BIODIVERSITAS
Volume 24, Number 7, July 2023
Pages: 4034-4045

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240741

Comparative study of the application fish apartments in Situbondo and Probolinggo, East Java, Indonesia

WAHYU ISRONI[1,♥], ZULKISAM PRAMUDIA[2,3], ANJAS SASANA BAHRI[4], MEGA ASRI RISQIANA[3,5], NURUL MAULIDA[1], TIA DWI IRAWANDANI[6]

[1]Departement of Fish Health Management and Aquaculture, Fisheries and Marine Faculty, Universitas Airlangga. Jl. Dharmahusada Permai 330, Surabaya 60115, East Java, Indonesia. Tel.: +62-31-5911541, ♥email: wahyu.isroni@fpk.unair.ac.id
[2]Aquaculture Study Program, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia
[3]Coastal and Marine Research Center, Universitas Brawijaya. Jl. Veteran, Malang 65145 East Java, Indonesia
[4]Sekolah Tinggi Ilmu Perikanan Malang. Jl. Cengger Ayam I/5, Malang 65145, East Java, Indonesia
[5]Graduate School of Agriculture, Forestry, and Fisheries, Kagoshima University. Korimoto 1-21-24, Kagoshima 890-8580, Japan
[6]Departement of Biosystem Engineering, Faculty of Agricultural Technology, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia

Manuscript received: 6 February 2023. Revision accepted: 23 July 2023

Abstract. *Isroni W, Pramudia Z, Bahri AS, Risqiana MA, Maulida N, Irawandani TD. 2023. Comparative study of the application fish apartments in Situbondo and Probolinggo, East Java, Indonesia. Biodiversitas 24: 4034-4045.* Fisheries resources which are common property in their utilization are vulnerable to overfishing conditions due to exploratory actions. In addition, the use of destructive fishing gear and habitat degradation has a great impact on fisheries productivity which continues to decrease. Fish apartments as alternative artificial habitat have been successfully applied in Probolinggo, especially for coral organisms. This study compares the application of fish apartments in two different locations, Karang Katon Probolinggo and Karang Mayit Beach Situbondo. Through descriptive and valuative approaches, the survey results showed that in Karang Katon there were 5 species, the highest composition level is *Acanthurus achilles* (51.56%). Karang Mayit Beach there were 3 species, the highest composition level is *Chaetodon octofasciatus* (60.56%). The highest abundance is *Acanthurus achilles* (34.4 ind/m^2) in Karang Katon and *Chaetodon octofasciatus* (42.2 ind/m^2) in Karang Mayit Beach. The diversity index in Karang Katon -1.280, while in Karang Mayit Beach -0.853. The dominance index in Karang Katon 0.343, while in Karang Mayit Beach 0.496. Based on this research, the analysis showed positive results for both different locations, indicating it can be used as new habitats for sustainability and increased productivity of fisheries resources.

Keywords: Composition, diversity index, dominance index, fish apartment, Probolinggo, Situbondo

INTRODUCTION

Indonesia is known as an archipelagic country consisting of around 17,504 islands with a coastline of approximately 81,000 km, the land connected by the ocean (Kench and Mann 2017; Djunarsjah and Putra 2021; Tranggono et al. 2021). Indonesia's sea area is 62% of the national area, not including the EEZ of 2.7 million km^2. Indonesia's oceans are so wide with abundant fisheries resources that if properly utilized for development (Pramoda et al. 2021). Indonesia has more than 8500 species of fish, which are categorized based on their habitat (Hasan et al. 2023). It is predicted that development in Indonesia will advance rapidly (Tranggono et al. 2021).

Fisheries resources in their utilization are common property or open access representing a fundamentally problematic situation (Primyastanto et al. 2013; Arthur 2020). Open access resources are available to all comers (Acheson 2015). This condition has the potential to cause inefficient levels of fishing effort because fishermen must compete with one another for fish and cause overfishing if the concept of environmental friendliness and sustainability is not applied (Fuller et al. 2013). Its common property always triggers exploitative actions in its utilization (overfishing) due to unclear ownership rights (Acheson 2015; Sapriani et al. 2021). This can raise symptoms of dissipated resource rent, namely the loss of the resource chain that should be obtained from optimal resource management (Homans and Willen 1997; Fauzi 2005).

The production of large pelagic fish has decreased every year (Gomez-Campos et al. 2011). Based on the Situbondo District Statistics Center (2018), the results from fisheries catch have increased more than twofold in 2017 (13,83 tons) when compared to 2016 (5.5 tons), this can mean two meanings, the number of fish that is more abundant or the number of fish caught is higher. Because a different case occurred in Probolinggo where there was a decrease in catches in 2017 (19.26 tons) when compared to 2016 (19.74 tons). The decrease of fisheries resources is not only due to exploitative actions that cause overfishing, but the use of fishing gear that is not environmentally friendly such as trawl bottom trawling, and decreased carrying capacity of waters due to the degradation of important fisheries habitat (Jia and Zhuang 2009; Wang et al. 2010; Yu et al. 2015; Hasan et al. 2021). In ecology, the habitat especially coral for some aquatic organisms functions as a spawning ground (Mahendra et al. 2020; Sektiana et al. 2022), nursery ground (Whitfield and Pattrick 2015) and feeding ground (Brandl et al. 2020; Higgins et al. 2022). Thus, the existence of an optimal habitat is very important to support sustainable fisheries resources (Yu et al. 2015).

One of the fast alternative innovations to making habitat for aquatic organisms especially fish is the application of fish apartments (Isroni 2019; Layman and Allgeier 2020; Paxton et al. 2020; Brochier et al. 2021; Vivier et al. 2021). The fish apartment is a means to preserve the environment and increase fisheries resources (Yu et al. 2015). Fish apartment consists of a building with a hollow structure, consisting of solid matter and placed in the water column (Isroni et al. 2019). The function as an assembling place for aquatic organisms, especially fish (Higgins et al. 2022). Fish apartments are manipulated to increase the complexity of damaged coral reefs thereby increasing natural productivity, by providing new artificial for aquatic organisms (Gratwicke and Speight 2005) so that they can contribute to the food chain process, including the organisms that are target of production (Xu et al. 2017). Other advantages, fish apartment can protect and restore habitats for small or juvenile aquatic organisms as a nursery ground (Hamel et al. 2021), and also protects against waves, strong currents, and predators. The existence of the fish apartments will also increase the complexity of essential habitat, so the ecological functions are similar to coral reef ecosystems (Isroni et al. 2019).

The application of fish apartment requires technical considerations regarding the potential location also monitoring of the existing condition of the surrounding fish production. According to Bambang et al. (2011), the placement or installation of fish apartments must have several technical criteria that need to be considered in relation to the conditions of the aquatic environment. In addition, previous research on the application of fish apartments has been successfully carried out in Probolinggo (Isroni 2019). However, the application of fish apartment Situbondo has not been evaluated. This study will analyze the comparison of application fish apartments based on different locations. This study will analyze the oceanographic, accessibility, catch productivity and most important is community through composition, diversity and dominance of the fish in two different locations, namely Situbondo and Probolinggo, East Java, Indonesia. Furthermore, this study also analyzes the business feasibility in Situbondo for additional consideration.

MATERIALS AND METHODS

Study area

This research was conducted for one year, starting from the application of the fish apartments. There are two locations in East Java, Indonesia used for the application of fish apartments, Karang Katon in Probolinggo District and Karang Mayit Pasir Putih Beach in Situbondo District. The details of location fish apartment application can be seen in Table 1 and Figure 1.

