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Reef fish monitoring as a coral reef resilience indicator in the Sempu Strait, South of East Java, Indonesia

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Abstract. *Bintoro G, Isdianto A, Harahab N, Kurniawan A, Wicaksono AD, Mahardítha R, Fathah AL, Putri BM, Haykal MF, Asadi MA, Setyanto A, Lelono TD, Luthfi OM, Pratiwi DC. 2023. Reef fish monitoring as a coral reef resilience indicator in the Sempu Strait, South of East Java, Indonesia. Biodiversitas 24: 4950-4959.* Sempu Island is designated as a nature reserve which is surrounded by a fairly high diversity of coral reefs. Since the high activities of fishing ports near this island, the anthropogenic pressure seriously became a threat to the biodiversity of coral reefs in this nature reserve. Continuous observation of reef fish is an important activity to monitor the coral reef health condition. Since then, bimonthly monitoring using an underwater visual census has been conducted from October 2021 to May 2022. Based on these observations obtained that the average reef fish abundance was in the "low" category, namely 0.516 ind/m^2 in October 2021, 0.527 ind/m^2 in December 2021, 0.522 ind/m^2 in February 2022, and 0.378 ind/m^2 in May 2022. The abundance of reef fish obtained consisted of three categories: indicators, targets, and majors. Overall, the Pomacantridae family, from the major fish category, has the largest abundance compared to other families. While the range of coral coverage was 6-21.3%, which was included in the "bad" category. There was a relationship with a value of 0.462 (medium) between coral cover and fish abundance. The abundance of reef fish at 21.4% was influenced by coral cover, while the remaining 78.6% was influenced by other factors outside of the tested variables. The decline in reef fish abundance in 2015-2022 can be caused by a decrease in coral cover in the Sempu Strait.

Keywords: Anthropogenic pressure, coral reef fish, fish diversity, marine fish resilience, underwater visual census

INTRODUCTION

Reef fishes were used by marine ecologists as bioindicators of biodiversity in coral reef ecosystems (Tony et al. 2020). It was estimated that there are 12,000 species of marine fish in the world and approximately 7,000 species (58.3%) (Quimbayo et al. 2021). Based on FishBase, there are 2,139 species of reef fish in Indonesia (Froese and Pauly 2020) and around 197 species are endemic species (Hamuna et al. 2022). In a study by Luthfi et al. (2019) the families found in the Sempu Strait, South of East Java, are Chaetodonidae, Haemulidae, Lutjanidae, Scaridae, and Muraenidae. Due to their trophic interactions, fish communities have a role in coral reefs (Duffy et al. 2016). Hence, coral reef destruction affects reef fish biodiversity (Harvey et al. 2018). There are fish whose lives depend heavily on coral reefs as corallivores, such as butterflyfish and triggerfish (Luthfi et al. 2023), which can be said to be bioeroders because they can peel more than 50% of coral polypsina colonies, such as the green humphead parrotfish from the Scaridae family (Luthfi and Siagian 2017; Guntur and Arisandi 2021). Glynn and Manzello (2015), indicated that bioeroder would accelerate coral fragmentation and impair coral structures (Luthfi et al. 2023). Certain corallivorous fish can facilitate coral health by reducing disease, and non-corallivore fish (herbivorous fish control the macroalgae and predators that control the dangerous coralivorous fish) (Renzi et al. 2022). This link suggests that losing reef fish trophic groups will degrade coral reef ecosystems (Plass-Johnson et al. 2015).

