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Characteristics of *Meretrix meretrix* and mangroves in the main clam-producing area of Bagan Asahan, North Sumatra, Indonesia

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Abstract. *Purwoko A, Mulya MB, Basyuni M, Gandeseca S, Daulay UA, Mubaraq A. 2026. Characteristics of* Meretrix meretrix *and mangroves in the main clam-producing area of Bagan Asahan, North Sumatra, Indonesia. Asian J For 10 (1): r100118. https://doi.org/10.13057/asianjfor/r100118.* The Bagan Asahan mangrove ecosystem is one of the east coast ecosystems of North Sumatra, Indonesia, with enormous potential, including the *kepah* (*Meretrix meretrix*). This research aims to analyze the morphological characteristics of *kepah* shells through morphometric studies, distribution patterns, and substrate C-organic content, and to assess the suitability of vegetation and ecosystems. Field observations were conducted over six months at three stations representing different dominant mangrove genera (*Sonneratia*, *Avicennia*, and *Rhizophora*). Shell morphometric analysis was performed by measuring the length, height, and thickness of each individual's shell at each station. Distribution was analyzed based on shell length and frequency patterns. A total of 646 clams were recorded, with an average density of 11.96 individuals m^{-2}. Shell lengths ranged from 1.5 to 4.5 cm, with the most frequent size class between 2.70 and 2.99 cm, indicating dominance of small-sized individuals. The Morisita Index showed a grouped distribution pattern at all stations. Morphometric relationships among shell dimensions exhibited strong positive correlations (R^2=0.91-0.96), indicating proportional growth. Substrate C-organic content ranged from 1.48% to 1.74%, falling within ranges suitable for clam habitat. Mangrove vegetation consisted of six genera, with *Rhizophora* showing the highest importance value index (127.06%) at the station with the highest clam density (14.94 individuals m^{-2}). Mangrove characteristics are suitable for *kepah* habitat. *Rhizophora* genus are more closely associated with *kepah* than other mangrove genus in this region. These findings provide baseline ecological information to support sustainable management of mangrove ecosystems and clam resources in this key production area. Therefore, *Rhizophora* genus are recommended for the highest level of protection and enrichment, as they greatly support mussel sustainability in this main production area.

Keywords: Bagan Asahan, C-organic, distribution pattern, mangrove, *Meretrix meretrix*

INTRODUCTION

Kepah (*Meretrix meretrix* (Linnaeus, 1758)) is a member of the Mollusca phylum and belongs to the Bivalvia (Pelecypoda) class (Ihsan and Retnaningrum 2020). *Kepah* usually inhabits coastal waters, mangrove ecosystems, and marine environments. *Kepah* generally lives permanently and burrows or hides in the substrate. *Kepah* is quite widespread in several countries. In Indonesia, *kepah* is found across various areas, from the coastal waters of Sumatra to Papua (Gruwier 2017). *Kepah* is a good, affordable source of animal protein for the community. Abdullah et al. (2016) reported that the moisture, ash, fat, protein, and carbohydrate contents of *M. meretrix* were 79.98%, 1.37%, 0.11%, 9.39%, and 9.02%, respectively.

Ward et al. (2016) stated that mangrove ecosystems are characterized by trees located between land and sea in (sub) tropical regions, influenced by tides (Giri et al. 2011; McKee et al. 2012; Reef and Lovelock 2015). Mangrove roots stabilize this environment and provide a substrate for the survival of many plant and animal species (Schaeffer-Novelli et al. 2016; Donnelly et al. 2017). Mangroves are crucial spawning and breeding sites for shrimp, fish, mollusks, crabs, and other marine organisms (Sukardjo 2004; Lee et al. 2014; Ningsih et al. 2020). Mangroves in Asahan District, particularly in Bagan Asahan, located around the Asahan River estuary, play a special economic role for the people of North Sumatra, Indonesia. This area is the largest long-standing mussel production base in North Sumatra, and its products are well known and marketed in neighboring countries.

Kepah is mainly caught by fishermen and the community for a livelihood, given its abundance in nature. Fishermen catch it in various sizes, ranging from large to small (Silalahi et al. 2014; Desrita et al. 2019). Ginting et al. (2017) state that there are 2,393 individuals of bivalves, comprising six families and 14 species, in these waters. One type of bivalve found is the *M. meretrix*. The fishing community in the Bagan Asahan mangrove ecosystem generally does not consider the number and size of *kepah* caught. *Kepah* caught are often immature. Continuous shellfish harvesting without accounting for quantity and size can reduce the availability of wild clams. Furthermore, the mangrove ecosystem, which serves as a buffer for shellfish production in this area, continues to face the threat of destruction. Stakeholders are carrying out various mangrove preservation and restoration programs to maintain the sustainability of *kepah* production in this area. Data on the suitability of the *kepah* habitat for the ecosystem and on the types of mangrove vegetation that are positively associated with it in this area are not yet available and remain urgently needed. Data on the suitability of *kepah* habitat for the ecosystem and the types of mangrove vegetation that are positively associated with it in this region are not yet available and remain urgently needed. Previous studies on *kepah* in this region have addressed only biological and growth aspects (Desrita et al. 2019), bivalve diversity (Susetya et al. 2018) and heavy metal content (Syafril 2024). Data on morphometric characteristics, mussel distribution patterns, substrate organic carbon content, mangrove vegetation conditions, and the suitability of these factors as mussel habitat in the Bagan Asahan mangrove ecosystem are not yet available. The suitability of *kepah* habitat for the ecosystem, and the types of mangrove vegetation that are positively associated with it in the region, are also unknown.

Therefore, it is necessary to conduct a study to determine the morphometric characteristics, distribution patterns of kepah, C-organic content of the substrate, condition of mangrove vegetation, and the relationship between various kepah characteristics and dominant tree species in the Bagan Asahan mangrove ecosystem. The results of this study will answer the need for important data and information that is not yet known as a basis for strategic policy making on how to manage the mangrove ecosystem in the Bagan Asahan area, to ensure that the *kepah* and its habitat can be sustainable as the main source of livelihood for the surrounding community.

This study was guided by the hypothesis that variations in mangrove vegetation structure and substrate characteristics influence the distribution, density, and morphometric patterns of *kepah* (*M. meretrix*) in the Bagan Asahan mangrove ecosystem. Specifically, it was hypothesized that stations dominated by different mangrove genera exhibit distinct clam density, distribution patterns, and shell morphometric characteristics, reflecting differences in habitat suitability. Alternatively, this study addressed the research question of whether dominant mangrove genera and substrate C-organic content are descriptively associated with spatial variation in *M. meretrix* populations within this main production area.

MATERIALS AND METHODS

Time and location

The study was conducted over six months in the mangrove ecosystem of Bagan Asahan, North Sumatra Province, Indonesia (Figure 1). In this study, three stations were established, representing the location with each dominant genus. Station 1 (3°02'20.0"N 99°51'22.2"E) is dominated by the *Sonneratia* genus, the *Avicennia* genus dominates Station 2 (3°02'11.8"N 99°51'16.9"E), and the *Rhizophora* genus dominates Station 3 (3°01'57.3"N 99°51'12.7"E).