Fish apartment

The main material for the construction of fish apartment buildings is made of polypropylene or PP type plastic, as can be seen in Figure 2. The choice of plastic as the main material is due to the nature of the material which is easy to shape, easy to ship, not easily damaged or rotted and easy to assemble. According to Bambang et al. (2011), PP type plastic is a transparent plastic that is not clear or cloudy, and is stronger and lighter in nature with low vapor permeability. Has good resistance to lipids, stable to high temperatures and is quite shiny. Plastic is best when used as food or beverage packaging. PP also has a fairly high melting point (190-200°C) and a crystallization point (130-135°C) and very high chemical resistance.

Table 1. Details of location fish apartment application

Location	Coordinates	Water depth	Administrative area	Location description
Karang Katon	113°12’45.70” E, 7°41’23” S	15 m	Probolinggo District	Moderate water flow, sandy mud substrate, gentle breeze wave
Karang Mayit Beach	113°49'46.31" E, 7°41'26.83" S	13 m	Situbondo District	Moderate water flow, sandy mud substrate, gentle breeze wave

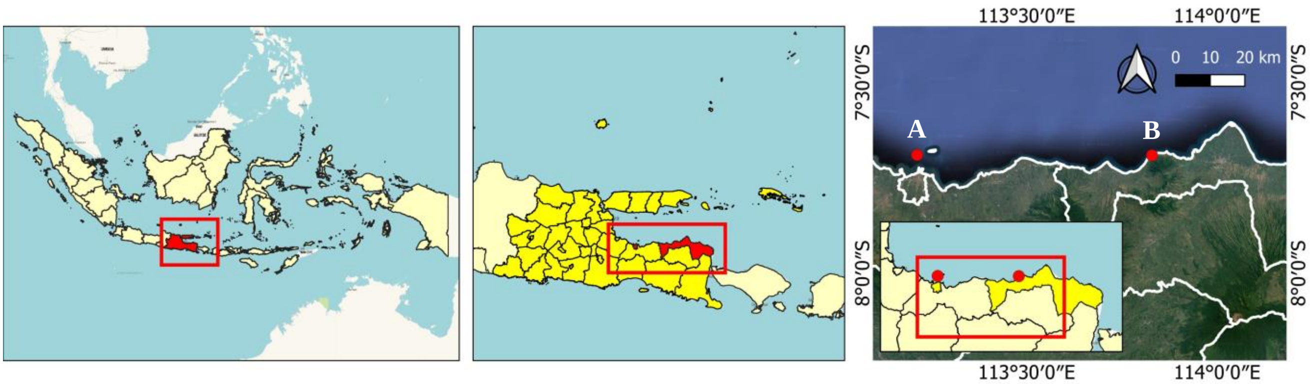

Figure 1. The location of fish apartments in East Java, Indonesia: A. Karang Katon (Probolinggo), B. Karang Mayit Beach (Situbondo)

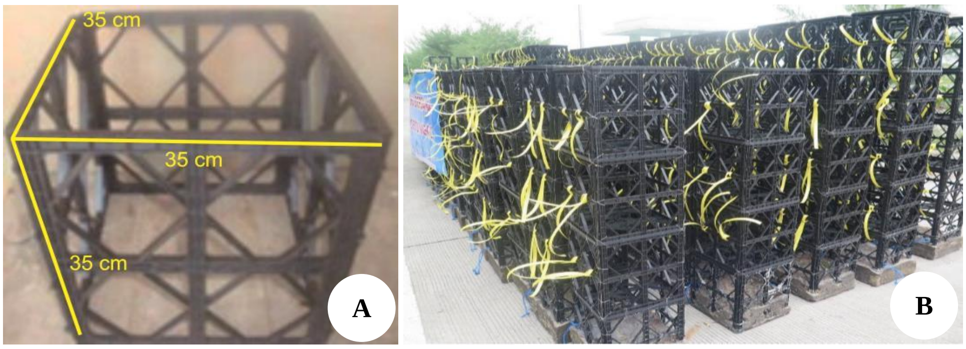

Figure 2. Fish apartment contruction has the main material of polypropylene; A. fish apartment partition, B. fish apartment design (Isroni et al. 2019)

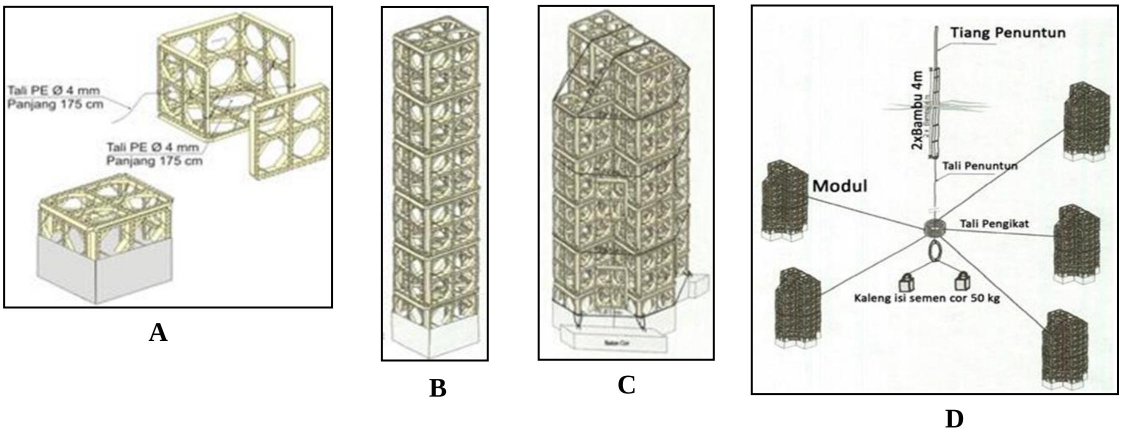

Figure 3. Fish apartment contruction design; A. partition, B. submodule, C. module, D. Colony

The construction of the fish apartment is a frame that is arranged to form a cube called a partition, the parts arranged vertically and horizontally have the same size, 35 cm x 35 cm. Partitions are arranged vertically with a height of about 140-175 cm or consist of 4-5 partitions forming submodules. The four submodules are combined to form a module and are given concrete ballast with a weight of 3 kg and a size of 1100 mm x 125 mm x 125 mm. Groups of 4-6 modules are strung together using poles and guidelines. Connected using a strap and given a can filled with cast cement with a weight of 50 kg, called a colony. Several colonies (50-60 colonies) placed in a certain area are called groups. The fish apartment construction design in more detail can be seen in Figure 3.

Data collection

The data consist of primary and secondary data. The primary data is the collection of data directly at the research location using field observation techniques, interviews and questionnaires. The types of interviews conducted in this study were structured interviews by providing closed questions and providing a choice of answers, and unstructured interviews by providing open questions and respondents being able to detail the answers. Secondary data is a method of collecting data obtained from agencies or literature studies. Secondary data include the data collected from relevant references such as journals, article reviews, books and other valid resources.

Data analysis

The analytical method used in this study is a descriptive approach using the Underwater Visual Census (UVC) and a valuative approach using community structure analysis of catch productivity, scoring analysis, spatial maps and business feasibility.

The Underwater Visual Census obtains data in the form of photo or video documentation, recording species and individual fish in and around the fish apartments, collecting data on catches, monitoring the development and maintenance of the fish apartments.

Community structure analysis included fish species composition, abundance, diversity index, dominance index.

Fish species composition aims to determine the percentage of the total species caught, the composition of fish species is calculated by the following formula (Yang et al. 2021):

$$KJ = \frac{ni}{N} x\, 100\%$$

Where: KJ: Composition of species, *ni*: Number of individuals of each species, N: Number of individuals of all species.

