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Short Communication: Application of artificial reefs for fisheries enhancement in Probolinggo, Indonesia

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Abstract. *Isroni W, Samara SH, Santanumurti MB. 2019. Short Communication: Application of artificial reefs for fisheries enhancement in Probolinggo, Indonesia. Biodiversitas 20: 2273-2278.* Overfishing is one of the biggest challenges in the fisheries sector in Probolinggo, Indonesia. The fish apartment (artificial reefs) was one of the solutions to increase the fish resource since it serves as the habitat for fish to live, spawn, and search for food. In this study, the fish apartment was installed in Probolinggo (Karang Katon and Dringu Beach) from 2017 to 2018. This study showed that five fish species (*Caesio cuning*, *Acanthurus achilles*, *Acanthurus albipectoralis*, *Sphyraena jello*, and *Apagon novemfasciatus*) were found in Karang Katon while four species (*Chaetodon octofasciatus*, *Chromobotia macracanthus*, *Nemipterus japonicas*, and *Lates calcarifer*) lived in Dringu Beach. From a total of 333 fishes, *A. achilles* was the species with the highest composition level of 51.65% (172) in Karang Katon station. In Dringu Beach station, *C. octofasciatus* had the highest fish species composition level of 46% (183) from a total of 402 fishes. The diversity index and dominance index in Karang Katon station were low at-1.280 and 0.343, respectively. The diversity index and dominance index in Dringu Beach station were also low at -1.115 and 0.3503. *A. achilles* had the highest density of 34.4 ind/m^3 in Karang Katon station while *C. octofasciatus* had the highest species density of 36.6 ind/m^3 in Dringu Beach Station. From this study, it could be concluded that artificial reefs application enhanced the fisheries in Probolinggo, Indonesia, and help its sustainability.

Keywords: Density, diversity index, dominance index, fish apartment, Probolinggo

INTRODUCTION

Indonesia is known as an archipelagic country that consists of more than 17,000 small islands with a coastline of 81,000 km (Nikijuluw 2017). Consisting of mainly coastal areas, Indonesia has high marine and coastal potential such as marine fish. However, Indonesia faces overfishing problems. Overfishing is a serious problem because it reduces fishery production, causes conflict between fisheries actors, reduces community income, and damage the coastal communities (Muawanah et al. 2012).

Overfishing also occurs in Probolinggo, Indonesia. Probolinggo's capture fisheries experienced a production decline in 2017 compared to 2016, where the 2017 production was recorded at 19,239.80 tons while it was 19,740.78 tons in 2016 (Badan Pusat Statistik Probolinggo 2018). The decreasing fish resource is an impact of the increasingly intensive fishing activities. The use of non-environmentally friendly fishing gear, violation of fishing lanes, and decreased carrying capacity due to degradation of essential fish habitats are also the cause for the decreasing fish resource. The habitat is critical in sustaining fish resource reproduction because it functions as a spawning ground, nursery ground, and feeding areas (Bambang et al. 2011). Given this situation, one quick alternative to increase fish catches is by installing a fish apartment as artificial reefs.

The fish apartment is one of the tools intended to maintain the sustainability of fish resource utilization. It is a hollow structure composed of solid objects placed in the water which serves as a gathering place for organisms, especially fish. The installed fish apartment can increase fishing efficiency and natural productivity by providing new habitat for attaching organisms that contribute to the food chain as well as the target species. It can also protect small or juvenile organisms as a nursery ground and protect from waves, strong currents, and predators. Furthermore, it also increases the complexity of essential habitats, so it functions similar to the components of a physical reef environment (Pickering et al. 1998; Jensen 2002; McLean et al. 2014; Rendle and Rodwell 2014; Wu et al. 2015).

Based on its function, the fish apartments have been proven to be an artificial habitat that efficiently attracts fish and increase catches of the fishing communities (Kuhl 1992; Bombace et al. 1994; Pickering and Whitmarsh 1997; Brickhill et al. 2005; Creque et al. 2006; Dumont et al. 2011; Kelch 2012). In East Java, many studies showed that fish apartment had been used to enhance the fisheries sustainability (Yanuar and Aunurohim 2015; Fuad et al. 2016; Kamaali et al. 2017; Sabrini and Nugraha 2019).

