

**COMMUNITY STRUCTURE AND ECOLOGICAL DISTRIBUTION
OF BENTHIC ANIMALS IN TIEN HAI MANGROVE FOREST,
NORTHERN VIETNAM**

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ABSTRACT

Mangroves are a diverse and rich ecosystem, in which many animals are associated, including benthos. Species composition and occurrence of these animals are driven by the mangroves and tidal conditions. To examine how the benthic animal is distributed in mangrove habitats from northern Vietnam, two surveys in 2019 were conducted in Tien Hai Wetland Nature Reserve, which resulted in a total of 89 species, belonging to 56 genera and 35 families of zoobenthos. This is the first publication of these animals in the study site. The two major groups of benthic animals in the ecosystem were Crustacea and Mollusca, which occupy 54.02% and 36.78% of the total species, respectively. There are several new records of these animals from the coastal mangroves of Vietnam. Two species were new data for northern Vietnam (*Scopimera curtelsoma* and *Parasesarma eumolpe*), and four species were new records for Vietnam (*Laemodonta punctigera*, *Cassidula nucleus*, *Pythia cecillei* and *Microtralia alba*). Also, the present study shows distributional characteristics of the benthic animal community in mangrove forests. The present study indicates that benthic animals show an increase in species diversity and density from the river mouth to the continent. Seasonally quantitative data of benthic from the study site are the first work in mangrove forests of Vietnam. Recent findings are fundamental data for further studies on zoobenthos and related issues to preserve biodiversity in the mangrove forests in Vietnam.

Keywords: Brachyura, species diversity, distributional pattern, estuarine mangroves of Tien Hai, zoobenthos.

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INTRODUCTION

Mangroves are one of the highly productive ecosystems. Species diversity, biomass, and abundance of invertebrates relate to the structure of the mangrove bed. Thus, the diversity and abundant information of these animals reflect the status of this ecosystem and can be used as a forecast of changes in both natural and plantation forests. Comparing the composition of invertebrates at different tidal zones shows that diversity of vegetation and salinity have a great impact on species composition and distribution of benthos (Hutching & Saenger, 1987). The research results also show the zonal characteristics of benthos in mangrove ecosystems are different amongst Bivalvia, Gastropoda, and Brachyura (Zvonareva et al., 2015; Wada, 2019). Several groups are widely distributed both inside and outside mangroves, and some only occur within mangroves. In general, benthic animals in the mangrove ecosystem are abundant in the mid-tidal area, where the tidal conditions are most suitable for the activities of benthic animals during ebb tides, and they are less diverse than in the high tide and lower tide zones (Zvonareva et al., 2015). Species composition also depends on mangrove forests height and its covers. Families Ellobiidae, Ocypodidae, Dotilidae are high abundance in the high tide, while mid-tidal areas are dominant by many species in Potamididae, Assimineidae, Neritinae, Sesarmidae, and species from Ostreidae, Veneridae, and Penaeidae are mainly distributed in low tidal areas (Do Van Nhuong et al., 2004a; Zvonareva et al., 2015).

Vietnam's coastal mangroves play an important role in natural disaster prevention, climate change, economy, and ecotourism. There are many studies on mangrove ecosystems and their roles as well as other aspects (Phan Nguyen Hong et al., 1997, 2004). Benthic animals in this habitat have been received much attention (Pham Dinh Trong, 1996; Kitaura et al., 2002; Do Van Nhuong et al., 2004; Zvonareva et al., 2015). Located in the mouth of the Red River, Tien Hai Wetland Nature Reserve Thai Binh

province is one of two cores of the Red River Delta Biosphere Reserve, which is a significant area for biodiversity conservation. Different from Xuan Thuy National Park, Nam Dinh province at the opposite side of the river mouth (Fig. 1), where many studies on benthos have been conducted (Hoang Ngoc Khac & Do Van Nhuong, 2001; Do & Wada, 2004; Do Van Nhuong & Hoang Ngoc Khac, 2004ab; Do Van Nhuong et al., 2006, 2014), information about these animals in the Tien Hai mangrove forests are still limited. However, recent studies on other benthic animal groups (goby fish) reveal the importance of this mangrove forest (Tran Duc Hau et al., 2020, 2021). This paper firstly reports species diversity and distributional pattern of benthos in the study site, for a further contribution to biodiversity conservation and the function of this mangrove habitat for benthic animals.

MATERIALS AND METHODS

Study area

The research was conducted in the Tien Hai mangrove forest, Thai Binh province (20°18'8N - 106°36'55E to 20°16'37N - 106°34'47E) (Fig. 1). The chosen mangrove forest is located on the banks of the Red River mouth, on the west coast of the Gulf of Tonkin. The mangroves herein have been mixed with natural forests including *Aegiceras corniculatum*, *Kandelia obovata*, *Acanthus ebracteatus*, *Deris trifliata*, and plantations consisting of *Sonneratia caseolaris*, *Kandelia obovata*.

Sampling sites

The first site (TH1) consists of a natural mangrove forest, with large coverage, and the height of mangrove trees is from 3 to 5 m. The dominant trees are Trang (*Kandelia obovata*), Su (*Aegiceras corniculatum*), and Coc ken (*Acanthus ebracteatus*). The substrate of organic humus is thick and muddy due to clay mud (Fig. 2).

The second site (TH2) is a natural forest and intercropping, including natural trees (*Aegiceras corniculatum*, *Kandelia obovata*,

Acanthus ebracteatus, *Deris trifliata*) and supplementary crops (*Sonneratia caseolaris*). The height of the trees is quite different, from

4 to 10 m. The substrate is similar to TH1 (Fig. 2).

