructed using the Bray-Curtis similarity index and the Primer 5 software package (Clarke & Warwick, 1994).

RESULTS

Population characteristics. – A total of 47 species of molluscs, 31 gastropods and 16 bivalves, were found at the six sites (Table 1). Ten molluscan species were found in each of the unvegetated habitats of the channel and the mudflat; another 19 species were found in *Rhizophora* and 28 species in *Avicennia.* Diversity at individual sites was low, ranging from 11 species at Ban Num Chieo to 24 species at Khlong Khon (Table 2). Mangrove tree habitats tended to have higher diversity (0–16 species) than unvegetated habitats (0–4 species). Molluscs were not found in either unvegetated habitat at Ban Num Chieo, whereas the maximum number of

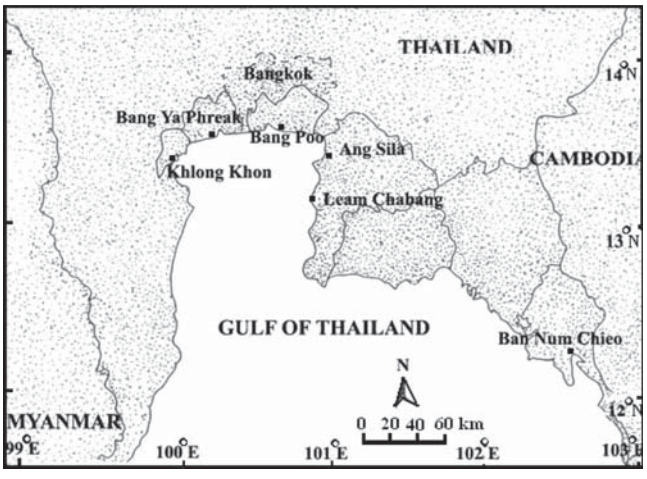

Fig. 1. Six study sites in the upper Gulf of Thailand.

Table 1. Biological characteristics of molluscs found at six sites in mangroves in the upper Gulf of Thailand. Habitat: Arb, arboreal; Epi, epifaunal; Inf, infaunal. Salinity tolerance (Sal.): Est, estuarine; Fw, freshwater; Mar, marine. Feeding strategy (FS): Carn, carnivore; Detr, detritivore; Herb, herbivore; Filt, filter feeder; Sca, scavenger.

Family	Species	Habitat	Sal.	FS
Gastropods				
Assimineidae	*Assiminea brevicula* (Pfeiffer, 1854)	Epi	Est	Herb
Amphibolidae	*Salinator burmana* Blanford, 1867	Epi	Mar	Herb
Ellobiidae	*Ellobium aurisjudae* (Linnaeus, 1758)	Epi	Mar	Herb
	Cassidula aurisfelis (Bruguière, 1789)	Epi	Mar	Herb
	Cassidula multiplicata (Deshayes, 1830)	Epi	Mar	Herb
	Lemodonta siamensis (Morelet, 1875)	Epi	Mar	Herb
	Melanopus siamensis (Martens, 1865)	Epi	Mar	Herb
	Pythia scarabaeus (Linnaeus, 1758)	Epi	Mar	Herb
Haminoeidae	*Haminoea* sp.	Epi	Mar	Herb
Iravadiidae	*Fairbankia cochinchinensis* Bavay & Dautzenberg, 1910	Epi	Fw	Det
	Iravadia ornata Blanford, 1867	Epi	Fw	Det
Littorinidae	*Littoraria articulata* (Philippi, 1846)	Arb	Mar	Herb
	Littoraria carinifera (Menke, 1830)	Arb	Mar	Herb
	Littoraria intermedia (Philippi, 1846)	Arb	Mar	Herb
	Littoraria melanostoma (Gray, 1839)	Arb	Mar	Herb
	Littoraria pallescens (Philippi, 1846)	Arb	Mar	Herb
	Littoraria strigata (Philippi, 1846)	Arb	Mar	Herb
Muricidae	*Chicoreus capucinus* (Lamarck, 1822)	Epi	Mar	Carn
	Thais gradata (Jonas, 1846)	Epi	Mar	Carn
Nassariidae	*Nassarius foveolatus* (Dunker, 1847)	Epi	Mar	Sca
	Nassarius stolatus (Gmelin, 1791)	Epi	Mar	Sca
Neritidae	*Clithon oualaniensis* (Lesson, 1831)	Epi	Est	Herb
	Neritina violacea (Gmelin, 1791)	Epi	Est	Herb
	Neritodryas dubia (Gmelin, 1791)	Epi	Est	Herb
Onchidiidae	*Onchidium* sp.	Epi	Mar	Herb
Potamididae	*Cerithidea cingulata* (Gmelin, 1791)	Epi	Mar	Herb
	Cerithidea obtusa (Lamarck, 1822)	Epi	Mar	Herb
	Cerithidea quadrata Sowerby, 1866	Arb	Mar	Herb
	Telescopium telescopium (Linnaeus, 1758)	Epi	Mar	Herb
Stenothyridae	*Stenothyra* sp.	Epi	Fw	Det
Thiaridae	*Sermyla riqueti* (Grateloup, 1840)	Epi	Fw	Det
Bivalves				
Arcidae	*Anadara granosa* (Linnaeus, 1758)	Inf	Mar	Filt
Anomiidae	*Enigmonia aenigmatica* (Holten, 1802)	Arb	Mar	Filt
Corbiculidae	*Gelonia erosa* (Lightfoot, 1786)	Inf	Mar	Filt
	Gelonia expansa (Mousson, 1849)	Inf	Mar	Filt
Glauconomidae	*Glauconome virens* (Linnaeus, 1767)	Inf	Mar	Filt
Isognomonidae	*Isognomon ephippium* (Linnaeus, 1758)	Arb	Mar	Filt
Lucinidae	*Austriella* sp.	Inf	Mar	Filt
Mactridae	*Mactra cumingii* (Reeve, 1854)	Inf	Mar	Filt
	Mactra iridescens (Kuroda & Habe, in Habe, 1958)	Inf	Mar	Filt
Mytilidae	*Modiolus* sp.	Arb	Mar	Filt
Noetiidae	*Striarca olivacea* (Reeve, 1844)	Inf	Mar	Filt
Ostreidae	*Crassostrea gigas* (Thunberg, 1793)	Arb	Mar	Filt
	Saccostrea cucullata (Born, 1778)	Arb	Mar	Filt
Tellinidae	*Macoma* sp.	Inf	Mar	Filt
Veneridae	*Anomalocardia squamosa* (Linnaeus, 1758)	Inf	Mar	Filt
	Marcia hiantina (Lamarck, 1818)	Inf	Mar	Filt

