Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(3): 1463 – 1480 (2024)
www.ejabf.journals.ekb.eg

The Role of the Mangrove Ecosystem in the Habitat of the Hilsa Fish (*Tenualosa ilisha*)

Rumondang[1]*, Juliwati P. Batubara[1], Heru Gunawan[2], Umaiyu Siregar[1], Safrida Tambunan[1], Nurhadi[1]

[1]Department of Aquaculture, Faculty of Agriculture, Universitas Asahan, North Sumatra, Indonesia
[2]Department of Agrotechnology, Faculty of Agriculture, Universitas Asahan, North Sumatra, Indonesia
[*]Corresponding Author: rumondang1802@gmail.com

ARTICLE INFO

Article History:
Received: Feb. 20, 2024
Accepted: June 4, 2024
Online: June 30, 2024

Keywords:
Mangrove biodiversity,
Water quality,
Hilsa fish,
Mangrove growth

ABSTRACT

The hilsa fish (*Tenualosa ilisha*) is highly sought after by the community in Labuhanbatu Regency, Indonesia. The population of the hilsa fish has been declining in the waters of North Sumatra Province. It is believed to be linked to the excessive exploitation of the hilsa fish resources by local fishermen, the practice of catching the hilsa fish during their spawning period, deteriorating water quality, and degradation of the mangrove areas that serve as their breeding habitat. This study aimed to analyze the mangrove community structure along the coastal waters of the hilsa fish spawning habitat, to assess the influence of mangrove density on water quality, and to examine its impact on the feeding habits of the hilsa fish. The method used was the transect line method. The findings of this study revealed the presence of 13 true mangrove species in the research location. The mangrove species most commonly found at nearly every station is *Rhizophora apiculata*. Values of relative density (Rd), relative frequency (RF), and relative dominance (RD) were determined for each level of mangrove growth: seedling, sapling, and tree. Meanwhile, the importance value index (IVI) values indicate that the species with a better chance of maintaining their growth and survival is *Rhizophora mucronata*. The results of the linear regression analysis testing showed that the mangrove density does not significantly impact water quality parameters, such as temperature, turbidity, salinity, dissolved oxygen, nitrate, biological oxygen demand, phosphate, and lead. In addition, gastric analysis of the hilsa fish stomach content revealed that the most consumed food type by the hilsa fish is the mangrove detritus, accounting for 51% of the total gut content. This underscores the crucial role of mangrove availability as a feeding ground for the hilsa fish.

INTRODUCTION

Fisheries and mangroves are highly potential marine resources in the Indonesian waters. The significant potential of fisheries can provide sustainable and maximum benefits for both the nation and people of Indonesia. They can also become one of the main sources of capital for present and future development if managed well and responsibly. As mandated by the Indonesian Republic Law No. 45 of 2009, Article 6, Paragraph 1, the management of fisheries is directed toward achieving optimal and sustainable benefits, as well as ensuring the conservation of fishery resources. However, in reality, most of the national fishery's activities have not yet demonstrated an optimal, sustainable performance, nor have they ensured the conservation of fishery resources as stipulated in the Law No. 45 of 2009. Illustratively, in capture fisheries activities: 1) illegal, unreported, and unregulated (IUU) fishing activities persist; 2) symptoms of overfishing are observed in various Indonesian waters; 3) the use of destructive fishing gear continues; and 4) the supervision system for resource utilization remains weak and ineffective **(Bappenas, 2014)**.

The high population growth and rapid development activities along the coast for various purposes are increasing ecological pressures on coastal and marine ecosystems and resources. This, in turn, directly or indirectly threatens the existence and sustainability of these ecosystems and their resources **(Perera-Valderrama *et al.*, 2020; Gallardo *et al.*, 2021)**. One significant impact of this pressure is the decrease in population and scarcity of several aquatic species. One such species is the hilsa fish. As emphasized by **Suwarso *et al.* (2018)** and **Amri *et al.* (2020)**, the hilsa fish population in several regions in Indonesia has declined.

The hilsa fish (*Tenualosa ilisha*) is a group of the pelagic fish from the Clupeidae family, known as herring in Europe. In Indonesia, the hilsa fish are only found on the eastern coast of Sumatra, including *Tenualosa macrura* in the Bengkalis estuary waters (Riau), the hilsa fish (*T. ilisha*) in Labuhanbatu, North Sumatra, and *Tenualosa toli* in the Pemangkat area (West Kalimantan) **(Machrizal *et al.*, 2019)**. The hilsa fish is highly favored by the community in Labuhanbatu Regency. It holds a significant place in the waters of Labuhanbatu due to its historical and cultural value. The presence of the hilsa fish is believed to be linked to leadership legends and traditional ceremonies to the extent that Labuhanbatu Regency is nicknamed the "City of Hilsa." The hilsa fish has economic importance, with prices reaching USD 15.25- 24.40 per kg for the fish and USD 182.98-213.48 per kg for its eggs **(Rumondang, 2018)**. The high price of the hilsa fish has led to excessive fishing in the coastal waters of Labuhanbatu, making it difficult to obtain this fish.

Efforts to anticipate the decline in the population and potential extinction of the hilsa fish from the waters of Labuhanbatu led to the Republic of Indonesia Ministry of Marine Affairs and Fisheries Decision No. 43/KEPMEN KP/2016, which designates the limited protection status for the hilsa fish. Various research studies were conducted to examine the causes of the declining hilsa fish population in the waters of North Sumatra Province. The scarcity of the hilsa fish population is believed to be linked to several factors: the practice of catching the hilsa fish during their spawning period **(Efizon *et al.*, 2012)**, the lack of institutions for the hilsa fish management **(Taryono, 2015)**, the decline in water quality and degradation of the mangrove areas that serve as the hilsa fish spawning habitats **(Amri *et al.*, 2018)**, the excessive utilization of the hilsa fish resources by local fishermen **(Suwarso *et al.*, 2018)**, and the weak enforcement of laws against those violating the ban on the hilsa fish capture. Current research and management of the hilsa fish tend to be carried out at the local level (focused on a single district, Labuhanbatu Regency) and in a partial manner (examining individual aspects separately), which has not yet effectively addressed the problem of the hilsa fish population's decline from upstream to downstream. Based on these factors, there is a need for an analysis of the hilsa fish spawning habitat, specifically the mangrove communities along the coast, and the influence of mangrove quality on water quality.

MATERIALS AND METHODS

1. Research sites

The research was conducted from June to August 2023 in the mangrove forest area located along the coastal waters of the hilsa fish spawning habitat in the Barumun River, Labuhanbatu Regency, North Sumatra. The research area was divided into 5 sampling stations. Fig. (1) shows the map of the Barumun River. The determination of stations was carried out during the initial survey of the research. The selected research stations and their details are as follows:

- Station 1: The estuarine area of the Barumun River, influenced by the waters of the Malacca Strait.
- Station 2: An area significantly influenced by human settlements and various human activities, including harbors, fishing villages, industries, and the like.
- Station 3: Similar to Station 2, but also affected by plantation areas and the freshwater flow from the Barumun River.
- Station 4: The estuarine area of the Bilah River, influenced by various community and industrial activities, as well as freshwater inflow from the upper reaches of the Bilah River.
- Station 5: The area along the Barumun River, influenced by various community activities, palm oil processing industries, and freshwater flow from the upper reaches of the Barumun River.

