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Relationship of macroinvertebrate species and mangrove species in Xuan Thuy National Park, Vietnam

Mối quan hệ của các loài động vật không xương sống cỡ lớn với các loài cây ngập mặn ở Vườn quốc gia Xuân Thủy, Việt Nam

Research article

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Associative relationships among mangrove species and macroinvertebrate species were analysed for ecosystems of Xuan Thuy National Park. Census of mangrove species with allometric measurements was conducted in selected plots, and census of macroinvertebrate species was conducted in quadrats inside of mangrove species census plots. Correlational analysis among allometrically estimated aboveground biomass of mangrove species and population of macroinvertebrate species was examined by clustering method. High level of similarity was resulted for specific macroinvertebrate species with specific mangrove species in annual and seasonal basis. Moreover, indicator macroinvertebrate species is proposed based on indicator value index method.

Các mối quan hệ giữa thực vật ngập mặn và động vật không xương sống cỡ lớn được phân tích trong các hệ sinh thái của Vườn quốc gia Xuân Thủy. Khảo sát về số lượng của các loài cây ngập mặn cùng với các phép đo tương quan sinh trưởng được tiến hành trong các ô tiêu chuẩn, và nghiên cứu về thành phần loài và mật độ động vật không xương sống cỡ lớn được thực hiện trong các ô tiêu chuẩn này. Phân tích tương quan giữa sinh khối ước tính trên mặt đất của các loài cây ngập mặn và các quần thể động vật không xương sống cỡ lớn đã được thực hiện bằng phương pháp nhóm. Giữa các loài động vật không xương sống cỡ lớn đặc trưng với các loài cây ngập mặn đặc trưng đã cho thấy mức độ tương đồng cao theo năm và theo mùa. Hơn thế nữa, các loài động vật không xương sống cỡ lớn chỉ thị được đề xuất dựa trên phương pháp chỉ số giá trị chỉ thị.

Keywords: Xuan Thuy National Park, macroinvertebrate species, mangrove ecosystem

1. Introduction

Xuan Thuy National Park (XTNP) is distributed in the Ba Lat estuary area of Red river, in Nam Dinh province, around 90 km at southeast of Hanoi.

Based on the information from Hong et al. (2007), the core zone of XTNP consists of Ngan islet's northeastern area and the whole of Lu and Xanh islets. The zone distributes 3,100 ha of land and 4,000 ha of wetland at low tide, with a total extension of 7,100 ha. The coastal area of XTNP lies in the tropical monsoon region with two distinct seasons: a hot and rainy season occurring from April to October and a cold and dry season occurring from November to March.

According to Giesen et al. (2006), XTNP pertains to the Northern Delta Zone of Vietnam's mangrove forests. The area is formed by accretion of sediments from the Red river. Although the mudflats are large and rich in alluvium and freshwater, this zone is subjected to strong winds, storms and waves. Also, as winter temperatures are low, mangrove species stands are not extensive and the trees are relatively small.

Generally, mangrove forests in the XTNP can be classified into natural and planted mangrove forests. The natu-

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ral mangrove forests are mainly distributed in the northern area of the Park, dominated by the species *Aegiceras corniculatum* and *Sonneratia caseolaris* (Wösten et al., 2003). The planted mangrove forests are mainly distributed in the southern part, dominated by species of genus *Kandelia* (Tue et al., 2012). Significant communities of *Avicennia* spp., *Kandelia candel*, and *Rhizophora stylosa* are also present (Wösten et al., 2003).

The present work analyses the interrelationships among the mangrove species and macroinvertebrate species of XTNP, in order to provide basic indicators for the biodiversity therein.

2. Materials and methods

2.1 Mangrove species census

Taking into account the information collected from the bibliographic survey on the mangrove ecosystem of XTNP, and on the field reconnaissance works at initial stage of survey conducted in December 2012 (Haneji et al., 2014), it was decided to establish three locations for the monitoring of mangrove species.

Census of mangrove species was conducted in three plots (P1, P2, and P5: Figure 1) of 400 m^2 (20 m by 20 m) each in July and December 2013. Census was performed, by total counting of identified species, measuring their heights, and stem diameter at breast height and average stem diameter for lower individuals. The aboveground biomass (AGB) of mangrove species was estimated using the allometric equations proposed by Komiyama et al. (1988) based on the measured allometric data.