The degradation of coral reefs in Indonesia continues to increase, both due to natural and anthropogenic factors (Ernaningsih et al. 2022). One of the locations that

continue to experience coral reef degradation is the Sempu Strait, which is closely related to anthropogenic activities such as fishing ports, settlements, and tourism that have the potential to change environmental conditions, either directly or indirectly change ecosystem processes, biodiversity and community composition (Elston et al. 2020). The survival of these reef fish depends on the condition of the coral reefs and the physical, chemical, and biological conditions of the waters. The survival of these reef fish depends on the condition of the coral reefs and the physical, chemical, and biological conditions of the waters. The existence of reef fish is very closely related to the condition of coral reef resources, which are their habitat (Sani et al. 2021). The abundance of reef fish in the waters of the Sempu Strait has decreased, as stated in Luthfi's research in 2016, 2017, and 2019. The abundance of reef fish in the Sempu Strait has decreased, especially in 2018, followed by a decrease in coral cover in 2018 to "poor" levels (Luthfi et al. 2019).

Protecting coral reefs is the responsibility of the wider community, the government and local communities, such as the application of Marine Protected Areas and other conservation areas (Putra et al. 2021; Sektiana et al. 2022). Implementing conservation area priorities requires an understanding of the spatial distribution of richness and the organization of fish assemblages (Rosdianto et al. 2021b). In accordance with the Government Regulation of the Republic of Indonesia Number 60 of 2007 concerning the Conservation of Fish Resources ('Ecosystems need to be carried out on all types of ecosystems related to fish resources, one of which is coral reefs' [Chapter 2 Article 5]). The Ministry of Maritime Affairs and Fisheries Regulation No. 26/2021 ('Everyone can participate in the rehabilitation of fishery resources and their environment' [Article 67.1]). Law No. 27/2007 (amended by Law No. 1/2014) 'pay attention to the balance of the ecosystem and/or local biodiversity' [Article 32.1] and are 'environmentally sound' [Article 32.2d] (Razak et al. 2022). The decline of reef fish in the Sempu Strait is the goal of researchers to further discuss the condition of coral reefs. This is also supported because there is still little research discussing the relationship between the condition of fish and coral reefs in the Sempu Strait.

MATERIALS AND METHODS

Description of the study

Coral reef data collection was carried out in the Sempu Strait with four times of monitoring (October 2021, December 2021, February 2022, and May 2022), which covered five stations: Jetty Pelabuhan, Rumah Apung, Banyu Tawar, Waru Waru, and Watu Meja (Figure 1). The research area is in the reef flat zone and reef slope zone according to the distribution of coral reefs in the Sempu Strait, which is generally at a depth of 1-10 meters. This condition shows that the deeper the water, the lower the coral cover. Habitat characteristics are known to play an important role in shaping fish communities (Madduppa et al. 2012). description of each station is presented in Table 1.

Watu Meja is located in the east and is directly facing the open sea, so it is also far from the influence of anthropogenic activity. Waru-waru is the only location in the Sempu Strait that is a tourist attraction, while the next to it is called Banyu Tawar, which has run off of a small river, resulting in the low salinity on seawater. Jetty Pelabuhan is the busiest station, which has lots of fisheries activities. Rumah Apung is a station located at the western end of the Sempu Strait and directly adjacent to the Indian Ocean.

Reef fish data collection

Reef fish data collection was carried out using the Underwater Visual Census (UVC) at five stations, with a total of five points at each station and a depth of 3-6 meters. The collection of fish data refers to the data sheet specified in the Reef Health Monitoring (RHM) protocol of Coremap-CTI (Giyanto et al. 2014). The research area uses long-line transects with a length of 50 meters (Riskiani and Bahar 2019). The laying of the transects was done by purposive sampling and monitoring three times within a period of six months of observation. This method needed Self Contained Underwater Breathing Apparatus (SCUBA) equipment, an underwater camera, and required 3 divers (Figure 2). One diver is to set up the transect, one is to record reef fish in the transect area, and the other diver is to record using the SCUBA or underwater breathing device (Prato et al. 2017).

Coral reef data was collected by using the Underwater Photo Transect (UPT) method (Figure 3). Data collection is done by shooting underwater using an underwater camera or an ordinary digital camera that is given housing so that seawater does not hit the camera directly.

