

# Community Structure and Fish Diversity in Some Mangrove Ecosystems with Varying Levels of Naturalness and Human Activity on Bawean Island, East Java, Indonesia

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**Abstract.** The research aimed to evaluate the quality of some mangrove ecosystems on Bawean Island with varying levels of naturalness and human activity through community structure and diversity of fish species. Sampling was carried out in 11 mangrove ecosystems of Sawahmulya, Sungai Rujing, Hijau Daun, Sidogedungbatu, Pamona, Pasir Putih, Bangsal, Dekatagung, Jherat Lanjheng, Lebak and Pulau Cina. Fish were collected using the net (pore size 5 mm) and visual encounter method. Fish found were identified then the abundance of each species was used to determine the total abundance, taxa richness, and some indices of diversity, dominance, and evenness. Results showed that there were 18 fish species we found in all locations with varying taxa richness in each mangrove ecosystem. The total abundance of mangrove fish is in the range of 61-165 Idiv/25m<sup>2</sup>. All the research sites show a low value (less than 1) in the Diversity Index of Shannon Wiener, low evenness (0.02-0.07), and high variation of dominance Index (0.26-0.94). The higher the level of naturalness and the lower the hemeroby Index, it was found to have an impact on the higher diversity, taxa richness, and evenness of fish. This research indicated that the quality of some mangrove ecosystems on Bawean Island was still low and needed to be managed.

## 1 Introduction

The mangrove ecosystem is located in the intertidal zone and is often found along tropical and subtropical coastlines, including in Indonesia. The role of mangrove vegetation in the environment, especially as a provider of carbon stock, is almost the same as tropical rainforests [1-3]. Apart from having a conservation function as protecting the coast from

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waves, storms, floods, and abrasion, inhibiting seawater intrusion, as well as trapping or localizing sediment, the mangrove ecosystem also has provisioning services, especially as a feeding, nursery, and spawning ground for organisms in the mangrove ecosystem and its surroundings, especially fish [4, 5].

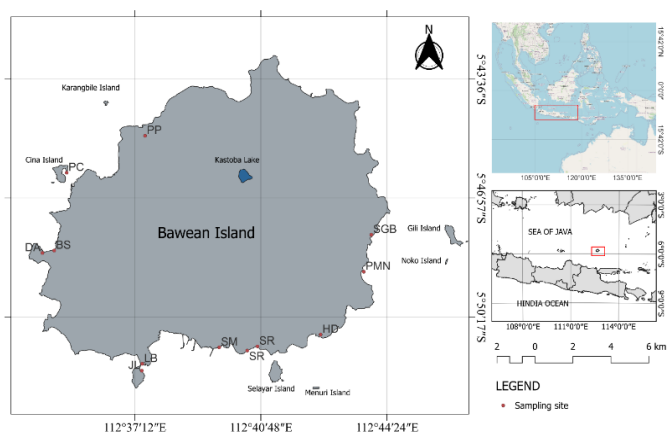
However, the function of mangrove ecosystem services in Indonesia is currently decreasing due to anthropogenic activities around the ecosystem such as the conversion of land into settlements, agriculture, aquaculture, industry, tourism, coastal development, illegal logging for firewood, charcoal and commercial purposes. as well as environmental pollution and climate change [6-9]. A similar case occurred in the mangrove ecosystem of East Java that was found to be deforested and its area decreased from 57,500 Ha to 22,700 Ha in 2008 and continued to decline to 11,800 Ha in 2019 [10-13].

Degradation of mangrove ecosystems can impact changes in the quality of aquatic habitats and will greatly affect the structure of the community as well as the diversity of biota that live in the ecosystem, such as fish [14]. On the coast of Bawean Island, Gresik Regency, East Java, many mangrove ecosystems are found. However, there was no report on the quality of the mangrove ecosystem on Bawean Island. Therefore, the objective of this research was to evaluate some mangrove ecosystems found on Bawean Island with varying levels of naturalness and human activity through the structure of the fish community and its diversity as provisioning services. The result of this research can be adopted as a basis for recommendations for mangrove ecosystem management on Bawean Island.