Table 2. Comparison of habitats occupied by molluscs in four habitats at six sites in mangroves in the upper Gulf of Thailand.

Habitat	Diversity		Density ± SE (N/m^2)	Biomass ± SE (g/m^2)
	No. of species	Mean ± SE		
Khlong Khon				
Mudflat	4	1.6 ± 0.4	37.0 ± 11.8	9.6 ± 3.2
Channel	4	3.0 ± 0.2	98.3 ± 20.4	14.2 ± 2.0
Avicennia	10	5.0 ± 0.5	65.2 ± 11.0	2.8 ± 0.9
Rhizophora	6	4.6 ± 0.2	1235.8 ± 311.4	15.9 ± 8.2
Total/Means	24	3.5 ± 0.3	359.1 ± 128.3	10.6 ± 2.3
Bang Ya Phreak				
Mudflat	3	1.0 ± 0.4	23.3 ± 13.4	2.1 ± 1.0
Channel	3	1.1 ± 0.4	10.3 ± 3.4	0.3 ± 0.1
Avicennia	7	1.8 ± 1.1	18.3 ± 11.2	1.9 ± 0.9
Rhizophora	5	1.6 ± 0.6	7.6 ± 4.2	1.2 ± 0.9
Total/Means	18	1.4 ± 0.3	14.9 ± 4.4	1.4 ± 0.4
Bangpoo				
Mudflat	3	1.6 ± 0.2	59.6 ± 13.8	0.7 ± 0.2
Channel	2	1.1 ± 0.1	17.0 ± 5.5	0.1 ± 0.1
Avicennia	16	7.0 ± 1.1	3289.6 ± 1919.3	2.8 ± 0.8
Rhizophora	0	-	-	-
Total/Means	21	2.4 ± 0.6	841.5 ± 535.8	0.9 ± 0.3
Ang Sila				
Mudflat	2	0.3 ± 0.2	2.3 ± 1.6	1.7 ± 1.6
Channel	1	0.6 ± 0.2	7.0 ± 3.3	0.2 ± 0.0
Avicennia	9	4.0 ± 0.6	43.2 ± 8.2	0.4 ± 0.2
Total/Means	12	1.6 ± 0.4	17.5 ± 5.2	0.7 ± 0.5
Leam Chabang				
Mudflat	3	2.3 ± 0.2	172.0 ± 35.6	6.7 ± 2.6
Channel	2	1.6 ± 0.2	1120.6 ± 434.2	0.1 ± 0.0
Avicennia	3	2.1 ± 0.3	6.9 ± 1.1	7.0 ± 3.0
Rhizophora	9	3.3 ± 0.8	13.9 ± 4.5	6.9 ± 2.8
Total/Means	17	2.3 ± 0.2	328.3 ± 140.0	5.1 ± 1.2
Ban Num Chieo				
Mudflat	0	-	-	-
Channel	0	-	-	-
Avicennia	6	2.0 ± 0.3	7.5 ± 3.3	3.7 ± 2.6
Rhizophora	5	1.8 ± 0.4	30.36 ± 10.5	27.0 ± 15.5
Total/Means	11	0.9 ± 0.2	9.4 ± 3.6	7.7 ± 4.3

species (4) was found on the mudflat and channel at Khlong Khon. *Avicennia* tended to have the most diversity, with 3–17 species, whereas *Rhizophora* varied from 0–9 species.

