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Spatial distribution management of Crustacea (Decapoda) based on conservation in tropical tidal lake

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Abstract. *Muhtadi A, Yulianda F, Boer MF, Krisanti M. 2022. Spatial distribution management of Crustacea (Decapoda) based on conservation in tropical tidal lake. Biodiversitas 23: 4064-4072.* Siombak Lake has a unique biological system impacted by high and low tides. Crustaceans (Decapoda) found in this lake are predicted to establish distinctive communities due to their interaction with two biological systems of seawater and freshwater. Therefore, this study aimed to determine the characteristics and distribution of crustacean communities in Siombak Lake, which were influenced by high and low tides. Crustacean samples were taken and observed every month at high and low tides with traps from September 2018 to August 2019. The crustaceans discovered included 5 families and 18 species, with 13 crabs and 5 shrimp. The communities' distribution is extremely dynamic, as seen by the emergence of mangrove crabs at high tide and fiddle crabs during low tide. The crustacean communities are more influenced by tidal ecology, characterized by a higher abundance of individuals at high tide. Furthermore, crustacean density fluctuates throughout the year and reaches the highest in March with 8679 ind/100m^2. Penaeid shrimp are always found at high and low tides, dominated by *Parapenaeopsis coromandelica*, while mangrove crabs are only found at high tide. Therefore, efforts are required to conserve mangrove crabs and enhance their habitats for sustainable usage.

Keywords: Biodiversity, coastal lake, crab, prawn, shrimp

INTRODUCTION

Crustaceans of the order Decapoda consist of shrimp and crabs, characterized by hard skin and segmented bodies (Arthropoda) from the phylum (Suwignyo et al. 2005; Thorp et al. 2015). Decapoda plays a very important role in the food chain as predators and prey. This order is omnivorous predators (Suwignyo et al. 2005) due to the consumption of phytoplankton, benthic (mollusk and worms), algae, macrobenthos, deposit, and detritus (Murniati 2015; Murniati and Pratiwi 2015; Thorp et al. 2015). Subsequently, Decapoda is preyed upon by various predators such as fish, reptiles, and birds (Suwignyo et al. 2005). Several species are also animals of high economic value, and their meat is a delicacy. These include species of shrimp and crabs from the Penaeid (commercial shrimp), Portunidae (mud crabs), Syllarid (sand and fan shrimp), Palinurid (crayfish or lobster), and Stomatopods (ronggeng or mantis shrimp) (Suwignyo et al. 2005; Thorp et al. 2015).

One habitat of shrimp and crabs partially or wholly in this ecosystem is the estuary including the mangrove and the surrounding waters (Kathiresan 2012; Rajpar and Zakaria 2014; Gita et al. 2015; Rangkuti et al. 2017). An estuary is an aquatic area or environment where river water and seawater mix. It has lower salinity water than the open ocean (Rangkuti et al. 2017) and serves as a habitat for shrimp and crabs. Therefore, these animals depend highly on estuary ecosystems, especially mangroves. Studies on crustaceans (Decapoda) related to spatial and temporal distribution in estuary and mangrove ecosystems have been widely conducted. For example, several studies related to crustaceans (Decapoda) in the estuary and mangrove ecosystems include the composition of crab species (Decapoda: Brachyura) in Lombok Island (Murniati 2015); the biodiversity of aquatic organisms (including crustaceans) in Purworejo (Central Java) (Wiryanto et al. 2017); diversity of decapod crustaceans in Lasongko Bay, Southeast Sulawesi (Hamid and Wardiatno 2018); in degraded mangrove area at Tanjung Panjang Nature Reserve in Gorontalo (Lapolo et al. 2018), and Setyadi et al. (2021) conducted documentation of crustaceans and mollusks in the mangrove area of Timika, Papua.

These studies are still spatial and have not been accommodated temporally in the estuary and mangrove areas. However, studies related to spatial and temporal contexts containing tidal lakes have never been conducted. This study was then conducted in the Belawan estuary by observing the high and low tide conditions. The Belawan River estuary is a special and unique ecosystem with brackish waters influenced by tides (Muhtadi et al. 2017; 2020a). Lake Siombak is one of the tropical tidal lakes located on the coast of Medan City, North Sumatra Province, Indonesia. This lake is unique because it receives water through the Belmera River 7 km from Belawan (Malacca Strait) and is still affected by tides (Muhtadi et al. 2017; 2020a). Therefore, studies related to crustacean biodiversity spatially and temporally in tropical tidal lakes

should be conducted and reported. This study will provide a comprehensive review of crustacean distribution in tidal lake ecosystem management.

MATERIALS AND METHODS

Study area

A sampling of crustaceans was carried out in the Siombak Lake ecosystem, Medan City, North Sumatra Province, Indonesia. Data collection points were 11, 8 were inside the lake, and 3 were outside (Figure 1). Data collection was performed every month for one year, from September 2018 to August 2019.

Procedures

The sampling of crustaceans was carried out at high and low tides using traps and direct observation (Ocypodid family). Furthermore, the crustacean samples were then preserved in a 10% formalin solution and were given labels and other necessary information. Identification was performed at the Integrated Resource Management Laboratory, Faculty of Agriculture, Universitas Sumatera Utara, according to Carpenter and Niem (1998), Purwati et al. (2009), as well as Murniati and Pratiwi (2015).

