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Mangrove Community Structure and Species Diversity in three small islands of the Setiu Lagoon, Terengganu, Malaysia

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Abstract

An assessment on tree stand structure and mangrove plant diversity was conducted in Pulau Semut, Pulau Busung, and Pulau Tok Haji of Setiu Lagoon, Terengganu. Three 100 m × 20 m plots were randomly set up at study sites. The trees were enumerated, identified and measured for their stem diameter in each plot. 18 species representing 11 families, including 13 exclusive and 5 non-exclusive mangrove species were recorded. *Rhizophora apiculata* from Rhizophoraceae dominated with the highest Important Value (IVI) of 89.49 (1491 individuals). This forest comprise mainly young trees with 80% of trees consist ≤ 10 cm DBH. Pulau Semut exhibited the highest species diversity and richness, compare to Pulau Busung and Pulau Tok Haji. Seven species had IVI values more than 10, indicating mixed mangrove forest characteristic. This study provides an important data for future sustainability management, protection and conservation of mangrove forest in east coast of Peninsular Malaysia.

Keywords: Mangrove forest, plant species diversity, mixed mangrove species, lagoon forest, vegetation diversity.

1. INTRODUCTION

Mangrove forest is a unique ecosystem located within intertidal zone between land and the sea. This forest is distributed between 25° N and 25° S along tropical and subtropical coastlines (Kauffman & Donato, 2012). Mangroves are resilient as they can thrive in daily tides variation, saline water, anaerobic soils, and high temperatures (Kathiresan & Bingham, 2001). The ecosystem offers wide range of ecosystem services, ecologically and economically. Ecologically, mangrove acts as a natural defense from tsunamis and tropical storms; nursery and spawning areas for marine life such as mammals, fishes, and other semi-terrestrial and aquatic fauna (Alongi, 2012). In addition, it also provides various resources and socio-economic benefits for local communities, for instance the ecosystem contributes to charcoal production, firewood, crab and fish as food and economic resources (Suratman, 2008).

Southeast Asia has the largest mangrove areas which cover 6.8 million hectares, and with the most diverse mangrove species (Md-Isa & Suratman, 2021) in the world. Indonesia, Malaysia, Myanmar, Papua New Guinea, and Thailand are countries in Southeast Asia with the most prominent mangrove (Faridah-Hanum et al., 2012). Malaysian mangrove is the third-largest mangrove forest in the Asia-Pacific (Amir, 2018) after Indonesia and Australia, with mangrove area of approximately 629,038 ha in 2017 where 60% can be found in Sabah, followed by Sarawak (22%) and Peninsular Malaysia (18%) (Omar et al., 2020). In Peninsular Malaysia, mangrove forest distribution varied across several geomorphological settings i.e estuarine, delta, lagoon (Nik-Jaafar et al., 2020). In the west coast of Peninsular Malaysia, mangrove forests are fronting the Malacca Straits and sheltered by Sumatera Island of Indonesia. Most mangroves in Peninsular Malaysia's west

coast are of estuarine and delta type. Whereas, in the east coast, the mangroves lying on protected estuaries and lagoons since the coastline are facing directly to the South China Sea (Chong, 2006).

Setiu lagoon, which is located within the Setiu Wetland, in the state of Terengganu, is one of the nine inter-connected ecosystems in Setiu Wetland. The lagoon stretches over 14 km along the coast with semi enclosed water body and shallow depth of approximately less than 2 m (Zainol et al., 2020). Consists of 26 small islands of various sizes, Setiu Lagoon endowed with various diversity of flora and fauna (Nakisah and Fauziah, 2003). Azmi (2014) reported a total of 63 species of mangrove fauna, comprising of groups of invertebrates, reptiles, and mammals. In addition, the lagoon also homes the painted terrapin (WWF-Malaysia, 2021) and 116 species of fishes (Kadir et al., 2019).

In term of flora composition, Muhammad-Nor et al. (2022) identified 74 mangrove species which belong to 23 exclusive species, 49 non-exclusive and two associate species within 13 islands of Setiu lagoon. Islam et al. (2022) reported 18 exclusive mangrove species with 11 mangrove associates of four islands. These plant communities comprise of typical classes of mangrove vegetation, categorised as exclusive, non-exclusive, and associate, as classified by Japar (1994). The mangrove area extent to approximately 418 ha with eight mangroves forest types i.e *Nypa, Melaleuca, Bruguiera-Lumnitzera, Bruguiera, Avicennia-Ceriops, Nypa-Eugenia, Rhizophora*, and mixed mangrove (Lim, 2002; Sulong & Siti-Aishah, 2003). Despite all the works that have been conducted in Setiu Lagoon, a comprehensive study on the community structure and the diversity of mangrove flora at Setiu lagoon, Terengganu, is still considered partially under-studied. Therefore this study aims to determine the community structure and mangroves diversity of the small island within the lagoon. The finding of this study hopefully and potentially can benefit Malaysian forest management by providing comprehensive floristic, as part of mangrove forest protection and preservation effort particularly in east coast of Peninsular Malaysia.

2. MATERIALS AND METHODS

2.1. Study site

Sampling was conducted in Setiu lagoon, in Setiu district, Terengganu, Malaysia (Figure 1), starting from January until September 2020. Setiu lagoon covers large area stretches from Kampung Penarik to Kuala Setiu Baharu. The lagoon consist of small islands covered by mangrove forests is situated on state land with some areas is being privately owned Out of the 26 small islands within the lagoon, three islands were chosen as the study sites. The chosen sites were Pulau Semut, Pulau Busung and Pulau Tok Haji. All the sites' mangrove area were boat-accessible and displayed mixed mangrove community.