Abundance is the number of individuals and the number of species found in the area of observation. The abundance of reef fish can be calculated using the formula (Odum 1971):

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

Where: X: Abundance of fish, *Xi* = Number of fish at the location, n = Observation transect area (m^2).

Diversity index is used to get a mathematical description of the population of organisms (Odum 1971). Diversity can be calculated by the following formula:

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

Where: H': Shannon Wiener species diversity index, Pi: The proportion of the ratio of the number of individuals species i (ni) to the number of individuals (N), i: 1, 2, … n, S: Number of fish species

Domination index can be seen from the uniformity and diversity index values. Small uniformity and diversity index values indicate a high dominance of a species over other species. The dominance index formula is as follows (Odum 1971):

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

Where: C: Shannon Weiner domination index, pi: Proportion of the i species (n) to the total number of fish , (N): n/N, s: Number of fish species.

The index value is based on between 0-1 with the following criteria: (i) 0 < C < 0.5: Low dominance, (ii) 0.5 < C = 0.75: Moderate dominance, (iii) 0.75 < C < 1.0: High dominance.

The productivity of the catch is obtained by comparing the catch before and after the existence of the fish apartment. Increases and decreases are expressed in percent.

Scooring analysis was carried out to determine potential points for placing fish apartements. *Spatial map analysis* is carried out so that all GIS information or data in an area can be stored, manipulated, and analyzed simultaneously via a computer. According to Mulyanto (2011), there are 3 stages of spatial map analysis. The first stage, the required input is the initial data or database, which is collected during the survey and entered into the computer. The second stage, process, GIS functions to call, manipulate and analyze data stored on the computer. The last stage, output, namely data that has been analyzed by GIS provides information to users as a basis for decision making.

Business feasibility analysis is divided into short-term and long-term analysis. Short-term analysis includes total revenue, profit, revenue cost (R/C) ratio, payback period.

Total revenue is formulated as follows:

$$TR = PxQ$$

Where: TR: Total revenue (IDR), P: Product (kg), Q: Product prize (IDR/kg).

Profit or net income/benefit is calculated by the following formula:

$$\pi = TR - TC$$

Where: TR: Total revenue, TC: Total cost (fixed cost + variable cost)

Revenue cost (R/C) ratio is the ratio between total revenue and total costs incurred, calculated using the following formula:

$$R/C = \frac{TR}{TC}$$

Where: TR: Total revenue, TC: Total cost (fixed cost + variable cost)

Criteria: R/C > 1 means the business is feasible, R/C < 1 means the business is not feasible

Payback periode (PP) is the period of return on investment capital that will be paid through profits earned by a business. PP is a method of knowing how quickly investment returns, calculated using the formula:

$$PP = \frac{Initial\ investment}{Average\ (Net\ benefit\ t1 - t10)}$$

Long term analysis includes net present value, internal rate of return, B/C (benefit cost) ratio.

Net present value NPV is the difference between revenue and expenditure that has been presented in value, formulated as follows:

$$NPV = \sum_{i=1}^{n} \frac{Bt - Ct}{(1+i)^t}$$

Where: Bt: Benefit in year t, Ct: Cost in year t, n: Economic life of a fishing business, i: Prevailing interest rate.

Criteria: NPV > 0: business is selected, NPV < 0: business is not selected/not feasible.

Internal rate of return (IRR) is the interest rate which illustrates that the present value of benefits and costs is equal to 0, formulated as follows:

$$IRR = i' + \frac{NPV'}{NPV' - NPV''} x(i'' - i')$$

Where: i': the interest rate at the first inteIDRolation, i": the interest rate at the second inteIDRolation, NPV': the NPV value at the first discount rate, NPV": the NPV value at the second discount rate.

Criteria: IRR > interest rate: business is selected, NPV < interest rate: business is not selected/not feasible.

B/C *ratio* is the ratio between total profit and total expenditure the formulation is as follows:

$$B/C = \frac{Gain}{TC}$$

Criteria: B/C>0 then it is feasible, PI<0 is not feasible

RESULTS AND DISCUSSION

Existing condition of fish apartment

Based on the survey results, physically the structure of the fish apartments in two locations, namely Karang Katon (Probolinggo) and Karang Mayit Beach (Situbondo), is still solid with moss and algae growing, after 1 year of application (Figure 4).

Community structure

The composition of fish species based on UVC survey results, in Probolinggo found 5 species of fish namely *Caesio cuning* (redbelly yellowtail fusilier), *Acanthurus achilles* (achilles tang), *Acanthurus albipectoralis* (whitefin surgeonfish), *Sphyraena jello* (banded barracuda), *Apogon novemfasciatus* (seven striped cardinalfish). While the composition of the fish on Situbondo, there were 3 species of reef fish. These species include *Acanturus nicricauda* (eye-line sturgeon), *Chaetodon octofasciatus* (butterfly fishes), *Lates calcarifer* (Asian sea bass). Comparison of fish composition can be seen in Figure 5. Picture of each species can be seen in Table 2.

Abundance based on UVC survey results, in Probolinggo the highest abundance was a *A. achilles* and the lowest was *A. novemfasciatus*, while in Situbondo the highest abundance was *C. octofasciatus* and the lowest by *L. calcalifer*. Comparison of fish abundance can be seen in Figure 6.

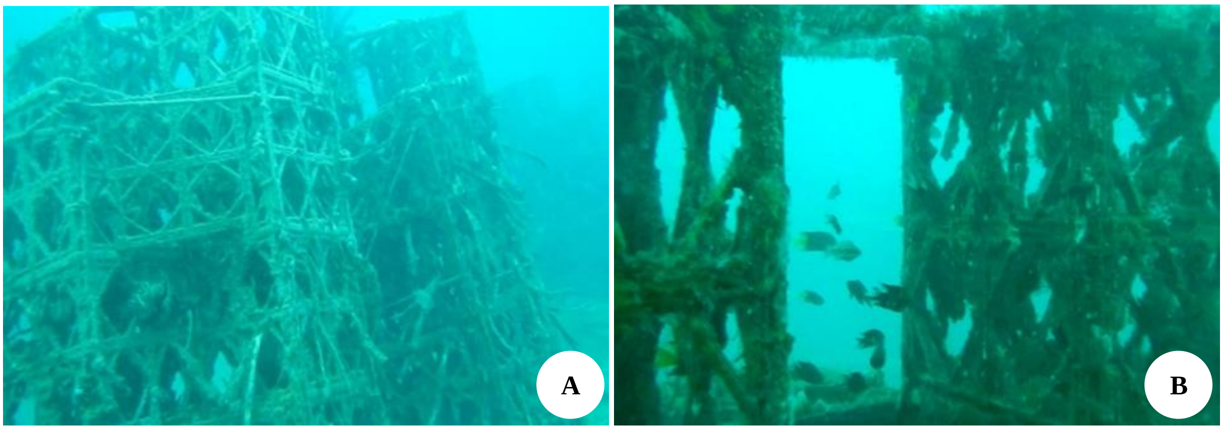

Figure 4. Primary photo of UVC results related to the physical condition of the existing fish apartment after one year of application. A. Karang Katon (Probolinggo). B. Karang Mayit Beach (Situbondo)