Data analysis

The data analysis carried out was the Shannon-Wiener diversity index (H'), evenness (E), and dominance (D) (Krebs 2014). Crustacean diversity was calculated using the index from Shannon and Wiener (H') (1963) in Krebs (2014) with the following formula:

$$H' = - (\sum pi \log_2 pi)$$

Where:
H' : Species diversity index
ni : Number of individuals from each species
N : Total number of individuals
Pi : Probability of significance for each species : ni/N

The uniformity of individuals caught between species (equitability) (E) was calculated using the following equation (Krebs 2014):

$$E = H'/H` max$$

Where:
E : Shannon-Wienner uniformity index
H : Species balance
H` max: Maximum diversity index ($\log_2 S$)
S : Total number of species

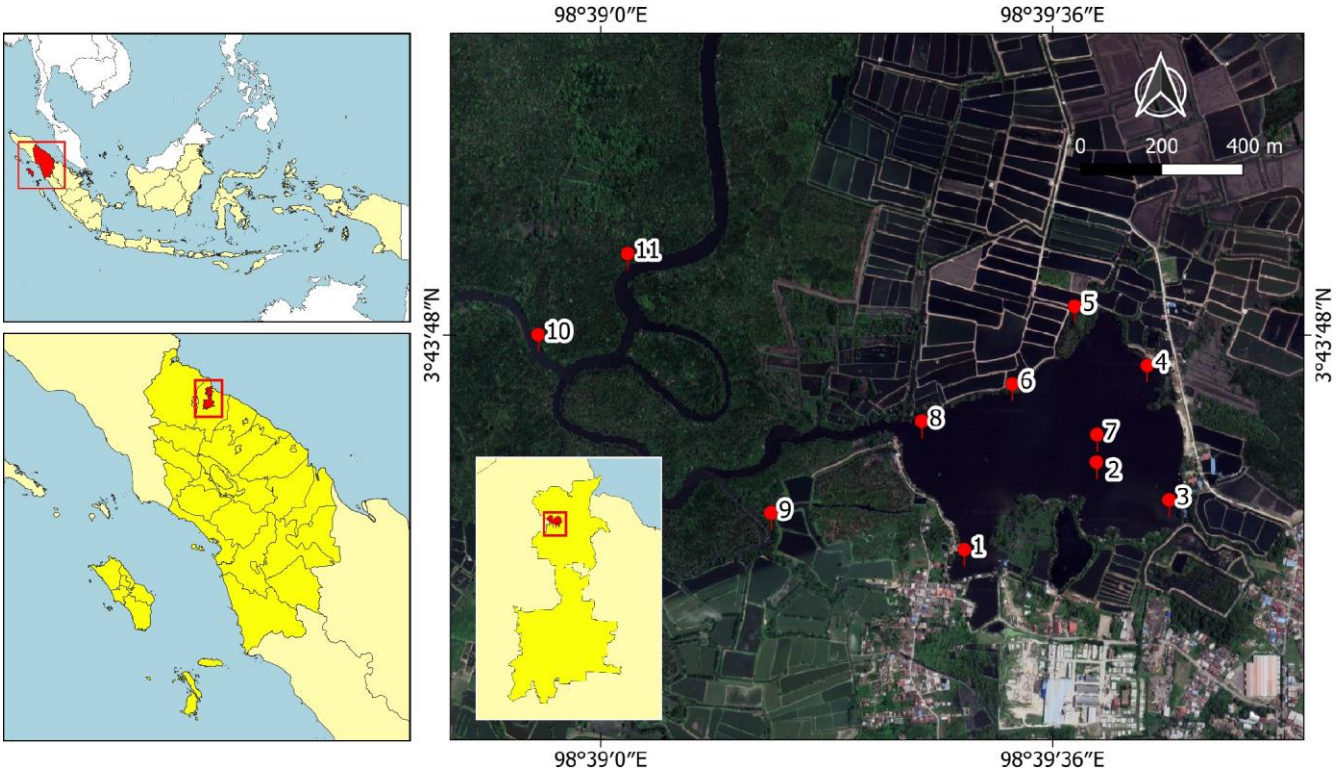


Figure 1. Location of tropical tidal lake ecosystem in the Siombak Lake, Medan City, North Sumatra Province, Indonesia. Point 1 (3°43'29.51"N, 98°39'29.00"E); point 2 (3°43'36.48"N, 98°39'39.54"E); point 3 (3°43'33.46"N, 98°39'45.32"E); point 4 (3°43'44.16"N, 98°39'43.57"E); point 5 (3°43'48.88"N, 98°39'37.79"E); point 6 (3°43'42.70"N, 98°39'32.82"E); point 7 (3°43'38.66"N, 98°39'39.58"E); point 8 (3°43'39.72"N, 98°39'25.61"E); point 9 (3°43'32.44"N, 98°39'13.60"E); point 10 (3°43'46.62"N, 98°38'55.04"E); point 11 (3°43'53.06"N, 98°39'2.16"E), and the detected sites

The dominance index (C) was calculated according to the Simpson index in Odum and Barret (2005) below:

$$C = \sum \left(\frac{ni}{N}\right)^2$$

Where:
C : Dominance index
ni : number of individuals from each species
N : Total community individuals

RESULTS AND DISCUSSION

Richness and composition of crustaceans

The crustacean communities of the order Decapoda in Siombak Lake consist of 18 species from 5 families divided into 5 shrimp and 13 crab species. Economically valuable Decapoda species consist of 4 penaeid shrimps, one Palaemon shrimps, and four mud crabs. Mud crabs consisting of four species, are significant at high tide at different times and places. Meanwhile, the shrimps discovered include *Palaemon concinnus* and Penaid, which provide care in the estuary region, a feature of Siombak Lake as an estuary and mangrove habitat (Muhtadi et al. 2017, 2020a,b; Leidonald et al. 2019).

