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The Impact of Mangrove Vegetation on Fish Species Diversity in Batu Ampar Village *(Dampak Vegetasi Mangrove terhadap Keanekaragaman Spesies Ikan di Desa Batu Ampar)*

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ABSTRACT

Mangrove forests a habitat for fish to breed and grow, providing numerous benefits such as conserving flora and fauna, sequestering carbon, and supporting human socio-economic activities. Therefore, this study aimed to examine the variations in fish species associated with different types of mangrove vegetation in the Batu Ampar Village region, Kubu Raya, West Kalimantan. The experiment was conducted in November 2023 at three observation stations according to the types of mangrove forest dominants, specifically Rhizophora stylosa Griff., Nypa fruticans Wurmb: vegetation, and their combination. Fish samples were collected using purposive sampling. A range of fishing gear was used for this process, such as nets, longlines or rods, ancau gear, and trawls. The results showed that the type of mangrove forest vegetation influenced the species of fish found. A total of twenty-eight fish species were identified; Stations I, II, and III contained 11, 13, and 15 species each, respectively. *A total of three fish species were found in three observation locations, namely* Setipinna melanochir *Bleeker,* Paratherina wolterecki *Aurich,* Arius maculatus *Thunberg,* Leiognathus equula *Forsskål, and* Zenarchopterus buffonis *Valenciennes. There were two species of fish with high market value, namely* Pomadasys argenteus *Forsskål and* Sphyraena barracuda *Edwards, as well as* Xenopterus naritus *Richardson, which had ornamental value. The muddy environmental factors and salinity levels led to an increase in the number of fish found. Stations I and III exhibit muddy characteristics, with 80 and 62 fish, respectively.*

Kata kunci:
Hutan Mangrove, Ikan, Vegetasi Mangrove

ABSTRAK

Hutan mangrove merupakan habitat bagi ikan untuk berkembang biak dan tumbuh, memberikan banyak keuntungan seperti konservasi flora dan fauna, penyerapan karbon, dan dukungan bagi kegiatan sosial ekonomi manusia. Oleh karena itu, penelitian ini bertujuan untuk mengkaji variasi spesies ikan yang berasosiasi dengan berbagai jenis vegetasi mangrove di wilayah Desa Batu Ampar, Kubu Raya, Kalimantan Barat. Penelitian dilaksanakan pada bulan November 2023 di tiga stasiun pengamatan sesuai dengan jenis vegetasi dominan hutan mangrove, yaitu vegetasi *Rhizophora stylosa* Griff., *Nypa fruticans* Wurmb., dan kombinasinya. Pengambilan sampel ikan menggunakan metode *purposive sampling* dengan alat tangkap seperti jaring, longline/pancing, ancau, dan pukat. Hasil penelitian menunjukkan bahwa jenis vegetasi hutan mangrove mempengaruhi spesies ikan yang ditemukan. Terdapat 28 spesies ikan yang ditemukan, dengan stasiun I, II, dan III masing-masing terdiri dari 11, 13, dan 15 spesies. Sebanyak tiga jenis ikan ditemukan di tiga lokasi pengamatan, yaitu *Setipinna melanochir* Bleeker, *Paratherina wolterecki* Aurich, *Arius maculatus* Thunberg, *Leiognathus equula* Forsskål, dan *Zenarchopterus buffonis* Valenciennes. Terdapat dua jenis ikan yang memiliki nilai jual tinggi, yaitu *Pomadasys argenteus* Forsskål dan *Sphyraena barracuda* Edwards, termasuk

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Xenopterus naritus Richardson yang memiliki nilai hias. Faktor lingkungan berlumpur dan tingkat salinitas menunjukkan adanya peningkatan jumlah ikan yang ditemukan. Stasiun I dan III memiliki karakteristik berlumpur, dengan jumlah total ikan masing-masing 80 dan 62 ekor.

1. Introduction

Indonesia has mangrove forests covering approximately 18-23% of the world's mangrove forest area (Marlianingrum *et al.,* 2021) and 59.9% in Southeast Asia (Darmawan *et al.,* 2020). Kalimantan Island has the third-largest mangrove area in Indonesia after Papua and Sumatra. This indicates the importance of mangrove forests in Kalimantan in maintaining the stability of the natural ecosystem.

The proximity to residential areas makes the mangrove forest an important economic area (Hagger *et al.,* 2022). The existence of mangrove forest can provide plants as medicines (Darmadi *et al.,* 2021), fish producers (Rahman *et al.,* 2024), crabs (Arisekar *et al.,* 2021), shrimp (Boyd *et al.,* 2022), bivalves (Yahya *et al.,* 2020), and gastropods (Hong *et al.,* 2020) that can be consumed. Furthermore, mangrove forest can also be used as conservation area migratory birds and breading fish (Arceo-Carranza *et al.,* 2021), (Mancini *et al.,* 2023).

The composition of animals such as fish in mangroves depends on the condition of the ecosystem (Nanjo *et al.,* 2014) and the type of habitat (Du *et al.,* 2020; Dunne *et al.,* 2023). Dunne *et al.,* (2023) and Du *et al.,* (2020) stated that coral, macroalgae, seagrass, and mangrove habitats host unique fish species. Generally, mangrove ecosystems have smaller fish than macroalgae and seagrass, as well as coral reef (Dunne *et al.,* 2023). Mangrove areas are often considered areas for fish breeding (Beh *et al.,* 2023). Dunne *et al.,* (2023) showed that juvenile fish dominated mangrove areas, while subadult and adult fish were found in macroalgae areas. However, other studies reported that mangrove areas had more fish species than seagrass or coral reef areas (Du *et al.,* 2020) due to differences in the ecosystem and sea tides (Dunne *et al.,* 2023). Areas dominated by *Avicennia marina* (Forssk.) Vierh trees in the Red Sea have smaller interstitial spaces, stems, and root structures than those of other mangroves. The limited water depth at low tide resulted in a small number of fish species (Dunne *et al.,* 2023). This showed that the number of species and individual fish found in mangrove areas with different vegetation types varied significantly (Du *et al.,* 2020; Dunne *et al.,* 2023).

Fish are animals with the potential to boost an area's economy, with varying resistance to environmental change, particularly in mangrove forests, where they serve as a bioindicator species (Ellis and Bell 2013). Research by Middleton *et al.,* (2025) shows that communities around mangroves, especially in Batu Ampar Village, Kubu Raya Regency, depend heavily on fish as a food source, especially during the dry season. The community relies on fish as a source of meat. However, the composition of mangrove vegetation in the Gunung Keruing, Teluk Air, and Sungai Limau hamlets in Batu Ampar Village differs (Sisriany *et al.,* 2021). This study aims to analyze fish diversity in mangrove vegetation in the Batu Ampar Village region, Kubu Raya, West Kalimantan.

2. Materials and Methods

2.1. Study Area

We conducted this study at the Mangrove Forest Ecosystem in Batu Ampar Village, Batu Ampar District, Kubu Raya Regency, in November 2023 (Figure 1). Several tools were used in this study including maps, cameras, longlines/fishing rods, trawls (with mesh sizes of 2 cm, 4 cm, and 6 cm), nets, pH meters, buckets, boats, rulers, black cloth, measuring tape and knives or scissors to remove fish hooks and Kottelat Identification Book to identify fish species (Kottelat, 2013).

2.2. Data Collection

Data collection was conducted using purposive sampling method. We conducted direct observation method at observation points based on the local community's information and experience (purposive sampling), following fishermen as they explored the catchment area. The study was conducted at Station I in Sungai Limau Hamlet, Station II in Gunung Keruing Hamlet, and Station III in Teluk Air Hamlet, which describe three different types of vegetation.