Figure 1. Locations of plots for mangrove census and quadrats for macronivertebrate species census

Source (satellite image): USGS. LandsatLook Viewer. http://landsatlook.usgs.gov/ (Dec. 27, 2013)

2.2 Macroinvertebrate species census

Census of macroinvertebrate species was also performed, by total counting of identified species taken from surface layer (50 cm by 50 cm with 30 cm depth) inner of each plots for mangrove species census, in order to recognize the relationships among macroinvertebrate and mangrove species.

The selected three plots for plant species census was targeted for macroinvertebrate species census for the survey of July 2013, corresponding to summer season; and in December of 2013, corresponding to winter season, in consequent with mangrove species census. In addition, quadrats in tidal flats without vegetation were established in Lu (L1h, L1m, L4h, and L4m) and Xanh (X1h and X1m) islets, in order to compare the results between mangrove forest zones and sandy-flat zones without mangrove species (Figure 1).

2.3 Analysis of collected data

The collected data from census of mangrove species and macroinvertebrate species were analysed by single linkage (nearest neighbour) agglomerative clustering using

the Pearson's correlation of data. And similarity indexes of all clustered variables were analysed in order to identify the correlations among them.

The dendrograms of clustering analysis outputs and similarity indexes were obtained using PAST (Paleontological Statistic) version 3.0. Single linkage with similarity indexes based on Pearson correlation was used for the clustering criteria. In addition, in order to identify indicator species, indicator value index proposed by Dufrêne and Legendre (Legendre and Legendre, 2012) was calculated for censed macroinvertebrate species. The indicator species add ecological meaning to groups of sites discovered by clustering, they provide criteria to compare typologies derived from data analysis, to identify where stop dividing clusters into subsets, and to point out the main levels in a hierarchical classification of sites (Legendre and Legendre, 2012). The indicator value index is based only on within-species abundance and occurrence comparisons; its value is not affected by the abundance of other species. The indicator value index is defined as follows. For each species j in each cluster of sites k, one computes the product of two values, A_{kj} and B_{kj}. A_{kj} is a measure of specificity (positive predictive value) based on abundance values whereas B_{kj} is a measure of fidelity (sensitivity) computed from presence data:

Specificity:

$$A_{kj} = Nindividuals_{kj} / Nindividuals_{+k}$$

where;

$Nindividuals_{kj}$: mean abundance of species j across the sites pertaining to cluster k

$Nindividuals_{+k}$: sum of the mean abundance of species j within the various clusters

Fidelity:

$$B_{kj} = Nsites_{kj} / Nsites_{k+}$$

where;

$Nsites_{kj}$: number of sites in cluster k where species j is present

$Nsites_{k+}$: total number of sites in the cluster

Indicator value index:

$$IndVal_{kj} = A_{kj} / B_{kj}$$

Indicator species in a given cluster should be the species which obtains the higher value of indicator value index.

3. Results and discussion

Usually, large expanses of tropical coastlines are inhabited by mangrove forest, to the extent that they play a major role in supporting coastal food webs and nutrient cycles in the coastal zone (Alongi et al., 2000). The foremost abundant species of mangrove observed in XTNP are *Kandelia candel*, *Aegiceras corniculatum*, *Sonneratia caseoralis*, and *Rhizophora stylosa*. In a small amount, shrubs of *Acanthus ilicifolius* were also identified.

Cannicci et al. (2008) emphasizes that some species of small, but very abundant crabs ubiquitous in mangrove environments are considered as ecosystem engineers, able to change the particle size distribution and to enhance soil aeration and mangrove primary production (Nielsen et al., 2003; Kristensen and Alongi, 2006; Kristensen et al., 2008). The results of macroinvertebrate species counting in quadrats inside the plots P1, P2, and P5 and tidal flats without mangrove species are listed in Table A (Appendix).