Density varied considerably, both between sites and between habitats at each site. Mean density varied from $9.4/m^2$ at Ban Num Chieo to $841.5/m^2$ at Bangpoo, a difference of almost two orders of magnitude. Although there was considerable variation between habitats at a site, all habitats at Khlong Khon, Bangpoo and Leam Chabang tended to have higher molluscan densities than the same habitat types at Bang Ya Phreak, Ang Sila and Ban Num Chieo. There was no clear pattern of density in the different habitats. Three habitats (mudflat, *Avicennia* and *Rhizophora* tree zones) each had one site where there were no molluscs found; the lowest density in the channel was $7.0/m^2$ at Ang Sila. Similarly, the greatest densities were recorded in three different habitats of three different sites: $1,120.6/m^2$ in the channel at Laem Chabang, $1,235.8/m^2$ in *Rhizophora* at Khlong Khon, and $3,289.6/m^2$ in *Avicennia* at Bangpoo. The high densities in these three habitats were contributed entirely by three different species: the oyster *Crassostrea gigas* was 87.0% of total density in *Rhizophora* at Khlong Kong, the bivalve *Glauconome virens* was 79.4% of total density in *Avicennia* at Bangpoo, and the thiarid gastropod *Sermyla riqueti* was 99.2% of total density in the channel at Leam Chabang.

Because large animals have a disproportionate amount of biomass, the sites where biomass was highest did not match those with the greatest density (Table 2). The greatest mean biomasses, ranging from 5.1 to 10.6g/m^2, were found at Khlong Khon, Laem Chabang, and Ban Num Chieo. The greatest biomasses in a particular habitat were both in *Rhizophora*: 15.9g/m^2 at Khlong Khon and 27.0g/m^2 at Ban Num Chieo. The channel zone at Khlong Khon had a total biomass of 14.3g/m^2. As with density, biomass was concentrated in one species in each habitat, and the dominant species was different in each of the three habitats with high biomass: *Crassostrea gigas* was 91.4% of total biomass in *Rhizophora* at Khlong Khon, *Anadara granosa* was 64.9% of total biomass in the channel at Khlong Khon, and *Geloina expansa* was 91.4% of total biomass in *Rhizophora* at Ban Num Chieo.

The dendrogram (Fig. 2) shows the relationships between species present at 21 sites. No *Rhizophora* habitat was available at Ang Sila, and no molluscs were collected in the mud and channel habitats at Ban Num Chieo. There are three groupings on the dendrogram. The largest is comprised of all the *Avicennia* and *Rhizophora* habitats and the channel habitats at Bangpoo and Bang Ya Phreak. All other channel and mudflat habitats are separated from the main grouping, indicating a clear differentiation between the molluscs that live in the mangrove tree zones and those in the unvegetated areas of the mudflat and the channel. All five mudflat and two channel habitats form a second group on the dendrogram and the Leam Chabang channel forms an isolated group of its own.

***Habitats occupied.* –** Gastropods were mostly epifaunal species (24), with seven, primarily *Littoraria,* being arboreal. In contrast, 11 of the bivalve species were infaunal. In the cumulative data for the six sites, epifaunal species dominated density in channel habitats (1,188.3/m^2), but large infaunal bivalves dominated biomass (13.7g/m^2) (Fig. 3). In contrast, infaunal species dominated both density (263.3/m^2) and biomass (20.2g/m^2) on the mudflat. Infaunal species dominated density in *Avicennia* (2,620.0/m^2) and large epifaunal species dominated biomass (12.6 g/m^2). Arboreal species dominated density in *Rhizophora* (1,212.4/m^2) and infaunal species dominated biomass (24.7g/m^2). There was considerable variation in the relative proportions of infaunal, epifaunal, and arboreal species at the six sites. Density was dominated by epifaunal species at Leam Chabang (1,146.4/m^2), by infaunal species at Bangpoo (2,668.3/m^2), and by arboreal species at Khlong Khon (1,231.3/m^2). In terms of biomass, epifaunal species dominated at Leam Chabang (13.2 g/m^2), and infaunal species at Khlong Khon (23.3 g/m^2) and Ban Num Chieo (27.6 g/m^2).