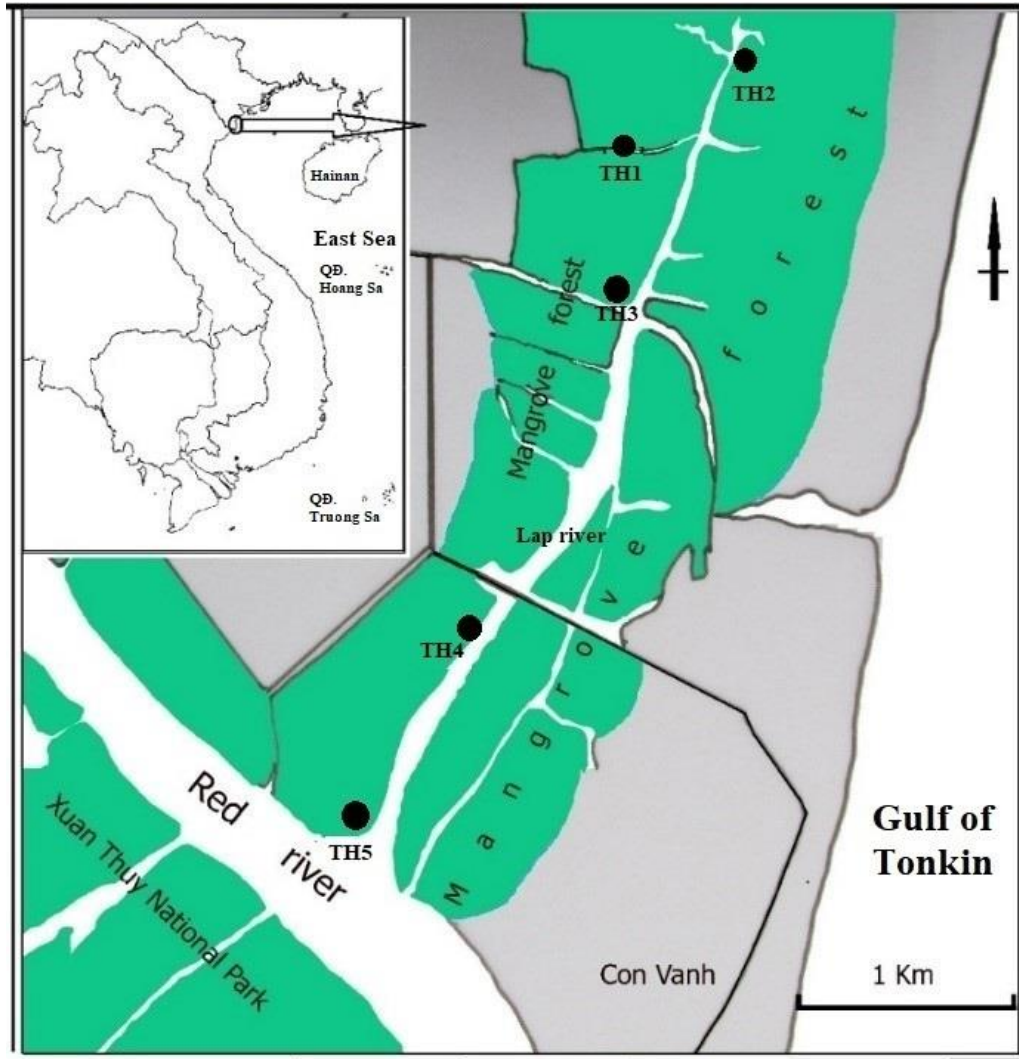


Figure 1. A diagram showing the study site in Tien Hai mangrove forests, northern Vietnam

The third site (TH3) is an entire mangrove plantation consisting of *Sonneratia caseolaris* and *Kandelia obovata* species. The height of trees is in a range of 8 to 10 m. The substrate is soft, easy to walk, less organic humus (Fig. 2).

The fourth site (TH4) is close to the river mouth, the forest is mixed between planting and natural trees (*Aegiceras corniculatum*) on the banks. The height of the tree is not as tall

as the previous three sites, about 4 m. The bottom is muddy and swampy (Fig. 2).

The fifth site (TH5) is located at the main course of the Red River, which is strongly influenced by waves, salinity, and tides. Low, medium trees are intercropped with additional crops (*Sonneratia caseolaris*) and natural plants (*Aegiceras corniculatum* and *Avicennia marina*). The bottom sediment is muddy sand (Fig. 2).



Figure 2. The scenes at five sampling sites in the Tien Hai mangrove forest, Northern Vietnam

Benthic collection

Quantitative samples were collected in Spring (March 2019) and Autumn (August 2019). Samples were collected from the trees down to the depths of the bottom where no animals are observed. The plot area is 50 x 50 cm (0.25 m²). Samples were taken randomly on the substrate at low tide. Animals in the bottom are separated from the sediment by a metal screen with a 2 mm mesh. Qualitative samples were collected directly by observation from the bottom surface, mangrove stems and leaves at the study sites, and fishermen's nets were used to collect benthos animals. Samples were cleaned by water then fixed in 70% alcohol, and deposited in the Department of Zoology, Hanoi National University of Education.