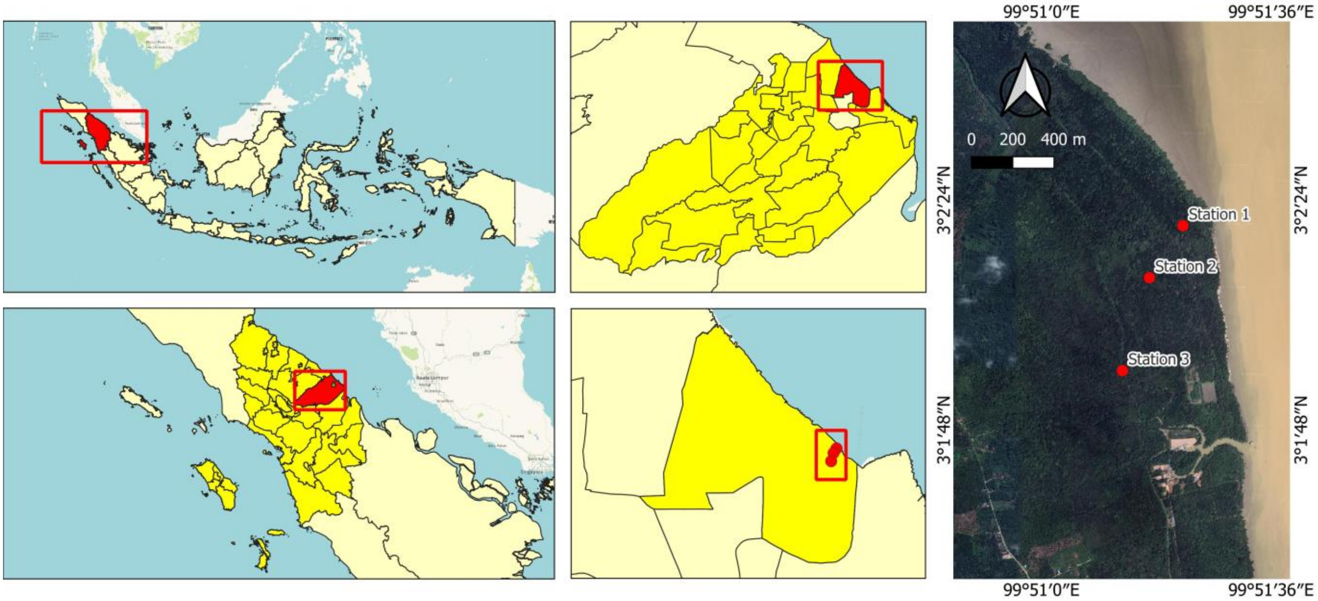

Figure 1. Map of research location

Data collection

Mangrove vegetation data were collected from each transect using a quadratic method: three 10×10 m plots were placed on either side of the transect, and mangrove density, relative density, relative frequency, relative cover, and importance value index were calculated. Transects were placed perpendicular to the shoreline towards the landward/backside of the mangrove forest. At each station, three line transects were installed, with a distance of 20 m between transects.

Kepah sampling at each station and time was carried out by placing three 1×1 m transect plots as replicates within a 10×10 m plot (mangrove vegetation measurement plot). Samples are collected monthly at the lowest tide using a scraper (Desrita et al. 2019). Measurements of sample plots were conducted over 6 months to better assess diversity and trends. The number of *kepah* individuals obtained from each replicate plot, station, and sampling time was summed. All of the fractures obtained are observed for their morphometric characteristics by measuring the shell length from anterior to posterior end, measuring the height of the shell from dorsal side to ventral side, and measuring the thickness of the shell starting from the outer side of the left shell to the outer side of the right shell using a caliper. Measurement of substrate C-organic content is carried out by taking a 500-g substrate sample from each station (Susetya et al. 2020), which is then taken to the Soil Science Laboratory of the Faculty of Agriculture, Universitas Sumatera Utara, for analysis.

Data analysis

Analysis of the spread and growth of the kepah

The distribution of *kepah* is analyzed by measuring the number of individuals, density, and distribution patterns. The following is the method used to measure these health indicators.

Kepah density and mangrove density (D)

To analyze the abundance of *kepah* in each habitat with different characteristics, the number of individuals and the density of *kepah* were measured. The density of *kepah* is analyzed by calculating the number of individuals in the area of the plot, and mangrove density (Di) is analyzed by looking at the number of stands for species i in an area unit using the formula proposed by Michael (1994):

$$D_i\ (ind/m^2) = \frac{ni}{A} \qquad [1]$$

Where:
ni: Number of individuals of type i (ind)
A: Plot area (m^2).

Mangrove diversity analysis

To analyze mangrove conditions, a diversity analysis was conducted using the Important Value Index (IVI) as an indicator, calculated from Relative Density, Relative Frequency, and Relative Coverage.

Relative Density (RD) of mangroves

Relative Density is the ratio between the number of stands for species i and the total stands of all species (English et al. 1997):

$$RD_i\ (\%) = \frac{ni}{\sum N} x100\% \qquad [2]$$

Where:
RD: Relative density (%)
ni: Number of individuals of type i (ind)
ΣN: Number of all individuals (ind).

Relative Frequency (RFi) of mangroves

The relative frequency of mangroves is analyzed by calculating the ratio of the number of plots occupied by one genus to the total number of plots occupied by all genera, using Michael's formula (1994).

$$RF_i = \frac{pi}{\sum P} x100\% \qquad [3]$$

Where:
pi: Number of plots occupied by type i
ΣP: Number of plots occupied by all species

Type and relative coverage

The type cover (Ci) is the coverage of type i in an area (English et al. 1997):

$$Ci = \frac{\sum BA}{A} \qquad [4]$$

Where:
Ci: The coverage area of type i
BA: π DBH2 / 4; π = 3.14
DBH: Tree diameter of species i
A: Total area of sampling area (m^2)

Relative Coverage (RCi) is the ratio between the coverage area of type i (Ci) and the total coverage area of all types (∑ C) (English et al. 1997):

$$RC_i = \frac{Ci}{\sum C} x100\% \qquad [5]$$

Where:
RCi: Relative coverage (%)
Ci: The area of the type i coverage
ΣC: Total area covered by all species

Importance Value Index

Importance Value Index is the sum of Relative Density values for species (RDi), species Relative Frequency (RFi), and species Relative Cover (RCi).

$$IVI = RDi + RFi + RCi \qquad [6]$$

Where:
IVI: Important value index (%)
RDi: Relative density value (%)
RFi: Relative frequency of species (%)
RCi: Relative coverage of species (%)

Analysis of the kepah *and mangrove association*

The analysis of the *kepah* and mangrove association was conducted descriptively due to limitations resulting from differences in the data structure of *kepah* indicators and the mangrove habitat.

Morphometric analysis

Morphometric analysis related to growth properties using isometric and allometric growth pattern formulas is based on regression equations (Gosling 2008), namely:

$$Y = a X^b \text{ or } Log\ Y = Log\ a + b\ Log\ X \qquad [7]$$

Where:

Y: Shell dimensions (height or thickness) in cm
X: Shell dimensions (length or height) in cm
a and b: Constants

The value of b is also an allometric coefficient that reflects relative growth. If the value of b=1, then the growth characteristic of the *kepah* is isometric, where the development of the shell dimensions (length, height, and thickness) is the same. If the value of b is <or> 1, then the growth is allometric. If b is <1, it is negative allometric, and if b is >1, it is positive allometric, or in other words, the growth between the shell dimensions is not proportional (Gosling 2008).

The relationship between shell dimensions is analyzed by calculating the correlation coefficient. Data analysis and processing were carried out by entering data on shell length and thickness, shell length and height, and shell thickness and height, which had been converted to logarithmic form, and then using SPSS 22.0 software with the log-log regression method (Jungers et al. 1995).

Kepah distribution pattern

Kepah distribution patterns are analyzed using the Morisita distribution index, as described by Krebs (1989).

$$\mathrm{Id} = n\left[\frac{\left(\sum_{i=1}^{n} x_i^2\right) - N_i}{N_i\,(N_i - 1)}\right] \qquad [8]$$

Where:
Id: Morisita Distribution Index
n: Sample size
$\sum x$: Total number of individuals in squared ($x_1 + x_2 + \ldots$)
$\sum x_i^2$: Total squared of the number of individual pieces in squared ($x_1^2 + x_2^2 + \ldots$)

This coefficient does not depend on population density but is influenced by the sample size (i.e., the number of squares). If Id>1, then the distribution is clustered, Id~1 is random, and Id<1 is uniform (Rimelahas et al. 2022).

To fulfill the statistical characteristics of the sampling distribution, a null hypothesis test regarding randomness is proposed using the chi-square test, namely:

$$X^2 = \mathrm{Id}\,(\sum x - 1) + n - \sum x \;(db = n - 1) \qquad [9]$$

If the x^2 count is smaller than the x^2 table value, it indicates that the population's spread is random.