Sampling at each station was done in three sampling locations, totaling 15 sampling locations. The sampling used stratified sampling with the transect line method, making the samples representative of the population in each station.

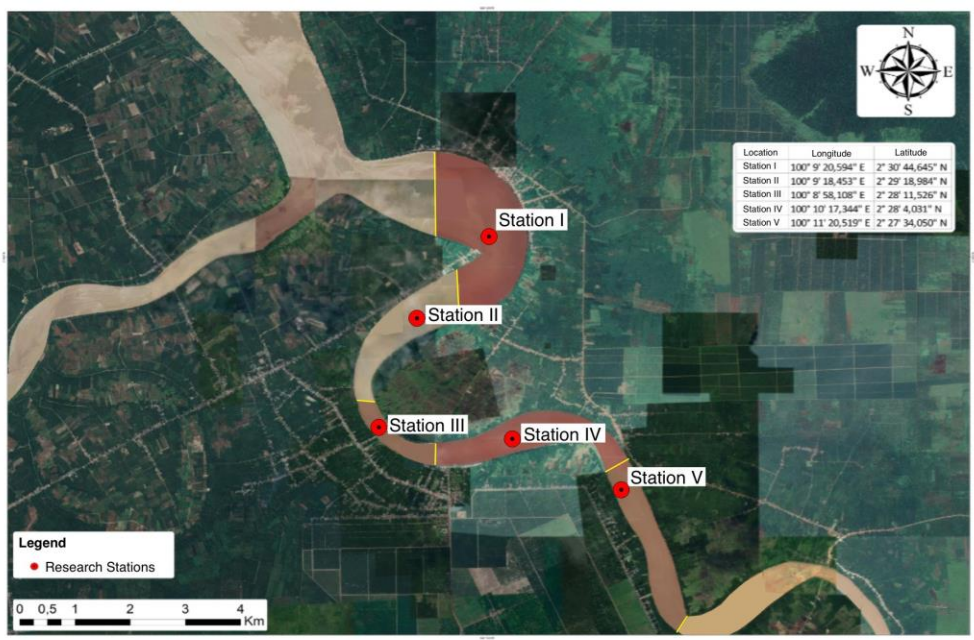

Fig. 1. Research sites

2. Sampling technique

The data used in the research were primary data consisting of mangrove density, the hilsa fish stomach content, and water quality data. Ground checks were conducted for mangrove validation in the field. The measurement and data collection method employed the transect line method developed by **Kusmana (2017)**. Sampling stations were determined in the research location based on representativeness of the areas. Field data collection for mangrove vegetation included mature trees, saplings, and seedlings. At each station, a perpendicular line was drawn from the coastline for 100m, and along this line, three observation plots were established, each measuring 20×20m (Fig. 2). This study utilized shovels, cameras, a measuring meter, stationary, filters, ropes, and sample bags. In addition, the material utilized in this study was 70% alcohol.

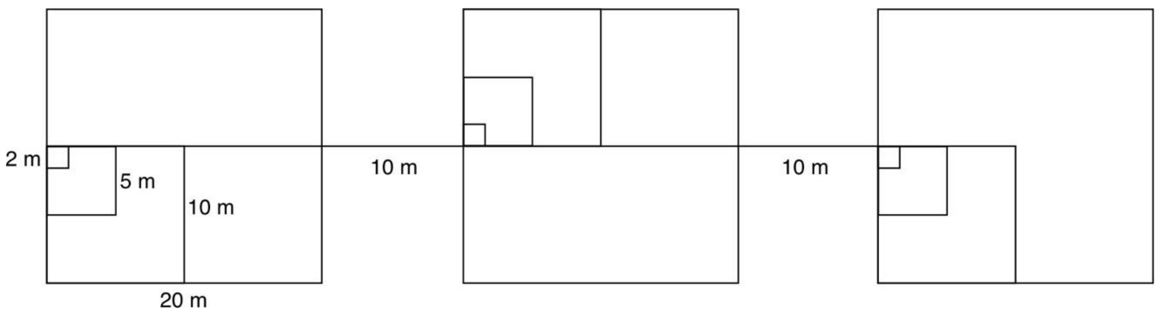

Fig. 2. The transect line method design **(Kusmana, 2017)**.

In each designated plot, the identification of each mangrove plant species encountered was carried out based on the mangrove recognition guidelines provided by Wetlands International **(Noor *et al.,* 2006)**. Subsequently, the number of individuals of each species was counted, and the circumference of the stem of each mangrove tree was measured at the chest height (for trees with diameters greater than 4cm and heights greater than 1m). To determine the stomach contents (feeding habits) of the hilsa fish, a total of 30 hilsa fish samples were collected from the research location. The collection of the hilsa fish samples at each station was carried out using gill nets with mesh sizes of 2, 3, and 4 inches. The collected fish samples were counted, measured for standard length and weight (g), and then preserved with ice in a cool box. The hilsa fish samples were preserved using formalin and later subjected to stomach content analysis in the laboratory.

3. Data analysis

The mangrove vegetation data were then subjected to vegetation analysis, which included species density (d), relative density (Rd), species frequency (F), relative frequency (RF), species dominance (D), relative dominance (RD), and the importance value index (IVI) using the following equations:

$$\text{Species density (d)} = \frac{\text{Total individual}}{\text{Plot area}} \quad (1)$$

$$\text{Relative density (Rd)} = \frac{\text{d of a species}}{\text{d total of all species}} \times 100\% \quad (2)$$

$$\text{Species frequency (F)} = \frac{\text{Total plot of a species found}}{\text{Total plot}} \quad (3)$$

$$\text{Relative frequency (RF)} = \frac{\text{F of a species}}{\text{F total of all species}} \times 100\% \quad (4)$$

$$\text{Species dominance (D)} = \frac{\text{The base area of a species}}{\text{Plot area}} \quad (5)$$

$$\text{Relative dominance (RD)} = \frac{\text{D of a species}}{\text{D total of all species}} \times 100\% \quad (6)$$

$$\text{Importance value index (IVI)} = \text{Rd} + \text{RF} + \text{RD} \quad (7)$$

Linear regression analysis was performed to identify the influence of independent variables on the dependent variable. In this study, the independent variable is the mangrove density, while the dependent variable is water quality. Normality testing was conducted using the Shapiro-Wilk test due to the small sample size (<50). The correlation test between the mangrove density and water quality was performed with the assumption that the mangrove ecosystem correlates positively with water quality **(Nugroho *et al.*, 2020; Bernardino *et al*., 2021; Xu *et al.*, 2022)**.