## 2 Materials and methods

### 2.1 Study site

The research was conducted in July-September 2023. Eleven mangrove ecosystems located on the Bawean Island, Gresik district, East Java Province, Indonesia including Sawahmulya, Sungai Rujing, Hijau Daun, Sidogedungbatu, Pamona, Pasir Putih, Bangsal, Dekatagung, Jherat Lanjheng, Lebak and Pulau Cina (Fig. 1) were determined to analyze the structure of fish community and its diversity. Fish were identified at the Ecology and Restoration of Tropical Ecosystem Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya Malang.



**Fig. 1.** Sampling Research Location (Note: SGB=Sidogedungbatu, PMN=Pamona, HD=Hijau Daun, SR=Sungai Rujing, SM=Sawahmulya, LB=Lebak, JL=Jherat Lanjheng, DA=Dekatagung, BS=Bangsal, PC=Pulau Cina, PP=Pasir Putih)

## 2.2 Fish sampling methods and environmental quality monitoring

Fish sampling and environmental quality monitoring in each mangrove ecosystem were carried out randomly at two to three locations as replications. Mangrove fish sampling was carried out in transect plots measuring 5 m x 5 m using double gill nets and fishing nets with pore size of 5 mm. Besides that, the structure of the fish community was also observed directly using the visual encounter method. The samples obtained were then stored in a collection bottle and given a 70% alcohol solution and labeled with the date, time and location according to the time of observation. Meanwhile, observations of environmental factors include land use conditions around the mangrove ecosystem and human activities using the naturalness index [15] and the hemeroby index [16].

## 2.3 Data analysis

The species abundance from all stations was compiled and used to determine the total density/abundance, taxa richness, and Importance Value Index (IVI). Some of the indices were also determined including (1) Diversity Index of Shannon-Wiener ( $H'$ ) with the following equation.

$$H' = -\sum_{i=1}^s Pi^2 \log \log Pi \quad (1)$$

where  $H'$  is the diversity index of Shannon-Wiener,  $s$  is the total number of species, and  $Pi$  is the proportion abundance of each species to the total abundance of all species, (2) Index of Evenness ( $E$ ) with the following equation.

$$E = \frac{H'}{H'_{max}} \quad (2)$$

where  $E$  is the index of evenness,  $H'_{max}$  is  $^2\text{Log } S$ , and  $H'$  is the diversity Index of Shannon-Wiener, and (3) Dominance Index of Simpson ( $D$ ) with the following equations.

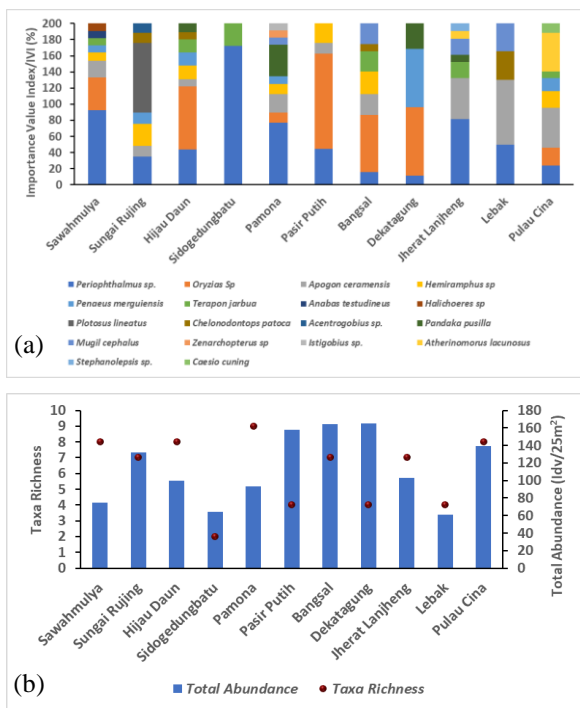
$$D = Ni(Ni - 1)/N(N - 1) \quad (3)$$

where  $D$  is the Simpson dominance index,  $Ni$  is the number of individuals of the  $i$  species, and  $N$  is the total number of individuals found.