Distribution of shell length frequency

The distribution based on shell length is analyzed by determining the number of class intervals required using the Fish Stock Assessment Tools 2 program. All assumptions for the analyses used were checked and confirmed to be met.

RESULTS AND DISCUSSION

Kepah density

The results showed that 646 *M. meretrix* individuals were present, with an average density of 11.96 individuals per m². The density of *M. meretrix* varied at each station (Figure 2) and each month (Figure 3). The *M. meretrix* species was most commonly found at station 3, with 269 individuals and a density of 14.94 individuals/m², followed by station 1, with 203 individuals and a density of 11.28 individuals/m², and station 2, with 174 individuals and a density of 9.67 individuals/m². These mussel densities are considered normal, except for station 3, where the density is relatively high (above the normal range). The typical density of *M. meretrix* in mangrove ecosystems ranges from 4 to 12 individuals per square meter, depending on substrate type, ecological pressure, and habitat quality. The average density reported in several local studies ranges from 4-6 individuals/m² in areas with high anthropogenic pressure, and 10-12 individuals/m² in conservation or minimally disturbed areas. Bahtiar and Purnama (2023) stated that the normal density of mussels in the Kambu River of Kendari Bay, Southeast Sulawesi, is 5-12 individuals/m². Rimelahas et al. (2022) reported that the density of *M. meretrix* varied significantly across sampling stations in the Karang Gading estuary, Indonesia, ranging from 4.67 to 11.33 individuals/m², depending on sediment type and salinity level. Based on the research results above, the density of mussels at stations 2 and 1 remains within the normal range, and station 3 is above the average for an ecosystem with minimal disturbance. This indicates that environmental conditions at the three stations remain within the tolerance range for habitat damage in *M. meretrix*, despite anthropogenic pressure.

The highest density of mussels was found at station 3. This station is an area dominated by mangrove plants of the genus *Rhizophora*, with distinctive roots (having taproots), thus strongly supporting the life of this biota. This condition is similar to the findings of Desrita et al. (2019), who reported that several stations in the mangrove ecosystem dominated by *Rhizophora* had higher densities than those farther from the mangrove ecosystem. This may indicate a positive association between *Rhizophora* mangrove dominance and mussel density. The complexity of *Rhizophora* roots provides a wider rooting surface, better sediment stabilization, and the ability to retain more and more diverse leaf litter. At all three stations, the substrate temperature also ranged from 26°C to 30.5°C. This temperature range is still considered optimal for the life cycle of *M. meretrix*. Wati et al. (2019) reported a normal temperature range for mussel life of 20-35°C. A temperature of 30°C will stimulate females to lay eggs.

Distribution pattern

The distribution pattern of the *M. meretrix* (*kepah*) is analyzed using the Morisita distribution index equation, as shown in Table 1. The results of the analysis show that the distribution of *M. meretrix* at each station is grouped. Bengen (2001) and Duncan (1957) states that individuals in a population can be distributed according to three distribution patterns: random distribution (Id=1.0), normal distribution (Id<1), and group distribution (Id>1). The group distribution pattern is a pattern of organisms or biota in a habitat that live in groups in specific numbers. The distribution pattern results from differences in response to their local habitat. The group distribution pattern with varying levels of classification is the most common distribution because individuals in the population tend to form groups of varying sizes. The group distribution pattern occurs when individuals are attracted to specific places in their habitat or to nearby individuals.

Shell length frequency distribution

A total of 646 individuals were selected during the study. The lengths of the shells obtained range from 1.5 cm to 4.5 cm, with an average of 2.91 cm (Table 2). The most captured *M. meretrix* have shell lengths of 2.70 cm to 2.99 cm. The distribution of the *M meretrix* shell length frequency is presented in Figure 4.

Figure 4 illustrates that there is a difference in the size of the *kepah* obtained every month within the period of 6 months of observation. Different environments influence the differences in size across locations. Octavina et al. (2015) state that differences in size frequency are caused by variations in location, sample representativeness, high fishing pressure, genetics, age, parasites, and disease. Overstreet (2021) also states that differences in size frequency are caused by suboptimal environmental conditions, heredity, age, parasites, food, temperature, and water quality.

Table 1. The distribution pattern of *M. meretrix*

	Station		
	1	**2**	**3**
Id	22.72	3.72	20.35

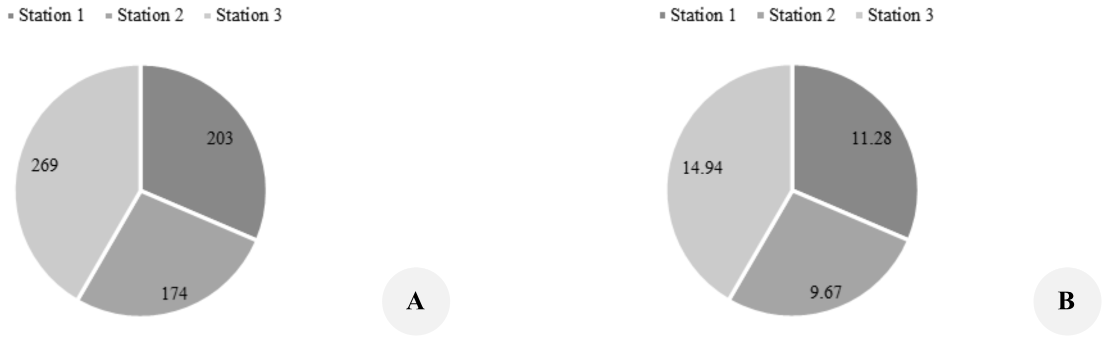

Figure 2. A. Number of individuals of *Meretrix meretrix* at each station, B. Density of *M. meretrix* at each station

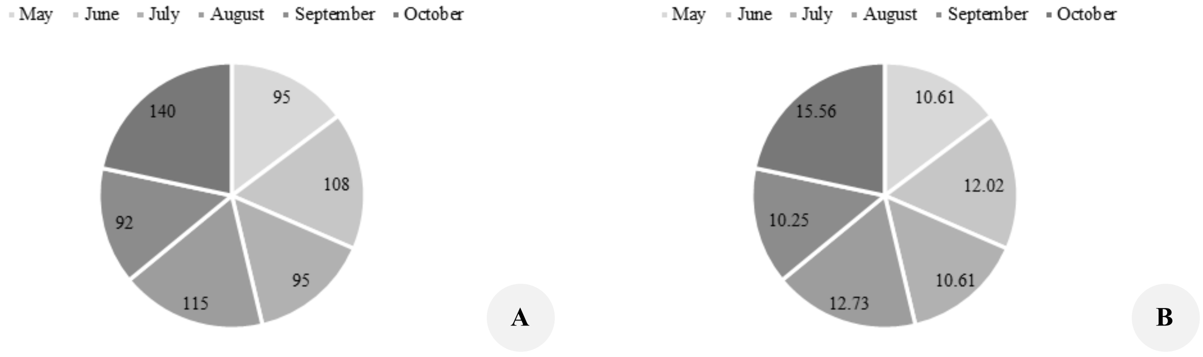

Figure 3. *Meretrix meretrix* during the six months of observation. A. Number of individuals, B. Density

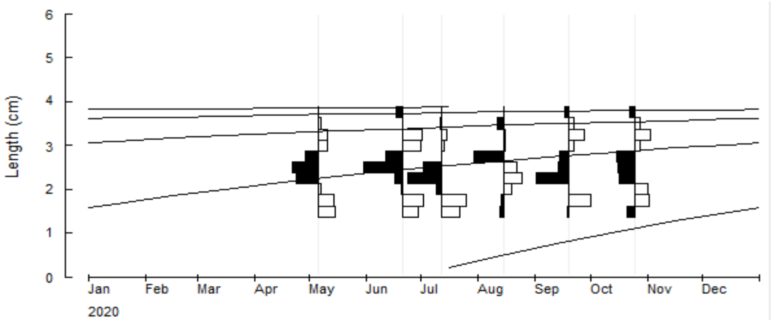

Figure 4. Distribution based on shell length frequency

The study also showed a high prevalence of small-sized *kepah*. This is because scallops can reach 6 cm in length, with an ideal average size of 4.5-5.0 cm (Wiharyanto et al. 2013), whereas in Bagan Asahan, the average length was only 2.91 cm. The large number of small-sized *kepah* is thought to result from the high activity of the people who catch this commodity. Sofiana et al. (2023) state that the poor quality of the aquatic environment can cause the natural death of *kepah*, preventing this biota from growing from young to adult stages. This is consistent with the statement by Román et al. (2023) that an increase in clam size to adulthood indicates that the exploited species are categorized as recovering. However, the high level of community fishing activity is more likely the main cause, given that the Bagan Asahan area and its surroundings are the center of *kepah* production in North Sumatra Province, which is already very famous.