Analysis of the hilsa fish stomach content was conducted at the Aquaculture Laboratory, Faculty of Agriculture, Universitas Asahan. Initially, the length and total weight of the hilsa fish were measured. Then, a surgical procedure was performed on the abdominal area, starting from the anus toward the vertebrae up to the operculum bone, and then descending towards the ventral fin. The fish's digestive tract was extracted and placed in 4% formalin. Subsequently, the length of the intestine, intestinal weight, and volume of the digestive tract were measured. The analysis of the stomach content was carried out by dissecting the stomach and extracting its contents, which were categorized by type.

RESULTS

1. Characteristics of mangrove vegetation at the research sites

Based on the mangrove vegetation analysis in the Barumun River, Labuhanbatu Regency, a total of 13 true mangrove species were identified (Table 1). The abundance of these true mangrove species in the research location is likely due to the favorable environmental conditions, including substrate conditions and salinity levels that can be tolerated by various mangrove species.

Table 1. Mangrove vegetation species at the research sites

Species	Indonesian name	Family	Station				
			1	2	3	4	5
Rhizophora apiculata	Bakau Minyak	Rhizophoraceae	×	×	×		×
Rhizophora mucronata	Bakau Korap	Rhizophoraceae		×	×		×
Bruguiera gymnorhiza	Putut	Rhizophoraceae			×		
Bruguiera sexangula	Tumu	Rhizophoraceae	×		×	×	
Bruguiera parviflora	Lenggadai/Tanjang	Rhizophoraceae			×		
Sonneratia caseolaris	Pedada	Sonneratiaceae		×		×	
Sonneratia ovata	Kedabu	Sonneratiaceae	×	×			
Sonneratia alba	Perepat	Sonneratiaceae	×	×	×		
Nypa fruticans	Nipah	Arecaceae	×		×	×	
Xylocarpus granatum	Nyiri	Meliaceae	×		×		
Scyphiphora hydrophylacea	Cingam	Rubiaceae			×		
Avicennia alba	Api-api	Avicenniaceae		×	×	×	
Avicennia marina	Api-api Putih	Avicenniaceae					×

Note: ×=available; blank means not available.

2. Relative density (Rd)

In this study, the reported data regarding the density values are relative density values. This is because relative density values already represent the density of the species itself. Based on the data in Fig. (3), the highest Rd value of tree-level species in this study is species *S. alba* at Station 2 with a value of 52.01. For the sapling-level mangrove, the highest Rd value is observed in *S. alba* at Station 3, with a value of 48.72. At the seedling-level, the highest Rd value is for *B. gymnorrhiza* at Station 3 with a value of 5.11.

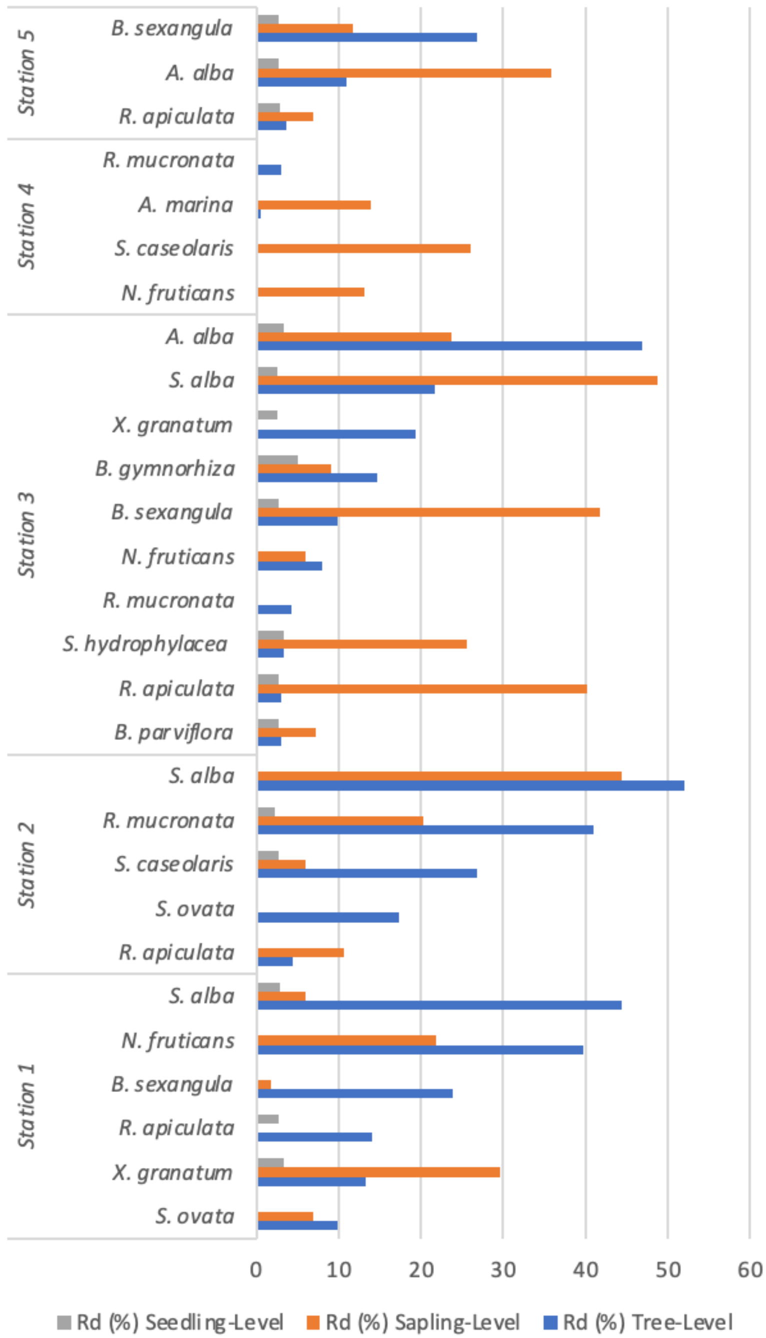

Fig. 3. Relative density values of mangrove species at the research sites

3. Relative frequency (RF)

Just as with Rd, the displayed frequency values are relative values because they already represent the frequency of the species itself. According to Fig. (4), the highest RF of tree-level species is found at Station 3, namely the species *R. mucronata* with a value of 8.17. The highest RF of sapling-level species is *R. mucronata* at Station 3 with a value of 9.02. Meanwhile, the highest RF of seedling-level species is *X. granatum* with a value of 10.00 at Station 1.