Among the 55 species identified in the surveyed quadrats, only five common species – two polychaeta, one bivalvia, and two gastropoda – were found reciprocally within mangrove area and area without vegetation. The rest, 50 species were found exclusively in mangrove areas or in areas without vegetation. The Table 1 lists the appearance of species in tidal-flats with mangroves and without vegetation, and the exclusive appearance of species. This behaviour is consistent with the statement of Nhuong and Khac (2004), observing that macroinvertebrates species of XTNP are much more diverse in mangrove forests than their surroundings. However, a species of Ampeliscidae malacostraca, the bivalvias *Donax incarnatus*, and a *Tellina* sp. showed seasonal high abundance partially in tidal-flats without mangroves. As listed in Table 1 most of the species, in both for mangrove and non-vegetated areas, appeared with seasonal preference. Among them, it is notorious the selective appearance of almost half of mangrove forest-associated gastropods in winter. According to Hogart (2007), mangrove forests offer opportunities to marine organisms, providing both a physical environment and a source of nutrients. Moreover, the dominant macroinvertebrate species associated to mangrove forests belong to two families, the Grapsidae –now generally regarded as subfamilies: the most important of these is the family Sesarmidae– and Ocypodidae. The presence of Sesarmidae species *Parasesarma pictum* and *Sesarma plicatum*, and Ocypodidae species *Uca* (*Tabuca*) *arcuata* and an identified *Uca* sp. was confirmed in censed plots of mangroves in XTNP. According to Nordhaus et al. (2006), Sesarmidae crabs are less abundant, but also to have a degree of impact, consuming huge amount of mangrove species litter production. Moreover, *Uca* spp. process large amounts of primary production in terms of microalgae, contributing consistently in retention of mangrove production (Cannicci et al., 2008). Based on Nhuong and Wada (2004), Ocypodidae are an important group for studying tidal animals' behaviour useful as an indicator species for substrate environments in mangrove forests and river mouths.

Table 1. Appearance of macroinvertebrate species

Phylum	Class	Tidal-flats with mangrove species			Tidal-flats without vegetation		
		Summer	Winter	Total	Summer	Winter	Total
Annelida	Polychaeta	1	1	2	2	2	3
Arthropoda	Malacostraca	5	6	10	3	6	7
Mollusca	Bivalvia	4	6	8	8	4	9

Phylum	Class	Tidal-flats with mangrove species			Tidal-flats without vegetation		
		Summer	Winter	Total	Summer	Winter	Total
	Gastropoda	9	14	18	2	2	3

Seasonal and habitat exclusive appearance of macroinvertebrate species

Phylum	Class	Tidal-flats with mangrove species			Tidal-flats without vegetation		
		Summer	Winter	Yearly	Summer	Winter	Yearly
Annelida	Polychaeta	0	0	0	1	0	0
Arthropoda	Malacostraca	4	5	1	1	4	2
Mollusca	Bivalvia	1	4	2	4	1	3
	Gastropoda	4	8	5	0	0	1

Meanwhile, the trophic position of gastropods is equally varied. Sediment dwellers feed on sediment organic matter and/or microphytobenthos. Nagelkerken et al., (2008) stated that *Littoraria spp*. feed on epibenthic crusts on stems and roots, and some species feed on mangrove species litter and/or propagules. In this case, *Littoraria melanostoma* was found in plots of XTNP where coexist *A. corniculatum* and *K. candel* species. According to Reid *et al*. (2008), all genera of Potamididae are associated with mangrove forests, using the trees for shelter, as a substrate, for food and protection from predators. A group of Potamididae species such as *Cerithidea cingulata*, *C. djadjariensis*, *C. largillierti*, *C. rhizophorarum* of XTNP showed presence only in plots with mangrove species.

3.1 Cluster analysis of collected data

Tang and Yu (2007) found that, the types of mangrove species communities influence the zonation of macroinvertebrate species owing to the growing environment provided by different mangrove species communities. The Table 2 lists the compilation of estimated AGB values, and censed macroinvertebrate species of XTNP.

Table 2. Compilation of data of plots P1, P2, and P5 (suffixes S: summer, W: winter)

Variable	Unit	P1S	P2S	P5S	P1W	P2W	P5W
Mangrove AGB							
Kandelia	kg/m^2	3.54	0.15	0.43	3.52	0.15	0.63
Aegiceras	kg/m^2	0.00	0.03	2.77	0.00	0.03	2.77
Sonneratia	kg/m^2	0.00	1.76	0.00	0.00	1.75	0.00
Rhizophora	kg/m^2	0.00	0.08	0.00	0.00	0.06	0.00
Total AGB	kg/m^2	3.54	2.02	3.20	3.52	1.99	3.40
Macroinvertebrate population							
Nephtyidae	individual/0.075 m^3	3	1	0	0	0	0
Polychaeta	individual/0.075 m^3	0	0	0	0	5	1
Cleistostoma	individual/0.075 m^3	0	0	0	14	4	10
Paracleistostoma	individual/0.075 m^3	5	4	25	0	0	0
Uca (Tubuca)	individual/0.075 m^3	6	0	0	0	2	1
Parasesarma	individual/0.075 m^3	0	0	0	1	0	0
Sesarma	individual/0.075 m^3	0	0	0	1	2	4
Helice	individual/0.075 m^3	0	1	1	0	2	2
Metaplax	individual/0.075 m^3	6	0	0	0	0	0
Laternula	individual/0.075 m^3	0	1	0	0	0	0
Pharella	individual/0.075 m^3	0	0	0	0	1	1
Brachidontes	individual/0.075 m^3	0	0	0	0	3	0
Polymesoda	individual/0.075 m^3	0	4	2	0	2	2
Glauconome	individual/0.075 m^3	0	0	0	0	2	0
Tellinidae	individual/0.075 m^3	0	1	0	0	1	0
Cyclina	individual/0.075 m^3	0	2	0	0	0	0
Veneroida	individual/0.075 m^3	0	0	0	0	1	0
Cerithidea	individual/0.075 m^3	51	4	9	83	19	0
Clithon	individual/0.075 m^3	0	0	1	0	0	0
Nereididae	individual/0.075 m^3	0	0	0	1	0	0
Odostomia	individual/0.075 m^3	2	0	0	260	0	1