The fisherman used fishing gear such as nets, longlines/fishing rods, ancau, and trawls to collect fish sample. The following are the steps in collecting fish at each observation station. The nets were initially baited and spread 10 times at each station for fish to gather and produce numerous catches. There was one longline thread comprising 150 hooks (size of no. 12), which were separated by one meter. Before deployment, each hook was individually baited, and the long line was set at the designated station. One seine line (mesh size 2 cm, 4 cm, and 6 cm) with a length of 20 m, and the installation of the seine was used to collect fish samples at high and low tide in each station, with two repetitions. Each sampling point was determined along 100 m to adjust the size of installed seine and longline. At each station, the data was recorded on the species and number of fish samples. For each fish, we measured total length from the tip of the snout to the end of the tail fin using a measuring board, recorded standard dimensions according to FishBase protocols. Then photographed each specimen and identified its species using the FishBase website (https://www.fishbase.se) and the Kottelat Identification Book (Kottelat, 2013). Environmental parameters were measured as follows: water current was measured with a flow meter, brightness with a light sensor, temperature and pH using portable meters, and salinity with a refractometer. Soil substrate was assessed visually, and sea tides were recorded based on local tide charts.

2.3. Data Analysis

We analize the diversity, dominance index, species evenness, species richness, and species similarity for each observation station. The dominance of fish species at each observation station was observed using the Simpson Dominance Index with the following formula (Simpson, 1949):

$$C = \sum_{S=1}^{S} (\frac{n_i}{N})^2$$

Where C: *Simpson's Dominance Index*, S: Total number of species (or categories), n_i: Number of individuals in species i. N: Total number of individuals across all species. There are two categories, namely high diversity (more even distribution or no species of fish dominates) ($0 < C \leq 0.5$) and low diversity (one species dominates or the one species of fish that dominates) ($0.5 < C \leq 1$).

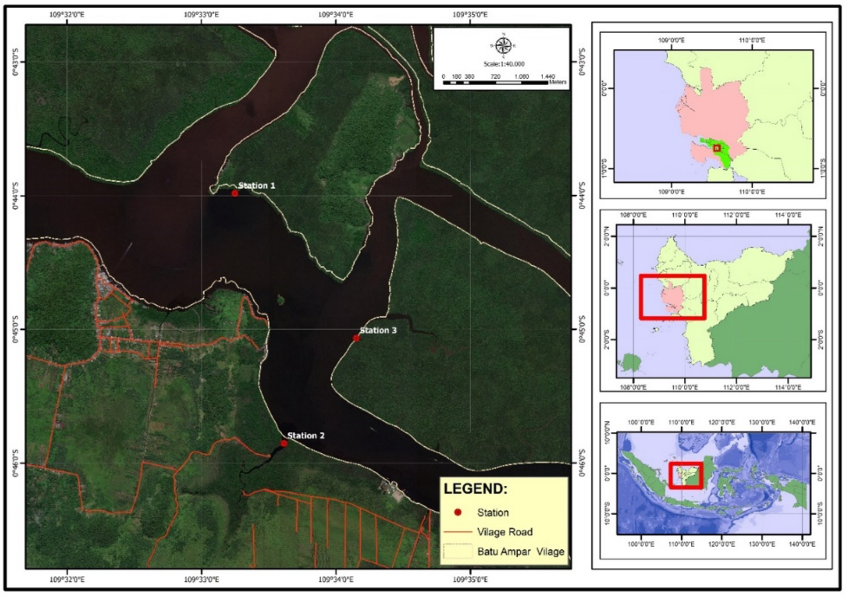

Figure 1. Study site: The main figure illustrates three observation stations (A). The right-hand panels, from top to bottom, depict inset maps of Batu Ampar Sub-district (B), Kubu Raya Regency (C), and West Kalimantan Province, Indonesia (D).

Index of Diversity (*H'*) is a quantitative measure that shows the type of fish present in a forest community or mangrove ecosystem. The calculation of *H'* uses the following formula (Shannon and Weaver, 1998):

$$H' = -\sum\left[\left(\frac{ni}{N}\right) x \ln\left(\frac{ni}{N}\right)\right]$$

Where H': Shannon–Wiener Diversity Index (also written as Shannon Index or Shannon Entropy); n_i: Number of individuals of species I; and N: Total number of individuals of all species. The diversity index criteria of a species are categorized as low when $H' < 1$, medium when $1 \leq H' \leq 3$, and high at $H' > 3$. The Index of Species Evenness (*E*) of fish species is the distribution of individual fish between different species and is analysed using the following formula (Pielou, 1966):

$$E = \frac{H'}{ln\ (S)}$$

Where E: *Species Evenness Index*, showing how evenly individuals are distributed among species; H': Shannon–Wiener Diversity Index (Shannon Index); S: Total number of species; $\ln(S)$: Natural logarithm of the number of species. The diversity index (*E*) categorizes fish population uniformity into low ($0 < E \leq 0.5$), medium ($0.5 < E \leq 0.75$), and high ($0.75 < E \leq 1$). The Species Richness Index (*R*) is the number of fish species present in mangrove water and is calculated using the following formula (Margalef, 1958):

$$R = \frac{S - 1}{ln\ (N)}$$

Where R: *Species Richness Index*, also known as Margalef's Richness Index; S: Total number of species observed in the community; N: Total number of individuals of all species combined; $ln\ (N)$: Natural logarithm of the total number of individuals. The species richness index is divided into three categories, namely the low, medium, and high when $R < 3.5$, $R = 3.5–5$, and $R \geq 5$, respectively. Species similarity index (IS) is a comparison between the number of fish species that are the same as the observation stations being compared and the total number of fish species from each observation station. IS is calculated using the Sorensen formula (Sorensen, 1948):

$$IS = \frac{2C}{A+B} \text{ x } 100\%$$

Where IS: Species Similarity Index (%) between two sampling sites or communities; A: Number of species found in community/site A; B: Number of species found in community/site B; C: Number of species shared (overlapping) between community A and community B; $2C$: Doubled shared species count—this emphasizes common species between sites. The criteria for the species similarity index are grouped into the same, different, and very different categories when IS = 80−100%; 50−80%; and <50%, respectively.

3. Results and Discussion

3.1. Environmental Factors

This study was conducted in a mangrove forest with different vegetation types. Station I in Sungai Limau Hamlet consisted of secondary forest with *Rhizophora stylosa* Griff, *Bruguiera cylindrica* (L.) Blume, *Nypa fruticans* (Thunb.) Wurmb, and *Xylocarpus moluccensis* (Lam.) M. Roem dominated the area. Environmental characteristics, including water currents, brightness, temperature, pH, salinity, soil substrate, and sea tides, are listed in Table 1. The type of soil was found to be muddy clay substrate, and the watercolor was bright (clear) at water current conditions ranging from 0.7 ms^{-1} at a depth of 0.5 m. Station II in Gunung Keruing Hamlet had been dominated by *R. stylosa,* which lined the river coast. The type of soil substrate was found to be dusty and muddy clay with reddish watercolor (rather dark), alongside relatively calm current conditions around 0.3 ms^{-1} at a depth of 0.5 m. Furthermore, Station III in Teluk Air Hamlet had a dominant vegetation *N. fruticans* on the riverbank and *R. stylosa* behind *N. fruticans* on the expanse. The substrate type was found to be muddy clay, and the watercolor was bright (clear) at water current conditions ranging from 0.3 ms^{-1} to a depth of 0.5 m.

Water currents are one of the environmental factors determining the species of fish found during observation. Station I have a high-water current (0,7 ms $^{-1}$) near the estuary, compared to stations II and III, which have water currents of 0.3 ms^{-1}. The type of soil substrate at each station are relatively same, which was found to be mud. However, Station II was dominated by a dusty mud substrate, affecting the lower brightness level compared to others, which was only 1.7 m. The brightness of the water was also directly affected by the height of the sea tide. The existence of stations with seawater affected the level of salinity of the water produced. Station I, close to the estuary, has a high salinity level (23.5%) compared to Stations II (12%) and III (20%). Observations showed that the water had a normal pH of 7 at every station.