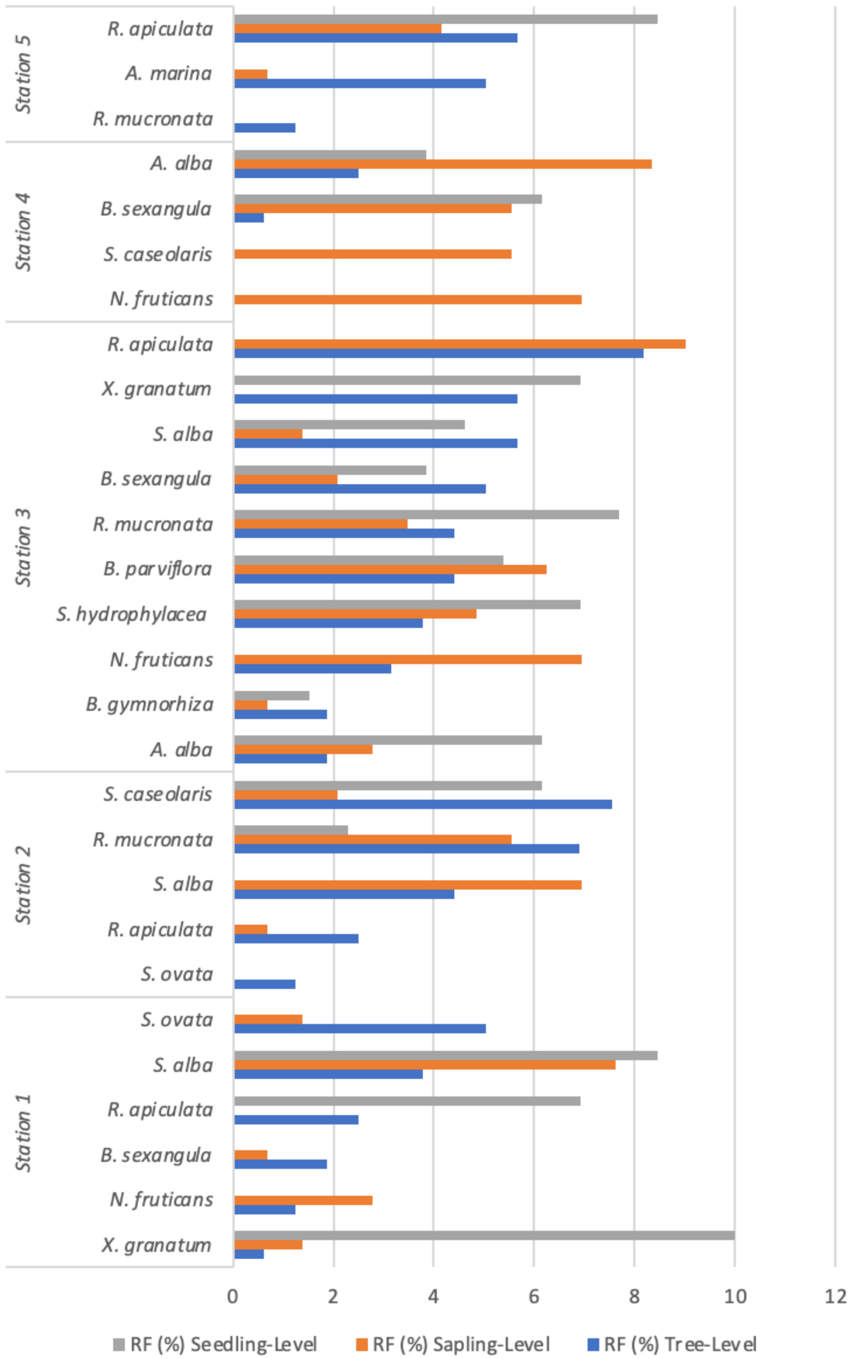

Fig. 4. Relative frequency values of mangrove species at the research sites

4. Relative dominance (RD)

Based on Fig. (5), the highest RD value in the tree-level mangrove vegetation is *R. apiculata* at 7.83% (Station 1). In the sapling-level mangrove vegetation, the highest RD value is *B. sexangula* at 6.76% (Station 1). For the seedling-level mangrove vegetation, *X. granatum* has the highest RD value of 12.35% (Station 1). These findings indicate that Station 1 has the highest RD value among the other stations.

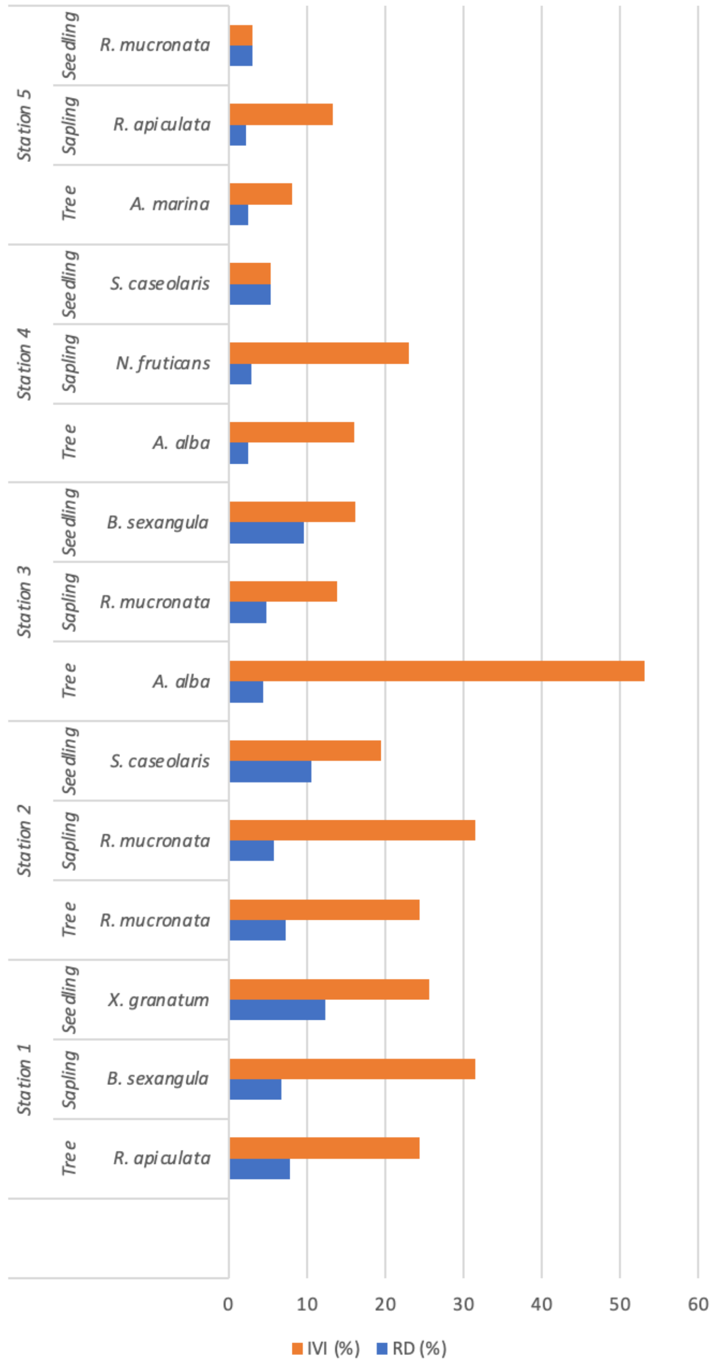

Fig. 5. Relative dominance values and importance value index of mangrove species at the research sites

Note: The displayed RD and IVI values are the highest value from each station.