Identification

Zoobenthos were identified at the species level, and their ecological information was obtained from Jocelyn (1975); Dai & Yang (1991); Carpenter et al. (1998); Arthur & Ivan

(2000); Nguyen Van Chung et al. (2000); Peter & Michael (2000); Joe & George (2001); Freitas (2004); Phan Nguyen Hong et al. (2004); Raven & Vermeulen (2006); Tan & Clement (2008); Hoang Ngoc Khac et al. (2011); Wada (2019). In addition, studies on zoobenthos in mangroves of Vietnam were used for identifications and classification (Do Van Nhuong, 2003, 2014; Do & Wada, 2001, 2004; Do Van Nhuong & Hoang Ngoc Khac, 2004ab, 2006; Hoang Ngoc Khac & Do Van Nhuong, 2001; Hoang Ngoc Khac et al., 2011, 2012). The species richness used in the present study is the total number of species per collection in Spring and Autumn 2019.

RESULTS

A total of 89 species of zoobenthos belonging to 56 genera, 35 families in 3 classes of Gastropoda, Bivalvia, and Crustacea (herein mainly *Decapoda* and *Brachyura*) from the Tien Hai mangrove forest were identified (Tables 1, 2). Amongst

these three classes, Crustacea was the group with the highest number of species (accounting for 54.54%), followed by the Gastropoda (making up 36.36%) and Bivalvia

had the lowest number (Table 2). Bellows are information about the diversity and distributional features of each major group in the study site.

Table 1. List of benthic animals collected in the Tien Hai mangrove forest.

No.	Species	Sampling site									
		3-2019					8-2019				
		TH1	TH2	TH3	TH4	TH5	TH1	TH2	TH3	TH4	TH5
	GASTROPODA										
	Order Sorbeoconcha										
	Littorinidae										
1	<i>Littoraria melanostoma</i> (Gray, 1839)	+	+	+			+		+		
2	<i>Littoraria scabra</i> (Linnaeus, 1758)	+		+	+	+					+
	Assimineidae										
3	<i>Assiminea brevicula</i> (Pfeiffer, 1855)	+	+	+	+				+	+	
4	<i>Assiminea interrupta</i> Dautzenberg et Fischer, 1905	+	+		+				+		
5	<i>Assiminea lutea</i> (A. Adams, 1861)		+	+	+						
	Fairbankiidae										
6	<i>Fairbankia cochinchinensis</i> (Bavay et Daut., 1912)		+		+					+	
	Stenothyridae										
7	<i>Stenothyra polita</i> (A. Adams, 1851)	+									
8	<i>Stenothyra messengeri</i> (Bavay et Daut., 1912)			+							
9	<i>Stenothyra alba</i> Dang et Ho, 2010	+	+								
	Iravadiidae										
10	<i>Iravadia ornata</i> Blanford, 1867			+							
	Thiaridae										
11	<i>Melanoides tuberculatus</i> (O. F. Muller, 1774)		+								
12	<i>Sermyla tornatella</i> (Lea, 1850)		+	+		+			+	+	+
	Order Caenogastropoda										
	Potamididae										
13	<i>Cerithidea djadjaensis</i> (K. Martin, 1899)		+							+	
14	<i>Cerithidea sinensis</i> (Philippi, 1848)	+	+	+	+	+	+		+		+
15	<i>Cerithidea ornata</i> A. Adams, 1863						+		+		
16	<i>Pirenella incisa</i> (Hombron & Jacquinot, 1848)									+	+
17	<i>Pirenella cingulata</i> (Gmelin, 1791)										+
18	<i>Cerithidea obtusa</i> (Lamarck, 1822)			+							
19	<i>Terebralia sulcata</i> (Bruguiere, 1792)										+
	Order Cycloneritida										
	Neritidae										

20	<i>Neritina violacea</i> (Gmelin, 1791)	+	+	+	+	+	+	+	+	+	+
21	<i>Clithon oualanensis</i> (Lesson, 1831)					+					+
22	<i>Clithon faba</i> (Sowerby, 1836)								+		
	Order Ellobiida										
	Ellobiidae										
23	<i>Laemondonta punctigera</i> (Adams H. & A. Adams, 1854)	+	+		+		+				
24	<i>Laemondonta exaratooides</i> Kuroda, 1957				+						
25	<i>Cassidula aurisfelis</i> (Bruguiere, 1789)						+				
26	<i>Cassidula nucleus</i> (Gmelin, 1791)	+			+						
27	<i>Melampus singapoensis</i> Pfeiffer, 1855						+				
28	<i>Melampus fasciatus</i> (Deshayes, 1830)		+				+				
29	<i>Pythia cecillei</i> (Philippi, 1847)										+
30	<i>Ellobium aurisjudae</i> (Linnaeus, 1758)										+
31	<i>Microtralia alba</i> (Gassies, 1865)										+
	Order Systellommatophora										
	Onchidiidae										
32	<i>Onchidium</i> sp.	+					+				
	BIVALVIA										
	Order Myida										
	Aloididae										
33	<i>Aloidis laevis</i> (Hinds, 1843)			+	+	+					+
	Order Venerida										
	Corbiculidae										
34	<i>Geloina coaxans</i> (Gmelin, 1791)					+			+		+
	Veneridae										
35	<i>Meretrix lyrata</i> (Sowerby, 1851)										+
36	<i>Meretrix meretrix</i> (Linnaeus, 1758)										+
	Trapezidae										
37	<i>Neotrapezium sublaevigatum</i> (Lamarck, 1819)								+		
	Anomiidae										
38	<i>Enigmonia aenigmatica</i> (Holten, 1802)				+						+
	Ostreidae										
39	<i>Saccostrea cucullata</i> (Born, 1778)					+					+
40	<i>Crassostrea hongkongensis</i> Lam & Morton, 2003					+					+
	Teredinidae										
41	<i>Teredo navalis</i> (Linnaeus, 1758)				+	+					+
	CRUSTACEA										
	Order Sessilia Lamarck, 1818										
	Balanidae										
42	<i>Balanus amphritrite amphritrite</i> Darwin, 1854			+	+	+				+	+