Other species with no economic value, such as the Grapsidae and Ocypodidae family groups, are also found in high numbers, especially at low tide. Uca fiddle crab (family Ocypodidae) is the most common land crab species found compared to other families at 6 species. Fiddle crab is one species that has a habitat in tidal areas (Murniati 2015; Murniati and Pratiwi 2015). Most species diversity is found in mangrove areas with muddy substrates (Pratiwi et al. 2018), where fiddle crab lives by making nests in the form of holes in the ground (Murniati and Pratiwi 2015). This crab is very abundant in nature because it lives in the mangrove area and has not been exploited by humans. This contrasts with the mud crab and Penaid shrimp, the world's most economically viable crustaceans and the prima donna of seafood consumption. The dominance of Ocypodidae was reported by Rahayu and Setyadi (2009), where 103 species of crabs live in mangrove areas in Mimika, Papua. The largest number of species was only from Ocypodidae and Sesarmidae. Ocypodidae is generally found on the outskirts/coasts near river mouths, while Sesarmidae is more commonly found in dry areas, climbing on the roots and trunks of mangrove trees. Murniati and Pratiwi (2015) found at least 15 species of uca crabs in mangrove areas, muddy beaches, sandy beaches, and rocky substrates.

Several studies in tidal lakes showed that the species richness of crustaceans in Siombak Lake was higher than in the coastal Lagoon, Nallavadu village (India), at 14 species (Padmavathy and Anbarashan 2013), but lower than in other coastal lakes. For example, several previous studies found 45 species of Brachyura (crustaceans) in Chilika Lagoon, 20 species of Decapoda in Vembanad Lake (India) (Mogalekar et al. 2015), and 22 species of Penaeid in Songkhla Lake of Thailand (Samphan et al. 2015). In the estuary area, including the mangrove, the Decapoda richness in Siombak Lake is higher than the Western area of Segara Anakan Lagoon at 17 species (Rimadiyani et al. 2019). However, this is lower than the 103 species found in the Mimika mangrove area (Papua) (Rahayu and Setyadi 2009), the 19 species of Decapoda found in Purworejo mangrove area (Wiryanto et al. 2017), the 38 species of decapod found in s in Lasongko Bay, Southeast Sulawesi, (Hamid and Wardiatno 2018), 21 species in degraded mangrove area at Tanjung Panjang Nature Reserve in Gorontalo (Lapolo et al. 2018), and the 41 species of crustaceans found in the mangrove area of Mimika, Papua (Setyadi et al. 2021).

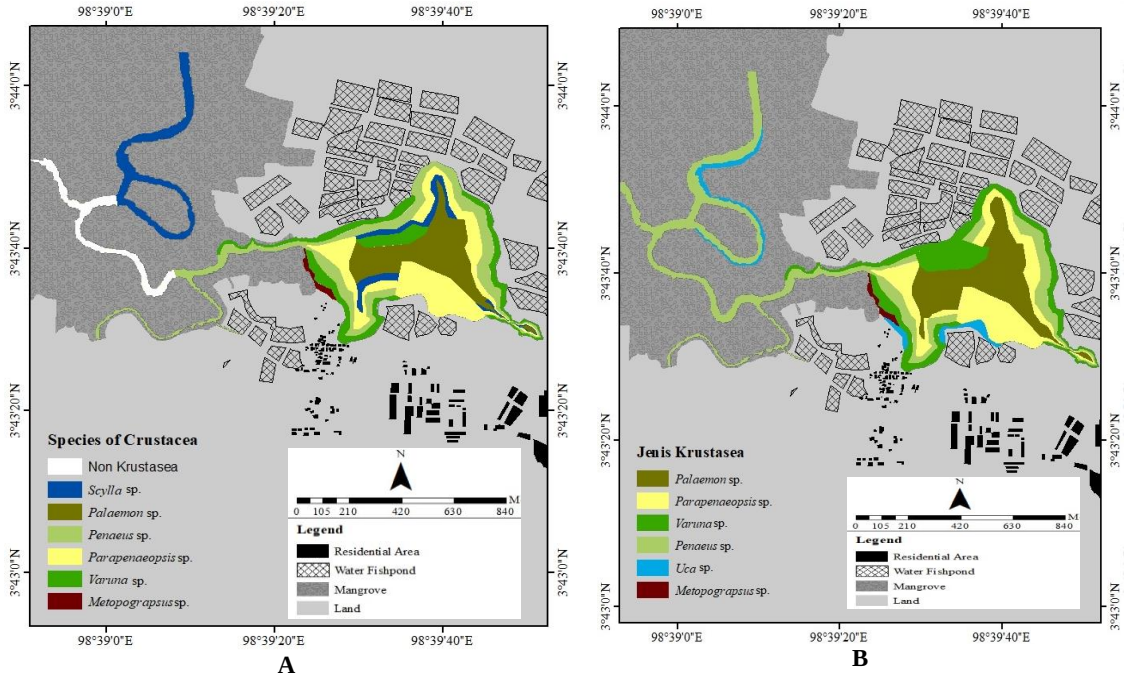
Spatial distribution

Spatially, there are habitat differences between shrimp and crabs in the number of individuals or species. Shrimp and Grapsidae crabs are only found in lake water bodies (stations 1-8) at high or low tides. Meanwhile, mud and fiddle crabs were found on the lake shores (stations 3,5,8) and river banks (stations 9-11). Mud crabs (Portunidae) were found at high tide, while Fiddle crabs were found at low tide (Figures 2-3). Coromandel shrimp (*P. coromandelica*) was the highest abundance, with an average of 657 ind/100m^2 at high tide and 391 ind/100m^2 at low tide. Tiger Shrimp (*P. monodon*) was the lowest abundance of only 3 ind/100m^2 at high tide. Furthermore, mud crab (*Scylla serrata*) and orange mud crab (*S. olivacea*) were the highest abundances at high tide, with an average of 280 ind/100m^2 and 164 ind/100m^2, respectively. At low tide, it should be the most were Thick-legged Fiddler (*Uca crassipes*) with an average of 42 ind/100m^2.