5. Importance value index (IVI)

The importance value index (IVI) is a method used in ecology to measure the relative significance of a species in a plant community. IVI combines parameters such as the frequency of a species' presence, the number of individuals, and its relative coverage in the community to provide an overview of the species' contribution to the overall community structure. By calculating IVI, the most influential species in an ecosystem can be identified. Species with the highest IVI values are likely to play a crucial role in maintaining their growth and survival in the community. According to Fig. (5), at the tree-level, the mangrove species with highest IVI is *A. alba* (53.17%). At the sapling-level, both *B. sexangula* and *R. mucronata* have an IVI of 31.49%, making them the species with the highest IVI. At the seedling-level, *X. granatum* has the highest IVI of 25.66%.

6. Mangrove ecosystem condition

The environmental quality parameters in the research location are presented in Table (2). The average temperature at the research site ranges from 28 to 30ºC. These results align with the Minister of Environment and Forestry of the Republic of Indonesia Decision No. 51 of 2004, which sets the water quality standards for mangroves in the range of 28 to 32ºC. Salinity at the research site varies between 25 to 30‰. The lowest salinity of 25‰ was found at Station 3, an area similar to Station 2, but influenced by plantation areas and freshwater flow from the Barumun River. The salinity range at the research site falls within the 'good' category for mangrove growth, according to the Minister of Environment and Forestry of the Republic of Indonesia Decision No. 51 of 2004, where salinity values conducive to mangrove growth are up to a maximum of 34‰.

Nitrate (NO_3) concentration at the research site ranges from 0.617 to 2.196mg/ L. The highest nitrate concentration was found at Station 5, and the lowest at Station 2. On the other hand, phosphate (PO_4) concentration at the research site varies from 0.007 to 1.665mg/ L. The highest phosphate concentration was observed at Station 3, and the lowest was at Station 1. By referring to the Minister of Environment and Forestry of the Republic of Indonesia Decision No. 51 of 2004, it can be concluded that the nitrate and phosphate concentrations observed in the habitat of the hilsa shad fish are quite high and exceed the minimum threshold for marine biota.

Table 2. Mangrove vegetation species at the research sites

Parameter	**Unit**	**Station**				
		1	**2**	**3**	**4**	**5**
Temperature	^oC	29	30	28	29	30
Turbidity	m	0.8	0.5	0.4	0.2	0.7
Salinity	‰	27	29	25	30	28
DO	mg/L	7.6	6.3	7,2	5.8	7.9
BOD	mg/L	8	5	0.8	11	7
NO_3	mg/L	0.819	0.617	1.172	0.915	2.196
PO_4	mg/L	0.007	0.048	1.665	0.032	0.086
Pb	mg/L	0.005	0.047	0.018	0.095	0.033

7. Relationship between mangrove biodiversity and water quality

The results of the linear regression analysis testing the influence of mangrove biodiversity on water quality are presented in Table (3). The simultaneous test of the influence of mangrove density on temperature, turbidity, salinity, dissolved oxygen (DO), nitrate, biochemical oxygen demand (BOD), phosphate, and lead (Pb) yielded significance values >0.05. These results indicate that mangrove density does not have a significant effect on these parameters.

Table 3. Linear regression analysis of mangrove density and water quality

Parameter	F	Sig	Remark
Temperature	0.256	0.617	Insignificant
Turbidity	0.212	0.649	Insignificant
Salinity	0.073	0.789	Insignificant
DO	1.640	0.211	Insignificant
Nitrate	1.061	0.312	Insignificant
BOD	0.302	0.587	Insignificant
Phosphate	0.710	0.407	Insignificant
Pb	0.448	0.509	Insignificant

8. Analysis of hilsa fish feeding habits

Fig. (6) illustrates the results of gastric content analysis aimed at understanding the feeding habits of the hilsa fish. The most consumed type of food by the hilsa fish is mangrove detritus, comprising 51% of the total gut content.

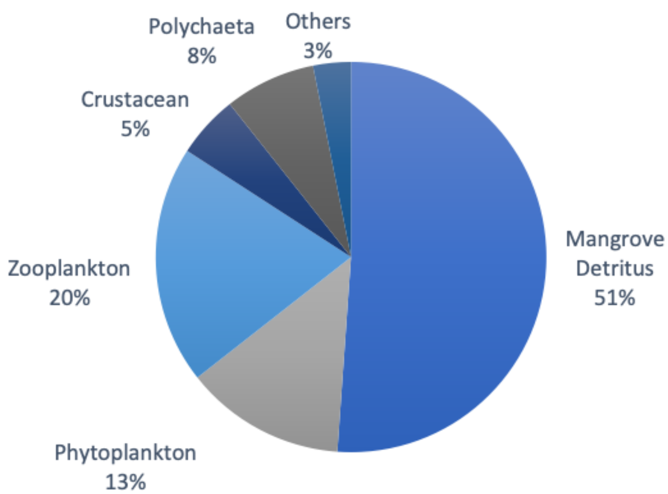

Fig. 6. Gastric analysis results of the hilsa fish

DISCUSSION

Station 3 has the highest number of species compared to the other stations, with a total of 10 species. This can be linked to the water quality parameters at that station. At Station 3, the lower salinity levels allow for the growth of a greater variety of mangrove species. This is supported by the study of **Noor *et al.* (2015)**, who revealed that lower salinity (in range 25- 30‰) is more conducive to mangrove growth. The temperatures across the stations are relatively similar, thus temperature alone might not be a major differentiating factor. Furthermore, Station 3 exhibits higher levels of nitrate (NO_3) and phosphate (PO_4) in comparison with the other stations. These elevated nutrient levels can contribute to enhanced plant growth and increased diversity by providing additional resources. Additionally, Station 3 has the lowest turbidity among the stations. This lower turbidity leads to clearer water, positively influencing light penetration and the growth of aquatic plants.

The salinity at the research location ranges from 25 to 30‰, where only true mangrove species are found. These mangroves are the main component of the mangrove ecosystem and are well adapted to the high salinity environment through morphological and physiological adaptations. Although associated mangrove species can also grow alongside true mangroves, these types of mangroves more commonly thrive in terrestrial vegetation environments **(Wang *et al.*, 2011; Muzaki *et al.*, 2012)**. Salinity is a key driver of the mangrove growth **(Ali *et al.*, 2021; Moslehi *et al.*, 2021; Sánchez *et al.*, 2021)**. The value of water salinity reflects the salt content in the water, expressed in parts per thousand **(Effendi, 2003)**. High salinity can be harmful to plants and animals, alter fish and bird habitats, and reduce the estuary's capacity to provide crucial services such as marine food production and shoreline protection from erosion **(Havens, 2015)**. As an anadromous fish, the hilsa fish live in the sea and return to their birthplace to spawn **(Smith & Zwollo, 2020; Melnyk *et al.*, 2021)**. In the migratory fish, the environmental conditions of the water influence their migration process and population size **(Duval *et al.*, 2021)**. Salinity is one of the critical factors in the spawning migration of the hilsa fish. The required salinity for the hilsa fish spawning ranges between 17.7 and 34.7‰ **(Blaber *et al.*, 1999)**. Like other *Tenualosa* species, the hilsa fish can tolerate a wide range of salinities, allowing them to be found in marine, estuarine, and freshwater environments **(Hossain *et al.*, 2019)**.

