Diversity of fish in different habitat type in urban mangrove estuaries Wonorejo, Surabaya – Indonesia

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Abstract. Mangroves are vegetation that have morphological adaptation in root type to grow in coastal area. This root type adaptation makes mangrove provide habitat for various fauna. In this study we compare fish abundance in three types of mangrove habitat (vegetated area, mangrove fringe area and mangrove sea area) in urban mangrove estuaries area of Wonorejo, Surabaya – Indonesia. A total of 26 species fish species in 17 families were collected. In terms of number of species per family, Engraulidae was the most diverse (7 species), followed by Carangidae (3 species). ANOVA analysis showed that fish abundance varies significantly in three different mangrove habitat types. Habitat type that have highest diversity of fish is mangrove sea area, followed by fringe mangrove area and vegetated area. Some specific species exclusively recorded in certain habitat type, 10 species occurring exclusively in the mangrove sea area, 7 species occurring exclusively in the mangrove fringe area but there is no fish species that exclusively occur in vegetated area. The results indicate that urban mangrove estuary area in Wonorejo has potentially provide habitat for fish, but this potency was combined by a connection of vegetated area, mangrove fringe area and mangrove sea area, not only by vegetated area.

1. Introduction

Mangrove ecosystems are coastal transition ecosystems that occur in the tropics and several subtropical regions [1]. Because of its position in the coastal area, mangroves have several different morphological adaptations from terrestrial plants [2]. One of them is the form of mangrove roots that adapt to grow in coastal sediments that tend to be unstable, shallow, anoxic and salted [3]. Various forms of mangrove roots include buttress root, knee root, pneumatophore root to prop (stilt) root [4]. The forms of mangrove roots make mangrove vegetation into structurally complex vegetation [5]. The structural complexity of mangrove roots can increase the surface area available for colonization of epiphytic organisms which are a food source for nekton can also provide protection from predation activity. In addition, mangrove roots can also be a buffer against waves, storms, winds to sea water intrusion in coastal areas [6, 7, 8]. Through the ecological functions that can be provided by mangrove roots makes it utilized by various marine biota taxa [5].

One of the faunas that utilizes mangrove roots in its life cycle is fish by using it as a place for breeding, spawning, nursery areas and dwellings, feeding grounds, and shelter) [9]. As a fish care area, mangroves play a major role in the survival and juvenile growth of fish. The juvenile phase is a critical phase (critical period) in fish development. This relates to food and predation (food and feeding), predator detection and ability to escape (predator detection and escape) and habitat shift (habitat shift) [11]. Because of their vulnerability to predatory activity, the nursery area must be able to provide...
juvenile fish protection functions from predators. So that the availability of protective functions from predators can then increase the survival of juvenile fish [11].

With the protection provided by mangroves, its effectiveness as an upbringing area increases. Furthermore, increasing the effectiveness of the care area will improve the survival of juvenile fish individuals and can increase the population of marine fisheries stocks [12, 13, 14]. The success of mangroves as an upbringing area is demonstrated by the high abundance and structure of coral reef fish communities in areas with wider mangrove forests [15, 7, 16].

The Wonorejo mangrove forest conservation area is one of the conservation areas to the east of Surabaya City. Aside from being a conservation area, the coastal area and waters of Wonorejo are also designated as capture fisheries and aquaculture areas. There are at least 45 fishermen who use Wonorejo waters in fishing activities. Where are the types of economical fish caught include Ponyfish (family Leiognathidae), Ariid catfish (family Ariidae), Snapper (family Lutjanidae), Croaker (*Johnius trachycephalus*), Mullets (family Mugilidae), Anchovy (family Engraulidae), to Hairtail fish (*Trichiurus lepturus*) [17]. So that the Wonorejo mangrove forest area is thought to play a role as a juvenile fish protection area from predatory fish and play a role in the success of marine fish recruitment, this encourages this study to analyze more deeply the complexity of the structure of mangrove roots as an area of fish protection against predators, especially in mangrove forest areas in Wonorejo - Surabaya.

2. Material and methods

2.1. Site description

The study was conducted in urban mangrove area of Wonorejo, an east coast mangrove of Surabaya – Indonesia. This urban mangrove area dominated by *Avicennia marina, A. alba, Sonneratia alba, Rhizophora mucronata* and *R. stylosa* with tree density is approximately 3333 tree/ha, with a large estuary near it (as shown in Figure 1). With those dominated mangrove tree species, the sampling sites has mixed mangrove root system, with different level of complexity each site (habitat type).

2.2. Sampling methods

Sample collections were conducted each two weeks from December 2019 to January 2020 three times. Three type of habitats, namely inside area of mangroves (DM), fringe area of mangrove (TM) and open sea of mangrove (LM). The specimens were collected by traditional fish trap called bubu that has umbrella form (mesh-size 1 cm, bottom diameter 90 cm, height 35 cm and has 8 oval holes sizes 20 cm of length and 12 cm of height), cast net (3-5 meter of diameter when open and ±1 cm mesh-size), gill net (1x30 meter in dimension and ±2 inch mesh-size) and scoop net (0,5 cm mesh size). Because of the vegetation, bubu and scoop net used in DM site while cast net and gill net used in TM and LM site. At each habitat type (each site), three replicate samples were obtained. All gear used in high tide during the day.