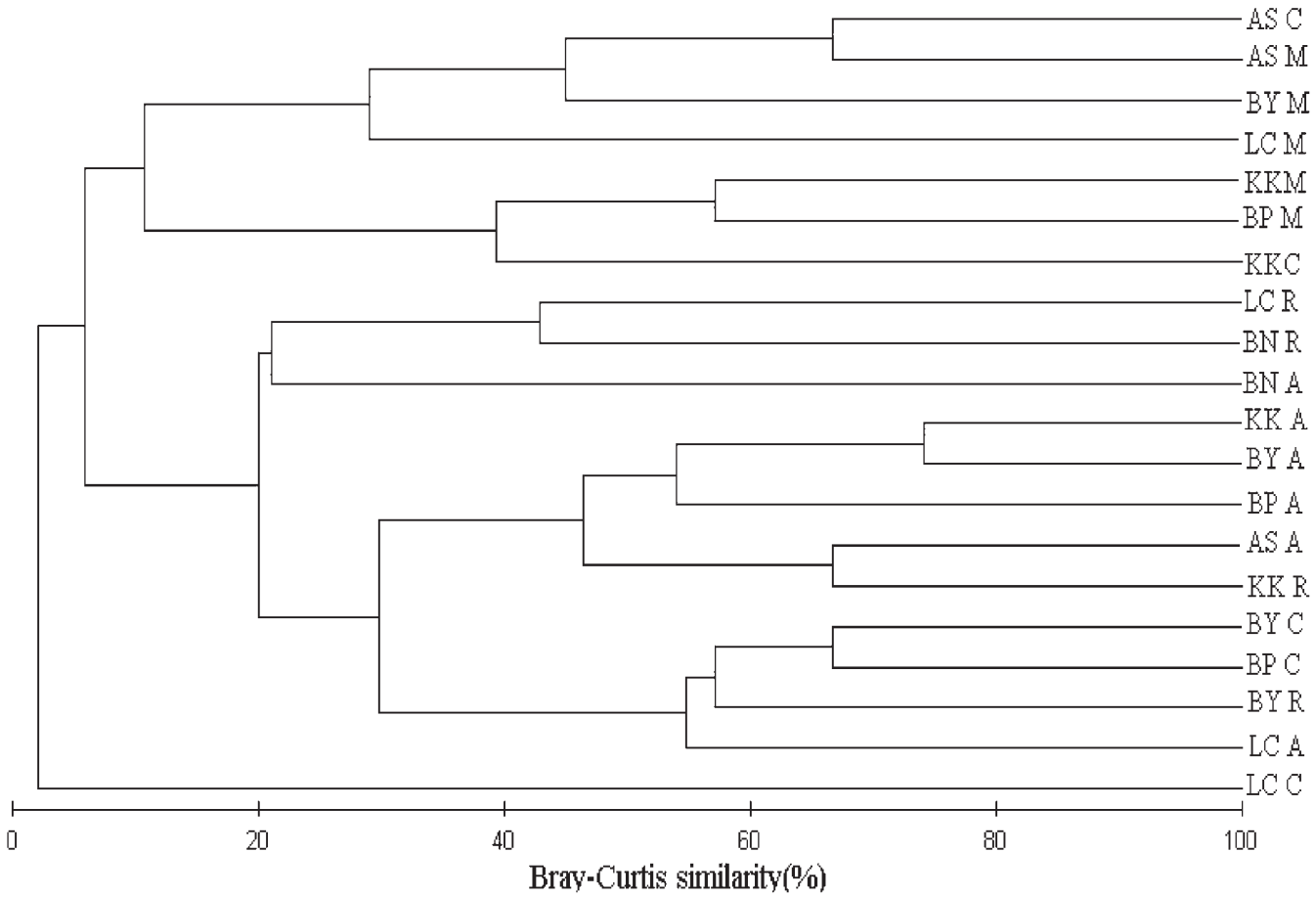

Fig. 2. Dendrogram of Bray-Curtis similarity based on presence and absence of molluscan species in four habitats at six study sites in the upper Gulf of Thailand: A, *Avicennia*; AS, Ang Sila; BN, Ban Nam Chieo; BP, Bangpoo; BY, Bang Ya Phreak; C, channel; KK, Khlong Khon; LC, Leam Chabang; M, mudflat; R, *Rhizophora*.

Feeding strategies. – Molluscs collected at the six sites were divided into five feeding strategies: filter feeders, herbivores, detritivores, scavengers, and carnivores (Table 1). All 16 of the bivalves were classified as filter feeders. Twenty-three of the gastropods were classified as herbivores, with four being classified as detritivores and two each as scavengers and carnivores (Table 1). Filter feeders were the dominant feeding strategy in terms of density and biomass in the mudflat and in *Rhizophora.* Detritivores dominated density in channel habitats, but filter feeders dominated biomass. In *Avicennia*, filter feeders dominated density, but herbivores dominated biomass (Fig. 4). The dominance of filter feeders breaks down when individual sites are examined, with density and biomass being clumped at particular sites. Over 95% of the mean density of filter feeders was contributed by the sites at Khlong Kong and Bangpoo; over 84% of the biomass was contributed by Khlong Kong and Ban Num Chieo.

Salinity preferences. – All 16 of the bivalves and 23 of the gastropods were classified as marine species; 4 gastropods were classified as estuarine and 4 as freshwater (Table 1). As would be expected from the dominance of diversity by marine species, they dominated mean density and biomass in the cumulative data for the six sites (Fig. 5), except that freshwater species dominated diversity in the channel and estuarine species dominated biomass in *Rhizophora.* The high diversity of freshwater species was contributed entirely by the site at Leam Chabang and the high biomass of estuarine species occurred only at Ban Num Chieo.

DISCUSSION

Population characteristics. – The general picture presented by the data from the six sites in mangroves in the upper Gulf of Thailand is that diversity is moderate. This is particularly true when it is considered that the six sites were spread over a wide geographical area in a region known for high biodiversity. In this extensive study, only 47 species of molluscs were collected and all were gastropods and bivalves; there were no chitons or scaphopods. Brandt (1974) recorded 56 species of estuarine molluscs in the same geographic region, compared to only four species in the present study. However, Brandt's study was a taxonomic one that would be expected to generate a larger species list. Frith et al. (1976) examined the zonation and abundance of molluscs in mangroves and on the sand and mudflat at Ao Nam Bor, on the Andaman Sea coastline near Phuket and found 43 species. Thirty-four species of molluscs were found in the Ranong Biosphere Reserve by Macintosh et al. (2002), who concluded that molluscan diversity in the upper Gulf of Thailand is less than in the Andaman mangroves.