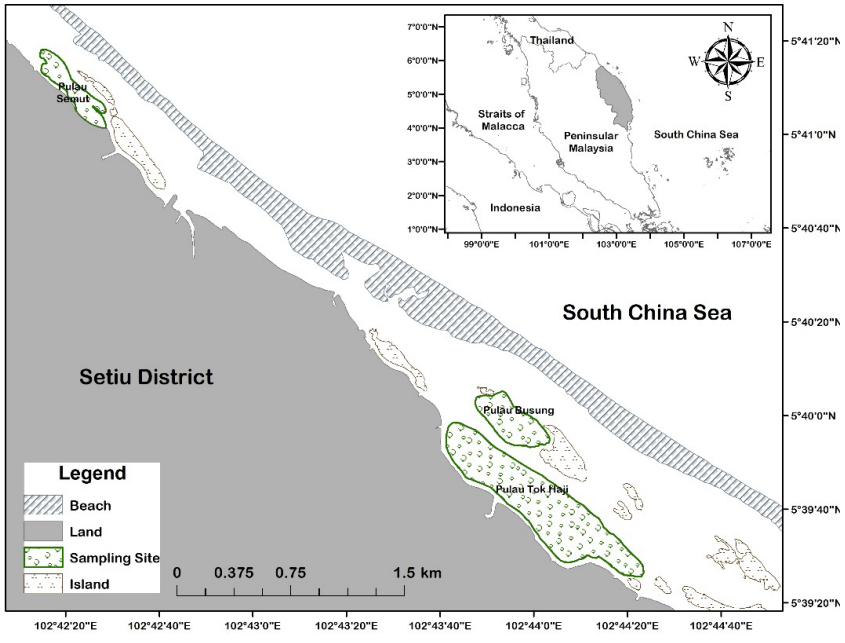

Figure 1. The location of the study site at Setiu Lagoon, Setiu, Terengganu, Malaysia.

2.2. Sampling design

A plot with a size of 100 m × 20 m plot (0.2 ha) was set up at each study site, haphazardly, based on the site accessibility. The haphazard sampling method is commonly carried out by ecologists, when the access to sampling sites is depending on the habitats and temporal factors (Andrew & Mapstone, 1987). Also, the method is convenient in condition when the target habitat is either remote, poorly studied, or in the underwater environments (Smith et al., 2017).

The 0.2 ha plot was then divided into four subplots of equal size (25 m × 20 m), in which, all mangrove trees were counted and identified *in-situ*. As part of identification process, mangrove trees were identified morphologically, to the species level, following Mohd-Lokman and Sulong (2001) and Wan-Juliana et al. (2018). Within the same plot, the tree diameter at breast height (dbh) of mangrove trees was measured at level of 1.5 m above the ground. Specifically, for *Rhizophora* species, the dbh measurement was taken at the level of 30 cm above the highest prop-roots (Kauffman & Donato, 2012; Komiyama et al., 2005). The recorded dbh data were then classified accordingly into four classes, which are 0 cm – 10.0 cm (class 1), 10.1 cm – 20.0 cm (class 2), 20.1 cm – 30.0 cm (class 3) and more than 30.1 cm (class 4).

2.3. Data analysis

2.3.1. Floristic species composition and community structure

To describe mangrove community structure of the lagoon, the collected data were analysed for Important Quantitative Analysis. The analyses that were performed were such as density, basal area, frequency, and Important Value Index (IVI), which indicates the structural importance of a species within a stand of mixed species. The mentioned analyses were calculated based on the given formula below:

$$Density = \frac{Number\ of\ each\ species}{Plot\ area} \times 10,000 \quad (1)$$

$$Basal\ Area = \frac{\pi \times (DBH)^2}{4} \quad (2)$$

$$Frequency = \frac{Number\ of\ plot\ with\ each\ species}{Total\ number\ of\ plots} \times 100 \quad (3)$$

$$Relative\ Frequency\ (Rfi) = \frac{Number\ of\ occurrence\ of\ the\ species}{Number\ of\ occurrence\ of the\ all\ species} \times 100 \quad (4)$$

$$Relative\ Dominance\ (RCi) = \frac{Total\ basal\ area\ of\ the\ species}{Total\ basal\ area\ of\ all\ the\ species} \times 100 \quad (5)$$

$$Relative\ Density\ (RDi) = \frac{Number\ of\ individual\ of\ the\ species}{Number\ of\ individual\ of\ all\ the\ species} \times 100 \quad (6)$$

$$Important\ Value\ Index\ (IVI) = Rfi + RCi + RDi \quad (7)$$

2.3.2. Diversity measurement and sampling efforts

Six diversity indices were performed to further investigate the diversity of the flora species; Shannon (H'), Simpson (1-D), Margalef (R1), Menhinick (R2), Evenness (E) and Equitability (EH) indices using Paleontological Statistic (PAST) software (Hammer et al., 2001). Both Shannon and Simpson indices were used to measure species diversity, Margalef and Menhinick indices were used to measure species richness, while Evenness and Equitability indices were used to measure species evenness in the study area. We applied six diversity measures in this study since a single diversity index will give a feeble result, which may limit to thoroughly delineate and measure the entire community structure (Aqmal-Naser et al., 2022; Mirzaie et al., 2013; Purvis & Hector, 2000).