Therefore, it is highly necessary to monitor the condition of existing fish apartments. The monitoring aims to assess the practical suitability of these devices, whether the fish apartments has an impact on the restoration of the fish resource ecosystem in the region. Eventually, this will lead to fish diversity in the area around the fish apartments in Probolinggo.

MATERIALS AND METHODS

Description of the study sites

This study was a survey study conducted in Karang Katon (113°12ˈ45.70" E and 7°41ˈ23 "S) and Dringu Beach (113^{0}15'57.89" E -7^{0}44'33.95"S and 113^{0}16'21.65" E-7^{0}45'7.96"S), Probolinggo District, East Java Province, Indonesia (Figure 1). The fish house location was determined as described in the previous study (Wibowo et al. 2016). The survey was conducted at a depth of 15 meters. The method used in this research was an Underwater Visual Census (UVC) survey (Puspitasari et al. 2013).

Fish apartment

The primary material used to build the fish apartment frames was Polypropylene (pp) type plastic. The polypropylene material was chosen because it was readily available and can be produced in the desired amount, relatively safe (non-toxic), insoluble in water, durable, and safe for humans and the environment (Bambang et al. 2011). The fish apartments were installed for one year from October 22nd, 2017 to October 22nd, 2018. The survey was conducted from October 23rd, 2018 to November 1st, 2018.

The fish apartment frames consisted of a vertical partition (35 cm x 35 cm) and horizontal partition measuring 35 cm x 35 cm. After the horizontal and vertical partition was formed, then the partition was arranged into a sub-module consisting of 4-5 partitions with a height of 175 cm. Four sub-modules were assembled and attached to weights 3kg with of sized 1100 mm x 125 mm x 125 mm made of size six iron and cast concrete and 6 mm PE rope for hooks. One fish apartment module consisted of 4 sub-modules which were put together with around 123 sets of the entire partition. The fish apartment design could be seen in Figure 2.

Data collection

The underwater visual census (UVC) method developed by Cappenberg (2009) was used to observe the condition of existing settlements for fish and aquatic organisms. The observation was conducted through diving and documented using Nikon Coolpix W300 (Japan) underwater camera. Recording of fish species and individuals were conducted by identifying the commodities that come across the transects.

The data collection used belt transects of slap rope type method placed in two locations (Karang Katon and Dringu) with 2 transects per site. The enclosed area was the fish house area. Each site was observed using visual techniques. The observed area per transect was 128 m x 500 m x 15 m.

Observation of the fish population was conducted through direct observation in water, focusing on areas per embedded module. Underwater observations were recorded and assisted by cameras for taking photos or videos.

The data obtained as either photos or videos were used to simplify the calculation and identify the fish species (Allen 1999) found in the fish apartment, which were then grouped by family. Data acquisition was processed to determine the value of species composition, density, fish diversity index, and species dominance index.