Table 1. Description of locations

Station	Coordinates	Description
Watu Meja	8°25'46.12"S, 112°41'51.24"E	Located in the east and is directly facing the open sea, so it is also far from the influence of anthropogenic activity
Waru-waru	8°25'48.99"S, 112°41'37.03"E	The only location in the Sempu Strait that commonly used as tourist attraction
Banyu Tawar	8°26'1.35"S, 112°41'19.65"E	This location has run off of small river, resulted the law salinity on sea water
Jetty Port	8°26'1.86"S, 112°41'3.22"E	This location is a usiest station which has lots of fisheries activities including a fishing boat docking facility, ship transit, and also offloading area
Rumah Apung	8°26'13.99"S, 112°40'48.14"E	Located at the western end of the Sempu Strait and directly adjacent to the Indian Ocean

Data analysis

Coral reef fish abundance

Analysis of reef fish abundance data was carried out with the following formula (Labrosse et al. 2002):

$$N = \frac{ni}{A}$$

Description:

N : Reef fish abundance (ind/m^2)

Ni : Number of fish on the transect (ind)

A : Transect area (m^2)

The category of reef fish abundance can be measured using categories in Table 2 (Gomez and Yap 1988).

Coral reef data analysis

Coral reef data analysis was carried out to find the proportion of coral cover using the CPCe application. The formula used to find out the value of coral cover is as follows (Giyanto et al. 2014):

$$Proportion\ of\ Coral\ Cover = \frac{Total\ point\ of\ category}{Total\ of\ random\ point}\ x\ 100\%$$

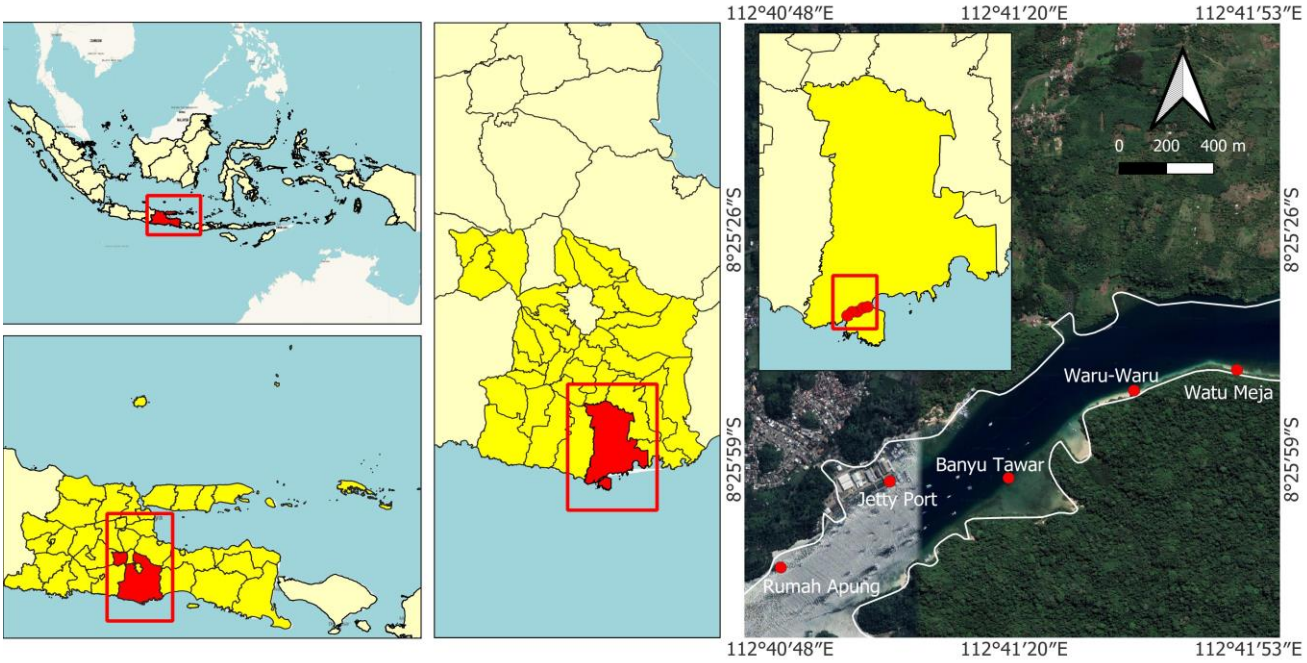

Figure 1. The localities of monitoring in the Sempu Strait, South of East Java, Indonesia