3.2. Species of Fish in the Mangrove Forest Waters

Observations at three different stations found 28 species of fish, with 185 individuals belonging to 21 families (Table 2), as shown in Figures 3, 4, and 5. A total of 11 families of brackish water fish were found in observation station I which were dominated by Engraulidae, Ariidae, Melanotaeniidae, Sciaenidae, Sphyraeni-dae, Zenarchopteridae, Cyprinidae, Dorosomatidae, Haemulidae, Leiognathi-dae, and Tetraodontidae. Station II had 13 families of fish dominated by the Engraulidae, Aplocheilidae Toxotidae, Ariidae, Melanotaeniidae, Zenarchopteri-dae, Tetraodontidae, Ambassidae, Scor-paenidae, Muraenesocidae, Mugilidae, and

Leiognathidae families. Meanwhile, Station III had 15 families consisting of Ariidae, Ambassidae, Anguillidae, Dasyatidae, Engraulidae, Haemulidae, Leiognathidae, Melanotaeniidae Platycephalidae, Polynemidae, Sciaenidae, Scorpaenidae, Tetraodontidae, Toxotidae, and Zenarchopterida.

Table1. Characteristics of environmental factors at three observation stations

No	Parameter	Station I	Station II	Station III
1	Water Currents	0.7 ms^{-1}	0.3 ms^{-1}	0.3 ms^{-1}
2	Water Brightness	2.2 m	1.7 m	1.9 m
3	Water Temperature	29.5°C	27.5°C	28°C
4	pH Water	7	7	7
5	Salinity	23.5‰	12‰	20‰
6	Soil Substrate	Muddy	Dusty muddy	Muddy
7	Sea Tides	1.85 m	1.5 m	1.75 m

Table 2. The fish species found at three observation stations

No	Family	Local Name	Scientific name	Station		
				I	II	III
1	*Ariidae*	Belukang	*Arius sagor* Hamilton, 1822	-	1	-
2	*Ariidae*	Duri	*Arius maculatus* Thunberg, 1792	4	3	7
3	*Ariidae*	Duri Moncong	*Arius truncates* Valenciennes, 1840	1	-	2
4	*Ambassidae*	Serinding	*Ambassis nalua* Hamilton, 1822	-	1	1
5	*Anguillidae*	Belut Laut	*Anguilla bicolor* McClelland, 1844	-	-	2
6	*Aplocheilidae*	Semangkah	*Apogon sangiensis* Bleeker 1857	-	8	-
7	*Cyprinidae*	Ikan Teri Kokang	*Rasbora argyrotaenia* Bleeker, 1849	1	-	-
8	*Dasyatidae*	Pari	*Hypolophus sephen* Fabricius, 1775	-	-	1
9	*Dorosomatidae*	Selangat	*Anodontostoma chacunda* Hamilton, 1822	1	-	-
10	*Engraulidae*	Pemperang Merah	*Setipinna breviceps* Cantor, 1849	-	1	-
11	*Engraulidae*	Pemperang Kuning	*Setipinna melanochir* Bleeker, 1849	34	2	23
12	*Engraulidae*	Runjing	*Coilia dussumieri* Valenciennes, 1848	-	4	-
13	*Engraulidae*	Bilis	*Stolephorus indicus* van Hasselt, 1823	6	-	-
14	*Haemulidae*	Gerot-Gerot	*Pomadasys argenteus* Forsskål, 1775	1	-	2
15	*Leiognathidae*	Kepetek	*Leiognathus equula* Forsskål, 1775	1	1	5
16	*Melanotaeniidae*	Ikan Besar Mata	*Paratherina woltereckі* Aurich, 1935	22	3	6
17	*Mugilidae*	Belanak	*Liza subviridis* Valenciennes, 1836	-	1	-
18	*Muraenesocidae*	Malung	*Congresox talabonoides* Bleeker, 1853	-	1	-
19	*Platycephalidae*	Baji-Baji	*Platycephalus indicus* Linnaeus, 1758	-	-	1
20	*Polynemidae*	Kurau	*Polydactylus plebejus* Broussonet, 1782	-	-	2
21	*Sciaenidae*	Gulama	*Johnius trachycephalus* Bleeker, 1851	-	4	3
22	*Sciaenidae*	Gulama Pendek	*Johnius coitor* Hamilton, 1822	4	-	-
23	*Scorpaenidae*	Lepu	*Leptosynanceia asteroblepa* Richardson, 1844	-	1	1
24	*Sphyraenidae*	Alu-Alu	*Sphyraena barracuda* Edwards, 1771	2	-	-
25	*Tetraodontidae*	Buntal	*Tetraodon nigroviridis* Marion de Procé, 1822	-	1	1
26	*Tetraodontidae*	Buntal Kuning	*Xenopterus naritus* Richardson, 1848	1	1	-
27	*Toxotidae*	Senyumpit	*Toxotes chaterus* Hamilton, 1822	-	8	1
28	*Zenarchopteridae*	Nyilung	*Zenarchopterus buffonis* Valenciennes, 1847	2	2	4
			Total	80	43	62

In this study, several species of fish could be found in all stations, such as the *Arius maculatus* Thunberg (Figure 2.B), *Setipinna melanochir* Bleeker (Figure 2.G), *Paratherina wolterecki* Aurich (Figure 3.R), *Leiognathus equula* Forsskål (Figure 3.N), and *Zenarchopterus buffonis* Valenciennes (Figure 4.A1). Several species of fish are found to have high selling value, such as *Pomadasys argenteus* Forsskål (Figure 3.O) and *Sphyraena barracuda* Edwards (Figure 4.W). During the study, a species *Xenopterus naritus* Richardson was also found, with the potential to be an ornamental fish (Figure 4.Z).

Figure 2. Species *Arius sagor* Hamilton (A)*, Arius maculates* Thunberg (B)*, Arius truncatus* Valenciennes (C)*, Ambassis Nalua* Hamilton (D)*, Apogon Sangiensis* Bleeker (E)*, Setipinna breviceps* Cantor (F)*, Setipinna melanochir* Bleeker (G)*, Coilia Dussumieri* Valenciennes (H)*, Stolephorus indicus* van Hasselt (I)*, Anguilla bicolor* McClelland (J)*, Rasbora argyrotaenia Bleeker* (K).

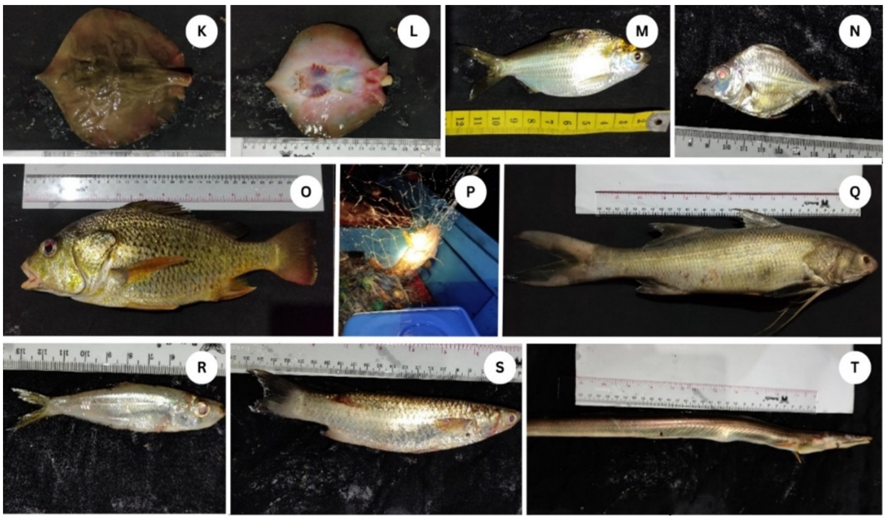

Figure 3. Species *Hypolophus sephen* Fabricius in upper side (K), *Hypolophus sephen* Fabricius in bellow side (L), *Anodontostoma chacunda* Hamilton (M), *Leiognathus equulus* Forsskål (N), *Pomadasys argenteus* Forsskål (O), *Leptosynanceia asteroblepa* Richardson (P), *Polydactylus plebejus* Broussonet (Q), *Paratherina wolterecki* Aurich (R), *Liza subviridis* Valenciennes (S)*, Congresox talabonoides* Bleeker (T)