Variable	Unit	P1S	P2S	P5S	P1W	P2W	P5W
Assiminea	individual/0.075 m^3	14	1	8	37	27	10
Littoraria	individual/0.075 m^3	0	0	1	2	0	0
Rissoina	individual/0.075 m^3	0	0	0	5	0	0
Stenothyra	individual/0.075 m^3	0	0	0	6	0	0
Cylindrotis	individual/0.075 m^3	0	0	0	0	10	0
Laemodonta	individual/0.075 m^3	4	0	1	0	12	14
Gastropoda	individual/0.075 m^3	0	0	0	0	0	2

In order to analyse the relations between mangrove species and macroinvertebrate species a combined analysis with clustering and similarity indexes was conducted. Figure 2a shows the result of cluster analysis among mangrove species AGB and macroinvertebrate species counts using data collected in July and December 2013 in P1, P2, and P5. Clustering analysis suggest that *Kandelia* and *Aegiceras* behave farther dissimilar with respect of the other species. Meanwhile, *Rhizophora* is quite similar to *Sonneratia*. In an annual basis, the associated macroinvertebrate species with *Kandelia* could be *Cerithidea* spp. and with lesser extent, gastropod species of *Odostomia*, *Littoraria*, and *Stenothyra*. In the same way, close association with *Sonneratia* and *Rhizophora* was observed for a species of Tellinidae bivalves. *Aegiceras* associated macroinvertebrate species resulted uncertain in annual basis.

In order to analyse the seasonal behaviour, similar analysis was conducted discriminating data gathered in July and December 2013. The Figure 2b shows the result of cluster analysis among mangrove species AGB and macroinvertebrate species counts using data collected in July 2013 (summer season). High association of *Paracleistostoma*, *Clithon*, and *Littoraria* species was observed with *Aegiceras*. Also, high association with *Sonneratia* and *Rhizophora* was observed for *Laternula*, a Tellinidae and *Cyclina* species; and, occypod *Uca*, *Metaplax* decapoda, and gastropod *Cerithidea*, and *Odostomia* species with *Kandelia*. The high similarity of *Assiminea* species with AGB suggests that these gastropod molluscs are ubiquitous in mangrove areas during summer season.

The Figure 2c shows the result of cluster analysis among mangrove species AGB and macroinvertebrate species counts using data collected in December 2013 (winter season). A species of gastropod mollusc and *Sesarma* have high similarity with *Aegiceras*. By the other hand *Sonneratia* and *Rhizophora* are highly associated with species of bivalves *Brachidontes*, *Glauconome*, a Tellinidae, and a Veneroida; and the gastropod *Cylindrotis*. Meanwhile, *Kandelia* associated macroinvertebrate resulted for a Nereididae polychaeta, a decapod *Parasesarma*, a group of gastropods encompassing *Stenothyra*, *Littoraria*, *Rissoina*, and *Odostomia* species. For the winter season, *Cleistostoma* seems to be the ubiquitous species in the mangrove areas of XTNP.