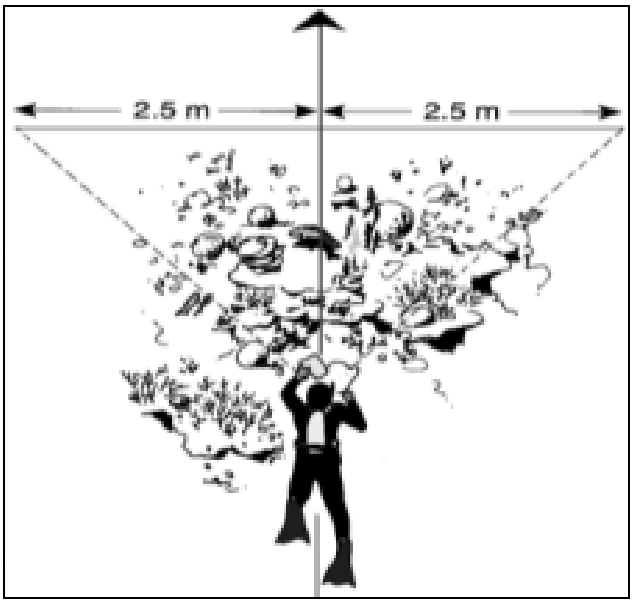

Figure 2. Underwater Visual Census (UVC) for reef fish. Image Source: English et al. 1998

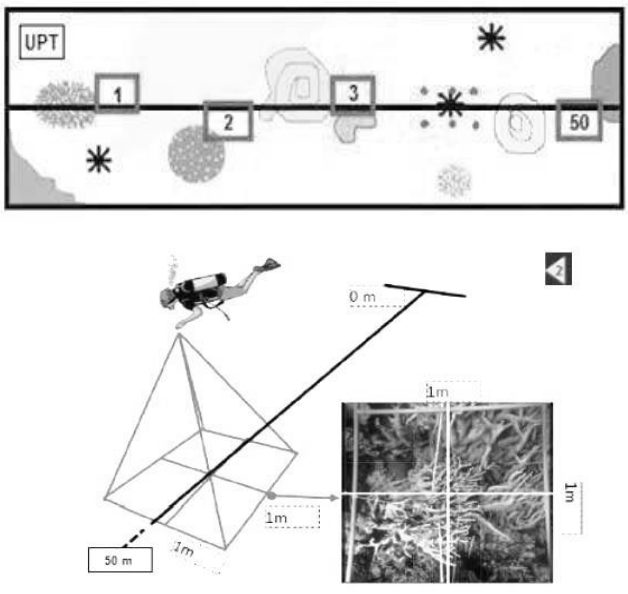

Figure 3. Underwater Photo Transect (UPT) for coral cover. Image Source: Giyanto et al. 2014

Table 2. The category of reef fish abundance

Abundance rate (ind/m^2)	Category
0.55-1.54	Low
1.55-2.53	Medium
2.54-3.54	High

Table 3. Standard criteria for coral reef damage

Parameters	Coral reef damage standard criteria (%)		
Proportion of live coral cover	Damaged	Proportion of live coral cover	00-24.9
		Medium damaged	25-49.9
	Good	Good	50-74.9
		Very good	75-100