The rank abundance curve (RAC) for each study site was plotted to demonstrate the pattern of flora species richness and species evenness following Magurran (2004). Diversity permutation test was also carried out to compare species evenness (the number of individuals for each species) between three study sites, using Evenness and Equitability indices, at significant differences $p < 0.05$. To determine the sampling efforts and estimated flora species in Setiu lagoon, we employed simple species accumulation curves (SAC) for each study site using iNEXT online software using abundance

data, following Chao et al. (2016) protocol. The six diversity indices were calculated as the given formula below:

$$Shannon\ Index\ (H^{'}) = -\sum[\left(\frac{ni}{N}\right)\ln ln\left(\frac{ni}{N}\right) \quad (8)$$

$$Simpson\ Index\ (1-D) = 1 - \sum (Pi)^2 \quad (9)$$

$$Margalef\ Index\ (R1) = \frac{(S-1)}{\ln ln\ (N)} \quad (10)$$

$$Menhinick\ Index\ (R2) = \frac{s}{\sqrt{N}} \quad (11)$$

$$Evenness\ Index\ (E) = \frac{H^{'}}{H^{'}max} \quad (12)$$

$$Equitability\ Index\ (EH) = \frac{H'}{\log log\ S'} \quad (13)$$

Where,
ni = total individuals belonging to the *i* species;
N = total individuals of populations sampled;
Pi = the proportion of individuals of *i*th species;
S = total number of species recorded;
N = total number of individuals recorded;
s = total number of different species;
H' max = diversity index observed to a maximum diversity;
S' = number of taxa;

3. RESULTS

3.1. Floristic species composition

A total of 5067 mangrove plants, that comprised of 11 families and 18 species were recorded at all study sites i.e Pulau Semut, Pulau Busung and Pulau Tok Haji (Table 1). Five mangrove families, the Acanthaceae, Euphorbiaceae, Malvaceae, Meliaceae, and Rhizophoraceae were recorded at all study sites. Arecaceae, Pandanaceae, and Primulaceae were the mangrove families occurred at least in two different locations in this study. Whereas mangrove families the Combretaceae, and Fabaceae were only found in one study site or island. In terms of mangrove exclusivity, the exclusive and non-exclusive mangrove species represented by 13 and 5 species, respectively. While the mangrove associate species was not observed and recorded in all study plots. Eight exclusive mangrove species were recorded in high abundance at all study sites with more than 100 individuals. Pulau Busung was the site with the highest mangrove tree individuals (2751). Most of the mangrove species reported in this study were categorized in the Least Concern category and only two species represented in Not Evaluated category (*Calamus erinaceus* and *Volkameria inermis)*.

Table 1. Floristic composition of Setiu Lagoon, Setiu, Terengganu, Malaysia assessed from January to September 2020.

Family	Scientific Name	Common Name	PS	PB	PTH	Total	Exclusivity	IUCN Status
Acanthaceae	*Avicennia alba* Blume	Api-api putih	4	5	4	13	Exclusive	Least Concern
Arecaceae	*Nypa fruticans* Wurmb.	Nipah	0	43	68	111	Exclusive	Least Concern
Arecaceae	*Calamus erinaceus* (Becc.) J. Dransf.	Rotan	0	0	3	3	Non-Exclusive	Not Evaluated
Combretaceae	*Lumnitzera littorea* (Jack) Voight	Teruntum merah	5	0	0	5	Exclusive	Least Concern
Euphorbiaceae	*Excoecaria agallocha* L.	Buta-buta	103	30	155	288	Exclusive	Least Concern
Fabaceae	*Dendrolobium umbellatum* (L.) Benth.	Petai laut	5	0	0	5	Non-Exclusive	Least Concern
Lamiaceae	*Volkameria inermis* L.	Lampin budak	1	0	0	1	Non-Exclusive	Not Evaluated
Malvaceae	*Heritiera littoralis* Aiton	Dungun	12	3	178	193	Exclusive	Least Concern
Malvaceae	*Talipariti tiliaceum* (L.) Fryxell	Baru-baru	39	0	2	41	Non-Exclusive	Least Concern
Meliaceae	*Xylocarpus granatum* (L.) Koenig	Nyireh bunga	118	418	120	656	Exclusive	Least Concern
Pandanaceae	*Pandanus tectorius* Parkinson	Pandan laut	4	0	40	44	Non-Exclusive	Least Concern
Primulaceae	*Aegiceras corniculatum* (L.) Blanco	Kuku helang	1	12	0	13	Exclusive	Least Concern
Rhizophoraceae	*Bruguiera cylindrica* (L.) Blume	Berus	52	115	460	627	Exclusive	Least Concern
Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam. Ex Savigny	Tumu merah	77	952	13	1042	Exclusive	Least Concern
Rhizophoraceae	*Bruguiera sexangula* (Lour.) Poir	Tumu putih	4	0	0	4	Exclusive	Least Concern

Family	Scientific Name	Common Name	PS	PB	PTH	Total	Exclusivity	IUCN Status
Rhizophoraceae	*Ceriops tagal* (Perr.) C.B.Rob.	Tengar	1	44	0	45	Exclusive	Least Concern
Rhizophoraceae	*Ceriops zippeliana* Blume	Tengar	57	421	7	485	Exclusive	Least Concern
Rhizophoraceae	*Rhizophora apiculata* Blume	Bakau minyak	353	708	430	1491	Exclusive	Least Concern
		Total	**836**	**2751**	**1480**	**5067**		

Note: PS= Pulau Semut; PB= Pulau Busung; PTH= Pulau Tok Haji.

Of the 11 mangrove families recorded, Rhizophoraceae was the most diverse. The family was represented by six species from three genera which covered 33.33 % of the whole species recorded at all study sites (Figure 2). Arecaceae and Malvaceae were the two families recorded with two identified genera (11.11%), making both families as the second largest families after Rhizophoraceae. Other mangrove families were only represented by one species (5.56%).