Fish sample were sorted and separated by the species and size in laboratory. Number of individuals of each species were counted. Identification to the level of species made use of the following sources: Allen and Steene (1994), Rainboth (1996), Carpenter and Niem (1998), Allen et al. (2000), Kuiter and Tonozuka (2001) and Peristiwady (2006).

2.3. Data analysis

One-way analysis of variance (ANOVA) used and followed by Tukey’s HSD test (both at p = 0,05) to compare the differences in fish abundance and species richness among habitat type. Species richness (S) was represented as the number of species in particular location and period; while diversity was expressed by Shannon-Wiener index:

\[ H' = - \sum_{i} \left( \frac{n_{i}}{n} \right) \ln \left( \frac{n_{i}}{n} \right) \]  

Where \( H' \) is the Shannon -Wiener diversity index; \( n_{i} \) is the number of individu of species-\( i \) and \( n \) is the total of specimen number in the sample.
3. Results and discussion
A total of 318 individual fish caught consisting of 26 species and 17 different families have been found at three habitat types in the urban mangrove of Wonorejo, Surabaya during the three sampling periods. Analysis of fish in abundance, number of species and fish phase (juvenile and adult will be discussed further in the following sections.

3.1. Fish composition and abundance by its phase
The results of observing the growth phase of fish for three periods at three sampling stations found 119 juvenile fish individuals (37.42%) and 199 adult fish individuals (62.58%). There are 14 species of fish that are found only in the juvenile phase, namely *Anabas testudineus*, *Alepes kleinii*, *Alepes djedaba*, *Scomberoides commersonnianus*, *Anodontostoma chacunda*, *Symphurus plagiua*, *Stolephorus indicus*, *Stolephorus insularis*, *Thryssa kammalensis*, *Thryssa mystax*, *Pomadasys argenteus*, *Leiognathus equulus*, *Eleutheronema tetradactylum* and *Terapon jarbua* (Figure 1). Species of fish that were only found in the juvenile phase with the highest abundance were *P. argenteus* (Silver grunt) with a total abundance of 35 individuals and *E. tetradactylum* (Fourfinger threadfin) of 11 individuals. While other species are found between 1 to 3 individuals. *P. argenteus* is a demersal carnivorous species that is commonly found in coastal waters with smooth mud substrates [18]. The species reproduces and lays eggs in offshore areas and afterwards will return to areas near the coast to find food. Eggs in the offshore area will hatch and become larvae which will be carried by currents to areas near the coast and estuaries which then develop into juveniles [19, 18]. In contrast to *E. tetradactylum* which is a pelagic carnivorous species living in shallow coastal areas with a depth of 20 to 100 meters. Adult *E. tetradactylum* reproduces in the estuary area when salinity levels increase. Juvenile *E. tetradactylum* prefers and colonizes in shallow waters, warm temperatures, without vegetation, relatively high salinity and low predation pressure [20]. So that in the study area, *P. argenteus* and *E. tetradactylum* are found in the juvenile phase.

![Abundance diagram of each fish species found only in the juvenile phase at three sampling stations during the three sampling periods. Abbreviation: At. *Anabas testudineus*; Ak. *Alepes kleinii*; Ad. *Alepes djedaba*; Scom. *Scomberoides commersonnianus*; Ac. *Anodontostoma chacunda*; Sp. *Symphurus plagiua*; Sind. *Stolephorus indicus*; Sins. *Stolephorus insularis*; Tk. *Thryssa kammalensis*; Tm. *Thryssa mystax*; Pa. *Pomadasys argenteus*; Le. *Leiognathus equulus*; Et. *Eleutheronema tetradactylum* and Tj. *Terapon jarbua.*](image-url)
Six species were found in both juvenile and adult phases, namely *Ambassis nakensis*, *Stolephorus commersonnii*, *Thryssa hamiltonii*, *Ilisha megaloptera*, *Scatophagus argus* and *Johnius belangerii* (Figure 2). Fish species found in the juvenile and adult phases with the highest abundance are *I. megaloptera* (Bigaya ilisha) with a total abundance of 28 individuals (26 individuals in the juvenile phase and 2 individuals in the adult phase), while other species are found between 3 to 22 individuals. *Ilisha megaloptera* is a pelagic carnivorous fish species that lives in coastal areas, especially in estuary areas. Small juvenile *Ilisha megaloptera* (standard length <3 cm) tends to be found in estuary areas, whereas large juvenile *I. megaloptera* (standard length 6-9 cm) tends to be found in coastal waters with lower salinity (1-5 ‰) [21].

![Figure 2](image-url) An abundance diagram of each fish species found in the juvenile and adult phases at three sampling stations over three sampling periods. Abbreviation: Ab. *Ambassis buruensis*; Sc. *Stolephorus commersonnii*; Th. *Thryssa hamiltonii*; Im. *Ilisha megaloptera*; Sar. *Scatophagus argus* and Jb. *Johnius belangerii*.