Maximum and minimum size

The results of measurements of shell length and body weight of *M. meretrix* mussels carried out during a 6-month observation period showed variations in shell length and maximum and minimum body weight (Table 2). The minimum shell length of *M. meretrix* caught in the Bagan Asahan mangrove ecosystem ranges from 1.5 cm to 2.0 cm, with a body weight of 2.0 g to 4.1 g, and a maximum shell length ranging from 3.7 cm to 4.5 cm, with a body weight of 18.0 g to 28.7 g. These results indicate that the population of *M. meretrix kepah* caught in the Bagan Asahan mangrove ecosystem comprises individuals of varying sizes, from small to large. However, this condition also reflects intensive harvesting activities, as the potential length of adult *kepah* can reach 60 mm and body weight can reach 40 grams (Indraswari et al. 2014; Rimelahas et al. 2022).

Morphometric features

Meretrix meretrix caught during the six months of the research totaled 646 individuals. Morphometric measurements are carried out in the form of shell length, shell height, and shell thickness in cm. Shell length is measured from the posterior to the anterior side. Shell height measurements are made from dorsal to ventral, and shell thickness measurements are made from the outer surface of the left shell to the outer surface of the right shell (Figure 5).

Morphometric growth

The morphometric growth of the *kepah* in the mangrove ecosystem of Bagan Asahan is shown in Figure 6. The results of the study show that the correlation between shell length and shell height has a coefficient of determination (R^2) of 0.91 (Figure 6.A), shell length and shell thickness has an R^2 of 0.96 (Figure 6.B), and shell height and shell thickness has an R^2 of 0.96 (Figure 6.C).

Table 2. Shell length and body weight of *M. meretrix* for 6 months of observation

Observations	**Shell length**		**Body weight**	
Time	**Min**	**Max**	**Min**	**Max**
May	1.5	4.2	2.0	18.2
June	1.9	3.7	2.0	18.0
July	1.9	4.3	3.4	27.6
August	2.0	4.4	4.1	23.5
September	1.5	3.9	2.0	21.8
October	2.0	4.5	3.0	28.7

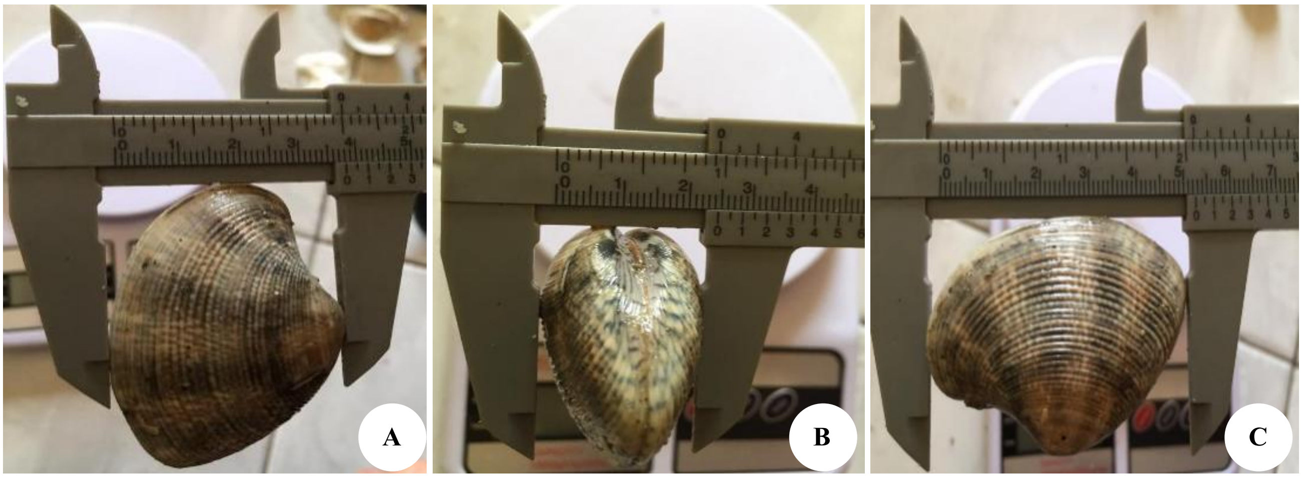

Figure 5. Measurement angle. A. Shell length, B. Shell width, C. Shell thickness

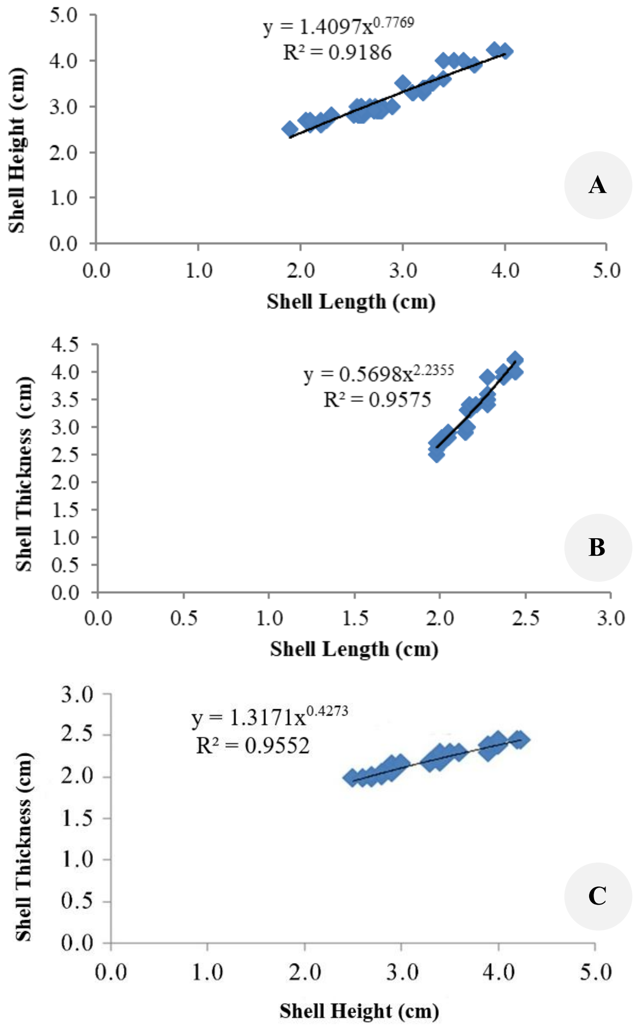

Figure 6. Relationship between *kepah* morphometric dimensions: A. Shell length with shell height, B. Shell length with shell thickness, C. Shell height with shell thickness

Based on the analysis of the relationship between morphometric dimensions, it can be seen that the morphometric growth between shell length and shell height, shell length and shell thickness, and shell height and shell thickness exhibits a very strong positive relationship. This means that every time there is an increase in the length of the shell, it is possible that the height and thickness of the shell will increase as well, and vice versa. If there is a decrease in shell length, there will be a decrease in the height and thickness of the shell. This relationship also applies to the dimensional relationship between the shell's height and thickness.