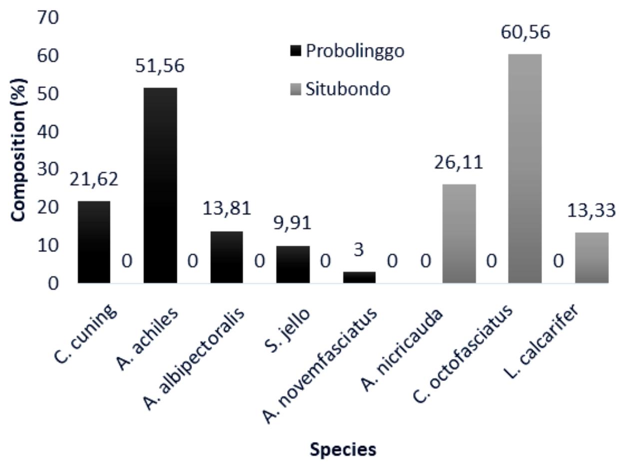

Figure 5. Comparison of fish apartments composition in Probolinggo and Situbondo

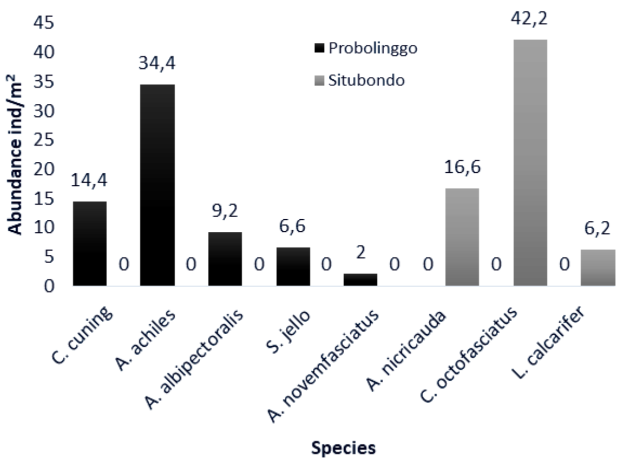

Figure 6. Comparison of the abundance of fish apartments in Probolinggo and Situbondo

Table 2. Picture of each species in the different location

Species	Picture
Caesio cuning (redbelly yellowtail fusilier)	
Acanthurus achilles (achilles tang)	
Acanthurus albipectoralis (whitefin surgeonfish)	
Sphyraena jello (banded barracuda)	
Apogon novemfasciatus (sevenstriped cardinalfish)	
Acanturus nicricauda (eye-line sturgeon)	
Chaetodon octofasciatus (butterfly fishes)	
Lates calcarifer (Asian sea bass)	

The diversity index based on the results of the UVC survey, in Probolinggo showed a value of-1.280, while in Karang Mayit Situbondo Beach it was-0.853. Comparison of fish diversity can be seen in Figure 7.

Catch productivity

The productivity of the catch can be known through the response of reef fish to fish apartments in two locations, the survey results show a positive pattern. The detail of difference in catch productivity in two different locations can be seen in Table 3.

Aspects of oceanographic parameters

The depth of the waters in Probolinggo was obtained from bathymetric sonding data in the study area with coordinate positions of 113°12’45.70” E and 7°41’23” S at a depth of 15 m. Meanwhile, Situbondo, with the coordinates of 112°40’40.80” E, 8°26’23.00” S at a depth of 13 meters. Both are in the category of ideal waters (Bambang et al. 2011). Bathymetry is used to understand the character of the environment, bathymetry data after being processed will produce a contour map and is used to know the location of the seabed which tends to be relatively flat so that it can be used for placing fish apartments.

The dominance index based on the results of the UVC survey, in Probolinggo obtained a value of 0.343, while in Situbondo it obtained a value 0.496. Comparison of fish dominance can be seen in Figure 8.

The slope of Probolinggo in this study has a slope with a percentage of 6-11%, while Situbondo has a slope of 4-10%. Both are in the bottom category of sloping waters suitable for placing fish apartments (Adiwijaya 2016). The currents in this study were also measured, in Probolinggo the results were 0.1-0.4 m/s classified as moderate currents, while in Situbondo the results were the same 0.1-0.4 m/s, also included in moderate currents (Yusuf et al. 2012). Waves were measured using the ECMWF which resulted in a maximum wave height of 1.2 m, a minimum wave of 0.05, and a significant wave of 0.569 m at Probolinggo. Meanwhile, a maximum wave height of 1.1 m and a minimum wave of 0.04 m were obtained at Situbondo. Both of these locations have sea wave values belonging to the Gentle Breeze on the Beaufort scale. Gentle Breeze is a scale with a value of 4 and belongs to a low wave height (Risanti and Marfai 2020).

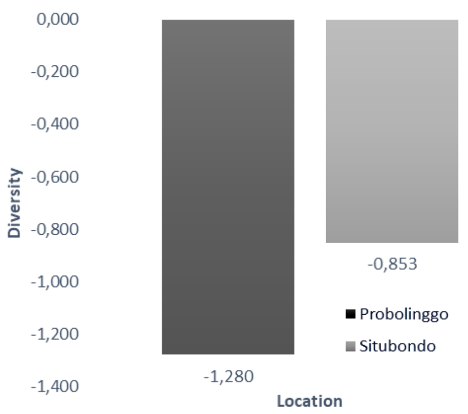

Figure 7. Comparison of the diversity of fish apartments Probolinggo and Situbondo

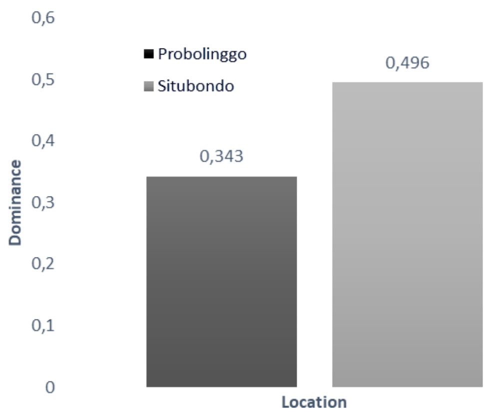

Figure 8. Comparison of the dominance of fish apartments Probolinggo and Situbondo

Table 3. Difference in catch productivity in two different locations

Aspects analyzed	Probolinggo	Situbondo
Percentage increase based on fish category	Increasing the percentage of fish categories in the area of herbivorous, omnivorous and carnivorous fish apartments based on the age at which the fish apartments were placed. The percentage of the plankton feeder reef fish category was dominated by juvenile fish with the percentage of 63.90%, the other is large fish.	Increasing the percentage of fish categories in the area of herbivorous and carnivorous fish apartments based on the age at which the fish apartments were placed. The percentage of the plankton feeder reef fish category was dominated by juvenile fish with a percentage of 90.46%, the other is large fish.
Fish dominance based on fish category	Plankton feeder fish: family of Caesionidae	Plankton feeder fish species *C. octofasciatus* and *A. nicricauda*
	Herbivorous fish: family of Achanturidae	Herbivorous fish: species *L. calcaliver*
	Carnivorous fish: family of Sphraenidae	-

Temperatures were measured in the afternoon and evening which showed a range of 28-31.3°C at Probolinggo, and a range of 28-32°C at Situbondo. Both are included in the good category according to Messmer et al. (2017), namely in the range of 28-31°C, also required by Riegl et al. (2015), concerning water quality standards for marine biota in coral reef areas is 28-32°C. The brightness was measured using a Secchi disk, at Probolinggo it showed 5-7 m or 50-70%, while at Situbondo it was 7-9 m or 70-90%. The brightness for marine life in good coral reef areas is >5 m (Kurnia 2019). pH measurements at Probolinggo showed results of 7.8-8.1, while those at Situbondo showed 7.4-7.8. The pH that meets seawater quality standards for the survival of marine biota is around 8.0 (Plaisance et al. 2021; Jha et al. 2023). Salinity was also observed, at Probolinggo the results were 33.3-34 ppt, while at Situbondo the results were 31.1-33.4 ppt. Salinity that meets seawater quality standards for the survival of marine biota is 33-38 ppt with average of 35 ppt (Rugebregt and Nurhati 2020).