The temperature range at the research location falls within the category suitable for the mangrove growth. Factors influencing water temperature include sunlight intensity and water depth. Temperature also plays a role in the photosynthesis process **(Moore *et al.*, 2021)**. One indicator to identify the availability of fish species in the waters is the sea surface temperature. Each fish species has a specific temperature tolerance for survival, which affects the availability and distribution of fish in the waters. The results of **Myers *et al.* (2017)** demonstrated a fairly strong positive correlation between sea surface temperature and fish catch yields.

The most commonly found type of mangrove at each station is *R. apiculata*. This is consistent with the findings of **Drexler (2001)** that *R. apiculata* propagules have a higher overall survival rate and are better suited for dispersal over shorter distances. **Usman *et al.* (2022)** stated that *R. apiculata* exhibits notable strengths that make it a promising candidate for mangrove rehabilitation efforts. Its adaptability to varying environmental conditions underscores its ability to thrive in diverse ecological settings, a crucial trait for successful restoration initiatives. The species' fast growth rate is a significant advantage, enabling it to establish quickly and compete effectively with other vegetation during the restoration process. The species' positive response to different treatments signifies its resilience and capacity to flourish under manipulated conditions.

Based on the analysis of density, the species that emerges as the most densely populated species at the tree-level and the sapling-level is *S. alba*, and at the seedling-level is *R. mucronata*. This indicates that *R. mucronata* is denser at the seedling stage, but when it reaches the tree stage, *S. alba* becomes more densely populated. The reason for this change could be attributed to various factors related to the growth and ecological preferences of these two species, such as differences in growth rates and competitive abilities. *S. alba* might have specific characteristics that enable it to grow faster and outcompete *R. mucronata* at the tree stage. These characteristics could include adaptations to local environmental conditions, reproductive strategies, resistance to pests or diseases, and efficient resource utilization. Environmental factors like soil type, water availability, light exposure, and salinity can also play a significant role in determining the success of each species at different stages of growth. Furthermore, the month of observation also has an influence, as stated by **Wang'ondu *et al.* (2022)**, where flower initiation, flowering period, and development of immature propagules showed variations and shifts in timing between *R. mucronata* and *S. alba*.

The dominance values of each vegetation type vary within each ecosystem type. Dominance values of vegetation types are calculated based on the diameter of the stems at breast height, thus the magnitude of dominance values is also influenced by species density and the average stem diameter size of each tree vegetation within the same species **(Gunawan *et al.*, 2011**). In general, the success of each vegetation type in occupying an area is influenced by its ability to adapt optimally to all physical environmental factors (such as temperature, light, soil structure, and humidity), biotic factors (including interactions between species, competition, and parasitism), and chemical factors, which include the availability of water, oxygen, pH, and soil nutrients that interact with each other **(Urrego *et al.*, 2014)**.

Based on the frequency of distribution, *R. mucronata* is widely found at both the tree-level and sapling-level, while *X. granatum* is widely distributed at the seedling-level. The distribution of *X. granatum* from seedling to tree level decreases drastically. This could be due to the utilization of this mangrove species, where communities use the wood of this mangrove type for boat building, construction, and wood production, whereas *R. mucronata* lacks these characteristics, resulting in its high distribution at the tree level. This is reinforced by the results of dominance analysis and IVI, where *X. granatum* dominates at the seedling level. The adaptability, diversity, and dominance of mangroves greatly depend on the ecological conditions and the environment of the respective area **(Singh, 2020)**.

Coastal waters continuously receive nutrients from various sources, both external and internal (natural and anthropogenic) **(Kesavan *et al.*, 2021; Lønborg *et al.*, 2021; Phan & Stive, 2022)**. High concentrations of nitrates and phosphates in coastal regions stem from anthropogenic activities, including plantations, industries, and households along the coast **(Ng & Ong, 2022)**. Pollution caused by anthropogenic waste can lead to a decline in mangrove biodiversity **(Celis-Hernandez *et al.*, 2020; Eddy *et al.*, 2021)**. This is consistent with the research conducted by **Rumondang *et al.* (2022a, 2023)**, which indicates that the mangrove ecosystem in Batu Bara Regency, Indonesia, has experienced a decline due to its utilization by the local community for various purposes, leading to a land use transition. This is also in line with the study by **Rumondang *et al.* (2022b)**, which shows a reduction in the mangrove forest area possibly resulting from community efforts to gain control over mangrove land. Moreover, a significant portion of the Batu Bara Regency, Indonesia coastline (the research sites), has experienced changes indicating erosion **(Rumondang *et al.*, 2022a)**.

A healthy mangrove ecosystem has an impact on nutrient richness and plankton diversity in the waters **(Xu *et al.*, 2022)**. Additionally, anthropogenic activities such as terrestrial runoff and waste disposal also influence the phytoplankton community in the waters **(Sekadende *et al.*, 2021)**. Physicochemical variables, including total phosphate, temperature, and salinity, are crucial factors affecting the variation in phytoplankton community structure **(Gao *et al.*, 2018)**. In this study, it is shown that the gut content of the hilsa fish indicates the largest presence of mangrove detritus, which supports the proliferation of phytoplankton, the primary food source for the hilsa fish. This aligns with the research by **Firmansyah *et al.* (2020)**, which states that the mangrove leaf litter provides the organic matter to enhance the fertility of the mangrove ecosystem, thereby supporting life within it. The primary productivity in the waters surrounding mangroves is relatively high, making the waters fertile. Leaves, branches, flowers, and other parts of mangroves that enter the water are broken down by microbes and form a food chain. Detritus is utilized by higher aquatic organisms such as bivalves, gastropods, fish, shrimp, crabs, and others. The organic material from mangrove litter serves as a main food source in the food web within the ecosystem **(Muro-Torres *et al.*, 2020; Alam *et al.*, 2022)**.

CONCLUSION

This study reports a total of 13 true mangrove species in the research location, with the species most commonly present at nearly every station being *R. apiculata*. The linear regression analysis results indicated that mangrove density does not significantly affect water quality parameters, including temperature, turbidity, salinity, DO, nitrate, BOD, phosphate, and Pb. The results show that the most consumed food type by the hilsa fish is mangrove detritus, accounting for 51% of the total gut content. This condition indicates that the availability of mangroves is crucial for the hilsa fish since they serve as their primary feeding ground.

ACKNOWLEDGMENT

The authors would like to express their gratitude to the Research and Community Service Institute of Universitas Asahan for facilitating this research and to the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for providing research funding under grant number 177/E5/PG.02.00.PL/2023.

REFERENCES

Alam, M. I.; Ahmed, M. U.; Yeasmin, S.; Debrot, A. O.; Ahsan, M. N. and **Verdegem, M. C. J.** (2022). Effect of mixed leaf litter of four mangrove species on shrimp post larvae (*Penaeus monodon*, Fabricius, 1798) performance in tank and mesocosm conditions in Bangladesh. Aquaculture., *551*: 737968.