The regression models for the length of the shell and the height of the shell, and for the length of the shell and the thickness of the shell, and for the height of the shell and the thickness of the shell are linear. The three dimensions of the shell found in the mangrove ecosystem of Bagan Asahan are long, tall, and thick; the shell shows a strong relationship in which the three dimensions are balanced in growth. This occurs because the *kepah* adapts to its environment by enlarging the thickness of its shell. To keep their bodies from sinking into the mud, the thickness of the shell of the *kepah* is used to weigh their bodies. This strong and positive inter-dimensional relationship indicates that the *kepah* in this ecosystem can still develop well. This demonstrates that mussels can grow well and generally in the mangrove habitat of Bagan Asahan. Healthy mussels (*M. meretrix*) exhibit morphometric characteristics such as proportional shell size, a strong length-to-width relationship, and balanced growth in body weight relative to shell size. Morphometric studies show that healthy mussels exhibit a strong correlation among their body parameters (Indraswari et al. 2014; Ramadhani et al. 2020; Zhang et al. 2023).

Content of C-organic substrate

Measurement of the C-organic content of the substrate was conducted to assess the substrate's suitability for the *kepah* habitat at each station. The C-organic content of the substrate, as determined by laboratory tests at each station, ranged from 1.48% to 1.74%. This content falls within the low (+0.5%) and medium (1-2%) categories and is very suitable for the life and growth of the *kepah* (*M. meretrix*). This is because the ideal organic carbon (C-organic) content of the substrate habitat for the *kepah* ranges from 0.5% to 2%, depending on environmental conditions and substrate type. The C-organic condition is not much different from several locations in North Sumatra, as reported in Belawan Port, where the C-organic concentration is in the range of 0.26-2.74% (Yolanda et al. 2019), in Percut Sei Tuan, around + 0.5% (Basyuni et al. 2018), and in Tanjung Tiram in the range of 1.04-2.10% (Susetya et al. 2021).

Mangrove density

The results of the mangrove vegetation analysis show that at the three stations, six genera of mangrove vegetation -five core mangrove genera and one peripheral mangrove type -were identified. Core mangroves are mangrove vegetation that ecologically play a role in mangrove forest formation, while peripheral mangroves ecologically play a role in mangrove forest formation and other forests. The core mangroves found consist of the genera *Avicennia* (local name: *api-api*; family: Avicenniaceae), *Xylocarpus* (family: Meliaceae), *Bruguiera, Rhizophora* (family: Rhizophoraceae), and *Sonneratia* (family: Sonneratiaceae). The peripheral mangrove genus found is *Excoecaria* (family of Euphorbiaceae).

Tables 3, 4, and 5 show that the highest mangrove density value at station 1 is found in the *Sonneratia* genus at 267 ind/ha, and the lowest is found in the *Excoecaria* genus at 144 ind/ha. The highest mangrove density at station 2 is found in the *Avicennia* genus at 244 ind/ha, while the lowest is found in the *Bruguiera* genus at 133 ind/ha. The highest mangrove density at station 3 is found in the *Rhizophora* genus, with a density value of 222 ind/ha. In contrast, the lowest density is found in the genera *Avicennia* and *Sonneratia*, at 56 individuals per ha.

Table 3. Density, relative density, relative frequency, relative dominance, and importance value index at station 1

Genus	Amount	D	RD (%)	RF (%)	RC	IVI
Fam: Avicenniaceae						
Avicennia	19	211	19.19	23.53	27.14	69.87
Fam: Euphorbiaceae						
Excoecaria	13	144	13.13	8.82	6.03	27.99
Fam: Meliaceae						
Xylocarpus	14	156	14.14	11.76	10.07	35.97
Fam: Rhizophoraceae						
Bruguiera	14	156	14.14	11.76	10.51	36.42
Rhizophora	15	167	15.15	17.65	17.92	50.72
Fam: Sonneratiaceae						
Sonneratia	24	267	24.24	26.47	28.33	79.04
Total	99	1,100	100.00	100.00	100.00	300.00

Note: D: Density, RCi: Relative coverage, RD: Relative density, IVI: Important value index RF: Relative frequency

Table 4. Density, relative density, relative frequency, relative dominance, and importance value index at station 2

Genus	Amount	D	RD (%)	RF (%)	RC	IVI
Fam: Avicenniaceae						
Avicennia	22	244	22.22	24.24	27.92	74.39
Fam: Euphorbiaceae						
Excoecaria	13	144	13.13	12.12	13.24	38.49
Fam: Meliaceae						
Xylocarpus	15	167	15.15	15.15	13.82	44.12
Fam: Rhizophoraceae						
Bruguiera	12	133	12.12	9.09	4.38	25.59
Rhizophora	19	211	19.19	21.21	20.72	61.13
Fam: Sonneratiaceae						
Sonneratia	18	200	18.18	18.18	19.92	56.28
Total	99	1,100	100.00	100.00	100.00	300.00

Note: D: Density, RCi: Relative Coverage, RD: Relative Density, IVI: Important Value Index RF: Relative Frequency

Table 5. Density, relative density, relative frequency, relative dominance, and importance value index at station 3

Genus	Amount	D	RD (%)	RF (%)	RC	IVI
Fam: Avicenniaceae						
Avicennia	5	56	9.80	6.45	5.34	21.60
Fam: Euphorbiaceae						
Excoecaria	8	89	15.69	19.35	11.83	46.87
Fam: Meliaceae						
Xylocarpus	6	67	11.76	16.13	7.41	35.31
Fam: Rhizophoraceae						
Bruguiera	7	78	13.73	19.35	11.42	44.50
Rhizophora	20	222	39.22	29.03	58.81	127.06
Fam: Sonneratiaceae						
Sonneratia	5	56	9.80	9.68	5.18	24.66
Total	51	567	100	100.00	100.00	300.00

Note: D: Density, RCi: Relative Coverage, RD: Relative Density, IVI: Important Value Index RF: Relative Frequency

Mangrove Relative Frequency, Mangrove Relative Cover, and Importance Value Index

The results of the analysis of relative density, relative frequency, relative cover, and the important value index of mangroves in the Bagan Asahan area, North Sumatra, show varying values across stations. The results of the calculations for relative density, relative frequency, relative cover, and the Importance Value Index of mangroves at each research station are presented in Tables 3, 4, and 5.

The analysis reveals that the highest relative mangrove density at station 1 is in the genus *Sonneratia*, at 24.24%. In contrast, the lowest relative density is observed in the genus *Excoecaria*, at 13.13%. The high relative density of the *Sonneratia* genus at this station results from the fact that this station is located in the middle of a mangrove ecosystem, which is approximately 100 m from the coastline. At station 2, the highest relative density value is found in the *Avicennia* genus at 22.22%, while the lowest is found in the *Bruguiera* genus at 12.12%. Station 2 is situated at the front of the mangrove ecosystem, approximately 5 meters from the coastline. At station 3, the highest relative density value is found in the *Rhizophora* genus at 39.22%, while the lowest value is found in the *Avicennia* and *Sonneratia* genus at 9.80% each.

Station 3 is situated in the deepest part of a mangrove ecosystem, approximately 200 meters from the coastline. The genus *Rhizophora* is a type of mangrove that can thrive in large areas. This genus can still be found in mangrove areas that are located far from the coastline, as long as the area is still affected by brackish or salty waters. The mangroves from the *Rhizophora* genus have a large area to live in so that they can develop well in the interior as long as they still get a good supply of salt water (Kusmana et al. 2003; DeYoe et al. 2020).

The results of the relative frequency analysis of mangroves indicate that the most frequently occurring genera in the Bagan Asahan mangrove ecosystem are *Sonneratia, Avicennia,* and *Rhizophora.* The *Sonneratia* genus is often found at station 1 with a relative frequency value of 26.47%. The *Avicennia* genus is often found at station 2 with a relative frequency value of 24.24%, while the *Rhizophora* genus is often found at station 3 with a relative frequency value of 29.03%. The number of *Sonneratia* and *Rhizophora* genera in this ecosystem is influenced by the substrate conditions at the research site, which are muddy sand. Mangrove forests grow well in areas with brackish to salty waters. These three genera have a high tolerance for salt content with salinity ranging from 0-30‰ (Arora and Dagar 2019; Juwari et al. 2020). Overall, mangroves of the genus *Rhizophora* are often found at the study site. Acharya et al. (2021) stated that the results of this study are consistent with those produced on the Odisha Coast, India, which reported that mangroves of the genus *Rhizophora* have the highest relative frequency value (100%)-also reported the same in South Sulawesi, Indonesia (Malik et al. 2015).