In total, the highest crustacean density at high tide is found at stations 3 (9332 ind/100m^2) and 5 (9190 ind/100m^2), while the lowest is at stations 7 (1 ind/100m^2) and 10 (none). At low tide, the highest crustacean density is at stations 8 (3839 ind/100m^2) and 5 (3715 ind/100m^2), while the lowest is at stations 1 (81 ind/100m^2) and 7 (92 ind/100m^2). The height in the northern part (stations 3 and 5) is an ideal habitat condition for crustaceans. The two stations have a more diverse microhabitat than others. Then the southeast and north parts with shallow water conditions (<4m) (Muhtadi et al. 2020a) are overgrown with mangrove trees with medium to high density (Muhtadi et al. 2020b). Ecologically, mangroves act as a nutrient pool for the availability of organic detritus in the surrounding waters. Crustaceans coexist with mangrove associations and feed on the substrate (including debris). Stations 7 and 10 with lower crustacean abundance are deeper habitats. At these stations, oxygen does not reach the bottom; hence, aquatic organisms, including crustaceans, are not favored. Furthermore, the quantity of crustaceans is spatially greater in the dry season than in the rainy season (Figure 5). The southeast and north (stations 3 and 5) have the most abundance during the dry season, while the north and west have the highest abundance during the rainy season.

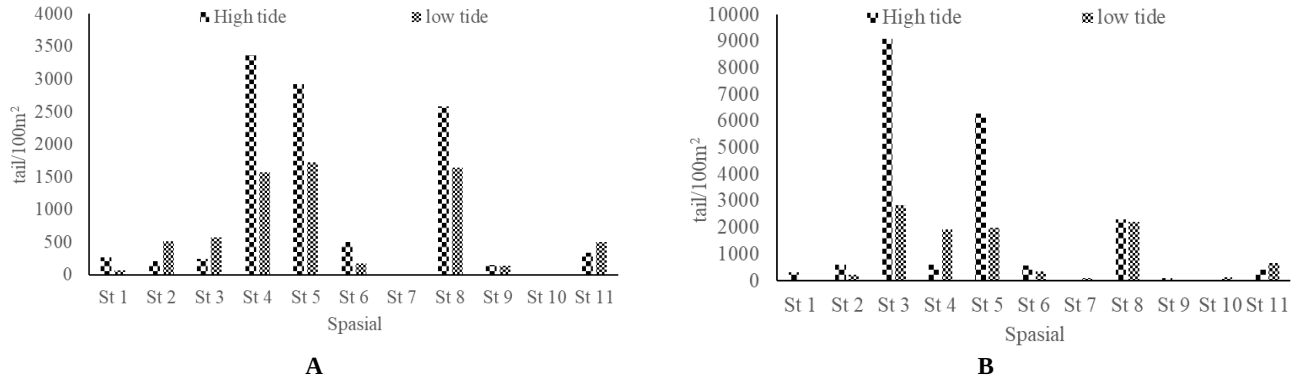
Table 1. Crustacean Richness in Siombak Lake, Medan City, North Sumatra Province. Indonesia

Family	Species	Indonesian name	Common name
Grapsidae	*Metopograpsus frontalis*	Kepiting	Messor gracilipes
Varunidae	*Varuna litterata*	Kepiting	Oceanic paddler crab
	Varuna yui	Kepiting	Sundaic paddler crab.
Ocypodidae	*Uca annulipes*	Kepiting biola	Ring-legged fiddler crab
	Uca coarctata	Kepiting biola	Compressed fiddler crab
	Uca crassipes	Kepiting biola	Thick-legged fiddler crab
	Uca forcipata	Kepiting biola	Fiddler crab
	Uca triangularis	Kepiting biola	Gelasimus triangularis
	Uca vocans	Kepiting biola	Orange fiddler crab
Palaemonidae	*Palaemon concinnus*	Udang	Mangrove prawn
Penaeidae	*Penaeus indicus*	Udang putih	Indian white shrimp
	Penaeus merguiensis	Udang putih	Banana prawn
	Penaeus monodon	Udang tiger	Tiger's shrimp
	Parapenaeopsis coromandelica	Udang putih kecil	Coromandel shrimp
Portunidae	*Scylla olivacea*	Kepiting	Orange mangrove crab
	Scylla paramamosain	Kepiting	Green mangrove crab
	Scylla serrata	Kepiting	Mud crab or mangrove crab
	Scylla tranquebarica	Kepiting	Purple mangrove crab



A B

Figure 2. Map of crustacean species distribution at high tides (A) and low tide (B)



A B

Figure 3. Spatial distribution of crustaceans in Siombak Lake, Medan City, Indonesia. A. rainy season; B. dry season