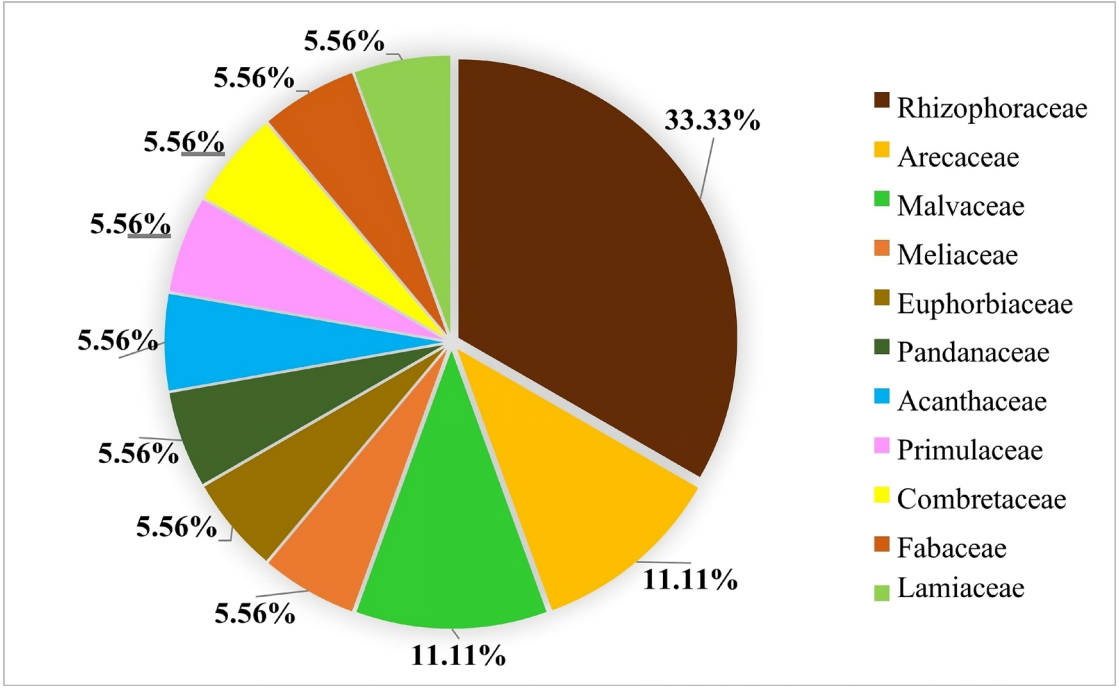

Figure 2. The family composition of mangrove species in Setiu Lagoon, Setiu, Terengganu, Malaysia.

The rank abundant curve (RAC) demonstrated the variability of the mangrove species abundance between study sites. In general, the log-normal models were universally used for describing the pattern in community structure with the expectation a high number of species in the community. RAC curves at all sites displayed log-normal distribution with several species recorded high number of individuals and many species recorded low number of individuals (Figure 3). By this, abundance distribution in the possible area can be seen through ranked most dominant to the rare species. Pulau Semut displayed the highest number of plant species among the three locations with 16 species followed by Pulau Tok Haji (12 species) and Pulau Busung (11 species). In Pulau Semut, the most abundant species with an individual of more than 100 was *R. apiculata* with 353 individuals, followed by *X. granatum* (118) and *E. agallocha* (103). Meanwhile, in Pulau Busung, *B. gymnorhiza* was the most abundant species with 952 individuals, followed by *R. apiculata* (708), *C. zippeliana* (421), and *X. granatum* (418). In Pulau Tok Haji the most abundant species was *B. cylindrica* with 460 individuals followed by *R. apiculata* (430), *H. littoralis* (178) and *X. granatum* (120).

Based on the number of trees and DBH data, 80% of the total trees were categorised under class 1, while 18% of the trees were categorised under class 2 and less than 1% of the trees were in the large DBH classes (class 3 and 4). The average of tree stem DBH in Pulau Semut was 7.12 ± 0.15 while Pulau Busung 4.22 ± 0.05 cm and Pulau Tok Haji 6.50 ± 0.11 cm (Table 2).

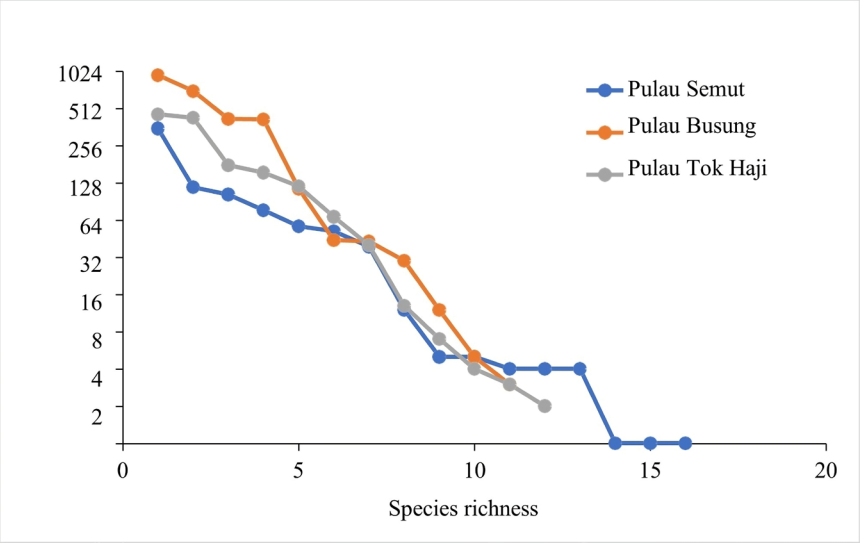

Figure 3. Rank abundance curves of mangroves communities from Pulau Semut, Pulau Busung, and Pulau Tok Haji.