The results of the analysis of relative mangrove cover show that there is a difference in the area of relative mangrove cover at the three observation stations, in which the highest relative cover at station 1 is from *Sonneratia* genus with 28.33%, at station 2 is found in Avicennia genus with a relative cover value 27.92%, and at station 3 is found in genus *Rhizophora* with a relative coverage value of 58.81. The overall results indicate that the *genus Rhizophora* has the highest relative coverage. The high relative cover of the mangrove genus *Rhizophora* indicates that the presence of the mangrove genus *Rhizophora* dominates in the Bagan Asahan mangrove ecosystem. The high relative cover of the *Rhizophora* genus is a result of the substrate conditions, which are muddy sand. This substrate condition is highly suitable for the growth of the mangrove *genus Rhizophora*, as it has a relatively high fertility (Costa et al. 2016).

The results of the importance value index analysis obtained from the sum of the relative density, relative frequency, and relative coverage at the three stations show that there are differences in the value of the index of importance at each observation station, where the *Rhizophora* genus has the highest index of importance, which is 127.06% at station 3, followed by *Sonneratia* genus at 79.04% at station 1, and *Avicennia* genus at 74.39% at station 2.

The importance value index describes the community structure and distribution patterns of mangroves in an area. The difference in the important value index of mangrove vegetation in the Bagan Asahan mangrove ecosystem is driven by competition within each genus for nutrients and sunlight. The results of this research are consistent with those of previous studies, which report that the *Rhizophora* genus has the highest importance index in Mandeh Bay, West Sumatra Province, and the Teluk Adang Nature Reserve (TANR), East Kalimantan (Mukhlisi et al. 2020; Rafiq and Mukhtar 2020).

Mangrove and clam interaction

A summary of research results on the interaction between mangrove vegetation characteristics and clam morphometrics is presented in Table 6. Table 6 shows that the best clam density indicator was observed at station 3, with Rhizophora as the dominant vegetation. The relative density, relative coverage, and important value index of *Rhizophora* at station 3 are also the highest among other mangrove genera. This indicates a positive correlation between mussels and several ecological indicators of *Rhizopora* in their habitat at this location. The distribution pattern of clams in this habitat type also shows a high degree of grouping. The complexity of Rhizophora roots provides a larger rooting surface, better sediment stabilization, and the ability to retain more and diverse leaf litter. The above explanation supports the theoretical assumption of several researchers that the *Rhizophora* genus is more suitable as a clam habitat (Yahya et al. 2020). Several studies have reported that *Rhizophora* has better biomass-forming abilities (Torres et al. 2019; Zhang et al. 2021). The high biomass in the substrate also stimulates biota growth, thereby supporting clam growth.

Table 6. Interaction of mangrove vegetation characteristics with clam morphometrics

	Station		
	1	**2**	**3**
Density of clam	11.28	9.67	14.94*
Clam distribution index	22.72	3.72	20.35*
Genus domination	*Sonneratia*	*Avicennia*	*Rhizophora*
Relative Density	24.24%	22.22%	39.22%*
Relative Frequency	28.33%	27.92%	58.81%*
Important Value Index	79.04%	74.39%	127.06%*

Note: Associations shown are descriptive and not derived from inferential statistical testing

This is also evident in the high clumping pattern of clams (20.35), which indicates the attraction that causes clams to group, either to obtain food or to follow other biota (Callier et al. 2018). The mangrove-shellfish relationship in this analysis is descriptive, not a causal relationship framed by statistical testing. Further research is needed to measure this positive correlation using a quantitative approach specifically.

Although *Rhizophora* species play a crucial role in mangrove ecosystems, other species also contribute to biodiversity, nutrient cycling, and habitat structure. A holistic ecosystem conservation approach encompassing various mangrove species remains necessary to increase the mangrove ecosystem's carrying capacity for mussel growth. Therefore, while immediate pressures, such as overfishing of mussels, are urgent issues to address, maintaining the presence and quality of mangrove ecosystems is crucial to ensuring a more sustainable long-term carrying capacity for mussel populations.

The Bagan Asahan mangrove area is a habitat and buffer for clam habitat, which is very important for the sustainability of clam production and the livelihood of the fishing community in this area. The economic dependence of communities on mussels is also found in other coastal areas in Southeast Asia. In Nha Phu Lagoon, Khanh Hoa Province, South Central Vietnam, mussels are cultivated and harvested in the coastal lagoon and serve as a primary livelihood for local residents (Lan et al. 2024). Other bivalves (e.g., *Meretrix*, *Perna*, *Crassostrea*) are also commonly used by communities in Mon State, Myanmar (Oo 2020). Consumption and various forms of shellfish utilization for community needs have become part of the coastal culture in this region. Over time, mangrove ecosystems are often disrupted by illegal logging and land conversion for other economic activities (Cahyaningsih et al. 2022; Ng et al. 2022; Hilmi et al. 2024). On the other hand, continued efforts to supervise, maintain, and rehabilitate are carried out by concerned government and non-government agencies.

In conclusion, this study demonstrates that the mangrove ecosystem of Bagan Asahan provides suitable habitat conditions for the Asiatic hard clam *M. meretrix*. A total of 646 individuals were recorded during six months of observation, with an average density of 11.96 individuals m^{-2}. Clam density varied among stations, reaching the highest value at the *Rhizophora*-dominated station (14.94 individuals m^{-2}), followed by *Sonneratia* (11.28 individuals

m^{-2}) and *Avicennia* (9.67 individuals m^{-2}). The Morisita Index indicated a grouped distribution pattern at all stations (Id=3.72-22.72), reflecting habitat heterogeneity and aggregation behavior. Shell lengths ranged from 1.5 to 4.5 cm, with the dominant size class between 2.70 and 2.99 cm, suggesting intensive harvesting pressure on larger individuals. Morphometric relationships among shell length, height, and thickness showed strong positive correlations (R^2=0.91-0.96), indicating proportional and balanced growth. Substrate C-organic content ranged from 1.48% to 1.74%, which is within the range considered to support mussel growth. Mangrove vegetation comprised six genera, with *Rhizophora* exhibiting the highest importance value index (127.06%) at station 3, followed by *Sonneratia* (79.04%) and *Avicennia* (74.39%), supporting a strong descriptive association between *Rhizophora* dominance and higher clam abundance.

Limitations of this study include the use of descriptive analyses for mangrove-clam associations, which preclude causal inference, and the focus on short-term observations without direct assessment of recruitment, mortality, or harvesting intensity. Future studies should apply quantitative statistical approaches to test mangrove-clam relationships, incorporate longer-term monitoring of population dynamics, and evaluate the effects of mangrove rehabilitation-particularly Rhizophora enrichment-on *kepah* sustainability and fishery productivity in Bagan Asahan, as this commodity has been a mainstay of the region for generations. Most fishermen in this region are involved in *kepah* catching, processing, and trading. Their economic contributions, both direct and indirect, are irreplaceable. Therefore, conserving the mangrove ecosystem as a *kepah* habitat in this region should be a primary local policy focus for all parties involved. Through the preservation and rehabilitation of the mangrove ecosystem, particularly by enriching the *Rhizophora* genus, the sustainability of *kepah* production in this area will be maintained.

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REFERENCES

Abdullah A, Nurjanah N, Hidayat T, Gifari A. 2016. Characterize fatty acids of *Babylonia spirata*, *Meretrix meretrix*, *Pholas dactylus*. Intl J Chem Biomol Sci 2 (1): 38-42.

Acharya S, Patra DK, Mahalik G, Mohapatra PK. 2021. Quantitative Ecological Study of Rhizophoraceae Mangroves of Bhitarkanika Wildlife Sanctuary Regions of Odisha Coast, India. Proc Natl Acad Sci India Sect B Biol Sci 91 (4): 897-908. https://doi.org/10.1007/s40011-021-01295-2.