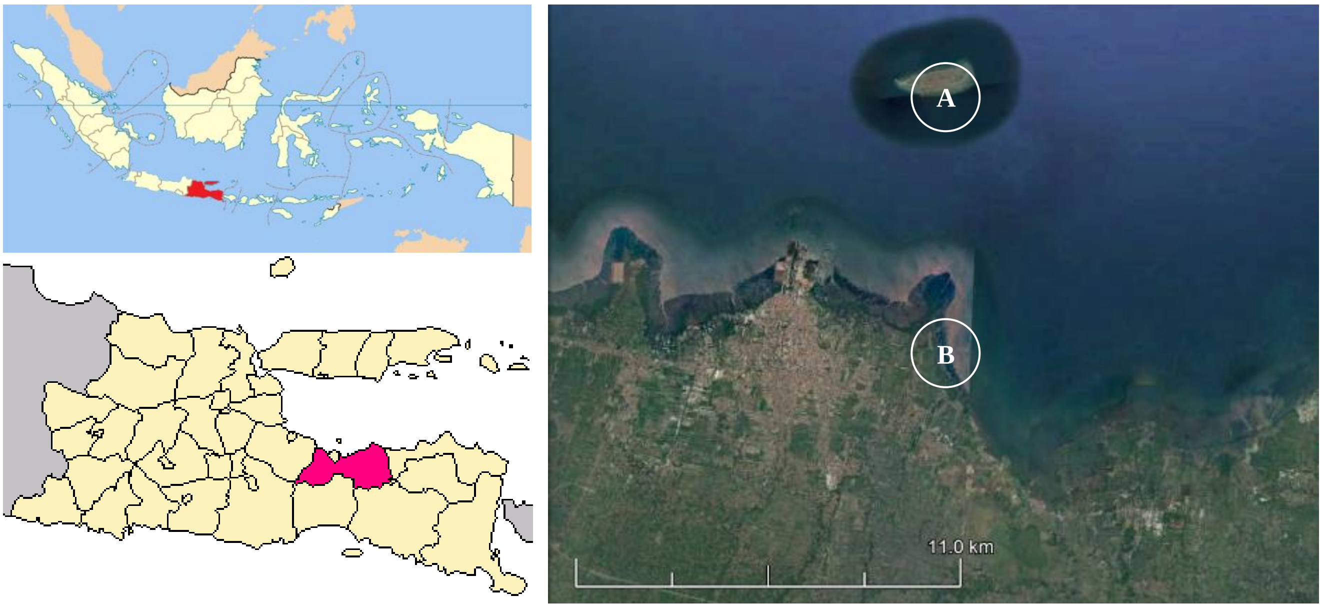

Figure 1. Sample point location of fish apartment in Probolinggo District, East Java Province, Indonesia. A. Karang Katon, B. Dringu Beach

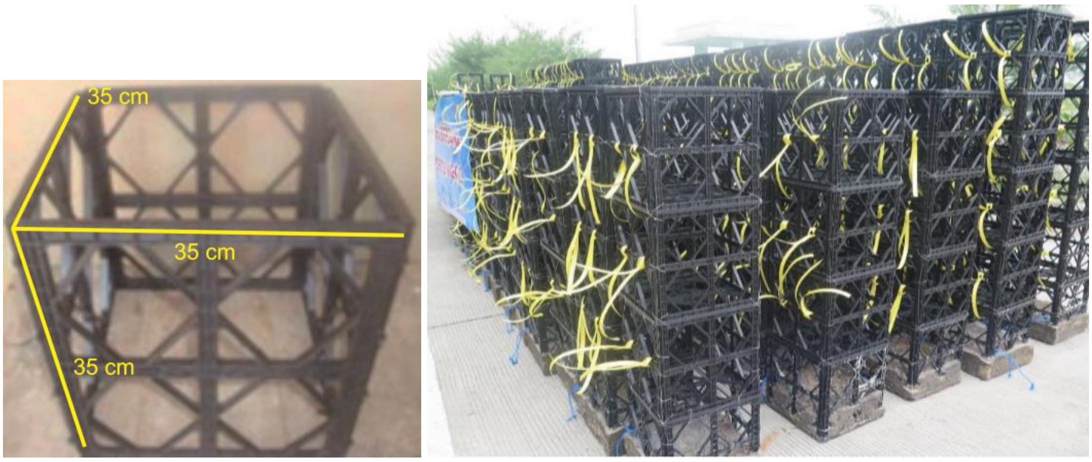

Figure 2. Fish apartment partition (*left*), fish apartment design (*right*)

Data analysis

The fish apartment success was measured by the parameters of fish species composition, density, diversity index, and dominance index. The analysis details were as follows:

Fish species composition. Fish species composition was the proportion of total fish for each species (Rappe 2010).

Density. Density was the number of individuals and the number of species found in the area of observation. The density of reef fish could be calculated using the following formula (Pope et al. 2010):

$$X = \frac{\sum Xi}{n}$$

Where: X: Fish density, Xi: Number of fish at location, n: Area of observation transect (m^3)

Diversity index. Diversity index was used to obtain a quantitative description of the organism's population (Odum 1971). This calculation could facilitate the analysis of information on the number of individuals in each reef fish community Diversity could be calculated using the following formula:

$$H' = \sum_{i=1}^{s} (Pi)\,(\ln pi)$$

Where: H': Shannon Wiener Diversity index, Pi: Proportion of comparison of the number of individuals i (ni) i with the number of individuals (N), i: 1, 2, 3, ..., n, S: Number of species of fish