The bottom substrate was sampled to determine the percentage of sediment fraction in the waters. Both locations consist of the same fractions namely gravel, sand and mud. This type of sandy sediment is suitable for fish apartment substrate (Bambang et al. 2011). More details regarding aspects of oceanographic parameters are tabulated in Table 4, which can be seen below.

Aspect of determining other potential locations

Apart from oceanographic parameter aspects, there are other technical aspects to determine potential locations for fish apartments. The accessibility aspect of the two locations seen from the distance of the fish apartment for installation and monitoring shows that the points are affordable, 4 m for Probolinggo and 320 m for Situbondo. Community aspects through interviews to get input regarding potential location points for fish apartments, as well as positive support from the community.

Business feasibility analysis

Business feasibility analysis of fishing with handline fishing gear in the fish apartment area, detailed in advance the costs required. Costs consist of investment costs, fixed costs and variable costs. More details can be seen in Table 5.

Analysis of short-term business feasibility includes total revenue or receipts obtained in the fishing unit business in the fish apartment area with handline fishing gear, which results from selling fish through grilled stalls and collectors. Annual average revenue of IDR 110,250,000.00. More details can be seen in Table 6.

Profit is the difference between the total revenue and total cost. The average profit earned in one year is IDR 69,283,333.00. More details can be seen in Table 7.

R/C (revenue cost) *ratio* for the handline fishing gear business in the fish apartment area in Situbondo District is 2.69. This means that the business can be said to be feasible and profitable because the R/C value is greater than 1 (R/C>1). The greater the R/C value, the more feasible the business. In other words, the R/C Ratio value of 2.69 means that for every IDR 10,000 spent, the Handline fishing business earns IDR 269,000 in revenue.

Payback periods, the faster the payback time, the better the business is to continue. Payback Periods calculation results show that the time required to be able to return all investment costs incurred for the handline fishing business in the fish apartment area is 2 months and 3 days. This shows that the business is feasible to run because investment capital can be obtained in less than 1 year.

Analysis of short-term business feasibility, net present value (NPV), internal rate of return (IRR), B/C (benefit-cost) ratio, the results of the analysis can be seen in Table 8.

Table 4. Aspects of oceanographic parameters in two different locations for the criteria of habitat live

Parameters	Measurement results		Criteria		Reference
	Probolinggo	Situbondo	Probolinggo	Situbondo	
Depth	15 m	13 m	Ideal	Ideal	10-25 m (Bambang et al. 2011)
Slope	6-11%	4-10%	Sloping (Suitable)	Sloping (Suitable)	4-10% (Adiwijaya 2016)
Current	0.1-0.4 m/s	0.1-0.4 m/s	Moderate (Suitable)	Moderate (Suitable)	<0.5 m/s (Yusuf et al. 2012)
Wave	Max: 1.1 m Min: 0.04 m	Max: 1.2 m Min: 0.05 m	Gentle breeze (Suitable)	Gentle breeze (Suitable)	Including scale 4 (Risanti and Marfai 2020)
Temperature	28-31.3°C	28-32°C	Ideal	Ideal	28-31 °C (Messmer et al. 2017) 28-32 °C (Riegl et al. 2015)
Brightness	5-7 m	7-9 m	Ideal	Ideal	>5m (Kurnia 2019)
pH	7.8-8.1	7.4-7.8	Still ideal	Still ideal	Around 8.0 (Plaisance et al. 2021; Jha et al. 2023)
Salinity	33.3-34 ppt	31.1-33.4 ppt	Ideal	Ideal	33-38 ppt. average 35 ppt (Rugebregt and Nurhati 2020)
Bottom substrate	Sandy mud	Sandy mud	Ideal	Ideal	Sandy mud (Bambang et al. 2011)

Table 5. Cost requirements for handline business analysis around fish apartments

Component	Volume	Value (IDR)
Investment		
Fiberglass boat	1 unit	8,000,000
Outboard engine size 15 PK	1 unit	5,000,000
Handline fishing gear	1 set	150,000
Total		13.150.000
Fixed		
Ship deprecation costs	15 years	533,333
Engine deprecation costs	10 years	500,000
Ship maintenance costs	1 year	2,000,000
Engine maintenance costs	1 year	1,000,000
Fishing equipment maintenance costs	1 year	50,000
Total		4.083.333
Variable		
Bait (@50.000/day)	7 months	10,500,000
Supplies (Food, etc) (@50.000/day)	7 months	10,500,000
Fuel (@75.000/day)	7 months	15,750,000
Total		36.750.000

Table 6. The average revenue of handline fishing gear in the fish apartment area

Description	Volume	Unit	Revenue (IDR)
Number of catch per day	15	kg	300,000
Catch day	210 (7 months)	day	110,250,000

Table 7. The average profit of handline fishing gear in the fish apartment area

Description	Amount (IDR)
Total revenue	110,250,000
Fixed costs	4,216,667
Variable costs	36,750,000
Profit	69,283,333

Table 8. Summary of the long term feasibility of handline fishing gear in the fish apartment area

Description	Value
NPV	IDR 302,373,601
IRR	0.38%
B/C Ratio	26.30

Based on Table 8, the average NPV value of handline fishing gear in the fish apartment area is IDR 302.373.601,67. The NPV of the business is positive, this indicates that the business is feasible to continue. The higher the NPV of the business, the better the business is.

The average IRR value for handline fishing gear in the fish apartment area is 0.38%. The criterion is if the IRR > the interest rate prevailing at that time then the project will be selected, if the IRR < the interest rate prevailing at that time then the project will not be selected.

The B/C (benefit cost) ratio value is 26.30. This shows that the handline business around the fish apartment area is feasible and profitable, because B/C>0. The greater the B/C value, the more feasible the business will be.

Discussion

Many studies related to coral damage have been carried out, which is an important habitat for marine organisms, coral damage can be due to natural factors such as climate change, waves, floods and earthquakes, while other factors are human factors, such as destructive activities on coral reefs, the use of fishing gear that destroys coral reefs, coral harvesting for calcium sources (Lamb et al. 2015; Isroni et al. 2019; Takeshige et al. 2021). In the last half-century, the degradation of coral reefs in Indonesia has increased from 10% to 50% (Burke et al. 2002). Case studies on coral damage at several points around the Paiton Probolinggo PLTU show that as much as 726 m^2 of the total observed area of 1.400 m^2 experienced bleaching due to temperature changes (Jaelani and Afifi 2016). Another case related to coral taking, in the Situbondo area has reached a dangerous level of more than 80% (Ainurohim et al. 2010). Damaged corals result in reduced catches, smaller fish catches, and the loss of several fish species in these waters (Edinger et al. 1998; Ragnarsson et al. 2017).

Based on the research results, the existing condition of the fish apartment physically for 1 year in Situbondo same if compare with Probolinggo, which showed good and sturdy condition, as well as overgrown with moss and algae, which indicated that a new ecosystem was starting to form. Fish apartments can be used for artificial corals, which will engineer upwelling and carry nutrients, thereby influencing phytoplankton growth (Yu et al. 2015). The existence of nutrients will trigger and increase the growth of phytoplankton, then zooplankton, as the basis for forming a food chain (Araujo et al. 2022).