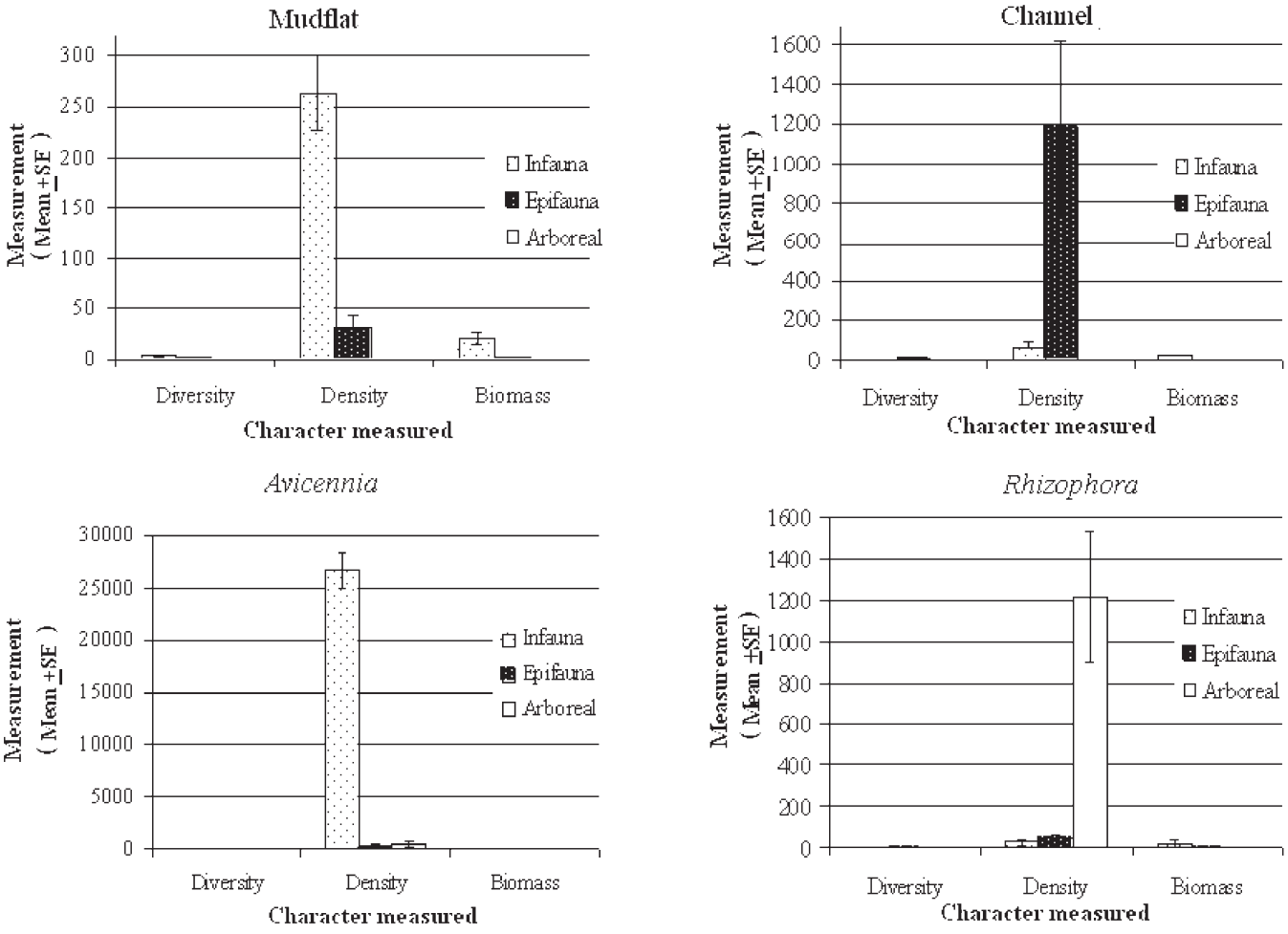

Fig. 3. Comparison of microhabitats occupied by molluscs in four habitats at six sites in mangroves in the upper Gulf of Thailand.

Wells (1983, 1984, 1986a) recorded 58 species in the Bay of Rest, northwestern Australia and 24 species in Hong Kong mangroves (Wells, 1986b, 1986c). Jiang & Li (1995) found 52 species in the Jiulong River estuary, China.