Table 2. Summary diameter breast height according to class size.

Class	DBH (cm)	Pulau Semut	Pulau Busung	Pulau Tok Haji
Average DBH	-	7.12±0.15	4.22±0.05	6.50±0.11
Class 1	0-10.0	659 (72.21%)	2632 (97.13%)	1107 (80.86%)
Class 2	10.1-20.0	160 (19.23%)	73 (2.70%)	250 (18.26%)
Class 3	20.1-30.0	11 (1.32%)	2 (0.07%)	12 (0.88%)
Class 4	> 30.1	2 (0.24%)	1 (0.04%)	0 (0.00%)
Total	-	**832**	**2708**	**1369**

3.2. Important value index of the species

Output of of important (IVI) species analyses of Setiu lagoon displayed that *R. apiculate* was the highest IVI value (89.49) followed by *X. granatum* (41.19), *B. cylindrica* (38.23), *B. gymnorhiza* (38.23), *E. agallocha* (25.15), *C. zippeliana* (20.79), and *H.littoralis* (15.81) (Table 3). The species with high IVI values were also concurrently recorded with high basal area measurement (Table 4). Interestingly, *R. apiculata* that was with the highest values for basal area (12.17m2), was also with high density (7455 individuals/ha), relative density (33.33%), relative dominance (44.00%), and relative frequency (12.16%). On the other hand, the species with the lowest IVI, *V. inermis,* with IVI value of 0.90, displayed low 0.0008 m2 basal area. Site-wise, *R. apiculata* displayed the highest IVI value at all study sites; Pulau Semut (90.88), Pulau Busung (78.47) and Pulau Tok Haji (99.12). In Pulau Semut, *X. granatum* contributed to the second highest IVI with a value of 48.40 followed by *E. agallocha* (31.42). Whereby, *B. gymnorhiza* (73.55) and *X. granatum* (46.16) in Pulau Busung and in Pulau Tok Haji, *B. cylindrica* ranked with the second highest IVI score of 67.60, followed by *E. agallocha* (33.80). Some of the mangrove species such as *L. littorea, B. sexangula, D. umbellatum* and *V. inermis* were only recorded in Pulau Semut with IVI score of 9.09, 3.33, 3.26 and 2.69, respectively (Table 4).

Table 3. Overall basal area (m^2), relative density (RD), relative dominance (RDom), relative frequency (RF) and important value index (IVI) of 15 plant species assessed in Setiu Lagoon.

Mangrove Species	Basal area (m^2)	Density (ha^{-1})	Frequency	RD	RDom	RF	IVI
Aegiceras corniculatum	0.03	65	0.75	0.19	0.13	3.08	3.39
Avicennia alba	0.66	65	1.25	0.32	2.44	4.97	7.73
Bruguiera cylindrica	3.33	3135	3.00	14.70	11.37	12.16	38.23
Bruguiera gymnorhiza	2.76	5210	3.00	15.12	10.94	12.16	38.23
Bruguiera sexangula	0.02	20	0.25	0.16	0.09	0.85	1.11

Mangrove Species	Basal area (m^2)	Density (ha^{-1})	Frequency	RD	RDom	RF	IVI
Ceriops tagal	0.08	225	1.25	0.58	0.33	5.30	6.21
Ceriops zippeliana	0.52	2425	2.75	7.64	2.07	11.09	20.79
Dendrolobium umbellatum	0.01	25	0.25	0.20	0.03	0.85	1.09
Excoecaria agallocha	2.31	1440	2.00	8.27	8.65	8.23	25.15
Heritiera littoralis	0.65	965	2.25	4.85	2.13	8.83	15.81
Taliparitiliaceum	0.11	205	1.50	1.61	0.48	5.57	7.66
Lumnitzera littorea	0.26	25	0.50	0.20	1.12	1.71	3.03
Rhizophora apiculata	12.17	7455	3.00	33.33	44.00	12.16	89.49
Volkameria inermis	0.00	5	0.25	0.04	0.00	0.85	0.90
Xylocarpus granatum	4.12	3280	3.00	12.79	16.23	12.16	41.19
Total	**27.02**	**24545**	**25.00**	**100.00**	**100.01**	**100.00**	**300.01**

Table 4. Importance value index (IVI) of associates mangrove and non-associates' species assessed in Pulau Semut, Pulau Busung, and Pulau Tok Haji of Setiu Lagoon, Setiu, Terengganu, Malaysia.

Mangrove Species	Pulau Semut	Pulau Busung	Pulau Tok Haji
Aegiceras corniculatum	2.71	7.47	nd
Avicennia alba	7.11	7.52	8.57
Bruguiera cylindrica	22.90	24.19	67.60
Bruguiera gymnorhiza	27.03	73.55	14.10
Bruguiera sexangula	3.33	nd	nd
Ceriops tagal	2.75	15.87	nd
Ceriops zippeliana	19.12	33.03	10.22
Dendrolobium umbellatum	3.26	nd	nd
Excoecaria agallocha	31.42	10.25	33.80
Heritiera littoralis	12.97	3.48	30.99
Taliparitiliaceum	16.36	nd	6.60
Lumnitzera littorea	9.09	nd	nd
Rhizophora apiculata	90.88	78.47	99.12
Volkameria inermis	2.69	nd	nd
Xylocarpus granatum	48.40	46.16	29.01
Total	**300**	**300**	**300**

Note: nd = not determine.

3.3. Diversity measurement and sampling efforts

Mangrove diversity at Pulau Semut scored with the highest Simpson, Shannon, Menhinick, and Margalef indices value. The Evenness and Equitability indices however were the highest in Pulau Tok Haji (0.48 and 0.71) (Table 5).