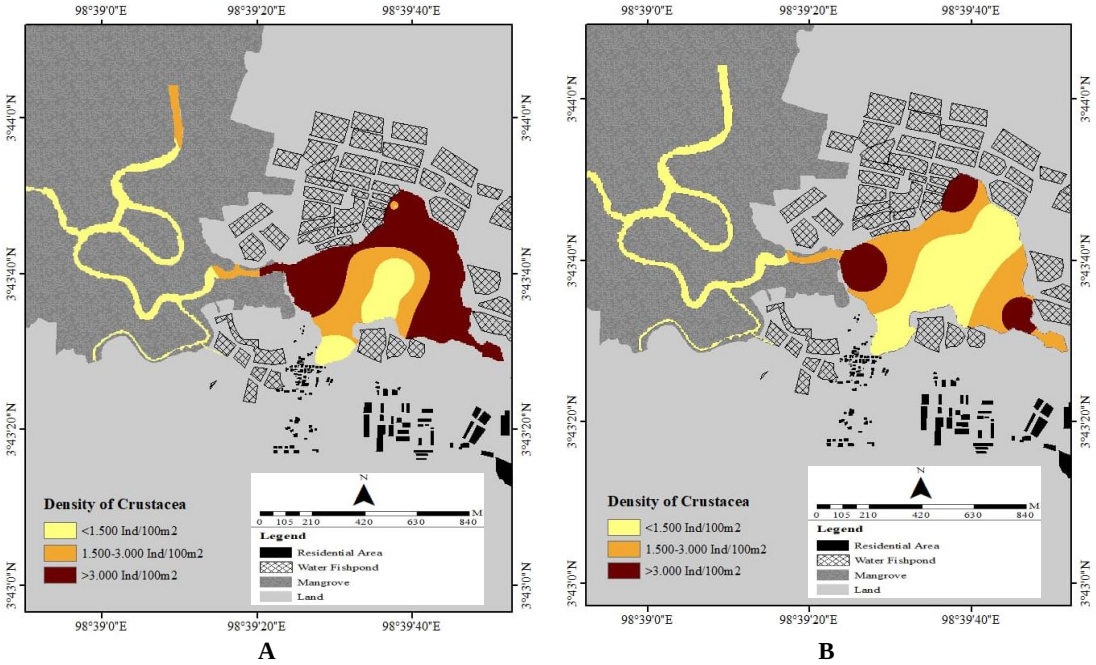


Figure 4. Map of crustacean density distribution at high tides (A) and low tides (B)

The spatial study shows that the density of crustaceans (Figure 4) in the lake (points 1-8, except 7), including species richness (Figure 2-3), is higher than in rivers (points 9-11); both at high and low tides. Therefore, the microhabitat conditions of lake waters (flooded) are more diverse than those in rivers. In this case, the current can be a limiting factor in the river. Odum and Barret (2005) stated that current is one of the limiting factors for the abundance distribution of aquatic organisms in estuaries and seas (Hummel et al. 2016). In the lake, crustaceans are mostly found in the southeast, east to north, and west, with a density of over 3000 ind/100m^2. Locations with lower depths (<3m) are also overgrown with mangrove trees; hence, they are suitable for crustaceans' habitat and food sources. Crustaceans are found in the central and southern parts with lower densities (<3000 ind/100m^2). This is due to deeper water conditions and fewer mangrove trees.

Temporal distribution

Seasonally, the density of crustaceans found in the study area is higher in the dry season (Feb-Jul) compared to the rainy season (Aug-Jan) at high and low tides (Figure 5). The density of crustaceans in the rainy season reaches 1195-4075 ind/100m^2 at high tide and 57-3527 ind/100m^2 at low tide. Meanwhile, the density of crustaceans in the dry season ranges from 784-8679 ind/100m^2 at high tide and 920-3666 ind/100m^2 at low tide. Figure 5 shows that the peak population of crustaceans in Siombak Lake is in March (peak summer), while the lowest period is in May and August-November. *Parapenaeopsis coromandelica* is a species with an abundant population of 53.37-74.95% and is always found every month at high and low tides. In this case, the peak population is found in March by 93.40% at high tide and 44.05% at low tide. Suradi et al. (2017) in the South Coast of Java (Indian Ocean) stated that the peak population of *P. coromandelica* is in the rainy season. This is different because of the geographical differences between the Indian Ocean (South of Java) and the Malacca Strait (East of Sumatra).

This study found several phenomena, including that mud crabs are always caught in the mangrove area at station 11 and are only found in the rainy season (September-December) during the lowest salinity conditions (<5 ppt). Mud crabs are found in protected estuaries and coastal areas associated with mangrove areas (Lapolo et al. 2018; Tetelepta et al. 2019; Yudiati et al. 2020) and only a few are found in the pond. Furthermore, Purwati et al. (2009) stated that the habitat of *S. paramamosain* was associated with mangrove forests and submerged coastlines with water salinity lower than seawater for most of the year; therefore, this species is frequently reported in estuaries. *Scylla olivacea* and *S. tranquebarica* are found with abundant populations at low salinity, while *S. serrata* at higher salinity (Ogawa et al. 2012). *Scylla serrata* is a mud crab with a high salinity range.