In the present study, the vegetated habitats (*Avicennia* and *Rhizophora*) had greater diversity than the unvegetated mudflat and channel zones. Similar findings were made by Sasekumar (1974), Frith et al. (1976); Wells & Slack-Smith (1981); Henriques (1980); Sheriden (1997) and Sasekumar & Chong (1998). The Thai mangrove areas studied here had greater diversity (28 species) in the vegetated zones than the 8 species recorded in the Kimberley, Western Australia (Wells & Slack Smith, 1981), the 6 species found at Klong Nga, Ranong, Thailand (Macintosh et al., 2002), and the 21 species in the Bay of Rest, Western Australia (Wells, 1983, 1984, 1986a) and was close in diversity to Sai Keng, Hong Kong, where 23 species were found (Wells, 1986b, 1986c). Molluscan diversity in *Rhizophora* (19 species) was lower than in *Avicennia,* but was still higher than in other *Rhizophora* areas: 7 species each in the Kimberley, Western Australia (Wells & Slack-Smith, 1981) and in the Bay of Rest (Wells, 1983, 1984), 11 species in a Malaysian mangrove (Sasekumar & Chong, 1998) and 6 species at Ranong (Macintosh et al., 2002). However, the pattern of greater diversity in the vegetated zones was the opposite of that found by Wells (1983, 1984) in the Bay of Rest, where the mudflat had the greatest diversity. As with density, biomass of molluscs in the present study was greater in the vegetated tree zones than on the mudflat or in the channel. The same trend was reported by Macintosh et al. (2002) but a somewhat opposite result was reported by Wells (1983, 1984), who showed that molluscs in *Avicennia* had a slightly higher biomass than on the mudflat; biomass in *Rhizophora* was very low.

Perhaps the key finding of the present study is that there is considerable variation in the diversity, density and biomass of molluscs at the six sites in the upper Gulf of Thailand. No generalizations can be made that any of the four habitats examined (mudflat, channel, *Avicennia* and *Rhizophora*) dominated in any of the three characteristics measured. Instead there was considerable variation between sites and habitats within and between sites. Where a high density or biomass was present in a given habitat, it was due to the presence of a single species. The other studies cited above all referred to one site in a geographic region, with the implicit assumption being made that the pattern at that site is a general pattern for the region. The present study throws this generalization into question, and suggests the need for multiple sites to be examined in other geographic regions.

***Habitats occupied.* –** Overall, molluscan diversity comprised about half epifaunal species (24), with infaunal (11) and arboreal species (12 species) each being approximately one quarter of the total diversity. As with the population

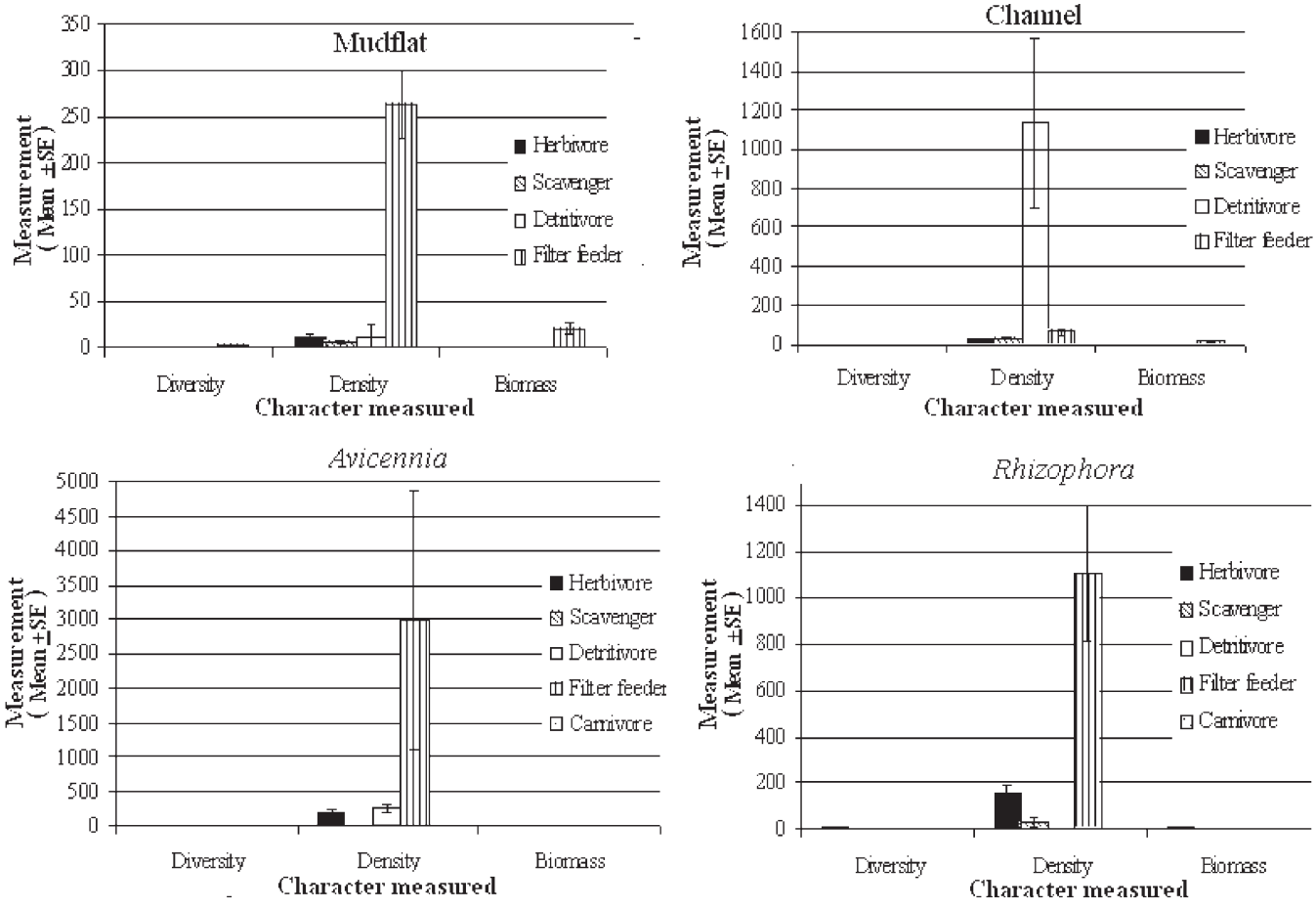

Fig. 4. Comparison of feeding strategies of molluscs in four habitats at six sites in mangroves in the upper Gulf of Thailand.