Fish species found in the adult phase consist of 6 species, namely *Mystus gulio*, *Sardinella albella*, *Lycengraulis poeyi*, *Planiliza subviridis*, *Trichopodus trichopterus* and *Dichotomyctere nigroviridis* (Figure 3). Adult fish species with the highest abundance are *S. albella* (Tembang Fish) with a total abundance of 95 individuals and *M. gulio* (Keting Fish) with 48 individuals, while other species are only found between 1 to 3 individuals. *S. albella* is one of the abundant and non-carnivorous species of pelagic that lives in tropical and subtropical coastal areas, especially in estuary areas [22]. Whereas *M. gulio* is a demersal carnivorous species that is commonly found in estuary areas with brackish water to river waters [23]. Both species are fish species that swim by forming groups (schooling). In general, pelagic fish groups such as the genus Sardinella form groups with densities of 0-300 individuals / 1000m³ [24] while adult *M. gulio* forms groups of 10 to 25 individuals [25]. So with these behaviors *S. albella* and *M. gulio* dominate fish catches with nets.
3.2. Fish abundance by its habitat type

The observations at three sampling stations during the three sampling periods showed different results both in individual abundance, number of species, fish phase and eating habits. Figure 4 shows a graph of total fish abundance at three sampling stations over three sampling periods. When viewed through its total abundance, LM (open sea area) stations have the highest total fish abundance with a total abundance of 168 individuals, which is then followed by TM stations (mangrove and sea transition areas) and DM (areas in mangrove forests) with total fish abundance each is 139 and 11 individuals. The significance of the sampling station factor on the total abundance of fish can be seen through the One-Way ANOVA results in Table 1.
Table 1. Results of One-Way ANOVA sample station factors on total fish abundance.

| Source       | Type III Sum Squares | df  | Mean Square | F      | Sig. |
|--------------|----------------------|-----|-------------|--------|------|
| Habitat Type | 1529.852             | 2   | 764.926     | 15.502 | .000 |

The One-Way ANOVA results in Table 1 show that there are differences in the total abundance of fish at different stations (the significance value of each independent variable <0.05), with the significance value of the station variable on the total abundance of fish being 0.000. To find out which station has a significant difference in total fish abundance, further testing is needed. The follow-up test used was Post-Hoc Tukey HSD with a 95% confidence level.

![Figure 5](image)

**Figure 5.** Graph of average total fish abundance at different sampling stations. Abbreviations: DM. inside area of mangroves; TM. fringe area of mangrove; LM. open sea of mangrove. The letter notation above each bar shows a significant difference (p <0.05) in the Tukey HSD Post-Hoc test.

Figure 5 shows that between sampling stations have significant differences in the total abundance of fish. In areas within mangrove forests (DM), the total abundance of fish is much lower when compared to the mangrove-sea (TM) and open sea (LM) transition areas. This is not in accordance with the hypothesis and various studies that mention coastal habitats with vegetation support the existence of fish compared to coastal areas without vegetation. But the same thing was reported by [26] in Dongzhaiigang Bay - China which stated that the attraction of fish in vegetated areas was significantly lower when compared to areas without vegetation and rivers both in terms of average biomass, abundance, number of species and number of individuals of each species.

3.3. Diversity of fish

The calculation results from the Shannon-Wiener diversity index (H’) of each sampling location are presented in Figure 4.13. The diversity index value at the LM station is the highest H’ value (H’ = 2.22) compared to the other two stations (TM = 1.74 and DM = 0.47). The high value of diversity indexes illustrates that no species dominates at a location [27].
Species diversity can be used as a measure of community stability, namely the ability of community structures to not be affected by interference from its composition, therefore a stable community will have a high value of diversity [28]. Overall, fish diversity values in all sampling stations were in the low category ($H' < 2$) at the DM and TM stations to the high category ($2 \leq H' \leq 3$) at the LM station (Table 2).

**Table 2. Shannon-Wiener ($H'$) Values and Category Diversity Index**

| Habitat Type | $H'$  | $H'$ Category |
|--------------|-------|---------------|
| DM           | 0.47  | Low           |
| TM           | 1.74  | Low           |
| LM           | 2.22  | Middle        |

Abbreviations: DM. inside area of mangroves; TM. fringe area of mangrove; LM. open sea of mangrove.

4. **Conclusion**

The study investigates the role of different mangrove habitat type in fish diversity at Wonorejo-Surabaya. The results show that total of 26 species from 17 families found in the sampling station are composed of 37.42% juvenile fish and 62.58% adult fish. The most abundant species is *Sardinella albella* which is a pelagic fish that prefers open water (without vegetation); so there is a negative or inverse influence between the complexity of mangrove roots on the abundance and composition of fish. Most of the fish caught are pelagic fish (57.86%), so that the distribution of fish is not affected by the complexity of mangrove roots.

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