When compared with survey data related to catch productivity which shows the presence of plankton feeder fish in both locations. The existence of herbivorous fish in two locations, shows that the initial organisms that make up the ecosystem are producer organisms, namely algae attached to the fish apartment, so herbivorous fish use the fish apartment as a place to feed ground, besides the presence of gastropods, mollusks and echinoderms live and settle in fish apartment. So, in the future, it will certainly stimulate higher consumer animals (carnivores) to come. Artificial reefs not only provide spawning, nursery and adult habitats but also increase fish abundance, many research that artificial reefs have been proven to attract fish and increase catch rates (McLean et al. 2015). This is consistent with what happened to the fish apartment in Probolinggo, namely from the Sphyraenidae family. Although carnivorous fish have not been found in fish apartments in Situbondo, according to the fish apartments that were successfully implemented in Probolinggo, and in terms of the pattern of ecosystem formation, fish apartments in Situbondo should after this invite the presence of more omnivorous or carnivorous fish.

Observation of community structure was carried out to determine the effect on organisms, especially reef fish. The composition of reef fish in both locations was divided into two major groups, namely indicator fish and major fish. In Probolinggo the dominating indicator fish were *A. achilles*, *A. albipectoralis*, and *A. novemfasciatus*, followed by the major fish, namely *S. jello* and *C. cuning*, while at Situbondo the indicator fish were dominated by *C. octofasciatus* and *A. nicricauda*, followed by the major fish, namely *L. calcalifer*. Indicator fish are fish that usually present healthy corals, it indicate the quality of the waters is still good and not polluted (Hamel et al. 2021). Major fish are small-sized fish, colorful fish species, commonly called ornamental fish. The presence of major fish whose characteristics are clustered will affect the overall ecological index of reef fish (Kojansow et al. 2022). Based on the survey, the composition of fish apartments in Probolinggo is indeed higher when compared to fish apartments in Situbondo. However, both represent indicator fish and major fish. The presence of indicator and major fish indicates that the fish apartment can carry out its function as an assembling place for fish (Isroni et al. 2019).

The highest abundance of fish in the fish apartment of Situbondo, is from the fish species *C. octofasciatus*. That difference if compared with fish apartments in Probolinggo were most abundant by *A. achilles*, besides that fish were also found in the same genus, namely *A. nicricauda*, in Situbondo. *C. octofasciatus* is an obligate collarivore or obligate coral feeder so its abundance is closely related to coral cover, especially hard corals (Madduppa et al. 2014).

Acanturus nicricauda was also found, the abundance in Situbondo was found quite a lot after *C. octofasciatus*. Sturgeon fish or *Acanthurus* indeed varied and belongs to the circumtropical species that live in coral reef ecosystems, this species plays a dominant ecological role as herbivores (Marshell and Mumby 2015), and small number of these species are also zooplankton eaters (Friedman et al. 2016; Rowlett 2018). *Acanthurus* is a kind of planktivorous fish (Goren et al. 2009). That is also different with fish apartment in Probolinggo, *C. cuning* is the second of high abundance fish after *A. Achilles*, including semi-pelagic associated with corals (Ackiss et al. 2013). *C. cuning* is the main catch of fishermen in Sulawesi Indonesia (Kojansow et al. 2022). *C. cuning* consume phytoplankton and zooplankton so that include plankton feeder (Valenzuela et al. 2021). The two species above play an important role in the formation of ecosystems. It means, the fish apartment in Situbondo also can become an artificial reef for habitat preservation.

The lowest abundance of *A. novemfasciatus* in Probolinggo is due to its habitat on a muddy bottom, and *L. calcarifer* which is also the lowest in Situbondo does not live coral, and only eats small fish (Isroni et al. 2019). Correlating to the results of fisheries catch survey, in which no carnivorous fish were found in Situbondo, because *L. calcarifer* does not live at coral and the abundance is low, from here it can be seen that the presence of fish in fish apartments stimulates carnivorous fish. *S. jello* is found in Probolinggo but not found in Situbondo, which has the nickname sea wolf because of its cruelty and aggressive behavior when preying. *S. jello* inhabits coral reefs as a safe shelter for it (Hosseini et al. 2009).

Diversity is high if the diversity index value (H') is >3; moderate 1<H'<3 and low if H'<1 (Magurran 1998). Fish apartments in Probolinggo include to moderate, however, fish apartments in Situbondo include to low index of diversity, which might be influenced by many factors, especially different aquatic environments, both locations have different depths of fish apartments application, although both have an ideal location seen from the survey results of oceanographic parameters. However, both locations do not have a high diversity it possible due to the relatively short time spent on fish apartments, but it is not impossible that the abundance of fish species in two locations has the potential to stimulate and trigger more complex and diverse food chain dynamics than before. According to Rizwan et al. (2017), many factors is threatened fish diversity, like human activity, but the most significant factors are habitat modification, overharvest and introduced species. The diversity index is influenced by species richness and the evenness of the individuals that make up a community. The higher the species richness, the higher the diversity index and vice versa.

The dominance index of both locations is low, namely in the range $0 < C < 0.5$. High dominance if the dominance index value (C) is $0.75 < C < 1.0$; moderate $0.5 < C = 0.75$ and low if $0 < C < 0.5$ (Odum 1971). Dominance index describes the size of the number of individuals between species/genus in a community. The more even distribution of individuals between species, the balance of the ecosystem will increase (Rizwan et al. 2017).

Based on oceanographic data and accessibility, although the application of a fish apartment in Situbondo is different when compared to the application of a fish apartment in Probolinggo, it is also included in the ideal category for application of a fish apartment. Furthermore, regarding the analysis aspect of the catch productivity of fisheries and the community structure, the application of fish apartments in Situbondo is successful and has a high potential to continue to increase. However, further monitoring is needed to determine the future existing condition of the fish apartment in Situbondo. In addition, analysis of business feasibility use handling fishing gear has good or profitable results. This result also corroborates the fact that fish apartments can become artificial habitats and serve similar ecological functions as natural reefs, this is also in accordance with other research about artificial reefs (Jones et al. 2020). So, fish apartment can be a location for new food chain dynamics and ecosystems, thereby spurring the sustainability of fishery resources and increasing fishery productivity.

ACKNOWLEGEMENTS

We thank all parties who collaborated to complete this study, especially the Maritime Affairs and Fisheries Office of East Java Province, Indonesia.

REFERENCE

Acheson JM. 2015. Private land and common oceans: Analysis of the development of property regimes. Curr Anthropol 56 (1): 28-55. DOI: 10.1086/679482.

Ackiss AS, Pardede S, Crandall ED, Ablan-Lagman MCA, Barber PH, CaIDRenter KE. 2013. Pronounced genetic structure in a highly mobile coral reef fish, *Caesio cuning*, in the Coral Triangle. Mar Ecol Progress Ser 480: 185-197. DOI: 10.3354/meps10199.

Ainurohim S, Raraswati I. 2010. Keanekaragaman Nudibranchia di Perairan Pasir Putih Sitobondo. Berk Penel Hayati Edisi Khusus 4: 1-7. [Indonesian]

Araujo GS, Pacheco D, Cotas J, da Silva JWA, Saboya J, Moreaira RT, Pereira L. 2022. Plankton: Environmental and economic importance for a sustainable future. Plankton Communities. IntechOpen. DOI: 10.5772/intechopen.100.433.

Arthur RI. 2020. Small-scale fisheries management and the problem of open access. Marine Policy 115: 103867. DOI: 10.1016/j.maIDRol.2020.103867.

Bambang N, Widodo, Suryadi A, Wassahua Z. 2011. Apartemen Ikan (*Fish Apartment*) sebagai Pilar Pelestarian Sumberdaya Ikan. Balai Besar Pengembangan Penangkapan Ikan, Direktorat Jendral Perikanan Tangkap, Kementrian Kelautan dan Perikanan, Indonesia. [Indonesian]

Brandl SJ, Johansen JL. Casey JM, Tornabene L, Morais RA, Burt JA. 2020. Extreme environmental conditions reduce coral reef fish biodiversity and productivity. Nat Commun 11 (1): 3832. DOI: 10.1038/s41467-020-17731-2.