Table 5. The diversity values of six diversity indices in three study sites at Setiu Lagoon, Setiu, Terengganu.

	Indices	Pulau Semut	Pulau Busung	Pulau Tok Haji
Species Diversity	Simpson	*0.78	0.77	0.77
	Shannon	*1.84	1.65	1.76
Species Richness	Menhinick	*0.55	0.21	0.31
	Margalef	*2.23	1.26	1.51
Species Evenness	Equitability	0.66	0.69	*0.71
	Evenness	0.39	0.47	*0.48

Note: '*' indicated the highest values.

Species accumulation curve in Figure 4 is important to determine the sampling effort of a field sampling. In this present study, both Pulau Busung and Pulau Tok Haji sampling efforts were sufficient since both curves reached asymptote. Contrarily, Pulau Semut curve did not show any sign of levelling off. If Pulau Semut's curve is extrapolated, it is expected that the number of individuals collected will reach up to 1600 individuals, whilst the number of species can increase up to 18 species. In contrast, Pulau Busung and Pulau Tok Haji show no increasing in species richness even though the number of individuals increase to 1600 individuals.

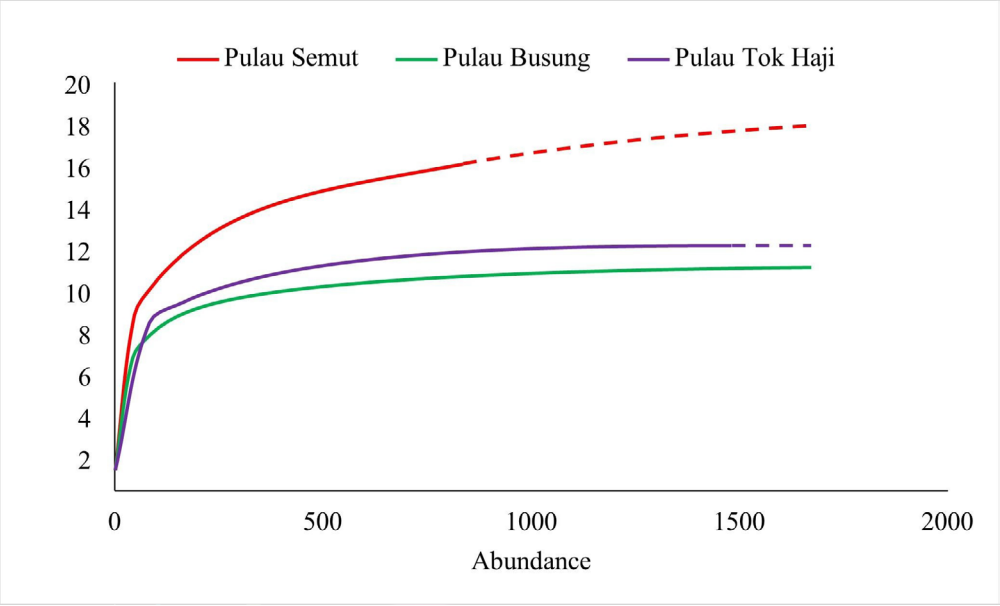

Figure 4. The species accumulation curves for each study site in Setiu Lagoon, Terengganu.

4. DISCUSSION

4.1. Floristic composition and community structure

In this study, a total of 18 species from 11 families which belongs to 13 exclusive mangroves were recorded in Setiu Lagoon. Islam et al. (2022) reported 18 exclusive mangrove species in Setiu Lagoon with additional of six mangrove species, including two mangrove species that never been reported in Setiu Lagoon, the *Avicennia officinalis* and *Bruguiera parviflora*. In addition, previous study by Razali et al. (2017) reported 33 exclusive species in Setiu Wetlands. Both Islam et al. (2022) and Razali et al. (2017) reported more species compared to this present study. Both works that encompassed not only the mangrove area of the lagoon, but also covers wide area of Setiu Wetlands including the other forest ecosystems i.e freshwater and peat swamp forest, BRIS including heath vegetation, *Melaleuca* vegetation, beach vegetation, riparian vegetation, lowland and disturbed forest, further explained the works' higher species compared to this present study. Regardless, the number of mangrove species is decreasing in the past 20 years. Initially, there were 62 species of mangrove trees as recorded and reported by Lim (2002).

Rhizophoraceae was the most widespread family in Setiu Lagoon mangrove forest, which explained by the occurrence of the three most abundant species of this family i.e *R. apiculata*, *B. gymnorhiza* and *B. cylindrica* at all study sites. Based on our analysis, *R. apiculata* showed the highest basal area, density, dominance, and frequency, thus the sum of the relative density, relative frequency and relative dominance contributed to the highest Importance value for this species (IVI). *R. apiculata* was also the most abundant species recorded at all study sites, representing 1491 individuals, and made up 30% of total tree population. A compilation data by Muhammad-Nor et al. (2022) stated that *R. apiculata* presented in all 13 small islands. While on the other hand, *Rhizophora mucronata* only occured in one small island in the Setiu Lagoon. Study carried out by Pesiu et al. (2022) also showed similar result where *R. apiculata* was the dominant species of the Setiu lagoon. Therefore, we suggested that *R. apiculata* was the dominant mangrove species in the lagoon, instead of *R. mucronata,* as reported by Islam et al. (2022). The dominancy of *R. apiculata* in the mangrove forest also reported in some studies that were carried in other mangrove forests in Malaysia (Table 6. For example, the studies by Faridah-Hanum et al. (2012) in Marudu Bay, Sabah, Nabila et al. (2011) in Langkawi Islands, Kedah, Zarawie et al. (2015) in Sungai Merbok, Kedah, Shah et al. (2016) in Sibuti, Sarawak and Rozainah et al. (2018) in Klang Islands, Selangor. Rozainah & Mohamad (2006) and Sivasankaramoorthy (2012) stated that *Rhizophora* species grows tremendously in saline soil and can thrive well in fresh water, which confirms that the Rhizophoraceae family demonstrates adaptability to extreme mangrove environments (Tomlinson, 2016).