Ali M.; Sulistiono, Imran Z. and **Simanjuntak C. P. H.** (2021). The potential development of ecotourism based on mangrove ecosystem in Ujung Pangkah of Gresik Regency, East Java Province, Indonesia. IOP Conf. Ser.: Earth Environ. Sci., *800*: 012054.

Amri, K.; Ma'mun, A.; Priatna, A.; Suman, A.; Prianto, E. and **Muchlizar, M.** (2020). Sebaran spasial, kelimpahan dan struktur komunitas zooplankton di estuari sungai siak serta faktor-faktor yang mempengaruhinya. Akuatika Indonesia., *5*(1): 7-20.

Bappenas. (2014). Perikanan berkelanjutan dukung percepatan pembangunan ekonomi nasional. Ministry of National Development Planning/Bappenas, Directorate of Marine and Fisheries, p. 120.

Bernardino, A. F.; Nobrega, G. N. and **Ferreira T. O.** (2021). Consequences of terminating mangrove's protection in Brazil. Mar. Policy., *125*: 104389.

Blaber, S. J. M.; Brewer, D. T.; Milton, D. A.; Merta, G. S.; Efizon, D.; Fry, G. and **Velde T. V. D.** (1999). The life history of protandrous tropical shad *Tenualosa macrura* (Alosinae: Clupeidae): Fishery implications. Estuar. Coast. Shelf. S., *4*(9): 689-701.

Celis-Hernandez, O.; Giron-Garcia, M. P.; Ontiveros-Cuadras, J. F.; Canales-Delgadillo, J. C.; Pérez-Ceballos, R. Y.; Ward, R. D.; Acevedo-Gonzales, O.; Armstrong-Altrin, J. S. and **Merino-Ibarra, M.** (2020). Environmental risk of trace elements in mangrove ecosystems: An assessment of natural vs oil and urban inputs. Sci. Total Env., *730*: 138643.

Drexler, J. Z. (2001). Maximum longevities of *Rhizophora apiculata* and *R. mucronata* propagules. Pac. Sci., *55*(1): 17-22.

Duval, E.; Skaala, O.; Quintela, M.; Dahle, G.; Delaval, A.; Wennevik, V.; Glover, K. A. and **Hansen M. M.** (2021). Long-term monitoring of a brown trout (*Salmo trutta*) population reveals kin associated migration patterns and contributions by resident trout to the anadromous run. BMC Ecol. Ev., *21*: 143.

Eddy, S.; Milantara, N.; Sasmito, S. D.; Kajita, T. and **Basyuni, M.** (2021). Anthropogenic drivers of mangrove loss and associated carbon emissions in South Sumatra, Indonesia. Forests., *12*: 187.

Effendi, H. (2003). Telaah kualitas air bagi pengelolaan sumberdaya dan lingkungan perairan. Kanisius, Yogyakarta.

Efizon, D.; Djunaedi, O. S.; Dhahiyat, Y. and **Koswara B.** (2012). Kelimpahan populasi dan tingkat eksploitasi ikan terubuk (*Tenualosa macrura*) di perairan Bengkalis, Riau. Berkala Perikanan Terubuk., *40*(1): 52-65.

Firmansyah, M.; Alamsyah, R.; Putra. A. and **Mapparimeng, M.** (2020). Laju dekomposisi serasah daun mangrove di Kelurahan Lappa Kecamatan Sinjai Utara Kabupaten Sinjai. Agrominansia., *5*(1): 114–119.

Gallardo, S. S.; Fossile, T.; Herbst, D. F.; Begossi, A.; Silva, L. G. and **Colonese, A. C.** (2021). 150 years of anthropogenic impact on coastal and ocean ecosystems in Brazil revealed by historical newspapers. Ocean Coast. Manag., *209*: 105662.

Gao, Y.; Sun, L.; Wu, C.; Chen, Y.; Xu, H.; Chen, C. and **Lin, G.** (2018). Inter-annual and seasonal variations of phytoplankton community and its relation to water pollution in Futian Mangrove of Shenzhen, China. Cont. Shelf Res., *166*: 138-147.

Gunawan, W.; Basuni, S.; Indrawan, A.; Prasetyo, L. B. and **Soedjito H.** (2011). Analisis komposisi dan struktur vegetasi terhadap upaya restorasi kawasan hutan Taman Nasional Gunung Gede Pangrango. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan., *1*(2): 93-105.

Havens, K. (2015). Climate change: Effects on salinity in Florida's Estuaries and responses of oysters, seagrass, and other animal and plant life. Florida Sea Grant College Program, UF/IFAS Extension, Gainesville

Hossain, M. A. R.; Das, I.; Genevier, L.; Hazra, S.; Rahman, M.; Barange, M. and **Fernandes, J. A.** (2019). Biology and fisheries of Hilsa shad in Bay of Bengal. Sci. Total Environ., *651*: 1720-1734

Kesavan, S.; Xavier, K. A. M.; Deshmukhe, G.; Jaiswar, A. K.; Bhusan, S. and **Shukla S. P.** (2021). Anthropogenic pressure on mangrove ecosystems: Quantification and source identification of surficial and trapped debris. Sci. Total Environ., *794*: 148677.

Kusmana C. (2017). Metode survey dan interpretasi data vegetasi. IPB Press, Bogor.

Lønborg, C.; Müller, M.; Butler, E. C. V.; Jiang, S.; Ooi, S. K.; Trinh, D. H.; Wong, P. Y.; Ali, S. M.; Cui, C.; Siong, W. B.; Yando, E. S.; Friess, D. A.; Rosentreter, J. A.; Eyre, B. D. and **Martin P.** (2021). Nutrient cycling in tropical and temperate coastal waters: Is latitude making a difference?. Estuar. Coast. Shelf Sci., *262*: 107571.

Machrizal, R.; Dimenta, R. H. and **Khairul, K.** (2019). Hubungan kualitas perairan dengan kepadatan populasi ikan terubuk (*Tenualosa ilisha*) di Sungai Bilah Kabupaten Labuhanbatu. Jurnal Pembelajaran dan Biologi Nukleus., *5*(2): 67–71.

Melnyk, L. J.; Lin, J.; Kusnierz, D. H.; Pugh, K.; Durant, J. T.; Suarez-Soto, R. J.; Venkatapathy, R.; Sundaravadivelu, D.; Morris, A.; Lazorchak, J. M., Perlman, G.; Michael, A. and **Stover, M. A.** (2021). Risks from mercury in anadromous fish collected from Penobscot River, Maine. Sci. Total Environ., *781*: 146691.

Moore, C. E.; Meacham-Hensold, K.; Lemonnier, P.; Slattery, R. A.; Benjamin, C.; Bernacchi, C. J.; Lawson, T. and **Cavanagh A. P.** (2021). The effect of increasing temperature on crop photosynthesis: from enzymes to ecosystems. J. Exp. Bot., *72*(8): 2822-2844.