The levels of naturalness and human activity (as seen from the hemeroby index) at each location were determined using descriptive analyses. The correlation between environmental factors (naturalness and hemeroby index) and structure community and diversity of mangrove fish was determined by principal component analysis (PCA) using PAST 4.05 software.

## 3 Results and discussions

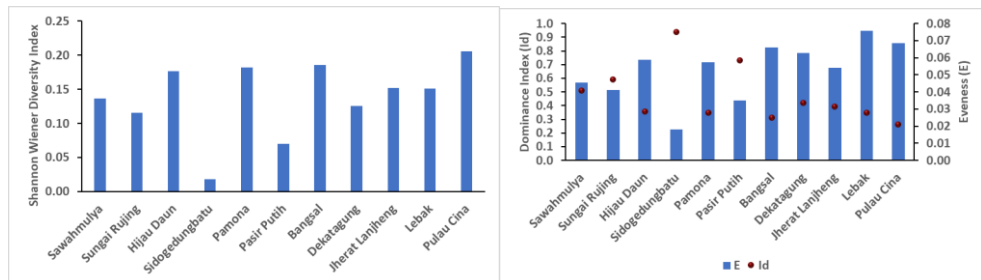
The results of monitoring fish communities in eleven mangrove ecosystems on Bawean Island found 18 fish species with varying taxa richness in each mangrove ecosystem. The fish species that were always found in all locations in the mangrove ecosystem was *Periophthalmus* sp. Meanwhile, *Apogon ceramensis*, *Oryzias* sp, *Hemiramphus* sp, *Penaeus merguensis*, and *Terapon jarbua* found in several mangrove ecosystems at sampling locations (Fig. 2). *Periophthalmus* is a species of mudskippers that is usually found in muddy habitats such as mangrove ecosystems which are classified as carnivores which main food is mangrove crabs *Uca* sp. [17]. Generally, the fish found in the Bawean Island mangrove ecosystem were larvae and juvenile fish. This is natural because mangroves have a functional role as a habitat for laying eggs, rearing, protection, and a feeding ground [4, 5, 18].



**Fig. 2.** Structure community of fish community in some mangrove ecosystems on Bawean Island, (a) Importance value Index and (b) taxa richness and total abundance

Eleven mangrove ecosystems of Bawean Island showed varying taxa richness and the total abundance of fish (Fig. 2). Taxa richness of fish ranges from 2-9 species while the total abundance of fish ranges from 61-165 individuals/25m<sup>2</sup>. Fish taxa richness in the Sidogedungbatu, Pasir Putih, Dekatagung and Lebak mangrove ecosystems was low (2-4 species) while in seven other mangrove ecosystems (Sawahmulya, Sungai Rujing, Hijau Daun, Pamona, Bangsal, Jherat Lanjheng and Pulau Cina) it was high, and ranges from 7-9 species. The total abundance of fish in Sawahmulya, Sidogedungbatu, Pamona and Lebak was low, ranging from 61-93 individuals/25 m<sup>2</sup>, while in other mangrove ecosystems, it was high and ranged from 103-165 individuals/25m<sup>2</sup>.

Research results showed that high taxa richness did not always correlate positively with the total abundance of fish found. This was influenced by the quality of the mangrove ecosystem habitat in supporting all the biota within it. A high total abundance of biota does not always indicate good ecosystem services, especially if the abundance is only dominated by one or a few particular species. Ecosystem services are high if the ecosystem can support higher species diversity with high species evenness and low dominance index. The level of fish community evenness in the 11 Bawean Island mangrove ecosystems was very low (0.018-0.076), while partial dominance was low to high with dominance Index values ranging from 0.263-0.938 (Fig. 3). This Simpson's dominance index is generally inversely proportional to the Index of evenness. The low value of the evenness Index and the high value of Simpson's dominance index indicated that the mangrove ecosystem on Bawean Island has a low supporting capacity for fish communities or it can be stated that the quality of the mangrove ecosystem on Bawean Island is generally low.