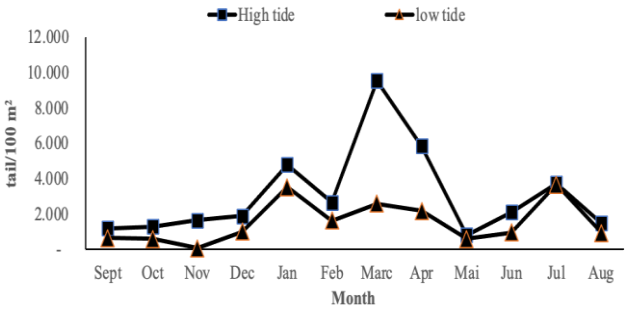


Figure 5. Temporal distribution of crustaceans in Siombak Lake, Medan City, Indonesia

Diversiy index

The species richness and diversity of crustaceans in Siombak Lake differ spatially and temporally (Figure 6). Crustacean diversity is greater in the lake than in the river, both at high and low tide. The highest diversity in the lake is in the north, southeast, and west. This is due to the high abundance with an even proportion between species (10 and 11). In the eastern part (point 4) and the river (point 11), the proportions between species are uneven, with lower species richness (4-8 species) due to lower diversity. Desrita et al. (2018, 2020) stated that the diversity index is not only based on species richness but influenced by the respective proportions of species in the community. The high diversity of crustaceans at stations 6 and 8 is also accompanied by a high evenness index close to 1 and the absence of a dominant one (C value <0.25). Therefore, stations 2, 7, 9, and 10 are less suitable habitats because of high diversity results in low dominance. This shows that the microhabitat at the four stations does not vary, except for station 9, where the water is deep, and there is no (low) mangrove.

Crustacean diversity was highest during the rainy season and lowest during the dry season. This is very different from crustacean density which is higher in the dry season than in the rainy season, including species richness in the dry season of 12 compared to the rainy season of 10. However, the proportion of each species in the rainy season is more evenly distributed than in the dry season (Tables 3 and 4). This shows that the high population of crustaceans in the dry season is only dominated by certain species, such as Coromandel shrimp which has C value >0.5 in the waters of Siombak Lake, especially in March. Temporarily (constant H' value >1), crustacean diversity in Siombak Lake is better than spatially since some H' values are zero. This demonstrates that Siombak Lake is a crustacean habitat, with remarks varying substantially depending on the microhabitat. The crustacean diversity index is moderate-high compared to other locations. For example, this index ranges from 0.37-1.12 in Lasongko Bay, Southeast Sulawesi (Hamid and Wardiatno 2018).

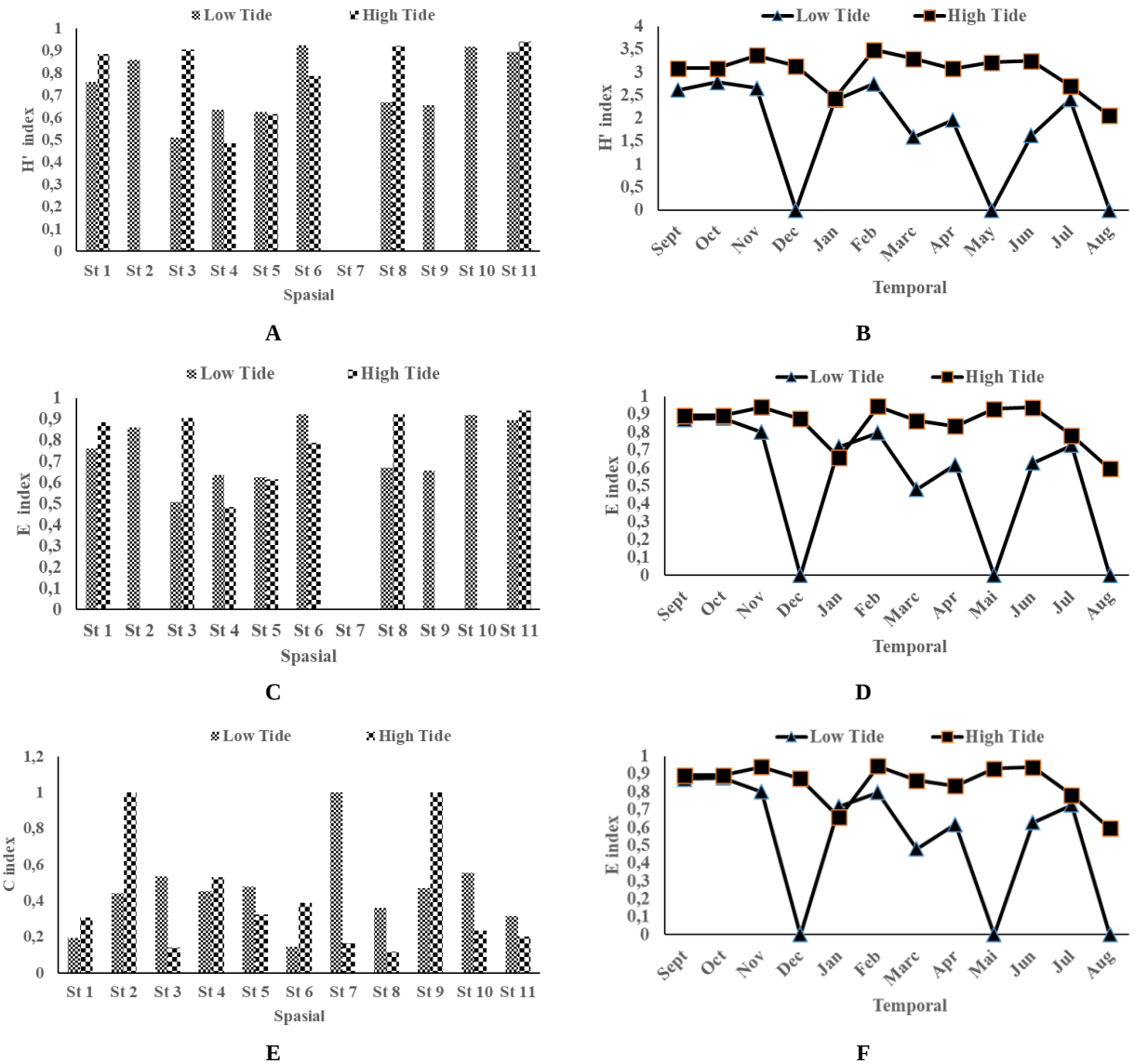


Figure 6. Spatial and seasonal variability of species diversity (A,B), evenness (C,D), and dominance (E,F) in Siombak Lake, Medan, Indonesia