Source: Ministry of Environment Decree No. 04/ 2001

RESULTS AND DISCUSSION

Reef fish abundance

Reef fish are grouped into 3 categories: (1) target fish, which are common in the market and most consumed by humans; (2) indicator fish, which are reef fish that have a strong relationship with coral habitats; and (3) major fish which play a role in the food chain (Sala et al. 2020). There was no significant difference in the abundance of fish in October 2021 at five stations (Figure 4). The highest abundance was at the Watu Meja at 0.564 ind/m^2, while the lowest abundance was at the Rumah Apung at 0.460 ind/m^2. The average abundance of reef fish in October 2021 was 0.516 ind/m^2, and 20 families. The largest abundance of the major fish category was Pomacantridae family, which is 0.640 ind/m^2. This family tends to be near food sources and shelter. This family is often found in large numbers in the coral branching area (Coker et al. 2014). The indicator fish, Chaetodonidae, has a lower abundance compared to the other two categories because their life cycle depends on coral reefs, which is 0.540 ind/m^2. In addition, corallivores such as Chaetodontidae, heavily depend on coral reefs can facilitate coral health by reducing disease (Renzi et al. 2022; Luthfi et al. 2023) and can be said to be bioeroders because they can peel more than 50% of coral polypsina colonies (Luthfi and Siagian 2017). Glynn and Manzello (2015), indicated that bioeroder would accelerate coral fragmentation and impair coral structures (Luthfi et al. 2023). Studies on coral damage also show that there is a decrease in the number of individuals from the Chaetodonidae family when the area is disturbed. Other factors such as human activity, environmental conditions, and water nutrition followed by algae growth in corals will also affect corals (Nugraha et al. 2020).

The abundance of reef fish in December 2021 (Figure 5) at five stations obtained an average abundance of 0.527 ind/m^2, with the highest abundance at the Waru-waru, which was 0.568 ind/m^2. While the lowest fish abundance value was at the Rumah Apung of 0.488 ind/m^2. Based on the values obtained, there has been an increase in abundance values at Watu Meja and Waru-Waru. This increased value was due to reduced ship traffic in December 2021. The highest abundance was in the target category, namely the Acanthuridae (Surgeon) family, as seen from the high number of individuals found. The presence and intensity of herbivores can control the distribution and growth of macroalgae (Guest et al. 2016; Ezzat et al. 2020).

Based on research in February 2022 (Figure 6) the highest abundance value was at the Banyu Tawar, with a value of 0.540 ind/m^2, and the lowest value was at the Jetty at 0.496 ind/m^2. The highest average fish abundance in February 2022 was 0.522 ind/m^2. Just like in December, the highest abundance of fish was in the target category, namely the Acanthuridae (Surgeon) family, as can be seen from the large number of individuals found. The existence of the Acanthuridae family, which includes herbivore fish, will help in the coral recovery process during the bleaching phenomenon. Herbivorous fish are able to clean algae from dead coral so that they can help the planula attachment process in the coral recruitment process (Chung et al. 2019). Basically, macroalgae grow more rapidly than corals, resulting in competition for growing space (Isdianto et al. 2023). Other research shows that the number of individuals, types, and sizes of herbivorous fish play a crucial role in coral reef resilience, which functions as a controller of algae growth, such as Scaridae (Plass-Johnson et al. 2015; Wulandari et al. 2022). Scaridae family sometimes caused coral and substrate erosion by excavating and scraping alga living on coral substrata with their jaws (El Rahimi et al. 2021).

The average abundance of fish in May 2022 (Figure 7) decreased quite a lot from the previous month, namely to 0.378 ind/m^2. The highest abundance was at the Rumah Apung, which was 0.556 ind/m^2, and the lowest was at the Banyu Tawar, which was 0.248 ind/m^2. At each station, the highest abundance value was obtained from the major fish, namely the Pomacantridae family. This is due to the large number of major fish families found, so the number of individuals found is also abundant.