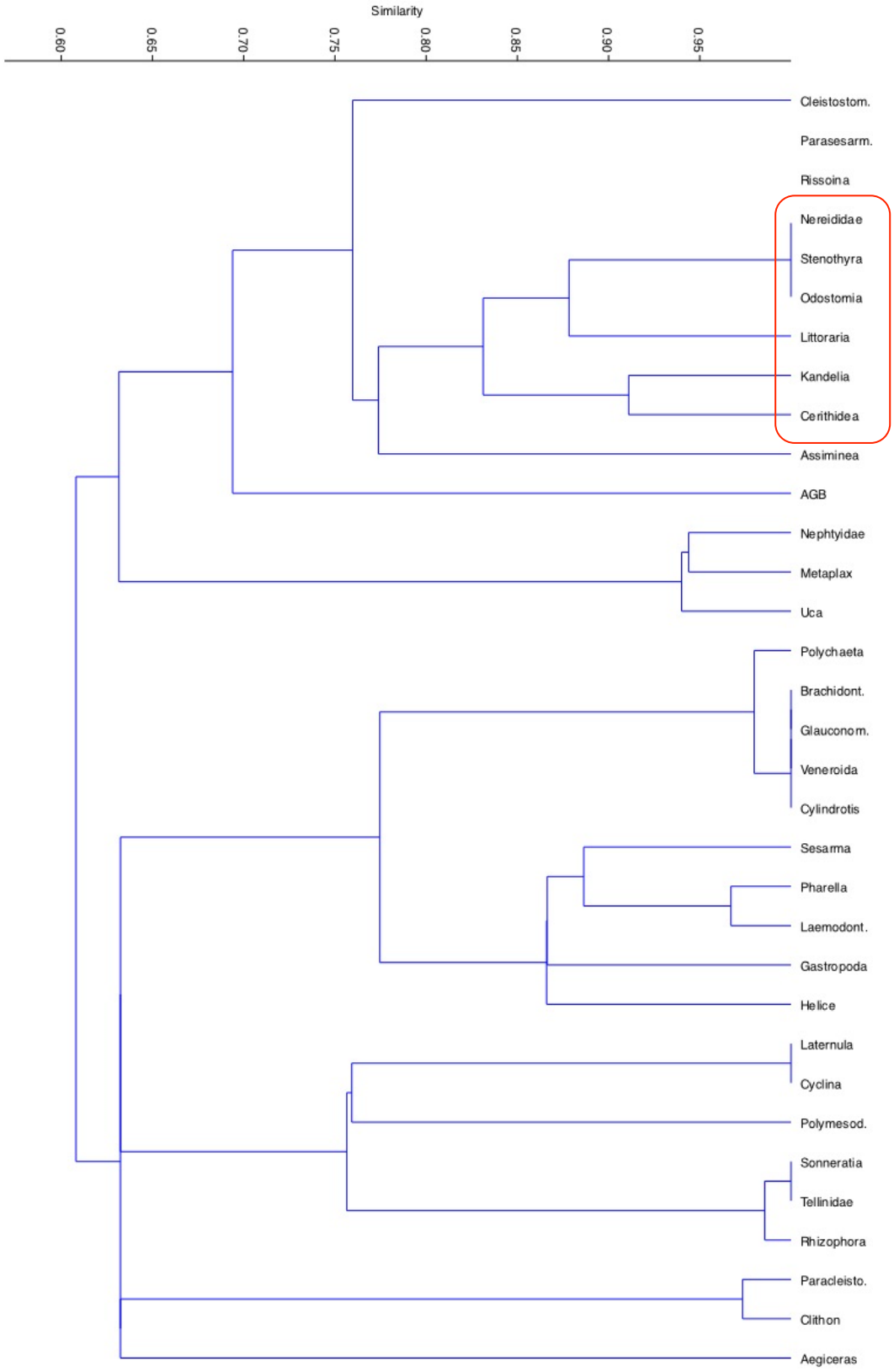

Figure 2a. Clustering dendrogram among mangrove species and macroinvertebrate species (summer and winter seasons)