characters, it is difficult to generalize about the relative importance of molluscs in the three different microhabitats examined: infaunal, epifaunal and arboreal. This is because of the clumped nature of populations of individual species at some sites, where their considerable abundance or biomass skewed the overall results for the habitat type. Wells (1983, 1984) reported very low densities and biomasses of infaunal molluscs in both *Rhizophora* and *Avicennia* zones, a feature also found for density by Wells & Slack-Smith (1981). However, the present study showed that, at least at some sites, high densities or biomasses could be found in the sediment in mangroves in the upper Gulf of Thailand.

Feeding strategies. **–** Overall in the present study, filter feeders dominated at three of the habitats: mudflat, *Avicennia*, and *Rhizophora.* Detritivores dominated at the channel zone. As would be expected, filter feeders dominated in those sites with high densities (Khlong Khon and Bangpoo), except at Leam Chabang where detritivores dominated. Again, this is a reflection of the clumping of high density of a single species in a particular habitat. Despite the fact that 23 of the gastropod species were classified as herbivores, the density and biomass of surface-rasping herbivores was very low. Scavengers and carnivores were found in very low numbers. There are few comparative data on feeding types of molluscs in mangroves, but similar results were obtained by Wells (1983, 1984). The importance of filter feeders and detritivores is consistent with the mangrove ecosystem being a detritus-based system dependent on the breakdown of mangrove products by a combination of physical, chemical, and biological activities (Hutchings & Saenger, 1987). The high density and biomass of molluscs in the sites examined is evidence of their ecological importance in converting primary production from the trees into animal tissue available to higher trophic levels.

Salinity preferences. **–** An estuary is simply defined as the region of interaction between inland freshwater sources and the salt waters of the open ocean, and can have both vegetated (mangrove) and unvegetated (mudflat) habitats (Macnae, 1968; Levin et al., 2001; Williams, 2003). Thirty-nine of the 47 species (83%) collected in the present study were classified as marine. Aside from the channel at Leam Chabang, marine species dominated in the sites examined in the present study. The results are somewhat surprising considered that mangroves are found in estuarine areas. However, they occur along the seaward margins of the estuaries, where salinities are higher.