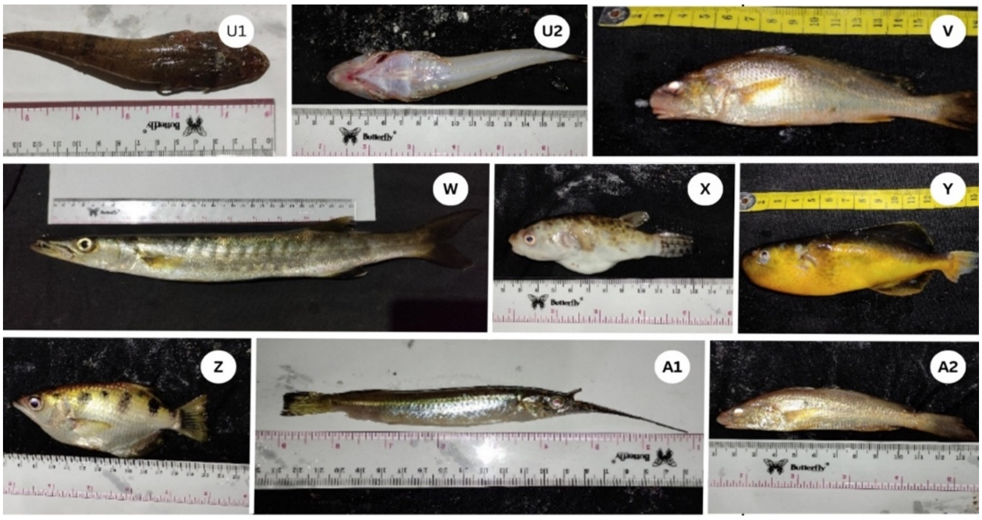

Figure 4. Species *Platycephalus indicus* Linnaeus in upper side (U1), *Platycephalus indicus* Linnaeus in bellow side (U2), *Johnius coitor* Hamilton (V), *Sphyraena barracuda* Edwards (W), *Tetraodon nigroviridis* Marion de Procé (X), *Xenopterus naritus* Richardson (Y), *Toxotes chaterus* Hamilton (Z), *Zenarchopterus buffonis* Valenciennes (A1), *Johnius trachycephalus* Bleeker (A2)

3.3. Biodiversity Indices of Fish Species in Mangrove Waters

The diversity of brackish water fish species found at the study location can be determined from the results of calculations of the dominance, species diversity, species evenness, and species richness indexes, as shown in Table 3. Based on dominance index calculation, fish showed varying abundances at different times and locations, with value (C) ranging from 0.11 to 0.27. The diversity index of fish species in the mangrove waters of Batu Ampar Village showed a moderate category. Furthermore, the species evenness index (E) of fish in this study was classified as moderate. Based on richness index (R) at Stations I, II, and III, a high value was obtained ranging from 6.16 to 7.18.

3.4. Similarity Index of Each Station in the Mangrove Waters

The species of brackish water fish at each station have similarities and significant differences. The level of similarity of brackish water fish species between stations is shown by the species similarity index, as presented in Table 4. Based on the calculation of the species similarity index at each station, the following values were obtained. Stations I and II had 40%, with criteria classified as low or significantly different. The species similarity index at Stations II and III was 60.6%, which was classified as moderate or different. The index of stations I and III was 48.3%, with criteria classified as low or considered significantly different.

Table 3. Biodiversity indice of fish species at three observation stations

No	Index	Station			Category
		Station I	Station II	Station III	
1	Dominance Index	0.27	0.11	0.18	Low
2	Species Diversity Index	1.73	2.51	2.21	Medium
3	Species Evenness Index	0.52	0.75	0.66	Medium
4	Species Richness Index	6.16	7.18	6.54	High

Table 4. Similarity index of species at each observation station

No	Station	Station 1	Station 2	Station 3
1	Station 1	-	40%	48.3%
2	Station 2	-	-	60.6%
3	Station 3	-	-	-

3.5. Discussion

Effect of Environmental Factors on the Diversity of Fish

Environmental factors are essential in the diversity of fish species in waters. This is shown by observations at Stations I and III which are greater than compared to III, as shown in Table 2. Station I had the strongest current (0.7 m/s), high brightness, a temperature of 29.5°C, a salinity of 23.5‰, and a muddy substrate, yielding 80 fish species across 15. Previous studies reported that muddy mangrove areas had higher digestible microphytobenthos as food for fish, showing potential for a greater number of fish (Sheaves *et al.,* 2016). Pelagic fish such as *Setipinna melanochir* and *Paratherina woltereck*i dominated due to the abundance of plankton and light, and the presence of euryhaline fish was driven by the ocean's salinity. The study area was affected by salinity levels, where higher values showed that the natural mangrove area could increase the fish species found (Seygita *et al.,* 2022).

Station II was calmer (current 0.3 m/s), low brightness, a temperature of 27.5°C, the lowest salinity (12‰), a dusty, muddy substrate, and dominated by *Rhizophora stylosa* vegetation. Forty-three individual fish across 18 species were found here, dominated by *Apogon sangiensis* and *Toxotes chaterus*. The low salinity supports a diverse range of estuarine species and small fish. Station III is transitional, with low current (0.3 m/s), 1.9 m clarity, 28°C temperature, 20‰ salinity, muddy substrate, and nipah palm vegetation. Sixty-two individuals of 17 species were found, including demersal and omnivorous species (*Setipinna melanochir, Arius maculatus, Paratherina woltereck*i), as well as rare species such as *Hypolophus sephen* and *Anguilla bicolor*. This zone is tidally influenced and rich in detritus. Furthermore, the type of subtraction also influences the types of fish found. In low-water-clarity conditions, juvenile fish prefer microhabitats to avoid predators (Zhang *et al.,* 2019).

The water in Batu Ampar Village provided an abundance of fish species, which could increase in fishing seasons. Tarimo *et al*. (2022) showed that certain seasons could increase the number of fish species found. There are four fishing seasons in the Batu Ampar Village area, namely the North (February to April), South (May to August), Southwest (August to September), and West Season (September to January). Since the study was conducted in November 2023 during fishing season, it provided a general description of the types of fish before entering the water of Batu Ampar Village.

Species of Fish in the Mangrove Waters of Batu Ampar Village

Variations in fish abundance at the three observation stations demonstrate a close relationship with differences in mangrove vegetation structure. Station I, dominated by secondary vegetation consisting of *Rhizophora stylosa*, *Bruguiera cylindrica, Nypa fruticans,* and *Xylocarpus moluccensis*, recorded 80 individuals from 15 species. The dominant fish species in this vegetation are *Setipinna melanochir, Paratherina woltereck*i*,* and *Stolephorus indicus*. This high abundance indicates that the complex vegetation combination creates numerous ecological niches for small pelagic fish. The presence of *Arius maculatus* and *Johnius coitor* further supports the productivity of Station I, supported by nutrient- and plankton-rich waters. This is in line with findings Zhang *et al.,* (2019) showing that the fish species diversity in *Sonneratia apetala* and *Avicennia marina* vegetation areas differs. This difference is due to differences in root types and pneumatophore densities (Zhang *et al.,* 2019). Sonneratia vegetation areas have a higher abundance of fish species because Sonneratia roots are large, cone-shaped compared to Avicennia roots, which are pencil-shaped. Furthermore, vegetated areas are dominated by small juvenile fish because they provide the best shelter from predators, thanks to their root structure that helps as a shelter (Zhang *et al.,* 2019).

The type of mangrove vegetation also influences the species of tropical fish that dominate (Zhang *et al.,* 2019). In contrast to Station I, Station II, dominated by *Rhizophora stylosa*, exhibited the fewest individuals (43) but the highest diversity (18 species). The dominant species, *Apogon sangiensis* and *Toxotes chaterus*, used the Rhizophora stilt roots for protection. Increased occurrences of *Coilia dussumieri* and *Johnius trachycephalus* were also recorded at this station. This low abundance but high diversity indicates a stable habitat with diverse microhabitats providing cover for juvenile fish and small carnivores.

In Rhizophora-dominated vegetation, the fish trophic type is predominantly herbivorous, with several omnivorous fish species (Utama *et al.,* 2022). However, in Nypah vegetation, the fish trophic type is dominated by carnivorous fish, although herbivorous tropical fish are still found due to the presence of Rhizopora vegetation. This indicates that the formed mangrove ecosystem is complementary. This is in line with research Utama *et al.,* (2022) which shows that native mangrove vegetation is dominated by juvenile fish and herbivorous tropical species because it serves as a nursery ground and shelter.