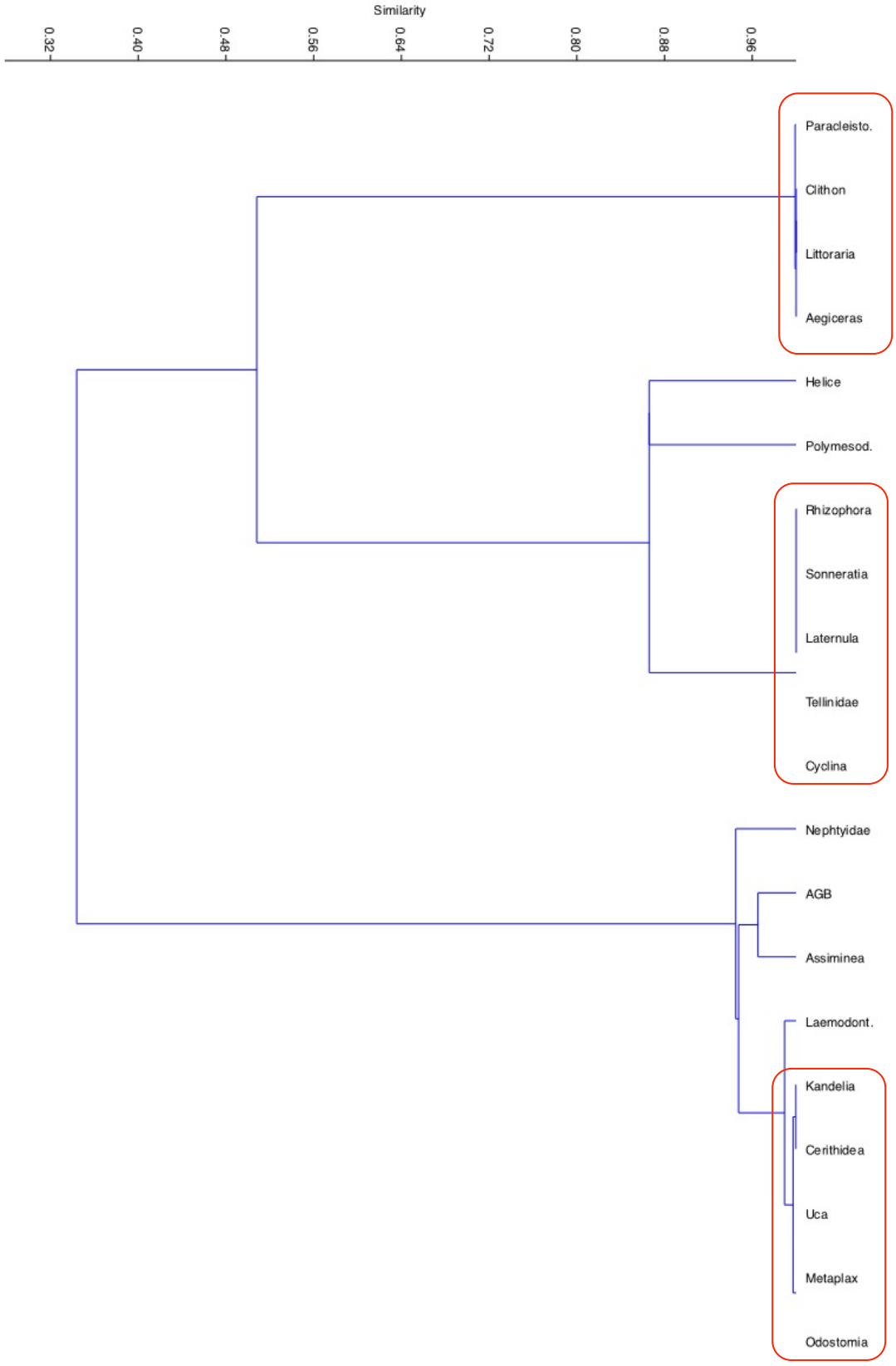

Figure 2b. Clustering dendrogram among mangrove species and macroinvertebrate species (summer season)