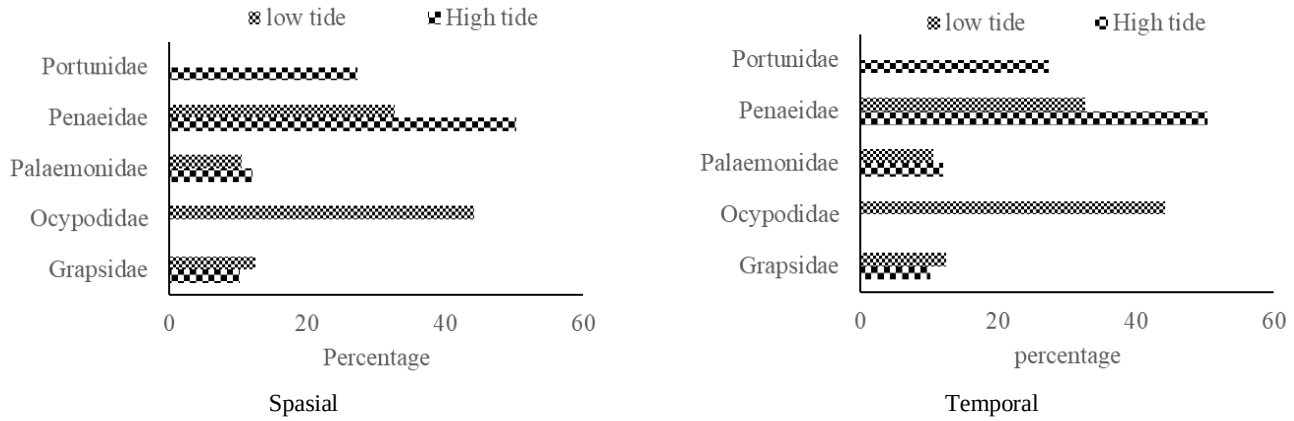


Figure 7. Distribution of crustacean percentage by family, spatially and temporally in Siombak Lake, Medan City, Indonesia