**Fig. 3.** Diversity, evenness and dominance indices of fish community in some mangrove ecosystems at Bawean Island

The low value of fish diversity also indicated the low quality of the mangrove ecosystem on Bawean Island on ecosystem services. The fish diversity value in the 11 mangrove ecosystems of Bawean Island ranges between 0.018-0.206 (Fig. 3). Diversity of fish in the mangrove ecosystem also depends on the evenness of species. The higher value of the evenness index results in the higher the diversity of fish species in the mangrove ecosystem [19].

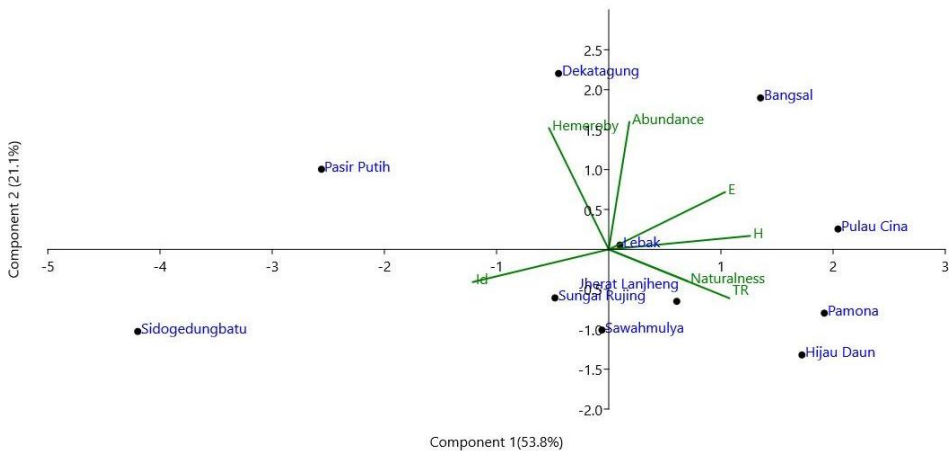
The low level of mangrove ecosystem services on Bawean Island is influenced by the level of naturalness and human activity around the mangrove ecosystem. The level of human disturbance in the Bawean Island mangrove ecosystem can be seen based on the hemeroby and naturalness index. The level of human disturbance to the 11 Bawean Island mangrove ecosystems varies. Based on hemeroby index, the mangrove ecosystem of Hijau Daun still has weakly influenced human activity and included in the category of  $\beta$ -mesohemerobic (2), whereas mangrove ecosystems of Sungai Rujing, Jherat Lanjheng dan Pulau Cina have moderately influenced level of disturbance and included in the category of  $\alpha$ -mesohemerobic (3). Mangrove ecosystems of Sawahmulya, Pamona, and Lebak are included in the category of euhemerobic (4) with strongly influenced by anthropogenic activity. Mangrove ecosystems of Sidogedungbatu, and Pasir Putih are included in the polyhemerobic category (5) and very strongly influenced by anthropogenic activity, whereas mangrove ecosystems of Bangsal and Dekatagung are extremely disturbed by anthropogenic activity so it is included in the category of metahemerobic (6). Ecosystems in the polyhemerobic and metahemerobic categories indicated high degradation of soil and vegetation caused by mechanical disturbance, and chemical disturbance [16].

Based on the naturalness index, Pamona had the best naturalness and was included in the semi-natural system category (6) while Hijau Daun which was the result of restoration and well-managed by NGOs was included in the category of cultural self-maintained system (5). Other mangrove ecosystems have a naturalness Index including the cultural assisted system category (4) and highly intervened system (3). The low level of naturalness in the Bawean Island mangrove ecosystem is caused by habitat fragmentation around the mangrove ecosystem moderately to very extended [15]. Besides that, much of the land around the mangrove ecosystem has been transformed or converted into residential areas, agriculture and plantations, which in turn can have an impact on the high level of pollutants entering the mangrove ecosystem habitat, both from anthropogenic waste and synthetic fertilizers and pesticides [20, 21]. Mangrove vegetation can significantly affect water quality in the mangrove ecosystem, whereas if anthropogenic activity in the ecosystem is high, it can have an impact on reducing water quality [22].