Moslehi, M.; Pypker, T.; Bijani, A.; Ahmadi, A. and **Hallaj, M. H. S.** (2021). Effect of salinity on the vegetative characteristics, biomass and chemical content of red mangrove seedlings in the south of Iran. Sci. For., *49*(132): 3748.

Muro-Torres, V. M.; Amezcua, F.; Soto-Jiménez, M.; Balart, E. F.; Serviere-Zaragoza, E.; Green, L. and **Rajnohova, J.** (2020). Primary sources and food web structure of a tropical wetland with high density of mangrove forest. Water., *12*: 3105.

Muzaki, F. K.; Saptarini, D.; Kuswytasari, N. D. and **Sulisetyono, A.** (2012). Exploring Mangrove Surabaya. Marine Study Center, LPPM Institut Teknologi Sepuluh Nopember, Surabaya.

Myers, S. S.; Smith, M. R.; Guth, S.; Golden-C. D.; Vaitla, B.; Mueller, N. D.; Dangour, A. D. and **Peter, H. P.** (2017). Climate change and global food systems: potential impacts on food security and undernutrition. Annu. Rev. Public Health., *38*: 259-277.

Ng, C. K. C. and **Ong, R. C. A.** (2020). Review of anthropogenic interaction and impact characteristics of the Sundaic mangroves in Southeast Asia. Estuar. Coast. Shelf Sci., *267*: 107759.

Noor, Y. R.; Khazali, M. and **Suryadiputra, I. N. N.** (2006). Panduan pengenalan mangrove. PHKA/Wetlands International-Indonesia Programme, Wetlands Indonesia, Bogor.

Noor, T.; Batool, N.; Mazhar, R. and **Ilyas, N.** (2015). Effects of siltation, temperature and salinity on mangrove plants. European Academic Research., *2*(11): 14172-14179.

Nugroho, P. E. R; Suryanti and **Purnomo, P. W.** (2020). Analysis of changes in mangrove area in the North Coast of Central Java Province Indonesia. Saintek Perikanan: Indonesian Journal of Fisheries Science and Technology., *16*(3): 208-218.

Perera-Valderrama, S.; Hernández-Ávila, A.; Ferro-Azcona, H.; Cobián-Rojas, D.; González-Méndez, J.; Caballero-Aragón, H.; de la Guardia-Llansó, E.; Ramón-Puebla, A.; Hernández-González, Z.; Espinosa-Pantoja, L. and **Lara A.** (2020). Increasing marine ecosystems conservation linking marine protected areas and integrated coastal management in southern Cuba. Ocean Coast. Manag., *196*: 105300.

Phan, M. H. and **Stive, M. J. F.,** (2022) Managing mangroves and coastal land cover in the Mekong Delta. Ocean Coast. Manag., *219*: 106013.

Rumondang; Feliatra, F.; Warningsih, T.; Yoswati, D. (2022a). Detection of coastline changing by using remote sensing imagery (case study in Talawi District, Tanjung Tiram District, Lima Puluh Pesisir District Batu Bara Regency). IOP Conf. Ser.: Earth Environ. Sci., *1118*: 1–10.

Rumondang; Feliatra, F.; Warningsih, T.; Yoswati, D. (2022b). Identifikasi mangrove di Kabupaten Batu Bara. Seminar Nasional Multi Disiplin Ilmu Universitas Asahan., 555–566. [in Indonesian].

Rumondang; Feliatra, F.; Warningsih, T.; Yoswati, D. (2023). Mangrove forest in Batu Bara Regency, Indonesia: Dynamics of forest area changes and perception of coastal communities in mangrove ecosystem management. AACL Bioflux., *16*(3): 1658-1668.

Rumondang. (2018). Kajian makanan ikan dan waktu makan terubuk (*Tenualosa ilisha*) di Kabupaten Labuhanbatu. Prosiding Seminar Nasional Multidisiplin Ilmu Universitas Asahan., 398–407.

Sánchez, A. R.; Pineda, J. E. M.; Casas, X. M. and **Calderón, J. H. M.** (2021). Influence of edaphic salinity on leaf morphoanatomical functional traits on juvenile and adult trees of red mangrove (*Rhizophora mangle*): Implications with relation to climate change. Forests., *12*: 1586.

Sekadende, B. C.; Michael, A.; Painter, S. C.; Shayo S.; Noyon, M. and **Kyewalyanga, M. S.** (2021). Spatial variation in the phytoplankton community of the Pemba Channel, Tanzania, during the south-east monsoon. Ocean Coast. Manag., *212*: 105799

Singh, J. K. (2020). Structural characteristics of mangrove forest in different coastal habitats of Gulf of Khambhat arid region of Gujarat, west coast of India. Heliyon., *6*(8): 1-7

Smith, M. K. and **Zwollo, P.** (2020). Transient increase in abundance of B lineage but not myeloid-lineage cells in anterior kidney of sockeye salmon during return migration to the natal grounds. Fish Shellfish Immunol., *107*: 395-402.

Suwarso, S.; Taufik, M. and **Zamroni, A.** (2018). Tipe perikanan dan status sumberdaya ikan terubuk (*Tenualosa macrura*, Bleeker 1852), di perairan estuarin

Bengkalis dan Selat Panjang. Jurnal Penelitian Perikanan Indonesia., *23*(4): 261-273.

Taryono. (2015). Kelembagaan untuk suaka perikanan ikan terubuk (*Tenualosa macrura*) di Perairan Bengkalis dan Sungai Siak, Provinsi Riau. Prosiding Seminar Nasional Ikan ke 8.

Urrego, L. E.; Molina, E. C. and **Suarez, J. A.** (2014). Environmental and anthropogenic influences on the distribution, structure, and floristic composition of mangrove forests of the Gulf of Urabá (Colombian Caribbean). Aquat. Bot., *114*: 42-49

Usman, A. H. A.; Hartoyo, A. P. P. and **Kusmana, C.** (2022). The growth performance of Rhizophora apiculata using the cut-propagule method for mangrove rehabilitation in Indonesia. Biodiversitas Journal of Biological Diversity., *23*(12): 6366-6378.

Wang, L.; Mu, M.; Li, X.; Lin, P. and **Wang, W.** (2011). Differentiation between true mangroves and mangrove associates based on leaf traits and salt contents. J. Plant Ecol., *4*(4): 292–301.

Wang'ondu, V. W.; Kairo, J. G.; Kinyamario, J. I.; Mwaura, F. B.; Bosire, J. O.; Dahdouh-Guebas, F. and **Koedam, N.** (2013). Vegetative and reproductive phenological traits of *Rhizophora mucronata* Lamk. and *Sonneratia alba* Sm. Flora., *208*(8-9): 522-531.

Xu, S. J. L.; Chan, S. C. Y.; Wong, B. Y. K.; Zhou, H. C.; Li, F. L.; Tam, N. F. Y. and **Lee, F. W. F.** (2022). Relationship between phytoplankton community and water parameters in planted fringing mangrove area in South China. Sci. Total Environ., *817*: 152838.