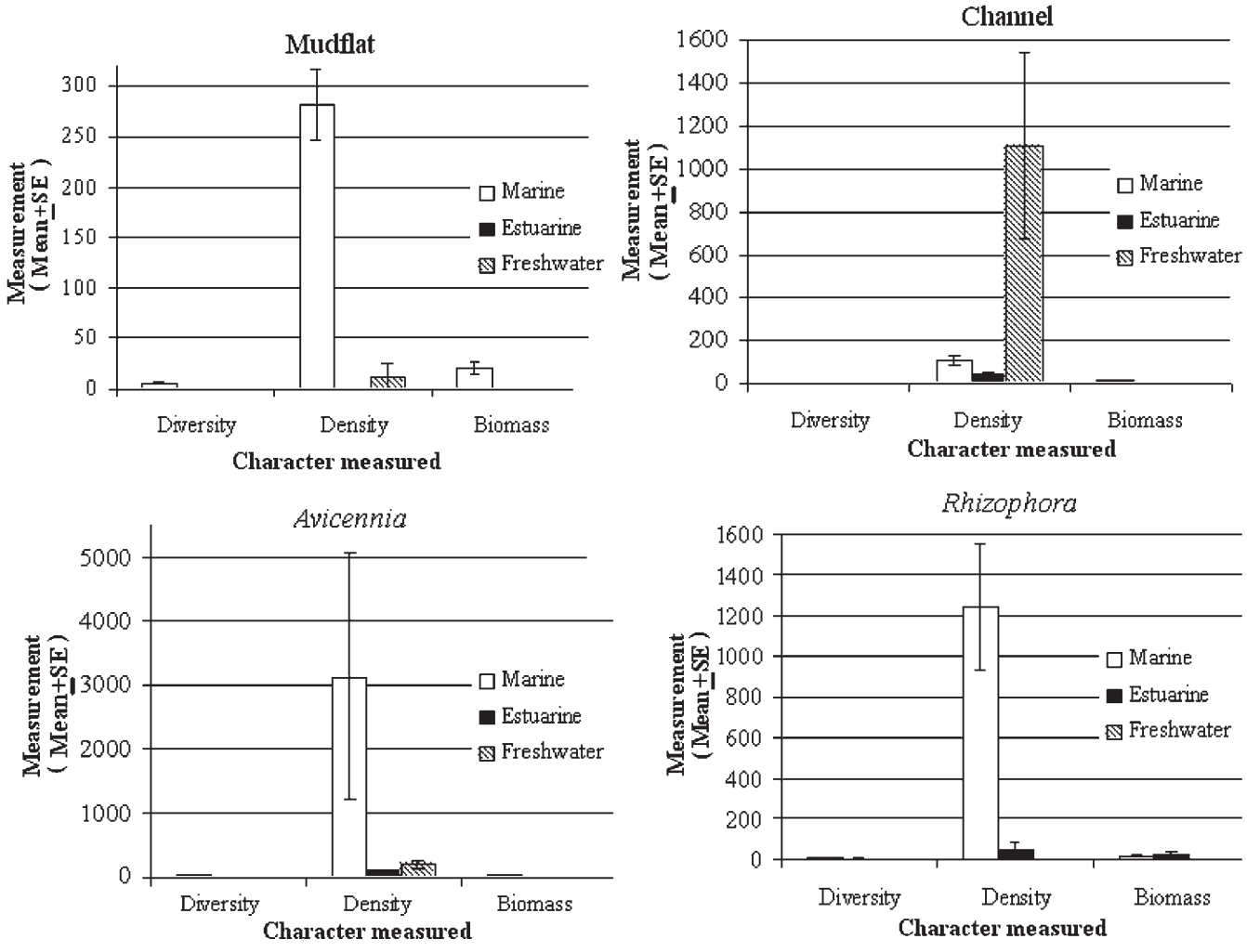

Fig. 5. Comparison of salinity tolerances of molluscs in four habitats at six sites in mangroves in the upper Gulf of Thailand.

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THAI ABSTRACT

คณะผู้วิจัยได้ศึกษาหอยในป่าชายเลนหกแห่งในอ่าวไทยตอนบน จากเดือนมีนาคม ถึง มิถุนายน พุทธศักราช 2547 โดยการวัดความหนาแน่น ความหลากหลายและชีวมวลของหอยในสิ่งแวดล้อม 4 ลักษณะ คือ ในเขตต้น *Avicennia* และ *Rhizophora* ในเขตหาดโคลน และภายในร่องน้ำในบริเวณอ่างศิลาที่ไม่มีต้น *Rhizophora* จากการศึกษาพบหอยทั้งสิ้น 47 ชนิด (หอยฝาเดียว 31 ชนิด หอยสองฝา 16 ชนิด) และมีความแตกต่างกันระหว่างลักษณะของประชากรกับสถานที่เก็บตัวอย่าง รวมทั้งสิ่งแวดล้อมภายในแต่ละสถานที่ เขตป่าชายเลนมักมีความหลากหลายของหอยสูงกว่าเขตไม่มีพรรณไม้ โดยความหนาแน่นของหอยมีค่าตั้งแต่ 9.4/ตรม ที่บ้านน้ำเชี่ยวถึง 841.5/ตรม ที่บางปู โดยไม่มีรูปแบบความหนาแน่นที่ชัดเจนในสิ่งแวดล้อมที่ต่างกัน ในสภาพแวดล้อมหาดโคลน *Avicennia* และ *Rhizophora* มีแห่งละ 1 ที่ ๆ ไม่พบหอยเลยและความหนาแน่นสูงสุดพบในสภาพแวดล้อมดังนี้คือ ร่องน้ำแหลมฉบัง (1,120.6/ตรม) *Rhizophora* ที่คลองโขน (1,235.8/ตรม) และ *Avicennia* ที่บางปู (3,289.6/ตรม) ความหนาแน่นดังกล่าวมาจากจำนวนหอย 1 ชนิด (ทั้ง 3 สถานี) ส่วนชีวมวลสูงสุดพบในสถานนีที่ ต่างจากสถานีที่มีความหนาแน่นสูงสุด ทั้งนี้มีหอยสองฝาเพียง 1 ชนิด ที่ทำให้ชีวมวลสูง ในทั้ง 3 สถานี คณะผู้วิจัยพบกลุ่มประชากรหอยที่มีลักษณะเฉพาะโดยกลุ่มใหญ่ที่สุดมาจากต้น *Avicennia* และ *Rhizophora* และร่องน้ำบริเวณบางปู และบางหญ้าแพรก หาดโคลนทั้ง 5 แห่ง และร่องน้ำอีก 2 แห่งเป็นกลุ่มที่สอง ส่วนร่องน้ำบริเวณแหลมฉบังเป็นกลุ่มสุดท้ายที่ไม่เหมือนกลุ่มอื่น หอยฝาเดียวที่พบส่วนมากอยู่บนพื้นผิว (24 ชนิด) หรืออยู่บนต้นไม้ (7 ชนิด) หอยสองฝาส่วนมากเป็นพวกฝังตัวและกินอาหารโดยการกรอง หอยฝาเดียว 23 ชนิด เป็นหอยกินพืช โดยทั่วไปหอยที่กินอาหารโดยการกรองและหอยที่กินตะกอนมีลักษณะเด่นที่สุดในด้านความหนาแน่นและชีวมวล ซึ่งตรงกับบทบาททางนิเวศวิทยาของหอยที่เป็นตัวเชื่อมระหว่างผู้ผลิตในป่าโกงกางและผู้บริโภคในลำดับที่สูงขึ้น

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