	Order Stomatopoda Latreille, 1817										
	Squillidae										
43	<i>Oratosquilla oratoria</i> (de Haans, 1844)				+						+
	Order Decapoda Latreille, 1802										
	Penaeidae										
44	<i>Metapenaeus ensis</i> (de Haans, 1844)				+						+
45	<i>Metapenaeus monoceras</i> (Fabricius, 1798)									+	+
46	<i>Metapenaeus affinis</i> (H. Milne Edwards, 1837)				+					+	+
47	<i>Parapenaeopsis hardwickii</i> (Miers, 1878)				+					+	+
48	<i>Penaeus ensis</i> (De Haan, 1844)				+					+	
	Atyidae										
49	<i>Caridina</i> sp.				+						
	Palaemonidae										
50	<i>Macrobranchium nipponense</i> (de Haans, 1849)				+						
	Alpheidae										
51	<i>Alpheus pacificus</i> Dana, 1852				+					+	+
52	<i>Alpheus strenuus</i> Dana, 1852								+		
	Infraorder Anomura MacLeay, 1838										
	Paguridae										
53	<i>Paguritta vittata</i> Komai & Nishi, 1996						+			+	+
	Infraorder Brachyura Latreille, 1802										
	Dorippidae										
54	<i>Neodorippe callida</i> (Fabricius, 1798)				+						
	Leucosiidae										
55	<i>Philyra pisum</i> De Haan, 1841				+						
	Portunidae										
56	<i>Scylla serrata</i> (Forsskål, 1775)				+	+					
57	<i>Portunus tridentatus</i> Yang, Dai & Song, 1979				+						
	Camptandriidae										
58	<i>Leipocten trigranulum</i> Dai et Song, 1986	+									+
59	<i>Paracleistoma crassipilum</i> Dai, 1958								+		
60	<i>Paracleistoma cristatum</i> de Man, 1895	+	+								
61	<i>Camptandrium sexdentatum</i> Stimpson, 1858		+				+				
62	<i>Camptandrium elongatum</i> Rathbun, 1931										+

	Ocypodidae										
63	<i>Uca arcuata</i> (de Haan, 1835)	+	+	+	+	+	+		+	+	+
64	<i>Uca borealis</i> Crane, 1975									+	+
65	<i>Uca dussumieri</i> (H. Milne Edward, 1852)									+	+
66	<i>Uca lactea</i> (de Haan, 1835)						+				+
	Macrophthalmidae										
67	<i>Macrophthalmus pacificus</i> Dana, 1851	+		+							+
68	<i>Macrophthalmus definitus</i> Adams & White, 1849										+
69	<i>Macrophthalmus</i> sp.										+
70	<i>Macrophthalmus tomentosus</i> Eydoux & Souleyet, 1842					+				+	+
	Dotilidae										
71	<i>Ilyoplax ningpoensis</i> Shen, 1940			+					+	+	+
72	<i>Ilyoplax serrata</i> Shen, 1931					+					
73	<i>Tmethypocoelis ceratophora</i> (Koelbel, 1897)								+	+	+
74	<i>Scopimera curtelsona</i> Shen, 1936					+				+	+
75	<i>Leipocten sordidulum</i> Kemp, 1915	+									
	Grapsidae										
76	<i>Metopograpsus latifrons</i> (White, 1847)			+		+					+
77	<i>Metopograpsus quadridentatus</i> Stimpson, 1858								+	+	
	Sesarmidae										
78	<i>Perisesarma plicata</i> (Latreille, 1806)	+	+				+				+
79	<i>Perisesarma bidens</i> (De Haan, 1835)			+				+			
80	<i>Parasesarma eumolpe</i> (De Man, 1895)			+	+		+		+	+	+
81	<i>Parasesarma dehaani</i> (H. Milne Edwards, 1853)			+			+				
82	<i>Neosarmatium smithi</i> (H. Milne Edwards, 1853)						+				
83	<i>Clistocoeloma merguiensis</i> de Man, 1888										
84	<i>Sarmatium germaini</i> (Milne-Edwards, 1869)				+						
	Pinnotheridae										
85	<i>Anomalifons lightana</i> Rathbun, 1929						+				+
	Varunidae										
86	<i>Metaplax elegans</i> de Man, 1888			+	+	+			+	+	+
87	<i>Metaplax sheni</i> Gordon, 1931					+				+	+
88	<i>Metaplax longipes</i> Stimpson, 1858					+				+	+
89	<i>Varuna litterata</i> (Fabricius, 1798)				+						
	Total	19	17	20	31	20	17	2	18	24	47

Table 2. Number of species of major groups of benthos in the Tien Hai mangrove forest

Taxa	Station					Total number of species
	TH1	TH2	TH3	TH4	TH5	
Gastropoda	11	12	11	14	13	32
Bivalvia	0	0	3	3	8	9
Crustacea						
<i>Decapoda</i>	0	0	1	9	6	10
<i>Brachyura</i>	12	5	10	18	23	36
Others	0	0	1	2	2	2
Total number of species	23	17	24	35	46	89

Species composition and distribution of Gastropoda

A total of 32 species of Gastropoda were found in 10 families and 19 genera in the study site (tables 1, 2, 3; Fig. 3). There were two abundant families in the study site, Ellobiidae (9 species) and Potamididae (7 species), accounting for 53.12% of the total number of species (Table 3).