Earlier work done by Sulong & Siti-Aisyah (2003) described mangrove forest of Setiu lagoon consists of eight forest types (also refer to the vegetation based classification) which are *Nypa*, *Melaleuca*, *Bruguiera-Lumnitzera*, *Bruguiera*, *Avicennia-Ceriops*, *Nypa-Eugenia*, *Rhizophora*, and mixed mangrove. However, our study has confirmed that Setiu Lagoon consists of mixed mangrove forest. We observed and recorded seven dominant species with IVI value of

more than 10 i.e *R. apiculata*, *X. granatum*, *B. cylindrica*, *B. gymnorrhiza*, *E. agallocha*, *C. zippeliana* and *H. littoralis*. This finding is in line with Sulong et al. (2002) that suggested if more than three dominant species are present, then the zone is interpreted as mixed mangrove.

The present study revealed mangrove community in Setiu lagoon comprised of juvenile stage with 80% of the trees were within 10 cm dbh and less than 1% were the tree with large dbh, confirming that the forest trees are within regeneration level. This condition may attribute to habitat modification of Setiu lagoon in the past. Meteorological phenomena such as dropped in sea level, 5 to 7 thousand years ago, reported to be the reason of the formation of nowadays Setiu lagoon (Jani et al., 2021). Interestingly, isotopic tracer study of Foraminifera proved that Setiu lagoon has been existed for over 500 years (Culver et al., 2015). This finding by Culver et al. (2015) potentially further explained the occurrence of few larger trees with more than 20 cm dbh that were recorded within the lagoon.

Majority of the trees that are still in the juvenile stage may reflect past disturbance at the study area. From personal communication with local people, Setiu lagoon in 1970s was a settlement area, where the fishing village took place within lagoon islands. Possibly, the mangrove forest was cleared for this settlement purposes. Even until now, there are few settlement residues can be seen at the island, for example, the cemetery and building parts, evidence of past settlement area. Unfortunately, the settlement area of the island is no longer intact, the abandoned area observed to be replaced by naturally grown mangrove tree communities, which explained why most of mangrove trees at Setiu lagoon are at juvenile age.

Mangrove plant communities at all study sites show log-normal distribution. This indicated that all sites have a stable mangrove community; fewer species with high and low abundance, while most of the species have intermediate abundance (see Magurran, 2004). Generally, log-normal distribution is associated with a community with higher species richness and several independent factors (Gray, 1987; Whittaker, 1965). Complementing the study done by Oliviera et al. (2005), however on woody plant species in the Cerrado fragment, Southeastern Brazil, the mangrove trees of Setiu lagoon potentially following the log-normal distribution as they exposed to various environmental stress. Aquaculture ponds, oil palm plantations, pollutants or anthropogenic disturbances are the main components that could be threatening mangrove community at Setiu Lagoon (Le et al., 2017, Poh et al., 2019, Zainol et al., 2020). In general, mangrove degradation and land conversion lead to dysfunction of mangrove in carrying out ecosystem services (Hong & San, 1993; Kautsky et al., 1997). However, this hypothesis needs to be attended by a more comprehensive data collection in the future.

4.2. Mangrove species richness and diversity

Recorded data confirmed that the mangrove diversity at Pulau Semut was higher than Pulau Busung and Pulau Tok Haji. Therefore, supported that Pulau Semut was the most diverse in term of species richness than the other two study sites. The sediment composition that makes up Pulau Semut at high potential to cause the various mangrove species of the sites. Based on our observation, sandy sediment of Pulau Semut possibly favours the non-exclusive mangrove species, co-occurring with exclusive mangrove species in its muddy sediment. Additionally, the location of Pulau Semut is adjacent to the mainland of Setiu Wetland possibly also enhances presence of various plant species. Looking at the species accumulation curve, it was noted that if the graph were extrapolated, the number of species may increase indicating the importance to increase the sampling effort. Hence in future, more intense sampling is required to document all known mangrove species in Pulau Semut.

In terms of species diversity, the diversity index (H') from this study was similar with that reported by another mangrove forest published works in Malaysia, for example Pulau Ketam, Klang, Selangor (Rozainah et al., 2018) and Semporna, Sabah (Wah et al., 2011). However, for the east coast Peninsular Malaysia, Rozainah & Mohamad (2006) in their study in Balok river Pahang, recorded higher H', while Tok Bali mangrove forest (Kasawani et al., 2007) showed a slightly lower H' as compared to our study. These comparisons highlighted that mangrove of the west coast of Peninsular Malaysia contains more species than mangroves of the east coast of Peninsular Malaysia (Table 6). For example, study by Nabila et al. (2011) reported the high mangrove diversity in River Kilim, River Kisap and River Ayer Hangat of Geoforest Park Kedah. Similarly, Saraswathy et al. (2009) also reported high mangrove diversity in another west coast Malaysia mangrove ecosystem, the Carey Island, Selangor. In the east coast of Peninsular Malaysia, only the study done by Rozainah and Mohammad (2006) in the mangrove of Balok River, Pahang, was reported with diversity index (H') of more than 2. The west coast mangrove that protected and sheltered by the calm Straits of Malacca, must be the best reason causing the high mangrove diversity in the west coast of Malaysia (Latif & Faridah-Hanum, 2014). Also, the west coast's sediment deposition that mainly consists of high organic materials may also promote more species occurrence at this site of Malaysia coast.