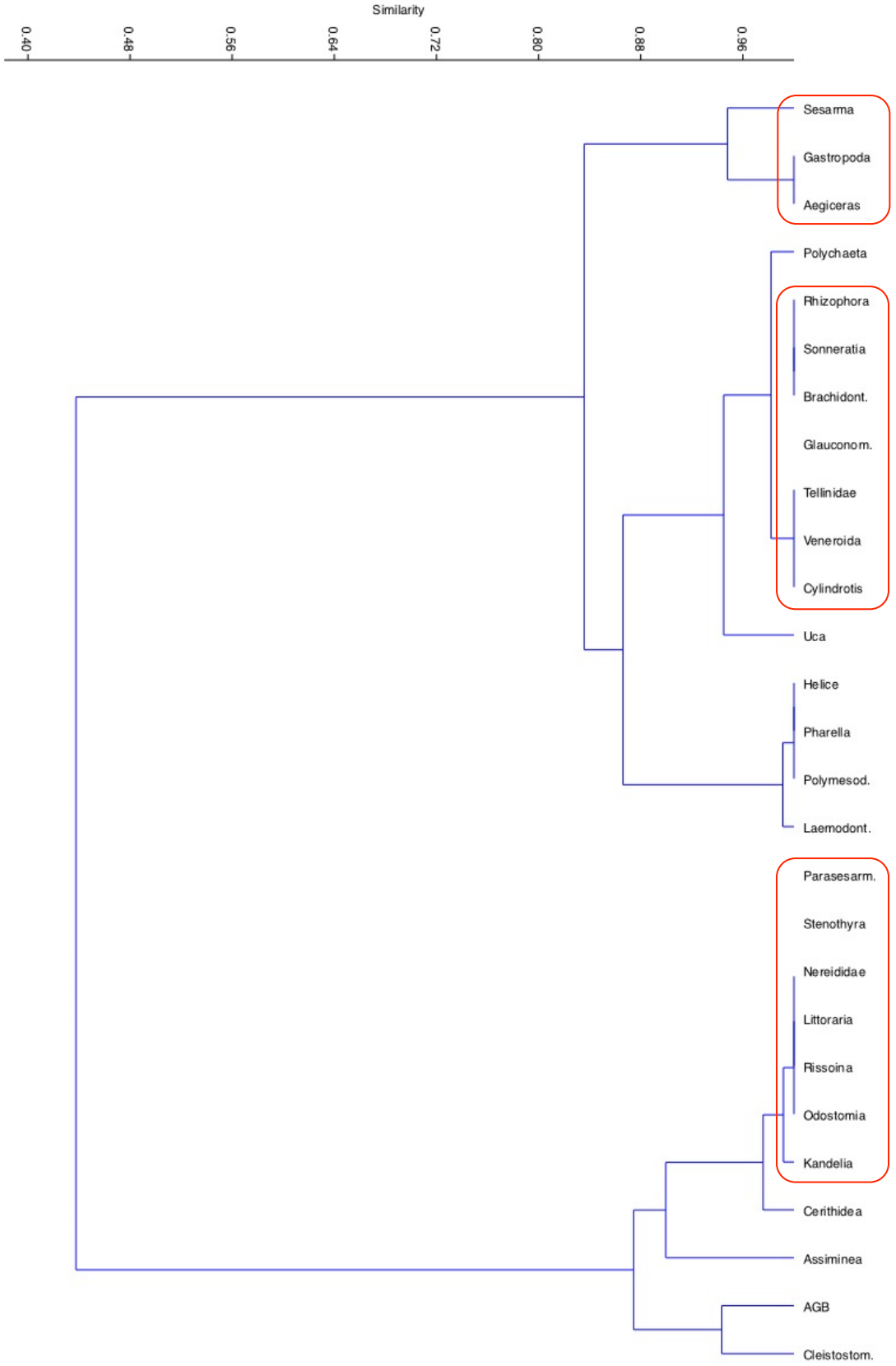

Figure 2c. Clustering dendrogram among mangrove species and macroinvertebrate species (winter season)

3.2 Macroinvertebrate species composition

The Institute of Ecology and Biological Resources had been inventoried macroinvertebrate species living in XTNP. In total 355 species was recorded encompassing 47 species of polychaeta, two unidentified species of diptera, 151 of malacostraca, one maxillopoda, two merostomata, one lingulata (brachiopoda), one anthozoa (cnidarian), 67 bivalvia, two cephalopoda, 80 gastropoda, and one phascolosomatidea (spincula). Indicator value index of macroinvertebrate species associated to mangrove forest ecosystem was calculated using Dufrêne and Legendre method based on the field data as listed in Table A (Appendix). The results are listed in Table 3.

Table 3. Indicator value indexes of macroinvertebrate species at genus level (results of genus groups with *IndVal* lesser than 0.5 were discarded)

	Summer				Winter			
	P1	P2	P5		P1	P2	P5	
Nephtyidae								
A_{k1}				1.0				0.0
B_{k1}	1	1	0	0.7	0	0	0	0.0
$IndVal_{k1}$				**0.7**				0.0
Polychaeta								
A_{k2}				0.0				1.0
B_{k2}	0	0	0	0.0	0	1	1	0.7
$IndVal_{k2}$				0.0				0.7
Paracleistostoma								
A_{k3}				0.5				0.5
B_{k3}	1	1	1	1.0	1	1	1	1.0
$IndVal_{k3}$				**0.5**				**0.5**
Sesarma								
A_{k3}				0.0				1.0
B_{k3}	0	0	0	0.0	1	1	1	1.0
$IndVal_{k3}$				0.0				**1.0**
Pharella								
A_{k3}				0.0				1.0
B_{k3}	0	0	0	0.0	0	1	1	0.7
$IndVal_{k3}$				0.0				0.7
Odostomia								
A_{k3}				0.0				1.0
B_{k3}	1	0	0	0.3	1	0	1	0.7
$IndVal_{k3}$				0.0				0.7
Assiminea								
A_{k3}				0.2				0.8
B_{k3}	1	1	1	1.0	1	1	1	1.0
$IndVal_{k3}$				0.2				0.8
Laemodonta								
A_{k3}				0.2				0.8
B_{k3}	1	0	1	0.7	0	1	1	0.7
$IndVal_{k3}$				0.1				0.6