From observations, we can see that many species of the families Ellobiidae, Potamididae, Naticidae, and Littorinidae were distributed in different parts of mangroves, on the substrate surface, root to the trunk, branches, or leaves as *Littorina scabra* and *L. melanostoma* were collected on leaves and *Cerithidea ornate* was found on the trunk, and *Pirenella cingulata* and *C.*

djadjariensis were abundant under the forest. Species of the genera *Ellobium*, *Cassidula*, *Melampus*, and *Pythia* in the family Ellobiidae could be found under the tidal submerged mangroves in the low-tide floodplains. Snails in Neritidae, such as *Neritina violacea* and *Nerita polita* were commonly seen on roots of mangroves.

Regarding the distribution of Gastropoda among five sampling sites (from TH1 to TH5), it can be seen that species from Potamididae were highly concentrated in the estuarine mangrove forest, at TH5, such as *Cerithidea sulcata*, *Pirenella microptera*, and *Clithon oualaniense*. In contrast, there were some species only found in the continent, at sampling sites TH1–2, such as *Melampus fasciatus*, and *Cassidula aurisfelis* (Table 1).

Table 3. The abundance of genera and species of Gastropoda in the Tien Hai mangrove forest

No.	Families	Abundance (%)					
		Genus		Species		Distribution	
		<i>N</i>	<i>n%</i>	<i>n</i>	<i>n%</i>	<i>Inside of mangrove</i>	<i>Outside of mangrove</i>
1	Onchidiidae	1	5.26	1	3.12	1	0
2	Iravadiidae	1	5.26	1	3.12	1	0
3	Fairbankiidae	1	5.26	1	3.12	1	0
4	Littorinidae	1	5.26	2	6.24	2	0
5	Neritidae	2	10.5	3	9.37	2	1
6	Thiaridae	2	10.5	2	6.24	2	0
7	Assimineidae	1	5.26	3	9.37	3	0
8	Stenothyridae	1	5.26	3	9.37	1	2
9	Potamididae	3	15.7	7	21.8	4	4
10	Ellobiidae	6	31.6	9	28.1	9	0
	Total	19	100	32	100	26	7

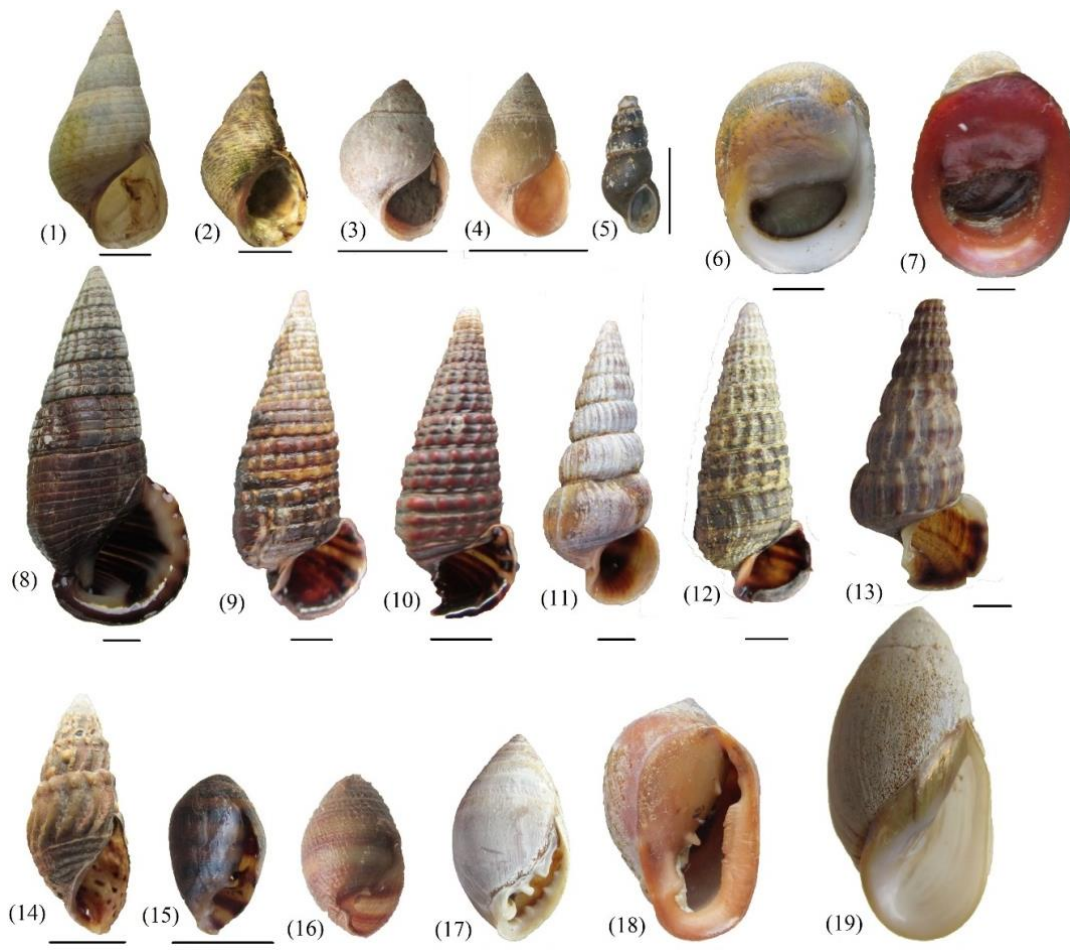


Figure 3. Some Gastropod species in the Tien Hai mangrove forest. (The line below each image is 5 mm). (1) *Littoraria melanostoma*; (2) *Littoraria scabra*; (3) *Assiminea brevicula*; (4) *Assiminea interrupta*; (5) *Fairbankia cochinchinensis*; (6) *Clithon faba*; (7) *Neritina violacea*; (8) *Terebralia sulcata*; (9), (12) *Pirenella incisa*; (10) *Pirenella cingulata*; (11) *Cerithidea sinensis*; (13) *Cerithidea tonkiniana*; (14) *Sermyla tornatella*; (15) *Melampus singapoensis*; (16) *Laemondonta punctigera*; (17) *Pythia cecillei*; (18) *Cassidula aurisfelis*; (19) *Ellobium aurisjudae*