Station III, which contained *Nypa fruticans* along the edge and *Rhizophora stylosa* in the back, yielded 62 individuals from 17 species. *Setipinna melanochir* remained the most dominant species, indicating flexibility across mangrove habitat types. The *S. melanochir* was found also in Malaysia (Abu Hena *et al.,* 2017). Fish from the genus Setipinna are often used for consumption (Mustafa *et al.,* 2023). High abundances were also recorded for *Arius maculatus, Paratherina wolterecki* and *Leiognathus equula* indicating the detritus-rich nature of Station III's habitat. *A. maculatus* species of fish can be found in the bottoms of rivers, estuaries, and coasts (Yang *et al.,* 2022). *A. maculatus* are easily found in subtropical and tropical water, and are widely distributed in the Indo-West Pacific (Chu *et al.,* 2011). *A. maculatus* are also closely related to Arius, Netuma, Occidentarius, and Bagre (Yang *et al.,* 2022). The presence of *Hypolophus sephen* and *Anguilla bicolor* indicates soft substrate and specific migration routes at these stations.

Several exclusive species were also found at each station: *Rasbora argyrotaenia, Anodontostoma chacunda,* and *Johnius coitor* at Station I; *Congresox talabonoides, Liza subviridis,* and *Setipinna breviceps* at Station II; and *Platycephalus indicus* and *Polydactylus plebejus* at Station III. The presence of these exclusive species confirms the separation of habitats based on mangrove vegetation structure. The *R. argyrotaenia* fish is found in the Asian Sea area and consumed by humans (Agustiana *et al.,* 2023). The species is also used as ornamental fish (Budi *et al.,* 2020), which contributes to further studies of breeding programs (Syafariyah *et al.,* 2023). Another species is *A. chacunda* fish, which lays eggs for nine months, with the peak month in December (Hasan *et al.,* 2024). *A. chacunda* fish consume diatoms, radiolarians, mollusks, copepods, and crustaceans (Rainboth, 1996) are included in the category of least concern globally, with higher protein and calcium concentrate content (Agustiana *et al.,* 2023). The growth and mortality model of *A. chacunda* fish has also been conducted for breeding this species (Salim *et al.,* 2024).

At Stations I and III, *P. argenteus* was found. In the aquatic ecosystem, *P. argenteus* predominantly consumes crustaceans, mollusks, and parts of fish (Baaoom *et al.,* 2023). There are several species of fish from the *Pomadasys* species (Damadi *et al.,* 2021), while *S. barracuda* is very important for human consumption (Ahmadoon *et al.,* 2023). The quality of the chemical composition of meat from *Sphyraena barracuda* fish depends on the fishing season, size, and area (Ahmadoon *et al.,* 2023). However, the content of meat from the *S. barracuda* fish needs to be examined for body chemical content due to the potential to accumulate mercury (Ritonga *et al.,* 2023) and other dangerous chemical contents (Arencibia-Carballo *et al.,* 2022). Other species of fish are also used by the local community as raw materials for making crackers, such as *Arius maculatus* Thunberg, *Arius truncates* Valenciennes, *Rasbora argyrotaenia* Bleeker, *Anodontostoma chacunda* Hamilton, *Stolephorus indicus* van Hasselt, *S. melanochir*, *Leiognathus equula* Forsskål, *P. wolterecki*, *Johnius coitor* Hamilton, and *Z. buffonis*.

The *S. indicus* is known as the Indian anchovies, which can be found in several areas in Indonesia (Hardianti *et al.,* 2021), (Fitri *et al.,* 2022). This species of fish has been consumed to fulfill human protein (Tiamsai *et al.,* 2022), although the content requires further investigation. Several studies have shown that *S. indicus* can accumulate heavy metals (Alizada *et al.,* 2020) and microplastics (Gayathri *et al.,* 2024) in body tissue.

Other species of fish, such as *S. melanochir* and *L. equulus*, are used as processed cracker ingredients by the local community. Leiognathus species can be found in the Indo-Pacific area (Banu *et al.,* 2020), while *J. coitor* fish are predominant in India (Basumatary *et al.,* 2017; Verma *et al.,* 2018) and Indonesia (Yuniar *et al.,* 2007). However, this species of fish is a place for parasitic crustaceans to develop, particularly copepods, causing a significant reduction in the quality (Yuniar *et al.,* 2007). Another fish that is used as the basic ingredient for making crackers is the *Z. buffonis* fish, which is found in several countries, such as Bangladesh (Hanif *et al.,* 2017), China (Xiong *et al.,* 2018), (Tan *et al.,* 2019), Thailand (Ikejima *et al.,* 2003), India (Podder *et al.,* 2021), and Indonesia (Hernawati *et al.,* 2023). The *Z. buffonis* fish can be consumed (Hanif *et al.,* 2017) and grow to approximately 23 cm (Tan *et al.,* 2019).

Another species of fish that can be bred is the *X. naritus,* which is often consumed by humans (Ayub *et al.,* 2013). This fish also has a good appearance and can be used as an ornamental or for aquaculture (Nasir *et al.,* 2017), but the toxic tetrodotoxin content requires investigation (Park *et al.,* 2021). The toxin content in the tissue of this fish increases during the maturation period (Ayub *et al.,* 2013). However, excessive tetrodotoxin content when consumed by humans can cause fatal health problems (Park *et al.,* 2021).

Biodiversity Indices of Fish Species in the Mangrove Forest of Batu Ampar Village

The highest dominance index was observed at station I with a value of 0.27. This showed that there were no dominant species, given the absence of abundant fish, suggesting a stable population. The phenomenon showed that from the three stations, there was no control of one species over another because the dominance index value obtained was not close to 1. In peat waters, the increase in fish species that can live depends on the dissolved oxygen (DO) and pH levels in the water (Rohim *et al.,* 2024). The higher the DO and pH of the water, the more fish can adapt (Thornton *et al.,* 2018). Although in mangrove, DO depends on the density of mangrove stands, because the litter produced will increase water nutrients causing an increase in fish species (Sihombing *et al.,* 2017). Dunne *et al.,* (2023) and Du *et al.,* (2020) showed that the fish species also depended on an ecosystem of coastal vegetation, such as coral reef ecosystems, seagrass meadows, macroalgae canopies, and mangroves. Several studies also reported that the dominance index in mangrove forests was included in the low category (Setiawan *et al.,* 2019; Manullang and Khairul, 2020; Dunne *et al.,* 2023)

The diversity index of fish species found depended on the location and environmental conditions (Wahyudewantoro, 2018). Several studies reported that various species of fish in mangrove areas were found in dominant numbers compared to others (Zagars *et al.,* 2013; Abu El-Regal and Ibrahim 2014). The species evenness index of fish found in the mangrove area depends on environmental conditions (Wahyudewantoro, 2018). Damaged mangrove forests can reduce the quality of the environment in mangrove water, thereby decreasing the evenness of species found (Abrogueña *et al.,* 2012). According to Setiawan *et al.,* (2019), mangrove of Karangsong Village was also included in the “high” category with a species richness index value of 5.882. The species richness of fish found could be because mangrove forests produced higher nutrients (Zagars *et al.,* 2013). Therefore, smaller fish and those included in the juvenile category were more diverse (Wahyudewantoro, 2018; Dunne *et al.,* 2023).

Stations I and II are classified as low or significantly different due to substantial variations in vegetation. Specifically, Station I dominates *R. stylosa* vegetation while Station II has *R. stylosa*, *B. cylindrica*, *N. fruticans*, and *X. moluccensis*. Moreover, Stations II and III have moderate criteria or are different because of the study location proximity. Stations I and III are considered significantly different due to several vegetation, predominantly covered with *N. frutican*. Differences in standing vegetation and mangrove environmental conditions will cause variations in the similarity of fish species (Sihombing *et al.,* 2017). The diversity of fish species found is also associated with high conductivity, water temperature, total dissolved solids (TDS), DO, pH, and water transparency (Rohim *et al.,* 2024).