Table 6. Comparison of important value index and Shannon diversity index diversity of Malaysian mangrove forest.

Location	References	The dominant species	Important value index (IVI)	Shannon diversity index
Balok River, Pahang (Plot A)	Rozainah & Mohamad (2006)	*Rhizophora mucronata*	82.98	2.72
Balok River, Pahang (Plot B)	Rozainah & Mohamad (2006)	*Rhizophora mucronata*	101.82	2.03
Balok River, Pahang (Plot C)	Rozainah & Mohamad (2006)	*Rhizophora apiculata*	116.31	1.12
Balok River, Pahang (Plot D)	Rozainah & Mohamad (2006)	*Rhizophora apiculata*	92.58	1.58
Tok Bali, Kelantan	Kasawani et al. (2007)	*Sonneratia alba*	146.86	1.60
River Kilim, Geoforest Park, Langkawi,	Nabila et al. (2011)	*Rhizophora apiculata*	89.84	2.44
River Kisap, Geoforest Park, Langkawi,	Nabila et al. (2011)	*Rhizophora apiculata*	79.04	3.00
River Ayer Hangat, Geoforest Park, Langkawi,	Nabila et al. (2011)	*Rhizophora apiculata*	95.31	2.08
Delta Tumpat, Kelantan (Undisturbed area).	Nor-Syahirah et al. (2018)	*Avicennia marina*	NA	1.54
Delta Tumpat, Kelantan (Disturbed area).	Nor-Syahirah et al. (2018)	*Rhizophora apiculata*	NA	0.38
Gaya Island, Tunku Abdul Rahman Park, Sabah	Mojiol et al. (2019)	*Rhizophora apiculata*	NA	0.72
Semporna Mangrove Forest, Sabah (Disturbed mangrove area)	Wah et al. (2011)	*Rhizophora apiculata*	173.60	1.73
Semporna Mangrove Forest (Non-disturbed mangrove area)	Wah et al. (2011)	*Rhizophora mucronata*	200.00	0.71
Kudat Mainland, Sabah	Mojiol & Salleh (2017)	*Rhizophora apiculata*	NA	1.51
Banggi Island, Sabah	Mojiol & Salleh (2017)	*Ceriops tagal*	NA	1.50
Sibuti mangrove forest, Sarawak	Shah et al. (2016)	*Rhizophora apiculata*	202.24	1.18
Carey Island, Selangor	Saraswathy et al. (2009)	*Avicennuiia alba*	46.71	2.40
Merlimau Mangrove Forest Reserve, Jasin, Melaka, (Intact)	Azman et al. (2021)	*Bruguiera cylindrica*	100.24	0.56
Merlimau Mangrove Forest Reserve, Jasin, Melaka, (Natural Regenerated Fringing Mangrove- 25 Years Old)	Azman et al. (2021)	*Avicennia marina*	186.64	0.26
Sg Pulai Forest Reserve, Johor	Nordatul-Akmar et al. (2011)	*Rhizophora apiculata*	123.15	1.46
Sg Belungkor Forest Reserve, Johor	Nordatul-Akmar et al. (2011)	*Rhizophora apiculata*	121.26	1.38
Sg Santi Forest Reserve, Johor	Nordatul-Akmar et al. (2011)	*Rhizophora apiculata*	157.59	1.14
Pulau Kukup, Johor	Tan et al. (2012)	*Bruguiera cyclindrica*	94.62	1.54
Tanjung Piai, Johor	Tan et al. (2012)	*Bruguiera cyclindrica*	92.85	1.44
Sg Haji Dorani, Selangor	Zhila et al. (2014)	*Avicennia marina*	138.48	0.91

Location	References	The dominant species	Important value index (IVI)	Shannon diversity index
Kuala Selangor, Selangor	Zhila et al. (2014)	*Bruguiera parviflora*	212.88	0.55
Pulau Klang, Klang, Selangor	Rozainah et al. (2018)	*Rhizophora apiculata*	181.4	1.17
Telok Gong, Klang Selangor	Rozainah et al. (2018)	*Avicennia marina*	134.1	1.49
Pulau Ketam, Klang, Selangor	Rozainah et al. (2018)	*Rhizophora apiculata*	64.0	1.81
Pulau Semut, Setiu lagoon, Terengganu	This study	*Rhizophora apiculata*	90.88	1.84
Pulau Busung, Setiu lagoon, Terengganu	This study	*Rhizophora apiculata*	78.47	1.65
Pulau Tok Haji, Setiu lagoon, Terengganu	This study	*Rhizophora apiculata*	99.12	1.76

Note: 'NA' indicated not available data.

5. CONCLUSION

This study highlights the mangrove community structure and species diversity among three small islands of Setiu Lagoon, Terengganu. Our findings reveal that the community structure of Setiu Lagoon consists of mixed mangrove species, with *Rhizophora apiculata* as the most dominant species. Eighty percent of young trees with a diameter at breast height (dbh) of 10 cm are dominated in Setiu Lagoon, indicating the regeneration state of the mangrove forest. Pulau Semut contains the highest mangrove species diversity in Setiu Lagoon, with a diversity index of 1.84 (H'). Considering the richness of the mangrove forest within the islands of Setiu Lagoon, immediate action is needed to protect this area to maintain its ecological functions and ensure sustainability for future generations. Future research should continue to explore the dynamics of plant community structure and its role in biodiversity conservation.

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