Species widely distributed at all sites were *Neritina violacea*, and *Cerithidea sinensis*. Temporally, it can be seen that the *Assiminea* species appeared mainly in Spring and Ellobidae in Autumn. Other families did not have a clear distributional pattern in the period of study (Table 1).

Species composition and distribution of Bivalvia

The Bivalves group was mainly distributed in submerged areas and outside of mangroves. In the mangrove forest, 5 families

(Aloididae, Corbiculidae, Trapezidae, Veneridae, and Ostreidae) could be obtained (Table 1). The Bivalve species found mainly in the forest was *Geloina coaxans* (Corbiculidae) at three sampling sites (Table 1). The group of oysters (Ostreidae), except species *Enigmonia aenigmatica* on the leaves, attached to mangrove trunks and roots by secreting calcium into the substrate. Distributional features of species from two families Veneridae and Tellinidae related to the substrate and salinity of the estuary. This area is suitable for two clam species (*Meretrix*

lyrata and *M. meretrix*), and round donor (*Neotrapezium ablongatum*) (Table 1).

Species composition and distribution of Crustacea

The composition of crustacean species in the Tien Hai mangrove forest was abundant and diverse, making up 53.93% of the total number of species (48 species). Of which Brachyura has 36 species, accounting for 75.0% of the total species number from

Crustacea (Tables 1, 2, 4). Crustacea was a regular group inhabiting waters in the mangroves, including species in the family Portunidae (2 species). Typical semi-submerged aquatic species were in genera *Macrophthalmus* (4 species), *Perisesarma* (2 species), *Parasesarma* (2 species), and *Metaplex* (3 species). The species that live mostly on land were in families Ocypodidae (4 species) and Dotillidae (5 species) (Table 1; Fig. 4).

Table 4. The abundance of genera and species of the Crustacean group in the Tien Hai mangrove forest

No.	Taxa	Abundance %					
		Genus		Species		Species distribution	
		N	n%	n	n%	Inside of mangrove	Outside of mangrove
1	Balanidae	1	3.33	1	2.08	1	1
2	Squillidae	1	3.33	1	2.08	0	1
3	Penaeidae	3	10.00	5	10.41	0	5
4	Atyidae	1	3.33	1	2.08	0	1
5	Palaemonidae	1	3.33	1	2.08	0	1
6	Alpheidae	1	3.33	2	4.16	2	0
7	Paguridae	1	3.33	1	2.08	0	1
8	Dorippidae	1	3.33	1	2.08	0	1
9	Leucosidae	1	3.33	1	2.08	0	1
10	Portunidae	2	6.66	2	4.16	1	1
11	Camptandriidae	3	10.00	5	10.63	5	0
12	Ocypodidae	1	3.33	4	8.33	1	4
13	Macrophthalmidae	1	3.33	4	8.33	2	4
14	Dotillidae	4	13.33	5	10.41	2	5
15	Grapsidae	1	3.33	2	4.16	2	0
16	Sesarmidae	4	13.33	7	14.89	7	0
17	Pinnotheridae	1	3.33	1	2.08	1	1
18	Varunidae	2	6.66	4	8.33	4	1
Total		30	100	48	100	27	27

A number of species can be found widely namely mud crab (*Scylla serrata*), sesarmid (*Parasesarma plicata*, *Perisesarma bidens*,

Metaplex elegans and *Metaplex longipes*), *Macrophthalmus pacificus*, parasitic crabs (*Pagurita vittata*), *Uca arcuata*,

Camptandrium sexdentatum and *Paracleistostoma cristatum* (Table 1). Species that were collected in all sampling sites are *Uca arcuata*, *Parasesarma eumolpe*

and *Metaplex elegans*. Among the sampling sites, TH5 is the most abundant in the number of species (Tables 1, 2).



Figure 4. Some Brachyura species in the Tien Hai mangrove forest. (The line below each image is 10 mm). (1) *Uca dussumieri*; (2) *Uca arcuata*; (3) *Uca borealis*; (4) *Macrophthalmus definitus*; (5) *Macrophthalmus pacificus*; (6) *Macrophthalmus* sp.; (7) *Macrophthalmus tomentosus*; (8) *Parasesarma eumolpe*; (9) *Leipocten trigranulum*; (10) *Neosarmatium smithi*; (11) *Sarmatium germaini*; (12) *Metaplex longipes*; (13) *Metaplex elegans*; (14) *Anomalifons lightana*; (15) *Ilyoplax ningpoensis*

Density of benthic animals in the study site

Densities of all benthic animals collected amongst different sampling sites ranged from 116 individuals/m² to 744 individuals/m² in the Spring and from 56 individuals/m² to 376 individuals/m² in the Autumn of 2019. The number of individuals increased in the

Spring probably is due to the presence of Gastropoda, especially of two species, *Assiminea brevicula*, and *Assiminea interrupta*. Density assessments in the study sites show that an average of 4.0 individuals/m² to 16 individuals/m² was collected in March and from 4 to 20 individuals/m² in August 2019 (Table 5).