4. Conclusions

In conclusion, we found 21 families of fish consisting of 28 species in the mangrove waters of Batu Ampar Village, Batu Ampar District, Kubu Raya Regency. The most common species were the *A. maculatus, S. melanochir, P. woltereck, L. equula, and Z. buffonis*. The fish dominance index was low at all stations, ranging from 0.11 to 0.27. The species diversity index was moderate at all stations, ranging from 1.73 to 2.51. Species evenness indices for Stations I and II were 0.52 and 0.66, respectively, both falling within the mild category, while Station III showed a higher value of 0.75, which is categorized as high. The species richness index was high at all stations, ranging from 6.16 to 7.18. The species similarity index in these stations was relatively low, with Station I and II as well as I and III being 40%-48.3%. Meanwhile, Stations II and III were included in the moderate category with a value of 60.6%. The biological index value at each station varied significantly, with a total value of 83, 107, and 77 at Stations I, II, and III, respectively.

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References

Abrogueña, J.B.R., Bagarinao, T.U., & Chicharo, L. (2012). Fish habitats in a small, human-impacted Sibunag Mangrove Creek (Guimaras, Philippines): a basis for mangrove resource enhancement. *Ecohydrology & Hydrobiology,* 12(4), 311–319. doi:10.2478/v10104-012-0025-z.

Abu El-Regal, M.A., & Ibrahim, N.K. (2014). Role of mangroves as a nursery ground for juvenile reef fishes in the southern Egyptian Red Sea. *Egyptian Journal of Aquatic Research,* 40(1), 71–78. doi:10.1016/j.ejar.2014.01.001.

Abu Hena, M.K., Idris, M.H., Rajaee, A.H., & Siddique, M.A.M. (2017). Length–weight relationships of three fish species from a tropical mangrove estuary of Sarawak, Malaysia. *Journal of Applied Ichthyology,* 33(4), 858–860. doi:10.1111/jai.13385.

Agustiana, Budhi, S., Noorhalisah, F., Khadijah, S.T., & Brillyana, S. (2023). Protein and calcium concentrate quality of chacunda gizzard scad (*Anodontostoma chacunda*), silver rasbora (*Rasbora argyrotaenia*), Bali sardinella (*Sardinella lemuru*). *Journal of Food and Nutrition Science,* 11(6), 161–165. doi:10.11648/j.jfns.20231106.11.

Ahmadoon, H.G.A., Elawad, A.N., Alamin, A.M., & Babiker, A.A. (2023). Chemical composition of *Sphyraena barracuda* with different area, size and season, in Sudanese Red Sea Coast. *Journal of Food and Nutrition Science,* 14(05), 415–420. doi:10.4236/fns.2023.145027.

Alizada, N., Malik, S., & Muzaffar, S.b. (2020). Bioaccumulation of heavy metals in tissues of Indian anchovy (*Stolephorus indicus*) from the UAE coast, Arabian Gulf. *Marine Pollution Bulletin,* 154(February). doi:10.1016/j.marpolbul.2020.111033.

Arceo-Carranza, D., Chiappa-Carrara, X., Chávez López, R., & Yáñez Arenas, C. (2021). Mangroves as Feeding and Breeding Grounds. *in Mangroves: Ecology, Biodiversity and Management*. Singapore: Springer. p. 63–95.

Arencibia-Carballo, G., Mendoza, L.R.F., Ríos, A.A., & Cetina, J.A.T. (2022). Toxicidad por ciguatera en consumo de barracuda (*Sphyraena barracuda*) en la costa norte de La Habana, Cuba. *Brazilian Journal of Animal and Environmental Research,* 5(2), 2454–2473. doi:10.34188/bjaerv5n2-082.

Arisekar, U., Jeya Shakila, R., Shalini, R., Jeyasekaran, G., Sivaraman, B., & Surya, T. (2021). Heavy metal concentrations in the macroalgae, seagrasses, mangroves, and crabs collected from the Tuticorin coast (Hare Island), Gulf of Mannar, South India. *Marine Pollution Bulletin,* 163, 111971. doi:10.1016/j.marpolbul.2021.111971.

Ayub, M.N.A., Mohamad, S., Mohammed, M., Othman, M., Imelda, R.R., Shabdin, M.L., & Ahmad, F.B. (2013). Tetrodotoxin in various tissues of yellow puffer fish, *Xenopterus naritus* (Richardson 1848) from Betong, Sarawak, Malaysia. *Asian Fisheries Science,* 26(3), 142–155. doi:10.33997/j.afs.2013.26.3.002.

Baaoom, K.A., Salem, T.S., & Al-nawi, E.A. (2023). Stomach contents and feeding habits of *Diaramma pictum* and *Pomadasys argenteus* family of Haemulidae from coasts of Aden Governorate-Yemen. *Hadhramout University Journal of Natural and Applied Sciences,* 20(1), 15–23.

Banu, F., Ramanadevi, V., Shalini, G., & Thangaraj, M. (2020). Molecular variation and phylogenetic status of ponyfish (Perciformes: Leiognathidae) in Karaikal, South India. *Notulae Scientia Biologicae,* 12(2), 251–257. doi:10.15835/nsb12210661.

Basumatary, S., Jabeen, F., Dey, A., Choudhury, H., Talukdar, B., Kalita, H.K., & Sarma, D. (2017). Length-weight relationships of *Garra birostris* Nebeshwar & Vishwanath, 2013, *Garra annandalei* (Hora, 1921), *Johnius coitor* (Hamilton, 1822) and *Raiamas bola* (Hamilton, 1822) from the Brahmaputra River basin, Northeast India. *Journal of Applied Ichthyology,* 33(6), 1242–1243, doi:10.1111/jai.13440.

Boyd, C.E., Davis, R.P., & McNevin, A.A. (2022). Perspectives on the mangrove conundrum, land use, and benefits of yield intensification in farmed shrimp production: A review. *Journal of the World Aquaculture Society,* 53(1), 8–46. doi:10.1111/jwas.12841.

Budi, D.S.D.S., Rizkyan, I., & Prayogo, P. (2020). The effect of stocking density on the survival and growth of silver rasbora (*Rasbora argyrotaenia*) larvae. *Polish Journal of Natural Science,* 35(113), 87–95.

Chu, W.S., Hou, Y.Y., Ueng, Y.T., Wang, J.P., & Chen, H.C. (2011). Estimates of age, growth and mortality of spotted catfish, *Arius maculatus* (Thunberg, 1792), off the coast of Yunlin, Southwestern Taiwan. *African Journal of Biotechnology,* 10(68), 15416–15421. doi:10.5897/AJB11.1552.

Damadi, E., Moghaddam, F.Y., Ghassemzadeh, F., & Ghanbarifardi, M. (2021). Aspects of morphometry, distribution, and key identification of the genus Pomadasys (Perciformes: Haemulidae) from the Persian Gulf and Gulf of Oman with descriptions of new records. *Thalassas,* 37(2), 671–682. doi:10.1007/s41208-021-00308-1.

Darmadi, J., Batubara, R.R., Himawan, S., Azizah, N.N., Audah, H.K., Arsianti, A., Kurniawaty, E., Ismail, I.S., Batubara, I., & Audah, K.A. (2021). Evaluation of Indonesian mangrove *Xylocarpus granatum* leaves ethyl acetate extract as potential anticancer drug. *Scientific Reports,* 11(1), 6080. doi:10.1038/s41598-021-85383-3.

Darmawan, S., Sari, D.K., Wikantika, K., Tridawati, A., Hernawati, R., & Sedu, M.K. (2020). Identification before-after forest fire and prediction of mangrove forest based on Markov-cellular automata in part of Sembilang National Park, Banyuasin, South Sumatra, Indonesia. *Remote Sensing,* 12(22), 1–25. doi:10.3390/rs12223700.

Du, J., Xie M., Wang, Y., Chen, Z., Liu, W., Liao, J., & Chen, B. (2020). Connectivity of fish assemblages along the mangrove-seagrass-coral reef continuum in Wenchang, China. *Acta Oceanologica Sinica,* 39(8), 43–52. doi:10.1007/s13131-019-1490-7.