Brochier T, Brehmer P, Mbaye A, Diop M, Watanuki N, Terashima H, Kapian D, Auger P. 2021. Successful artificial reefs depend on getting the context right due to complex socio-bio-economic interactions. Sci Rep 11: 16698. DOI: 10.1038/s41598-021-95454-0.

Burke LE, Elig S, Spalding M. 2002. Reefs at Risk in Southeast Asia. World Resources Institute, Washington, D.C.

Djunarsjah E, Putra AP. 2021. The concept of an archipelagic Province in Indonesia. IOP Conf Ser Earth Environ Sci 777: 012040. DOI: 10.1088/1755-1315/777/1/012040.

Edinger EN, Jompa J, Limmon GV, Widjatmoko W, Risk MJ. 1998. Reef degradation and coral biodiversity in Indonesia: Effects of land-based pollution, destructive fishing practices and changes over time. Mar Pollut Bull 36 (8): 617-630. DOI: 10.1016/S0025-326X(98)00047-2.

Fauzi A. 2005. Kebijakan Perikanan dan Kelautan: Isu, Sintesis, dan Gagasan. PT. Gramedia Pustaka Utama, Jakarta.

Fuller K, Kling D, Kroetz K, Ross N, Sanchirico JN. 2013. Economics and Ecology of Open-Access Fisheries. In: Shogren JF (eds). Encyclopedia of Energy, Natural Resource, and Environmental Economics. Elsevier Science. DOI: 10.1016/B978-0-12-375067-9.00114-5.

Friedman ST, Price SA, Hoey AS, Wainwright PC. 2016 EcomoIDRhological convergence in planktivorous surgeonfishes. J Evolution Biol 29 (5): 965-978. DOI: 10.1111/jeb.12837.

Gomez-Campos E, Borrell A, Cardona L, Forcada J, Aguila A. 2011. Overfishing of small pelagic fishes increases trophic overlap between immature and mature striped dolphins in the Mediterranean Sea. PloS ONE 6 (9): e024554. DOI: 10.1371/journal.pone.0024554.

Goren M, Galil BS, Diamant A, Gayer K, Stern N. 2009. First record of the Indo-Pacific cardinal fish *Apogon fasciatus* (White, 1790) in the Mediterranean Sea. Aquat Invasions 4: 409-411. DOI: 10.3391/ai.2009.4.2.21.

Gratwicke B, Speight MR. 2005. Effects of habitat complexity on Caribbean marine fish assemblages. Mar Ecol Progress Ser 292: 301-310. DOI: 10.3354/meps292301.

Hamel S, Gerung GS, Reppie E, Budiman J. 2021. Artificial reef habitat-supported integrated aquaculture. Aquaculture Aquarium Conserv Legislation Bioflux 14 (5): 2914-2928.

Hasan V, Gausmann P, Ottoni FP. 2021. First scientific observation of the threatened speartooth shark *Glyphis glyphis* (Müller & Henle, 1839) (Carcharhiniformes: Carcharhinidae) in Indonesia. Cybium 45 (4): 321-324. DOI: 10.26028/cybium/2021-454-010.

Hasan V, Andraini NE, Isroni W, Sari LA, Nafisyah AL, Dewi NN, Putri NAA, Prasasti TAB, Ramadhani AA, Daniel K, South J, Vieira LO, Ottoni FP, Maftuch, Faqih AR, Wirabuana PYAP, Tamam MB, Valen FS. 2023. Fish diversity of the Bengawan Solo River estuary, East Java, Indonesia. Biodiversitas 24 (2): 2207-2216. DOI: 10.13057/biodiv/d240433.

Higgins E, Metaxas A, Scheibling RE. 2022. A systematic review of artificial reefs as platforms for coral reef research and conservation. PloS ONE 17 (1): e0261964. DOI: 10.1371/journal.pone.0261964.

Homans FR, Wilen JE. 1997. A model of regulated open access resource use. J Environ Economics Manag 32 (1): 1-21. DOI: 10.1006/jeem.1996.0947.

Hosseini SA, Jamili S, Valinassab T, Vosoghi G, Fatemi SMR. 2009. Feeding and spawning of *Sphyraena jello* in the North-West of Persian Gulf. J Fish Aquatic Sci 4 (1): 57-62. DOI: 10.3923/jfas.2009.57.62.

Isroni W, Samara SH, Santanumurti MB. 2019. Application of artificial reefs for fisheries enhancement in Probolinggo, Indonesia. Biodiversitas 20 (8): 2273-2278. DOI: 10.13057/biodiv/d200823.

Jaelani LM, Afifi Z. 2016. Studi pemetaan pemutihan terumbu karang dengan citra resolusi tinggi (studi kasus: perairan PLTU Paiton Probolinggo). Metode 10 (2): 144-150. [Indonesian]

Jha DK, Wu M, Thiruchitrambalam G, Marimuthu PD. 2023. Coastal and marine environmental quality assessments. Front Mar Sci 10: 228. DOI: 10.3389/fmars.2023.1141278.

Jia CB, Zhuang SP. 2009. Present status and assessment of fisheries in the eastern waters of Shenzhen. Chin Fish 8: 21-23.

Jones ST, Asher JM, Boland RC, Kanenaka BK, Weng KC. 2020. Fish biodiversity patterns of a mesophotic-to-subphotic artificial reef complex and comparisons with natural substrates. PLoS ONE 15 (4): e0231668. DOI: 10.1371/journal.pone.0231668.

Kench PS, Mann T. 2017. Reef island evolution and dynamics: Insights from the Indian and Pacific Oceans and perspectives for the Spermonde Archipelago. Front Marine Sci 4: 145. DOI: 10.3389/fmars.2017.00145.

Kurnia R. 2019. Coral reefs status and fish species in coastal waters of Spelman Straits, Southeast Sulawesi, Indonesia. Aquaculture Aquarium Conserv Legislation 12 (5): 2020-2029.

Lamb JB, Williamson DH, Russ GR, Willis BL. 2015. Protected areas mitigate diseases of reef-building corals by reducing damage from fishing. Ecology 96 (9): 2555-2567. DOI: 10.1890/14-1952.1.

Layman CA, Allgeier JE. 2020. An ecosystem ecology perspective on artificial reef production. J Appl Ecol 57 (11): 2139-2148. DOI: 10.1111/1365-2664.13748.

Madduppa HH, Zamani NP, Subhan B, Aktani U, Ferse SC. 2014. Feeding behavior and diet of the eight-banded butterflyfish *Chaetodon octofasciatus* in the Thousand Islands, Indonesia. Environ Biol Fish 97 (12): 1353-1365. DOI: 10.1007/s10641-014-0225-z.

Magurran AE. 1998. Population differentiation without speciation. Phil Trans Royal Soc London Ser B Biol Sci 353 (1366): 275-286. DOI: 10.1098/rstb.1998.0209.

Mahendra AA, Kusdianti EM, Wiradana PA, Susilo RJK, Putranto TAC, Affandi M. 2020. Checklist of coral reef fish species composition at Bama Coastal Waters, Situbondo, East Java, Indonesia: A preliminary study. Economic Environ Conserv 26 (4): 1816-1819.

Marshell A, Mumby PJ. 2015. The role of surgeonfish (Acanthuridae) in maintaining algal turf biomass on coral reefs. J Exp Mar Biol Ecol 473: 152-160. DOI: 10.1016/j.jembe.2015.09.002.