As listed in Table 3 the higher value of indicator value index (*IndVal*) was resulted for a Nephtyidae species (0.7) for the summer season and genus of *Sesarma* (1.0) for the winter season; and for annual basis, *Paracleistostoma* genus (0.5 and 0.5).

4. Conclusions

The macroinvertebrate species of XTNP can be classified by those species preferring mangrove forest areas and those for sandy-flats without mangrove species. Among the 55 species, only five species were found in both areas. Furthermore, seasonal abundance of species in both areas was observed. The result of cluster analysis among the macroinvertebrate and mangrove species inferred high association of macroinvertebrates with a specific species of mangroves. *Cerithidea*, *Odostomia*, *Littoraria*, and *Stenothyra* gastropod species correlated with *K. candel*. With *A. corniculatum*, crabs of *Paracleistostoma* genus and the gastropod *Clithon* in summer season, while *Sesarma* crabs and a species of gastropoda in winter season. Also, a Tellinidae species correlated with *S. caseoralis* and *R. stylosa* in an annual basis. Based on the results using the method of indicator value index it is recommended to define as indicator species of macroinvertebrates for annual basis and others for seasonal basis. The spatially and seasonally ubiquitous *Paracleistostoma* crabs are the foremost suitable candidates for macroinvertebrate species. In addition, a Nephtyidae species for summer and *Sesarma* species for winter season is also recommended as indicator species of macroinvertebrates.

Appendix

Table A. Macrinvertebrate species accounts in 2013 (unit: individuals/0.075 m^3)

Species	P1		P2		P5		L1m		L1h		L4m		L4h		X1m		X1h	
	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W
Glyceridae											2				9		1	
Nephtyidae	3		1				21	8		21	9							
Polychaeta				5		1		11				1		16		4		
Ampeliscidae								167								8		20
Corophiidae										1		1						
Alpheus pubescens								1		1								1
Cleistostoma dilatatum		14		4		10												
Paracleistostoma depressum	4		4		25													
Paracleistostoma sp.	1																	
Dotilla wichmanni							5	6	2	7	19	6	33	1	80	5	10	19
Macrophthalmus dilatatus															2			
Ocypode ceratophthalmus														1			1	
Uca (Tubuca) arcuata	6			2														
Uca sp.						1												
Parasesarma pictum		1																
Sesarma plicatum		1		2		4												
Helice formosensis			1		1													
Helice latimera				2		2												
Metaplax sheni	6																	
Isopoda										1								
Laternula truncata			1												1			
Pharella acutidens				1		1												
Solen strictus															4			
Brachidontes striatulus				3														
Polymesoda coaxans			4	2	2	2												
Donax incarnatus								3			935	2	22	5		52	1	
Glauconome curta				2														
Tellina sp.							41	28		56					219			
Tellinidae			1	1														
Cyclina sinensis			2															
Dosinia japonica											1							
Meretrix lyrata															1			
Meretrix meretrix										1					24			
Veneridae															1			
Veneroida				1														
Bivalvia														1				
Cerithidea cingulata	36		1															
Cerithidea djadjariensis		30		5														
Cerithidea largillierti	13	46	3	5	9													
Cerithidea rhizophorarum	1																	
Cerithidea sp.	1	7		9											1			
Clithon oualaniensis					1													
Nereididae		1										2						
Odostomia sp.	2	260				1												
Assiminea lutea	14	37	1	23	8	10												

Species	P1		P2		P5		L1m		L1h		L4m		L4h		X1m		X1h	
	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W
Assiminea sp.				4														
Littoraria melanostoma		2			1													
Glossaulax didyma											4	2				1		
Rissoina sp.1		5																
Stenothyra polita		6																
Cylindrotis quadrasi				10														
Laemodonta octanfracta				12														
Laemodonta punctatostriata						14												
Laemodonta siamensis	4				1													
Gastropoda						2												

S: summer (July 2013); W: winter (December 2013)

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