Table 5. The number of species of the major taxa and total abundance of benthic animals collected in quantitative sampling 1 m² at sampling sites TH1 to TH5 from Tien Hai mangrove forests

Taxa	Sampling site					Total species
	TH1	TH2	TH3	TH4	TH5	
Gastropoda	3(2)	7(1)	6(4)	4(4)	4(3)	22(19)
Bivalvia	2(0)	0(0)	1(2)	1(1)	2(1)	3(8)
Crustacea						
<i>Decapoda</i>	0(0)	0(0)	0(1)	1(0)	1(1)	9(9)
<i>Brachyura</i>	4(0)	2(1)	3(1)	1(1)	1(3)	25(26)
Others	0(0)	0(0)	0(0)	0(1)	1(0)	1(1)
Total species	9(2)	9(2)	10(7)	5(7)	6(7)	57(63)
Total abundance (No. of indiv. m ²)	116(56)	240(12)	268(188)	744(376)	192(196)	

Note: Inside and outside () indicate data for August and March surveys, respectively.

DISCUSSION

Diversity of benthos

A total of 89 species and subspecies of benthos were collected in mangroves by qualitative and quantitative sampling methods (standard plots) along with five sampling sites from TH1 to TH5. The composition of benthic animals in the present study is consistent with other works conducted in the Red river basin (Do Van Nhuong & Hoang Ngoc Khac, 2004ab; Do Van Nhuong et al., 2014). The most common and abundant taxonomic groups in the study site are in three classes Bivalvia (*Geloina coxans*, *Saccostrea cucullata*, *Crassostrea hongkongensis* and *Aloidis laevis*), Gastropoda (*Clithon oualanensis*, *Laemondonta exaratoides*, species in Potamididae), and Brachyura (*Metaplax*, *Macrophthalmus*, *Uca*, *Scylla serrata* and *Ilyoplax ningpoensis*). The dominant species in the mangrove forest are *Assimineia brevicula*, *Neritina violacea*, *Cerithidea sinensis*, *Littoraria scabra*, *L. melanostoma*, *Uca arcuata* in families Sesamidae, Grapsidae, and Camptandriidae. This classification structure is quite similar to the previous results in coastal mangrove forests of the Red river delta (Do Van Nhuong & Hoang Ngoc Khac, 2004a).

Generally, it is stated that most benthic animals in mangrove forests of the Red River are widely distributed in northern and southern coastal areas of Vietnam (Gurjanova, 1972) and some species are widely found in coastal areas of South Asia and the Western Pacific (Carpenter et al., 1998). In the Red river basin, there are no endemic benthic species (Do Van Nhuong, 2003).

Features of the benthic fauna in the current site belong to the Indo-Western Pacific (Gurjanova, 1972) as many species of Decapoda and Bivalvia are from the tropical area, which has a rich and diverse species composition. However, compared to the other areas, such as Hainan island and the Philippines (Gurjanova, 1972), the number of species is much lower. Further surveys on a wider scale might increase the number of species in the study site. Rare species that are relatively large in size were seldom seen previously in mangroves namely *Neosarmatium smithi*, *Sarmatium germaini*, and *Anomalifons lightana*, and they could be recorded in Xuan Thuy National Park (Nam Dinh), Tien Hai (non-mangrove survey, Thai Binh) (Do Van Nhuong & Hoang Ngoc Khac, 2006).

It can be seen that benthic species in mangroves from the study area are characterized by coastal estuaries, including those that are inherently low in salinity and euryhaline species presenting in all groups. It can be generalized that the richest species composition is crabs from families Sesarmidae, Ocypodidae, Dotillidae,

Camptandriidae and Macrophthalmidae as well species of families Ellobiidae, and Potamididae from Gastropoda.

The number of species recorded in this study is more diverse than that from other areas in the Red river coastal zone, Tran De (Soc Trang province), Hong Kong and Thailand (Table 6).

Table 6. The number of species of major benthic groups in the study site and nearby mangroves of Vietnam

Benthic macrofauna	Hong Kong (Tam & Wong, 2000; Wong & Ng, 2018)	Tien Hai (this study)	Tran De - Soc Trang (Hoang Ngoc Khac et al., 2012)	Thailand (Suzuki et al., 1997)
Gastropoda	33	32	22	20
Bivalvia	6	9	15	7
Crustacea	15	48	34	20
Total	54	89	71	47

Gastropoda. The most two abundant families Ellobiidae (9 species) and Potamididae (8 species) also shared commonly with previous studies in the coastal mangrove forests of the Red river delta (Do Van Nhuong & Hoang Ngoc Khac, 2004a). It is worth noting that brackish and freshwater groups could be collected in the mangrove areas, such as some species from Stenothyridae, Thiaridae, and Assimineidae. The number of species in each family is low, but the number of individuals is high in quantitative samplings.

In general, the species of Gastropoda is abundant, being an important group in the fauna of the Tien Hai mangrove ecosystem. Families from this class are commonly recorded in coastal areas and mangroves in Vietnam, and nearby areas (Taiwan, Hong Kong, Singapore, Thailand, Indonesia) (Wada, 1988; Fan et al., 1993; Suzuki et al., 1997; Raven & Vermeulen, 2006; Hoang Ngoc Khac et al., 2012). The number of species in each family is from 1 to 8 species. Several species as first recorded in the coastal mangroves of northern Vietnam are *Iravadia ornata* (Iravadiidae), *Melampus singapoensis*, *Pythia cecillei*, *Microtralia alba*,

Laemondonta punctigera (Ellobiidae), and *Assimineia interrupta* (Assimineidae).