Arora S, Dagar JC. 2019. Salinity tolerance indicators. In: Dagar JC, Yadav RK, Sharma PC (eds.). Research Developments in Saline Agriculture. Springer, Singapore. https://doi.org/10.1007/978-981-13-5832-65 .

Bahtiar, Purnama MF. 2023. Density of Meretrix meretrix clams under ecological pressure on different substrate texture at the Kambu River of Kendari Bay, Southeast Sulawesi. Jurnal Biologi Tropis 23 (2): 29-37. https://doi.org/10.29303/jbt.v23i2.4684.

Basyuni M, Gultom K, Fitri A, Susetya IE, Wati R, Slamet B, Sulistiyono N, Yusriani E, Balke T, Bunting P. 2018. Diversity and habitat characteristics of macrozoobenthos in the mangrove forest of Lubuk Kertang Village, North Sumatra. Biodiversitas 19 (1): 311-317. https://doi.org/10.13057/biodiv/d190142.

Bengen DG. 2001. Ekosistem dan Sumberdaya Pesisir dan Laut serta Pengelolaan secara Terpadu dan Berkelanjutan. IPB Press, Bogor, [Indonesia]

Cahyaningsih AP, Deanova AK, Pristiawati CM, Ulumuddin YI, Kusumaningrum L, Setyawan AD. 2022. Causes and impacts of anthropogenic activities on mangrove deforestation and degradation in Indonesia. Intl J Bonorowo Wetlands 12 (1): 12-22. https://doi.org/10.13057/bonorowo/w120102.

Callier MD, Byron CJ, Bengtson DA, Cranford PJ, Cross SF, Focken U, Jansen HM, Kamermans P, Kiessling A, Landry T, O'Beirn F, Petersson E, Rheault RB, Strand Ø, Sundell K, Svåsand T, Wikfors GH, McKindsey CW. 2018. Attraction and repulsion of mobile wild organisms to finfish and shellfish aquaculture: A review. Rev Aquac 10 (4): 924-949. https://doi.org/10.1111/raq.12208.

Costa RS, de Araujo EC, de Aguiar ECL, Fernandes MEB, Daher RF. 2016. Survival and growth of mangrove tree seedlings in different types of substrate on the Ajuruteua Peninsula on the Amazon Coast of Brazil. OA Lib J 3 (7): 1-9. https://doi.org/10.4236/oalib.1102777.

Desrita, Susetya IE, Suriani M, Rahman A. 2019. Biology and growth of the Asiatic Hard Clam (*Meretrix meretrix*) population in Tanjung Balai, North Sumatera. IOP Conf Ser Earth Environ Sci 260 (1): 012108. https://doi.org/10.1088/1755-1315/260/1/012108.

DeYoe H, Lonard RI, Judd FW, Stalter R, Feller I. 2020. Biological flora of the tropical and subtropical intertidal zone: Literature review for *Rhizophora mangle* L. J Coast Res 36 (4): 857-884. https://doi.org/10.2112/jcoastres-d-19-00088.1.

Donnelly M, Shaffer M, Connor S, Sacks P, Walters L. 2017. Using mangroves to stabilize coastal historic sites: Deployment success versus natural recruitment. Hydrobiologia 803: 389-401. https://doi.org/10.1007/s10750-017-3155-x.

Duncan OD. 1957. The measurement of population distribution. Pop Stud 11 (1): 27-45. https://doi.org/10.1080/00324728.1957.10413229.

English S, Wilkinson C, Baker V. 1997. Survey Manual for Tropical Marine Resources 2nd Ed. Australian Institute of Marine Science, Townsville.

Ginting EDD, Susetya IE, Patana P, Desrita D. 2017. Identifikasi jenis-jenis bivalvia di Perairan Tanjungbalai, Provinsi Sumatera Utara. Acta Aquatica Aquatic Sci J 4 (1): 13-20. https://doi.org/10.29103/aa.v4i1.318. [Indonesian]

Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, Masek J, Duke N. 2011. Status and distribution of mangrove forests of the world using Earth observation satellite data. Glob Ecol Biogeogr 20 (1): 154-159. https://doi.org/10.1111/j.1466-8238.2010.00584.x.

Gosling E. 2008. Bivalve Molluscs: Biology, Ecology and Culture. Fishing News Books, Victoria.

Gruwier BJ. 2017. The large vertebrate remains from Binjai Tamieng (Sumatra, Indonesia). J Indo-Pac Arch 41: 22-29. https://dx.doi.org/10.7152/jipa.v41i0.15027.

Hilmi E, Anwar N, Santosa I, Mahdiana A, Rachman TM, Wardoyo T. 2024. Mangrove landscaping as an adaptation pattern to reduce the impact of climate change in Segara Anakan Lagoon, Cilacap Regency, Indonesia. Baghdad Sci J 21 (2): 0338-0338. https://doi.org/10.21123/bsj.2023.8828.

Ihsan B, Retnaningrum E. 2020. The numerical phenetics of taxonomy *Vibrio* in shellfish (*Meretrix meretrix*) at the edu-tourism mangrove Cengkrong Beach, Trenggalek. Jurnal Ilmiah Perikanan dan Kelautan 12 (2): 296-301. https://doi.org/10.20473/jipk.v12i2.17846.

Indraswari AGM, Litaay M, Soekendarsi E. 2014. Morfometri kerang tahu *Meretrix meretrix* Linnaeus, 1758 di Pasar Rakyat Makassar. Berita Biologi 13 (2): 137-142. https://doi.org/10.14203/beritabiologi.v13i2.687. [Indonesian]

Jungers WL, Falsetti AB, Wall CE. 1995. Shape, relative size, and size adjustments in morphometrics. Am J Phys Anthropol 38 (S21): 137-161. https://doi.org/10.1002/ajpa.1330380608.

Juwari RD, Aipassa MI, Ruslim Y. 2020. Carbon stocks of *Rhizophora apiculata* and *Sonneratia alba* of mangrove forest in Ngurah Rai Forest Park, Bali Province, Indonesia. J Biodivers Environ Sci 16 (3): 93-105.

Krebs JR, Sherry DF, Healy SD, Perry VH, Vaccarino AL. 1989. Hippocampal specialization of food-storing birds. Proc Nat Acad Sci 86 (4): 1388-1392. https://doi.org/10.1073/pnas.86.4.1388.

Kusmana C, Wilarso S, Hilwan I, Pamoengkas P, Wibowo C, Tiryana T, Triswanto A, Yunasfi, Hamzah. 2003. Teknik Rehabilitasi Mangrove. Faculty of Forestry, Institut Pertanian Bogor, Bogor. [Indonesian]

Lan NT, Dgebuadze PY, Huan PT. 2024. The diversity of commercial marine bivalves in the Nha Phu Lagoon, Khanh Hoa Province, South-Central Vietnam. Zool Zh 103 (4): 3-21. https://doi.org/10.31857/S0044513424040016.

Lee SY, Primavera JH, Dahdouh-Guebas F, McKee K, Bosire JO, Cannicci S, Diele K, Fromard F, Koedam N, Marchand C, Mendelssohn I, Mukherjee N, Record S. 2014. Ecological role and services of tropical mangrove ecosystems: A reassessment. Glob Ecol Biogeogr 23 (7): 726-743. https://doi.org/10.1111/geb.12155.

Malik A, Fensholt R, Mertz O. 2015. Mangrove exploitation effects on biodiversity and ecosystem services. Biodivers Conserv 24: 3543-3557. https://doi.org/10.1007/s10531-015-1015-4.

McKee K, Rogers K, Saintilan N. 2012. Response of salt marsh and mangrove wetlands to changes in atmospheric CO_2, climate, and sea level. In: Middleton BA (eds.). Global Change and the Function and Distribution of Wetlands. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-4494-32.

Michael P. 1994. Ecological Methods for Field and Laboratory Investigation. Tata McGraw-Hill Education Publishing Co. Ltd, New Delhi.