Dunne, A., Coker, D.J., Kattan, A., Tietbohl, M.D., Ellis, J.I., Jones, B., & Berumen, M. (2023). Importance of coastal vegetated habitats for tropical marine fishes in the Red Sea. *Marine Biology,* 170(7), 1–17. doi:10.1007/s00227-023-04234-z.

Ellis, W.L., & Bell, S.S. (2013). Intertidal fish communities may make poor indicators of environmental quality: Lessons from a study of mangrove habitat modification. *Ecological*

Indicator, 24, 421–430. doi:10.1016/j.ecolind.2012.07.008.

Fitri, A.D.P., Hapsari, T.D., Sabdono, A,. Adiyanto, F., & Fitriyani, A. (2022). Study on the effect of scoop net towards *Stolephorus indicus* and *Sardinella fimbriata* capture in Cilacap waters, *Indonesian Aquaculture and Aquatic Conservation Letters - Bioflux,* 15(2), 671–681.

Gayathri, V., Pavithra, R., Thangal, S.H., Ganapathy, S., Gurusaravanan, P., Santhanam , P., Radhakrishnan, S., & Muralisankar, T. (2024). Incidence of microplastics in Indian anchovy *Stolephorus indicus* from Tuticorin, southeast coast of India. *Marine Pollution Bulletin,* 202. doi:10.1016/j.marpolbul.2024.116406.

Hagger, V., Worthington, T.A., Lovelock, C.E., Adame, M.F., Amano, T., Brown, B.M., Friess, D.A., Landis, E., Mumby, P.J., Morrison, T.H., *et al.* (2022). Drivers of global mangrove loss and gain in social-ecological systems. *Nature Communications,* 13(1), 6373. doi:10.1038/s41467-022-33962-x.

Hanif, M.A., Siddik, M.A.B., Nahar, A., Chaklader, M.R., & Fotedar, R. (2017). A new distribution of the buffon's river garfish, *Zenarchopterus buffonis* (Valenciennes, 1847) in the southern coastal rivers of Bangladesh. *Journal of Applied Ichthyology,* 33(6), 1211–1214. doi:10.1111/jai.13462.

Hardianti, E., Wardhana, W., & Patria, M.P. (2021). Microplastic abundance in anchovy *Stolephorus indicus* (Van Hasselt, 1823) in the Lada Bay, Pandeglang, Banten. *Journal of Physics: Conference Series,* 1725(1). doi:10.1088/1742-6596/1725/1/012050.

Hasan, M.R., Mawa, Z., & Hossain, M.Y. (2024). Some biological aspects of chacunda gizzard shad, *Anodontostoma chacunda* (Hamilton, 1822) from the Bay of Bengal, Bangladesh. *Heliyon*, 10(16), e36123. doi:10.1016/j.heliyon.2024.e36123.

Hernawat, R.T., Wahyudewantoro, G., Wibowo, K., & Rusdianto, R. (2023). Update on fish community in the mangrove ecosystems of Banyuasin Regency, South Sumatra, Indonesia, with the addition of the first record of the genus Bostrychus. *IOP Conference Series. Earth and Environtal Science,* 1191(1):012005. doi:10.1088/1755-1315/1191/1/012005.

Hong, A.H., Hargan, K.E., Williams, B., Nuangsaeng, B., Siriwong, S., Tassawad, P., Chaiharn, C., & Los Huertos, M. (2020). Examining molluscs as bioindicators of shrimp aquaculture effluent contamination in a southeast Asian mangrove. *Ecological indicator,* 115, 106365. doi:10.1016/j.ecolind.2020.106365.

Ikejima K., Tongnunui P., Medej T., & Taniuchi T. (2003). Juvenile and small fishes in a mangrove estuary in Trang Province, Thailand: seasonal and habitat differences. *Estuarine, Coastal and Shelf Science,* 56(3–4), 447–457. doi:10.1016/S0272-7714(02)00194-4.

Kottelat, M. (2013). The Fishes of the Inland Waters of Southeast Asia : a Catalogue and Core Bibliography of the Fishes Known to Occur in Freshwaters, Mangroves and Estuaries. *The Raffles Bulletin of Zoology,* Suppl. 27, 1-663

Mancini, P.L., da Costa, T.V.V., Dias, .RA., Silveira, L.F., & Schunck, F. (2023). Mangrove and salt marsh migratory and resident birds. *in* Schaeffer-Novelli Y, Abuchahla, GMdO, Cintron-Morelo, G (ed.). *Brazilian Mangroves and Salt Marshes*. Springer, Cham. pp. 233–280.

Manullang, H.M., & Khairul. 2020. Monitoring biodiversitas ikan sebagai bioindikator kesehatan lingkungan di ekosistem sungai Belawan. *Jurnal Ilmu Alam dan Lingkungan,* 11(2), 1–7.

Margalef, R. (1958). Information theory in ecology. *General Systems,* 3:36–71.

Marlianingrum, P.R., Kusumastanto, T., Adrianto, L., & Fahrudin, A. (2021). Valuing habitat quality for managing mangrove ecosystem services in coastal Tangerang District, Indonesia. *Marine Policy,* 133. doi:10.1016/j.marpol.2021.104747.

Middleton, L., Astuti, P., Nurokhmah, S., Brown, B.M., Thilsted, S., Brimblecombe, J., & Stacey, N. (2025). Seasonal nutrient contribution of mangrove aquatic foods to fisher households in West Kalimantan, Indonesia. *BMC Public Health*, 25(1764). doi.org/10.1186/s12889-025-21952-9

Mustafa, M.G., Rajaee, A.H., Hamli, H., & Rahim, K.A.A. (2023). Body indices and population dynamics of *Setipinna breviceps* (Cantor, 1849) from Batang Lassa estuary, Sarawak, Malaysia. *Borneo Journal of Resource Science and Technology,* 13(1), 120–131. doi:10.33736/bjrst.4943.2023.

Beh, J.H.M., Sadio, O., Mbega J.D., Tchinga G., Tsinga F., Leboulanger C., Frida B.R.L., Luis T.d.M, & Loc'h F.L. (2023). Spatial and temporal structure of the fish assemblage in Akanda National Park (Gabon), an equatorial mangrove estuary. *Regional Studies in Marine Science,* 59, 10289. doi:10.1016/j.rsma.2022.102805.

Nanjo, K., Kohno, H., Nakamura, Y., Horinouchi, M., & Sano, M. (2014). Effects of mangrove structure on fish distribution patterns and predation risks. *Journal of Experimental Marine Biology and Ecology,* 46, 216–225. doi:10.1016/j.jembe.2014.08.014.

Nasir, A.S.A., Mohamad, S., & Mohidin, M. (2017). The first reported artificial propagation of yellow puffer, *Xenopterus naritus* (Richardson, 1848) from Sarawak, Northwestern Borneo. *Aquaculture Research,* 48(8), 4582–4589. doi:10.1111/are.13103.

Park B.K., Jang, W.J., Park, K-H., Lee, H-S., Lee, W-O, Choi, K-S., & Lee, J. (2021). Tetrodotoxin and its analogs: a review of analysis methods and levels in pufferfish. *Journal of Food Hygiene and Safety,* 36(2), 105–117. doi:10.13103/jfhs.2021.36.2.105.

Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology,* 13(C), 131–144. doi:10.1016/0022-5193(66)90013-0.

Podder, A., Panja, S., Chaudhuri, A., Roy, A., Biswas, M., & Homechaudhuri, S. (2021). Patterns of morphological traits shaping the feeding guilds in the intertidal mudflat fishes of the Indian Sundarbans. *Journal of Fish Biology,* 99(3), 1010–1031. doi:10.1111/jfb.14800.

Rahman, Lokollo, F.F., Manuputty, G.D., Hukubun, R.D., Krisye, Maryono, Wawo, M., & Wardiatno, Y. (2024). A review on the biodiversity and conservation of mangrove ecosystems in Indonesia. *Biodiversity and Conservation,* 33(3), 875–903. doi:10.1007/s10531-023-02767-9.