McLean M, Roseman EF, Pritt JJ, Kennedy G, Bruce A, Manny BA. 2015. Review: Artificial reefs and reef restoration in the Laurentian Great Lakes. J Great Lakes Res 41: 1-8. DOI: 10.1016/j.jglr.2014.11.021.

Messmer V, Pratchett MS, Hoey AS, Tobin AJ, Coker DJ, Cooke SJ, Clark TD. 2017. Global warming may disproportionately affect larger adults in a predatory coral reef fish. Global Change Biol 23 (6): 2230-2240. DOI: 10.1111/gcb.13552.

Odum EP. 1971. Dasar-Dasar Ekologi. Diterjemahkan oleh: Samingan T, Srigandono B. Fundamental of Ecology. Gadjah Mada University Press, Yogyakarta.

Paxton AB, Shertzer KW, Bacheler NM, Kellison GT, Riley KL, Taylor JC. 2020. Meta-analysis reveals artificial reefs can be effective tools for fish community enhancement but are not one-size-fits-all. Front Mar Sci 7: 282. DOI: 10.3389/fmars.2020.00282.

Plaisance L, Matterson K, Fabricius K, Drovetski S, Meyer C, Knowlton N. 2021. Effects of low pH on the coral reef cryptic invertebrate communities near CO_2 vents in Papua New Guinea. PLoS ONE 16 (12): e0258725. DOI: 10.1371/journal.pone.0258725.

Pramoda R, Shafitri N, Indahyanti BV, Zulham A, Koeshendrajana S, Yuliaty C, Muawanah U, Kurniasari N, Kurniawan T, Hafsaridewi R, Kuncoro HS. 2021. Utilization of fish resources in the Indonesia's exclusive economic zone within the fishery management area of 573: Case study in Rote Ndao District. IOP Conf Ser Earth Environ Sci 869: 012018. DOI: 10.1088/1755-1315/869/1/012018.

Primyastanto M, Efani SMSA. 2013. Fisheries resources management by empowering the local wisdom in Madura straits. Res Humanities Soc Sci 3 (6): 13-23.

Ragnarsson SA, Burgos JM, Kutti T, van den Beld I, Egilsdóttir H, Arnaud-Haond S, Grehan A. 2017. The Impact of Anthropogenic Activity on Cold-Water Corals. In: Rossi S, Bramanti L, Gori A, Orejas C (eds). Marine Animal Forests: The Ecology of Benthic Biodiversity Hotspots. DOI: 10.1007/978-3-319-17001-5_27-1.

Riegl B, Glynn PW, Wieters E, Purkis S, d'Angelo C, Wiedenmann J. 2015. Water column productivity and temperature predict coral reef regeneration across the Indo-Pacific. Sci Rep 5: 8273. DOI: 10.1038/srep08273.

Risanti AA, Marfai MA. 2020. The effects of hydrodynamic process and mangrove ecosystem on sedimentation rate in Kendal coastal area Indonesia. IOP Conf Ser Earth Environ Sci 451 (1): 012070. DOI: 10.1088/1755-1315/451/1/012070.

Rizwan T, Nasution TK, Dewiyanti I, Elrahimi SA, Putra DF. 2017. Fish diversity in the east coastal waters area of Aceh Besar District, Indonesia. Aquaculture Aquarium Conserv Legislation 10 (5): 1180-1185.

Rowlett JH. 2018. A hybrid surgeonfish, *Acanthurus triostegus* x *A. polyzona*, from Mauritius. J Ocean Sci Foundation 30: 39-42. DOI: 10.5281/zenodo.1256848.

Rugebregt MJ, Nurhati IS. 2020. Preliminary study of ocean acidification: Relationship of pH, temperature, and salinity in Ohoililir, Southeast Maluku. IOP Conf Ser Earth Environ Sci 618: 012004. DOI: 10.1088/1755-1315/618/1/012004.

Sapriani, Wiwoho J, Handayani IGAKR. 2021. Sustainable fisheries principles in fisheries management regulation in Indonesia. Proceedings of the International Conference on Environmental and Energy Policy. Universitas Sebelas Maret, Surakarta, 16 Oktober 2021. DOI: 10.2991/assehr.k.211014.045. [Indonesian]

Sektiana SP, Abdillah AA, Alam MJ, Isroni W, Dewi NN, Kim HW, Andriyono S. 2022. Diversity of the Tabuhan Island coral reef fish revealed by DNA barcoding and implication on conservation strategy in Banyuwangi, Indonesia. Biodiversitas 23 (9): 4844-4851. DOI: 10.13057/biodiv/d230953.

Takeshige A, Miyamoto M, Narimatsu Y, Yonezaki S, Kiyota M. 2021. Evaluation of impacts of bottom fishing on demersal habitats: A case study off the Pacific coast of north-eastern Japan. Fish Res 238: 105916. DOI: 10.1016/j.fishres.2021.105916.

Tranggono AL, Diamantina A, Sekar P. Duties and authority of fisheries in the State Fisheries Management Region of the Republic of Indonesia, Proceedings of the 1st International Conference on Science and Technology in Administration and Management Information. ICSTIAMI, Jakarta, 17-18 July 2019. DOI: 10.4108/eai.17-7-2019.2302913. [Indonesian]

Valenzuela J, Bellwood D, Morais R. 2021. Ontogenetic habitat shifts in fusiliers (Lutjanidae): Evidence from Caesio cuning at Lizard Island, Great Barrier Reef. Coral Reefs 40: 1687-1696. DOI: 10.1007/s00338-021-02180-0.

Vivier B, Dauvin JC, Navon M, Rusig AM, Mussio I, Orvain F, Boutouil M, Claquin P. 2021. Marine artificial reefs, a meta-analysis of their design, objectives and effectiveness.Global Ecol Conserv 27: e01538. DOI: 10.1016/j.gecco.2021.e01538.

Wang XH, Du FY, Qiu YS, Li CH, Sun DR, Jia, XP. 2010. Variations of fish species diversity, faunal assemblage, and abundances in Daya Bay in 1980-2007. J Appl Ecol 21 (9): 2403-2410.

Whitfield AK, Pattrick P. 2015. Habitat type and nursery function for coastal marine fish species, with emphasis on the Eastern Cape region, South Africa. Estuarine, Coastal Shelf Sci 160: 49-59. DOI: 10.1016/j.ecss.2015.04.002.

Xu Q, Zhang L, Zhang T, Zhang X, Yang H. 2017. Functional groupings and food web of an artificial reef used for sea cucumber aquaculture in northern China. J Sea Res 119: 1-7. DOI: 10.1016/j.seares.2016.10.005.

Yang J, Yan D, Yang Q, Gong S, Shi Z, Qiu Q, Huang S, Zhou S, Hu M. 2021. Fish species composition, distribution and community structure in the Fuhe River Basin, Jiangxi Province, China. Global Ecol Conserv 27: e01559. DOI: 10.1016/j.gecco.2021.e01559.

Yu J, Chen P, Tang D, Qin C. 2015. Ecological effects of artificial reefs in Daya Bay of China observed from satellite and in situ measurements. Adv Space Res 55 (9): 2315-2324. DOI: 10.1016/j.asr.2015.02.001.

Yusuf M, Handoyo G, Muslim M, Wulandari SY, Setiyono H. 2012. Karakteristik pola arus dalam kaitannya dengan kondisi kualitas perairan dan kelimpahan fitoplankton di perairan kawasan Taman Nasional Laut Karimunjawa. Buletin Oseanografi Marina 1(5): 63-74. [Indonesian]