Mukhlisi M, Nuryani A, Sayektiningsih T. 2020. Monitoring of floristic composition and species diversity: An initial step towards the restoration of mangrove forest in Teluk Adang Nature Reserve, Indonesia. Pol J Environ Stud 30 (1): 793-802. https://doi.org/10.15244/pjoes/123608.

Ng CKC, Ong RC. 2022. A review of anthropogenic interaction and impact characteristics of the Sundaic mangroves in Southeast Asia. Estuar Coast Shelf Sci 267: 107759. https://doi.org/10.1016/j.ecss.2022.107759.

Ningsih SS, Ariyanto D, Puspitasari D, Jayanegara A, Hamim H, Gunawan H. 2020. The amino acid contents in mangrove *Rhizophora mucronata* leaves in Asahan, North Sumatra, Indonesia. E3S Web Conf 151: 01047. https://doi.org/10.1051/e3sconf/202015101047.

Octavina C, Yulianda F, Krisanti M, Muchlisin ZA. 2015. Length-weight relationship of Ostreidae in the Kuala Gigieng estuary, Aceh Besar District, Indonesia. AACL Bioflux 8 (5): 817-823.

Oo NN. 2020. Habitats, local distribution and utilization of some marine bivalves of Mon Coastal Area in Myanmar. Environ Earth Sci Res J 7 (2): 89-94. https://doi.org/10.18280/eesrj.070206.

Overstreet RM. 2021. Parasitic diseases of fishes and their relationship with toxicants and other environmental factors. In: Couch JA, Fournie JW (eds.). Pathobiology of Marine and Estuarine Organisms. CRC Press, Boca Raton, Florida. https://doi.org/10.1201/9781003069058-5.

Rafiq M, Mukhtar E. 2020. The vegetation of the mangrove forest in Mandeh Bay, West Sumatra, Indonesia. Intl J Soc Sci World 2 (1): 95-102. https://doi.org/10.5281/zenodo.3964175.

Ramadhani R. 2020. Kelimpahan Populasi dan Morfometri Kerang Kepah Tahu (*Meretrix meretrix*) di Pantai Galuh Indah Permai, Kabupaten Batu Bara, Sumatera Utara. [Dissertation]. Universitas Islam Negeri Sumatera Utara, Medan. [Indonesian]

Reef R, Lovelock CE. 2015. Regulation of water balance in mangroves. Ann Bot 115 (3): 385-395. https://doi.org/10.1093/aob/mcu174.

Rimelahas WL, Mulya MB, Barus TA. 2022. Density, morphometric characteristics, and distribution pattern of Asiatic hard clam (*Meretrix meretrix*) in Karang Gading estuary, Deli Serdang District, Indonesia. Biodiversitas 23 (10): 5210-5216. https://doi.org/10.13057/biodiv/d231029.

Román S, Olabarria C, Weidberg N, Román M, Vázquez E. 2023. Population structure and habitat assessment for two commercial clam species exploited in small-scale fisheries. Rev Fish Biol Fish 33 (4): 1483-1504. https://doi.org/10.1007/s11160-023-09791-6.

Schaeffer-Novelli Y, Soriano-Sierra EJ, Vale CCD, Bernini E, Rovai AS, Pinheiro MAA, Schmidt AJ, de Almeida R, Júnior CC, Menghini RP, Martinez DI, Abuchahla GMDO, Cunha-Lignon M, Charlier-Sarubo S, Shirazawa-Freitas J, Cintrón-Molero G. 2016. Climate changes in mangrove forests and salt marshes. Braz J Oceanogr 64 (spe2): 37-52. https://dx.doi.org/10.1590/S1679-875920160919064sp2.

Silalahi HV, Amin B, Efriyeldi E. 2014. Analysis of Heavy Metal Content of Pb, Cu, and Zn in Meat and Shell of Clams (*Retrix retrix*) in the Bagan Asahan Waters, Tanjung Balai District, Asahan Regency. [Dissertation]. Universitas Riau, Pekanbaru. [Indonesian]

Sofiana MSJ, Safitri I, Apriansyah A, Irawan S. 2023. The concentration of lead (Pb) in Kepah (*Geloina expansa*), water, and sediment of mangrove Peniti Village Mempawah Regency West Kalimantan. Jurnal Sumberdaya Akuatik Indopasifik 7 (4): 401-410. https://doi.org/10.46252/jsai-fpik-unipa.2023.Vol.7.No.4.352.

Sukardjo S. 2004. Fisheries associated with mangrove ecosystem in Indonesia: A view from a mangrove ecologist. Biotropia 23: 13-39.

Susetya IE, Basyuni M, Susilowati A, Kajita T. 2021. Density and characteristics of green mussels (*Perna viridis*) in Percut Sei Tuan coastal, North Sumatra, Indonesia. Biodiversitas 22 (2): 1043-1050. https://doi.org/10.13057/biodiv/d220261.

Susetya IE, Desrita D, Ginting EDD, Fauzan M, Yusni E, Saridu SA. 2018. Diversity of bivalves in Tanjung Balai Asahan Waters, North Sumatra, Indonesia. Biodiversitas 19 (3): 1147-1153. https://doi.org/10.13057/biodiv/d190350.

Susetya IE, Fadillah P, Leidonald R, Fadhilah A. 2020. Relationship between substrate characteristics and abundance of Polychaeta in Tanjung Tiram Waters, Batubara Regency, Sumatera Utara Province. IOP Conf Ser Earth Environ Sci 454: 012135. https://doi.org/10.1088/1755-1315/454/1/012135.

Syafril IM. 2024. Analisis Kandungan Logam Berat Timbal (Pb) pada Kerang Kepah (*Meretrix* sp.) yang Terdapat di Perairan Belawan Medan Sumatera Utara. [Dissertation]. Universitas Sumatera Utara, Medan. [Indonesian]

Torres JR, Barba E, Choix FJ. 2019. Production and biomass of mangrove roots in relation to hydroperiod and physico-chem properties of sediment and water in the Mecoacan Lagoon, Gulf of Mexico. Wetland Ecol Manag 27: 427-442. https://doi.org/10.1007/s11273-019-09669-0.

Ward RD, Friess DA, Day RH, Mackenzie RA. 2016. Impacts of climate change on mangrove ecosystems: A region by region overview. Ecosyst Health Sustain 2 (4): e01211. https://doi.org/10.1002/ehs2.1211.

Wati L, Sirojul AM, Si IM. 2019. Density and distribution pattern of Kepah (*Polymesoda* spp.) in mangrove forests of Mendalok Village Sungai Kunyit Sub Districts Mempawah Regency. Jurnal Sains Pertanian Equator 8 (2): 1-10. https://dx.doi.org/10.26418/jspe.v8i2.33880.

Wiharyanto D, Salim G, Firdaus M, Awaluddin MY. 2013. Pendekatan metode Von Bertalanffy untuk analisis pertumbuhan kerang kapah (*Meretrix meretrix*) yang berasal dari pengepul Pantai Amal Lama Kota Tarakan. J Akuatika 4 (1): 102-114. [Indonesian]

Yahya N, Idris I, Rosli NS, Bachok Z. 2020. Mangrove-associated bivalves in Southeast Asia: A review. Reg Stud Mar Sci 38: 101382. https://doi.org/10.1016/j.rsma.2020.101382.

Yolanda Y, Effendi H, Sartono B. 2019. The concentration of C-organic and sedimentary substrates in Belawan Port Waters, Medan. J Environ Sustain Manag 3 (2): 300-308. https://doi.org/10.36813/jplb.3.2.300-308.

Zhang Y, Yu C, Xie J, Du S, Feng J, Guan D. 2021. Comparison of fine root biomass and soil organic carbon stock between exotic and native mangrove. Catena 204: 105423. https://doi.org/10.1016/j.catena.2021.105423.

Zhang Z, Wu Y, Zhang Y, Zhu Y, Cao Y, Chen S, Peng Y, Sun X, Chen A. 2023. Correlation of morphometric properties to meat yield and fatness index in the red strain of the saltwater hard clam *Meretrix meretrix*. PLoS One 18 (4): e0284730. https://doi.org/10.1371/journal.pone.0284730.