Dominance index. A small index of uniformity and diversity was used to indicate a high dominance of a species against other species. The dominance index formula was as follows (Odum 1971):

$$C = \sum_{i=1}^{s} (pi^2)$$

Where: C: Shannon Wiener dominance index, pi: Proportion of species number i (n), to total number of reef fish (N): n / N, s: Number of reef fish species, Index value based on 0-1 with category as follows: (i) 0 <C <0.5 = Low dominance, (ii) 0.5 <C = 0.75 = Moderate dominance, (iii) 0.75 <C <1.0 = High dominance

RESULTS AND DISCUSSION

Fish species

During the study, data from the underwater visual census (UVC) survey found that there were 5 fish species in Karang Katon, namely yellowtail fish (*Caesio cuning*), Achilles tang (*Acanthurus achilles*), whitefin surgeonfish (*Acanthurus albipectoralis*), pick handle barracuda (*Sphyraena jello*), and seven-striped cardinalfish (*Apagon novemfasciatus*). In Dringu Beach, four fish species were found, namely the butterflyfish (*Chaetodon octofasciatus*), clownfish (*Chromobotia macracanthus*), threadfin bream (*Nemipterus japonicus*), and white snapper (*Lates calcarifer*). The fish observation results obtained in this study can be seen in Table 1.

Karang Katon

Acanthurus achilles fish was the fish species with the highest composition level of 51.65% while the lowest was *A. novemfasciatus* at 3%. The UVC results showed that *A. achilles* had the abundance or density of 34.4 ind/m^3. On the other side, the *Apogon novemfasciatus* had the lowest abundance equal to 2 ind/m^3. The diversity index analysis showed that the fish in Karang Katon station had low diversity of -1.280. The dominance index analysis showed that fish in the fish apartments in KarangKaton station had a low dominance value of 0.343.

Table 1. Fish observation results in Karang Katon and Dringu Beach station fish apartments, Probolinggo District, East Java Province, Indonesia

Location	Fish Species	Number of fish	Density	Composition (%)	H'	Dominance
Karang Katon	*Caesio cuning*	72	14.4	21.62	-0.331	0.047
	Acanthurus achilles	172	34.4	51.65	-0.341	0.267
	Acanthurus albipectoralis	46	9.2	13.81	-0.273	0.019
	Sphyraena jello	33	6.6	9.91	-0.229	0.010
	Apogon novemfasciatus	10	2	3.00	-0.105	0.001
	Total	333	66.6	100	-1.280	0.343
Dringu Beach	*Chaetodon octofasciatus*	183	36.60	46	-0.358	0.2072
	Chromobotia macracanthus	97	19.40	24	-0.343	0.0582
	Nemipterus japonicus	117	23.40	29	-0.359	0.0847
	Lates calcarifer	5	1.00	1	-0.055	0.0002
	Total	402	80.4	100	-1.115	0.3503

Dringu

Chaetodon octofasciatus had the highest fish species composition level of 46% while the lowest was *Lates calcarifer* at 1%. Based on the UVC survey results, *C. octofasciatus* had the highest species abundance or density of 36.6 ind/m^3. Fish with the lowest abundance was *Lates calcarifer* at 1 ind/m^3. The diversity index analysis showed that fish in Dringu Beach station had a low diversity of -1.115. The dominance index analysis showed that fish in Dringu Beach station had a low dominance value of 0.3503.

Discussion

The presence of fish gathered in the fish apartments showed that this artificial reef could help fisheries sustainability in Probolinggo. Previously before the application of this device, many studies stated that the condition of coral reefs in Probolinggo was damaged up to 71.62%. (Jaelani et al. 2015; Puspitasari et al. 2013; Wiyanto 2016). The damage process of coral reefs in Probolinggo occurred due to the bleaching process, overwhelming fishing, destructive fishing methods, sedimentation and land pollution (Jaelani and Afifi 2016; Wiyanto 2016). Damage to coral reefs makes it challenging to find fish in the coastal waters of Probolinggo because of the inadequate stock (Permana 2017; Rachman et al. 2014). The decreasing fish was 500.98 lower than in 2016 (Badan Pusat Statistik Probolinggo 2018). In 2017, the rate of exploitation reached 0.71 per year with a utilization rate of 140%, and biomass in Probolinggo was low (Meyanti 2017). Even fishers from Probilinggo were looking for fish from the Aru Sea or the Arafura Sea and the Timor Sea to be traded in Mayangan, Probolinggo (Suprapto 2017).