Rainboth, W.J. (1996). *Fishes of the Cambodian Mekong.* FAO species identification field guide for fishery purposes. FAO. Rome. p. 265.

Ritonga, I.R., Bureekul, S., Luadnakrob, P., & Sompongchaiyakul, P. (2023). Status level of total mercury (T-Hg) in barracuda (*Sphyraena putnamae*) from the Gulf of Thailand. *Trends in Sciences***,** 20(8). 5353. doi:10.48048/tis.2023.5353.

Rohim, N., Sulistiono, S., Yulianda, F., & Muhtadi, A. (2024). Diversity and ecological drivers of fish in Singkil Swamp Wildlife Reserve, Aceh, Indonesia. *Biodiversitas,* 25(7), 2849-2856. doi:10.13057/biodiv/d250706.

Salim, G., Indarjo, A., Mujiyanto, M., Sugianti, Y., Anggoro, S., Ransangan, J., Nawir, D., Meiryani, Hartinah, S., Nurjanah, *et al.* (2024). Growth and mortality model of Chacunda gizzard shad *Anodontostoma chacunda* (Bleeker, 1852) in Tarakan waters, North Kalimantan, Indonesia. *Biodiversitas,* 25(2), 770–780. doi:10.13057/biodiv/d250237.

Setiawan, H., Mursidin, Purbarani, D., & Wulandari, T.A. (2019). Keragaman ikan di perairan ekosistem mangrove Desa Karangsong, Kabupaten Indramayu. *Prosidings Simposium Nasional Kelautan dan Perikananan, VI.* 137–146.

Seygita, V., Sulistiono, Kusmana, C., & Yulianto, G. (2022). Mangroves and the sustainability of longtail shad fish (*Tenualosa macroura*) in Riau Province Water, Indonesia. *Int. J. Adv. Sci. Eng. Inf. Technol.* 12(5):1744–1755.doi:10.18517/ijaseit.12.5.17421.

Shannon, C.E., & Weaver, W. (1998). *The Mathematical Theory of Communication*. University of Illinois Press.

Sheaves, M., Dingle, L., & Mattone, C. (2016). Biotic hotspots in mangrove-dominated estuaries: macro-invertebrate aggregation in unvegetated lower intertidal flats. *Marine Ecology Progress Series,* 556, 31–43. doi:10.3354/meps11860

Sihombing, V.S., Gunawan, H., & Sawitri, R. (2017). Diversity and community structure of fish, plankton and benthos in Karangsong Mangrove Conservation Areas, Indramayu, West Java, Indonesia. *Biodiversitas: Journal of Biological Diversity,* 18(2), 601–608. doi:10.13057/biodiv/d180222.

Simpson, E.H. (1949). Measurement of diversity. *Nature*, 163, 688. doi:https://doi.org/10.1038/163688a0.

Sisriany, S., Sulistyantara, B., & Budiarti, T. (2021). Multicriteria potential mapping for mangrove ecotourism in Batu Ampar, West Kalimantan. IOP Conference Series: Earth and Environmental Science, Volume 879, The 5th International Symposium of Sustainable Landscape Development (The 5th ISSLD) 22nd-24th September 2020, Bogor City, Indonesia, 879, 12023. doi:10.1088/1755-1315/879/1/012023.

Sorensen, T. (1948). *A Method of Establishing Groups of Equal Amplitude in Plant Sociology Based on Similarity of Species Content* and Its Application to Analyses of the Vegetation on Danish Commons. *Det Kongelige Danske Videnskabernes Selskab*, V(4). Bianco Lunos Bogtrykkeri

Syafariyah, N.K., Sulmartiwi, L., & Budi, D.S. (2023). Incubation temperature effects on some hatching parameters of silver rasbora (*Rasbora argyrotaenia*) egg. *Journal of Applied Aquaculture,* 35(1), 16–26. doi:10.1080/10454438.2021.1928580.

Tan, W., Liu, J., Wang, Y., Liu, H., Ke, H., Fan, J., Fu, S., Luo, M., Liu, L., Chen, F., *et al.* (2019). Complete mitochondrial genome of Buffon's river garfish *Zenarchopterus buffonis* (Valenciennes, 1847). *Mitochondrial DNA Part B,* 4(1), 2001–2002. doi:10.1080/23802359.2019.1617087.

Tarimo, B., Winder, M., Mtolera, M.S.P., Muhando, C.A., & Gullström, M. (2022). Seasonal distribution of fish larvae in mangrove-seagrass seascapes of Zanzibar (Tanzania). *Scientific Report,* 12, 4196. doi:10.1038/s41598-022-07931-9.

Thornton, S.A., Dudin, Page, S.E., Upton, C., & Harrison, M.E. (2018). Peatland fish of Sebangau, Borneo: Diversity, monitoring and conservation. *Mires*

Peat, 22(04). 1–25. doi:10.19189/MaP.2017.OMB.313.

Tiamsai, R., Waiprib, Y., Runglerdkriangkrai, J., & Somjit, K. (2022). Optimal level of added salt to minimize the risk of associated chemical hazards of small-sized anchovy (*Stolephorus indicus*) stored at ambient and refrigerated temperatures. *Agriculture and Natural Resources,* 56(1), 9–22. doi:10.34044/j.anres.2021.56.1.02.

Utama, R.S., Renyaan, J., Nurdiansah, D., Makatipu, P.C., Suyadi, Hapsari B.W., Rahayu, E.M.D., Sugiharto, A., & Akbar, N. (2022). Diversity of reef fish species in presence of mangrove habitat in Ternate, North Maluku, Indonesia. *Biodiversitas*, 23(10), 5184–5193. doi:10.13057/biodiv/d231026.

Verma, H.O., Verma, S.K., Mishra, S.K., Alam, A., Das, S.C.S., Thakur, V., Kumar, J., Jha, D.N., Srivastava, R.S., & Das, B.K. (2018). Length-weight relationships of *Johnius coitor* (Hamilton, 1822), *Osteobrama cotio* (Hamilton, 1822), and *Gonialosa manmina* (Hamilton, 1822), from the River Ganga, India. *Journal of Applied Ichthyology,* 34(6), 1361–1363. doi:10.1111/jai.13800.

Wahyudewantoro, G. (2018). The fish diversity of mangrove waters in Lombok Island, West Nusa Tenggara, Indonesia. *Biodiversitas,* 19(1), 71–76. doi:10.13057/biodiv/d190112.

Xiong, W., Zhu, G.P., Wang, Z.L., & Ye, N. (2018). Length-weight relationships of four fish species from mangrove of Zhanjiang, China. *Jornal of Applied Ichthyology,* 34(1), 167–168. doi:10.1111/jai.13516.

Yahya, N., Idris, I., Rosli, N.S., & Bachok, Z. (2020). Mangrove-associated bivalves in Southeast Asia: a review. *Regional Studies in Marine Science,* 38, 101382. doi:10.1016/j.rsma.2020.101382.

Yang, M., Yang, Z., Liu, C., Lee, X., & Zhu, K. (2022). Characterization of the complete mitochondrial genome of the spotted catfish *Arius maculatus* (Thunberg, 1792) and its phylogenetic implications. *Genes (Basel).* 13(11). doi:10.3390/genes13112128.

Yuniar, A.T., Palm, H.W., & Walter, T. (2007). Crustacean fish parasites from Segara Anakan Lagoon, Java, Indonesia. *Parasitology Research,* 100(6), 1193–1204. doi:10.1007/s00436-006-0391-9.

Zagars, M., Ikejima, K., Kasai, A., Arai, N., & Tongnunui, P. (2013). Trophic characteristics of a mangrove fish community in Southwest Thailand: important mangrove contribution and intraspecies feeding variability. *Estuarine, Coastal and Shelf Science,* 119, 145–152. doi:10.1016/j.ecss.2013.01.005.

Zhang, Y., Ding, Y., Wang, W., Li, Y., & Wang, M. (2019). Distribution of fish among Avicennia and Sonneratia microhabitats in a tropical mangrove ecosystem in South China. *Echosphere,* 10(6), e02759. doi:https://doi.org/10.1002/ecs2.2759.