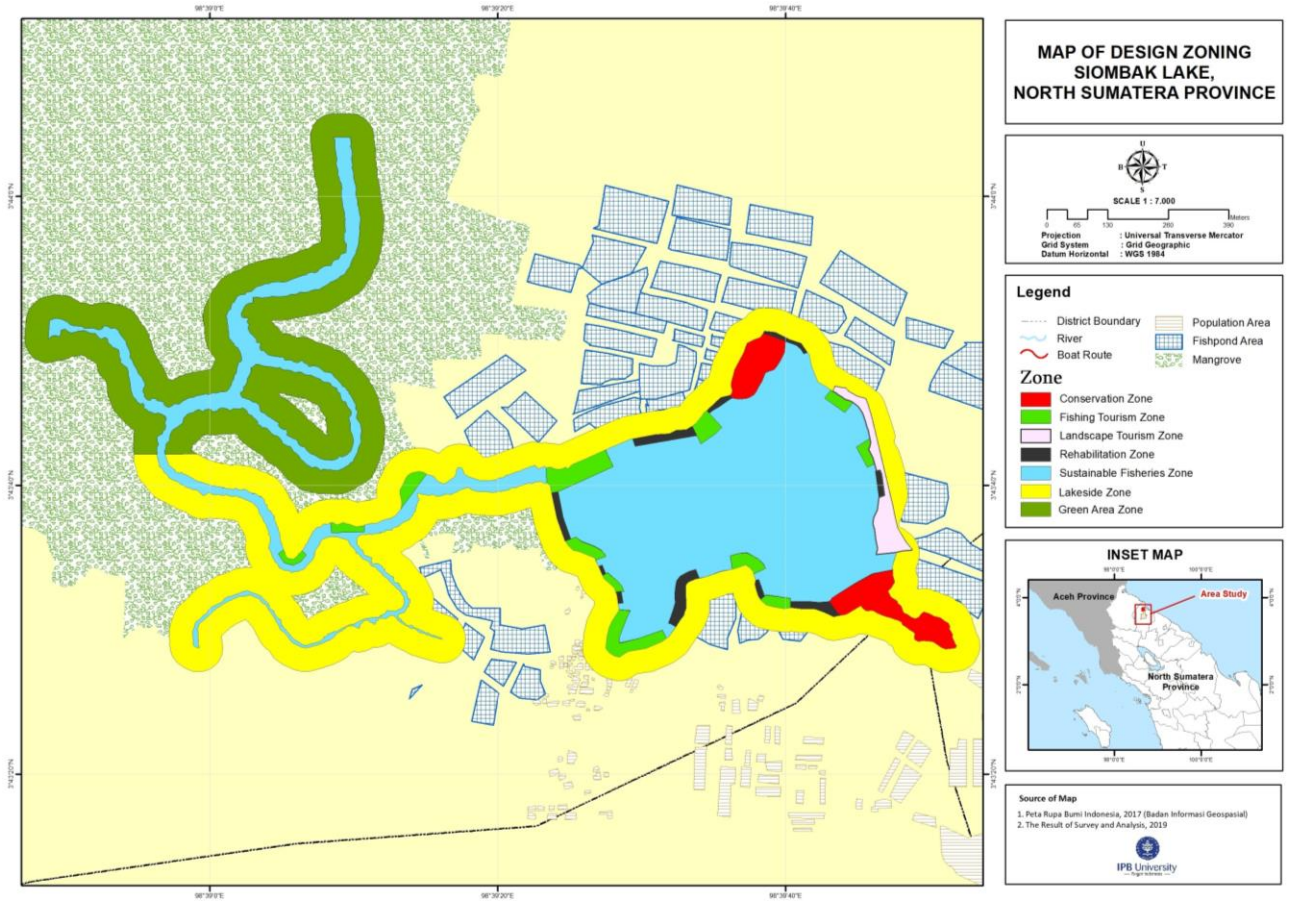


Figure 8. Mollusk, shrimp and crab conservation strategy in Siombak Lake, Medan City, Indonesia (revised map from Yulianda et al. 2020

Discussion

The previous study only found 3 species without *S. olivacea* in the Belawan River Estuary. In this study, *S. olivacea* has a high abundance besides *S. serrata*, possibly because the study time in Belawan River Estuary is shorter (3 months) than this study (1 year). It is unusual to discover four species in one location in multiple investigations, with at least two or three species present. The Siombak Lake area with various habitats with flooded, forests, rivers, and troughs is very suitable for breeding, protecting, and foraging mud crabs. Mud crabs spawn in marine waters and use estuaries and mangroves as nurseries, feeding, and protection area (Ogawa et al. 2012; El-Regal and Ibrahim 2014). The most preferred place for these crabs is shallow beaches with mangrove plants, such as mangrove and nipa palm forests. Furthermore, estuary and mangrove areas

containing four species of mud crab are reported on the North Coast of Java (Tegal-Brebes) (Purwati et al. 2009).

Fiddle crabs only appear at low tide and enter the burrow at high tide. This contrasts with the mud crab, which appears at high tide and hides at low tide. According to Murniati and Pratiwi (2015), fiddle crabs (genus *Uca*) live in burrows in intertidal mud and sand areas. The Siombak Lake ecosystem is found on the edge, "visible" at low tide. Murniati (2015) stated that the tides greatly determine the appearance of crustaceans in estuary and mangrove ecosystems. The crustaceans, especially Ocypodidae, can only be taken when the water is in low tide conditions.

This study also obtained *Varuna* spp. (Varunidae) where only two species of *V. yui* and *V. litterata.* Lapolo et al. (2018) only were found in mangrove area at Tanjung Panjang Nature Reserve in Gorontalo. According to Lapolo et al. (2018), *V. yui* is mostly found in pond areas, while *V. litterata* is found in freshwaters and the sea during reproduction (Mos et al. 2017; Lapolo et al. 2018; Susilo et al. 2020). Furthermore, Carpenter and Niem (1998) stated that *V. yui* is a rare crab where adults are usually found in the open sea while juveniles are found in sluice gates or water embankments in mangrove areas close to land.

The percentage of crustacean appearance differs between high and low tides (Figure 7). At high tide, 20-55% are penaeid shrimp and mud crab. Except for fiddle crabs, all crustaceans are found in lakes, rivers, and mangrove ecosystems at this high tide. Penaeid shrimp and fiddle crab make around 30-50% of the catch at low tide. Therefore, the appearance of the fiddle crab is the opposite of the mud crab. However, penaeidae and grapsidae can appear at high and low tides in the lake. The appearance of crustaceans spatially and temporally in the study area indicates that the Siombak Lake ecosystem is a suitable habitat for crustaceans, especially Decapoda. This is due to the high availability of food from the plankton group (Muhtadi et al. 2020c) as well as the high availability of organic matter both in water and sediment (Leidonald et al. 2022).

The management strategy is focused on crustacean species that have important economic value, such as the crab group of *Scylla olivacea, Scylla paramamosain, Scylla serrata, Scylla tranquebarica*, and the penaeid shrimp group of *Penaeus indicus*, *Penaeus merguiensis*, *Penaeus monodon*, *Parapenaeopsis coromandelica*, and *Palaemon concinnus.* Mud crabs' existence is controlled by the quality of the mangrove environment as defined by seawater through tides. However, the population is limited to mangrove habitats, where high tides can submerge with a rather high frequency. Some mangrove habitats do not get a good supply of tidal water, which causes the distribution of the mud crab population to be limited. As a result, efforts are required to increase the quality of mangrove habitat by flowing the amount of tidal water. Penaeid shrimp community is relatively low with limited population distribution on the edge of Siombak Lake. It is heavily influenced by the nature of the sea tide movement, with the abundance being higher at high tide than at low tide (Figures 4). Therefore, it is necessary to consider managing shrimp habitats with relatively high salinity qualifications to maintain their population.

Results Based on the research of Yulianda et al. (2020) on the distribution of mollusks and their conservation strategy in Lake Siombak shows the need for a zoning system consisting of a core zone and a utilization zone (Figure 8). This zoning can also be applied to the protection of shrimp and crabs in Lake Siombak. The core zone is an area that cannot be utilized but functions as a source of germplasm, while the utilization zone will later function as a shrimp and crab fishing area. The conservation function aims to make spillover function as a parent source that can contribute seeds in other areas so that the distribution and presence of shrimp and crabs is wider and more sustainable in Lake Siombak.

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