The fish apartments would affect upwelling and carry nutrients such as natural coral reefs (Yu et al. 2015). It could increase the nutrient content in the upper-lower of seawater and sediment that it had a role as fish foraging (Wang et al. 2018). It would attract the fishes to go to the fish apartment because of the abundant food such as phytoplankton and zooplankton growth. Over time, nutrients and organic matter concentrate in the apartment (Leitão 2013). The emerging phytoplankton and zooplankton invited plankton-eating fish to come to the apartment (Champion et al. 2015; Truong et al. 2017). Fish apartments were also a place for macroalgae to attach itself and gradually transform the fish apartments to be like real corals (Wu et al. 2015). Macroalgae also attracted herbivorous fish to come to the fish apartment.

In Karang Katon station, *A. achilles* had the highest species density. The high density might be due to the *A. achilles* nature which habitat was in the reef (Montanari 2016). In Dringu Beach, *C. octofasciatus* was the highest species density since its natural habitat was the coral reef (Nowicki 2018). The appearance of these two species (*A. achilles* and *C. octofasciatus*) showed that fish apartment helped fisheries sustainability. Chaetodontid fish such as *C. octofasciatus* and *A. achilles* were fish indicators species that indicated that these coral reef ecosystems are high nutritious (Hobson 1972; Yanuar and Aunurohim 2015). In East Java, *C. octofasciatus* was previously reported to be found only in Pasir Putih (Situbondo), Teluk Prigi (Trenggalek), and Pulau Kambing (Madura) (Sumadhiharga 2006; Wibowo and Adrim 2014; Yanuar and Aunurohim 2015).

While *A. achilles* was reported in Bangsring, Banyuwangi (Asadi and Andrimida 2017). On the other side, the *Apogon novemfasciatus* was the lowest density in Karang Katon since its habitat was a muddy bottom (Goren et al. 2009) while in Dringu, white snapper (*Lates calcarifer*) because its habitat that was not specific to coral, just finding small fish to be eaten (Campbell et al. 2017).

Acanthurus achilles main diet consisted of algae that grow in fish apartments while the *C. octofasciatus* ate plankton (Jones 1968; Sazima and Sazima 2001). Due to the abundant plankton and algae growing in the fish apartment, the two fish species dominated the location. Other fish, *C. cuning*, was a plankton feeder that consumes both phytoplankton and zooplankton (Zamani et al. 2011). *A. albipectoralis* fish was a planktivorous predator (Goren et al. 2009).

The existence of these fish also attracted animals at a higher level of the food pyramid to go to this area, carnivores, and omnivorous animals to come to fish apartments (Champion et al. 2015). The presence of *S. jello* showed in Karang Katon and *Lates calcarifer* fish appeared in Dringu proved that previous study. The interesting thing about this study was the discovery of barracuda (*S. jello*), which appeared in East Java had not been frequently reported. Previous research had stated that *S. jello* was found in Muncar (Banyuwangi) and Watukarung (Pacitan) (Sanjaya 2018; Wijaksono and Mudzakir 2014). Barracuda could be found in this study because barracuda used coral reefs as a place to find food and shelter (Bharathi and Ponni 2018; Hosseini et al. 2009). The presence of this fish would create a dynamic food chain and ecosystem, so fish apartments could be a habitat for fish to feed, spawn, and grow (McLean et al. 2015). Previous research reported that fish apartment had been applied in various places in East Java (Kamaali et al. 2017; Fuad et al. 2016; Yanuar and Aunurohim 2015; Sabrini and Nugraha 2019).

This study only provided a single snapshot in time, and ongoing monitoring was necessary to be conducted in the future since it needed time to develop as coral habitat. Previous research showed that artificial reef requires five years to get optimum results (Le Diréach 2015).

To conclude, this study had successfully documented fish apartment installation in KarangKaton and Dringu Beach station for one year. It could be concluded that the application of fish apartment could enhance the fisheries sustainability in Probolinggo.

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