Bivalvia. It is clear that this group is not diverse in Tien Hai mangroves. The number of species is low (9 species), accounting for a low rate of 10.11% of the total number of species. Most of the species in the bivalve group are not suitable for mangrove habitats, and they prefer living outside of the mangrove forests. Only some encrusting fauna (*Ostrea rivularis* and *Neotrapezium sublaevigatum*) and in the substrate (cramps, *Geloina coxans*) were found.

Crustacea. Abundant families in the study site are Sesarmidae, Dotillidae, Camptandriidae, Penaeidae (from 5 to 7 species for each family), which could be also found in previous works (Gujanova, 1972; Pham Dinh Trong, 1996; Do Van Nhuong, 1998, 2004a; Do Van Nhuong et al., 2004; Wada, 2019). It is possible to state that the species diversity of benthos in mangroves is predominant by Crustacea and Gastropoda. In the Crustacean group, Sesarmidae and Camptandriidae are the two abundant families, with 5 to 7 species, respectively. Some species that are common in the coastal crab fauna of Hainan Island (China) but are

rarely found in Vietnam's coastal mangroves, such as *Eriocheir sinensis* and *Varuna litterata* (Gurjanova, 1972). Comparing with the previous results (Do Van Nhuong & Hoang Ngoc Khac, 2004a-b), many species were not recaptured (*Eriocheir sinensis*, *Ilyoplax tansuiensis*, *Macrophthalmus abbreviatus*, *Baruna trigranuxlum*). Twelve species are new records for the study site *Oratosquilla oratoria*, *Metapenaeus monoceras*, *Parapenaeopsis hardwickii*, *Caridina* sp., *Macrobranchium nipponense*, *Alpheius pacificus*, *Alpheius strenuus*, *Paguritta vittata*, *Neodorippe callida*, *Scopimera curtelsoma*, *Leipocten sordidulum* and *Parasesarma eumolpe*).

Distributional patterns

Many studies of benthos were conducted in mangrove forests, but little is known about their distributional patterns on this typical biotype (Hutching & Saenger, 1987). In the Tien Hai mangrove ecosystem, it can be divided into four distributional areas of benthic animals: (1) Associated with mangroves: *Littoraria* species inhabit leaves and trunks (rarely at the base). Ellobiidae with an average size including *Cassidula aurifelis*, *Ellobium aurisjudae*, and *Neritina violacea* is usually found in the root and trunk of mangroves. Sesarmidae and Grapsidae are observed around mangrove tree bases. (2) On the substrate surface, there are snails Assimineidae, Potamididae (*Cerithidea sinensis*, *C. djadjanensis*), *Sermyla tornatella*, *Platyvindex* sp.; *Metaplax* crab, *Uca arcuata*. (3) In the deep bottom, the fauna consists of *Geloina coaxans*, *Aloidis laevis*, crabs in family Camptandriidae and *Scylla serrata*. (4) The gaps in the forest, estuaries, and on adjacent unvegetated mudflats of low coverage cover a wide range of crabs in the family Macrophthalmidae (4 species), Ocypodidae (4 species), Dotilidae (5 species); and gastropods, such as *Pirenella cingulata*, *P. incisa*, *Clithon oualanensis* are dominant in terms of biomass and abundance. These characteristics could be found in several studies from mangroves worldwide (Wada, 1988; Suzuki et al., 1997; Tan & Clement, 2008).

For quantitative samples, the diversity and plentifulness of species tend to increase from the river mouth to the inland. The dominant species in the mangroves are *Cerithidea sinensis*, *Neritina violacea*, *Uca arcuata*, *Scylla serrata*, *Alpheius pacificus*, and species from families Assimineidae Sesarmidae, Grapsidae, Varunidae, and Camptandriidae. The dominant groups in the bottom of the forest are *Uca arcuata*, *Ilyoplax ningpoensis*, *Tmethypocoelis ceratophora*, *Metaplax elegans*, and *M. sheni*. The dominant groups in the river and creeks through the forest are shrimp species of the family Penaeidae. This trait could be explained by the tolerant ability of benthos with salinity and bottom sediments.

Species from the three classes perform a different distribution pattern in the study site. Species from Gastropoda are widely distributed, and they are associated with the bottom of the forest. On the other hand, a few species from Bivalvia were found inside the forest. In addition, Gastropoda inhabits the surface of the bottom and are associated with the mangrove trees. From the study site, Brachyura accounted for 75.0% of the total species number from Crustacea. This is also found in other study sites in estuarine mangrove forests. Hence, they play an important role in this type of ecosystem. Species from this group attach to mangroves, do burrowing, and decompose organic humus from mangrove forests and sediments in the bottom (Do Van Nhuong & Hoang Ngoc Khac, 2006). These findings additionally support the significance of the mangrove forest for benthic animals, including goby fish (Tran Duc Hau et al., 2020, 2021).

CONCLUSION

A total of 89 species in three classes of benthos were identified from the Tien Hai mangrove forests. Two dominant groups are Crustacea and Mollusca, which account for 54.02% and 36.78% of the total species, respectively. Individual densities of benthos are from 12 to 744 individuals/m², being higher in the Spring season and inland sampling sites. The distributional pattern is

different between Gastropoda, Crustacea, and Bivalvia in the study site. Gastropoda inhabits the surface of the bottom and is associated with the mangrove trees, while species of Crustacea have different habitats, such as in the gap between forests, association with mangroves. The remaining group, Bivalvia, prefers inhabiting outside the mangroves. The benthic animals show an increase in species diversity and density from the river mouth to the continent.

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