Eleven mangrove ecosystems on Bawean Island can be grouped based on provisioning services in the form of community structure and fish diversity as well as their interactions with environmental factors based on naturalness and hemeroby indices using biplot analysis

from principal components analysis (PCA) (Fig. 4). From this figure, it can be seen that PC1 and PC2 were able to explain 74.9% of the data variance.

Mangrove ecosystem of Pulau Cina, Pamona and Hijau Daun are one group that has the best quality, characterized by the highest fish diversity index (0.18-0.21), taxa richness (8-9 species), evenness (0.06-0.08) and the lowest dominance Index (0.0. 26-0.35) with a high level of ecosystem naturalness (4-6) and low to moderate anthropogenic activity (hemeroby index 2-4). The mangrove ecosystem of Sawahmulya, Sungai Rujing, Lebak, and Jherat Lanjheng have medium quality with a fish diversity index of 0.12-0.15, taxa richness of 4-8 species, evenness of 0.04-0.08, dominance index of 0.35-0.59, naturalness and hemeroby index of 3-4. Mangrove of Sidogedungbatu and Pasir Putih have the lowest quality with a diversity Index of 0.02-0.07, evenness of 0.02-0.04, the highest dominance index (0.73-0.94), a naturalness index of 3-4 and a hemeroby index of 5. Mangrove ecosystem of Bangsal and Dekatagung are a group with different characteristics which was characterized by the highest total abundance of fish and the highest hemeroby index. Even though human activity is the highest (hemeroby index 6), the naturalness of this ecosystem is moderate (4) so it was able to support the highest fish abundance (164-165 individuals/25m<sup>2</sup> with a diversity index of 0.13-0.19, evenness of 0.06-0.07 and a dominance index of 0.3-0.4.



**Fig. 4.** Grouping of the quality profiles of 11 Bawean Island mangrove ecosystems based on community structure and fish diversity, naturalness and hemeroby Index using biplot analysis from PCA

Biplot analysis, also showed that the increase in mangrove ecosystem services is significantly influenced by the level of naturalness of the ecosystem and also anthropogenic activities around the ecosystem. The higher the naturalness index and the lower the anthropogenic activity can improve mangrove ecosystem services as indicated by the higher diversity, evenness and taxa richness of fish and the lower fish species dominance Index. Thus, to improve the quality of the mangrove ecosystem on Bawean Island, good management is needed to maintain the naturalness of mangrove vegetation, which can be done through planting activities and also controlling human activities around it. This needs to be done because mangrove vegetation plays a role in preventing eutrophication of waters [23]. Besides of that, mangrove vegetation also plays a role in the bioremediation of heavy metals and oil in waters [24-26]. With good water quality in the mangrove ecosystem, it will then become a suitable habitat to support the biota within it, including fish.

## 4 Conclusions

We found 18 fish species in 11 mangrove ecosystems of Bawean Island with different taxa richness at each location. *Periophthalmus* sp. always be found at all research locations. The total abundance of mangrove fish in each location was in the range of 61-165 individuals/25m<sup>2</sup> and showed a low diversity Index of Shannon Wiener which was less than 1. Eleven sites also showed a high variation of dominance Index (0.26-0.94), and low evenness index (0.02-0.07). The low value of diversity and evenness indices indicated that the quality of the mangrove ecosystem in Bawean Island categorized as poor because of anthropogenic activity in the surrounding of this ecosystem. The higher the level of naturalness and the lower the hemeroby Index, it was found to have an impact on the higher diversity, taxa richness and evenness of fish.

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