Species of reef fish

There are 23 families (Figure 8) and 62 species found in Sempu Strait during October 2021-May 2022 observation. Families found included Chaetodonidae, Acanthuridae, Serranidae, Scaridae, Nemiptidae, Siganidae, Caesionidae, Balistidae, Holocentridae, Haemullidae, Ephipidane, Muraenidae, Pomacantridae, Labridae, Pomacanthidae, Blennidae, Gobidae, Zanclidae, Aulosttomodonidae, Cirhitidae, Tetratoidae, Scorpionidae, and Pingupidae. According to Luthfi et al. (2019), they found 5 families in the Sempu Strait, such as: Chaetodonidae, Haemulidae, Lutjanidae, Scaridae, and Muraenidae.

Fluctuation of reef fish abundance in 2015-2022

From data collection within 4 periods with 2-month observation intervals, there was a decrease in abundance due to natural and anthropogenic factors. Research on fish abundance in the Sempu Strait has also been conducted by previous researchers from 2015 to 2022. The abundance of reef fish in Sempu Strait from 2015 to 2022 showed

fluctuations, especially in 2018 and 2022 (Figure 9). The value of the abundance of reef fish obtained was in the "low" category, seen from the abundance category according to Gomez and Yap (1988) in Table 2.

In December 2015, the results of monitoring by Luthfi et al. (2016) found an abundance of reef fish at Teluk Semut 1 and Teluk Semut 2 of 0.538 individuals/m^2. The results of the observations showed that the most common reef fish were those of the Chaetodontidae family. This family reflects the condition of coral reefs; a high amount of live coral cover is positively correlated with the number of fish in the ecosystem. The families with the second-highest number are Haemulidae and Lutjanidae. Other fish observations were of the Scaridae and Murainidae species.

Meanwhile, in 2016, the results of monitoring by Luthfi et al. (2017) showed that the abundance of reef fish at Teluk Semut 1, Teluk Semut 2, Watu Meja, and Fish Apartments was 0.432 individuals/m^2. The families Chaetodontidae, Haemulidae, Lutjanidae, Scaridae, and Murainidae were found. The Chaetodontidae family is found to be the most abundant because of its life cycle in coral reefs and because its food is widely available in coral reefs.

Then, the abundance of reef fish obtained in the study by Luthfi et al. (2019) took place in Teluk Semut 1, Teluk Semut 2, Watu Meja, and Waru Waru. Based on research, the highest fish abundance is in the Chaetodontidae family. The existence of these reef fish is influenced by the time of observation, the nocturnal habits of target fish or economically important fish, as well as tourist and fishing activities targeting reef fish and environmental factors of the reef fish themselves. The abundance of reef fish in the Sempu Strait has decreased, especially in 2018. This is due to a significant decrease in coral cover in 2018 in the "bad" category (Luthfi et al. 2019).

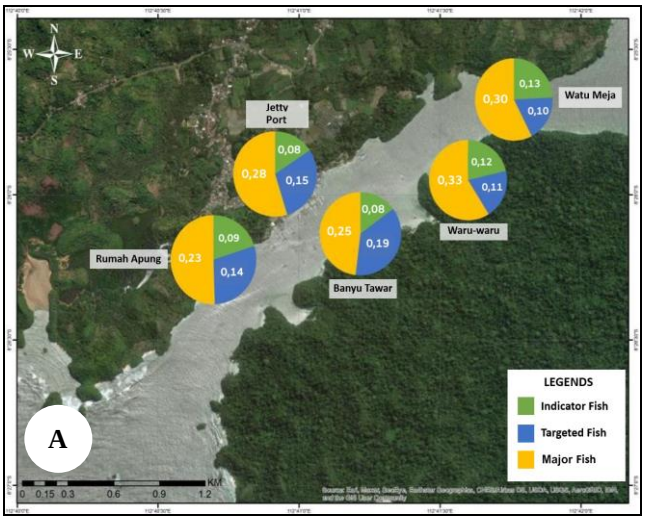

Figure 4. Map of The abundance of reef fish in Sempu Strait, October 2021

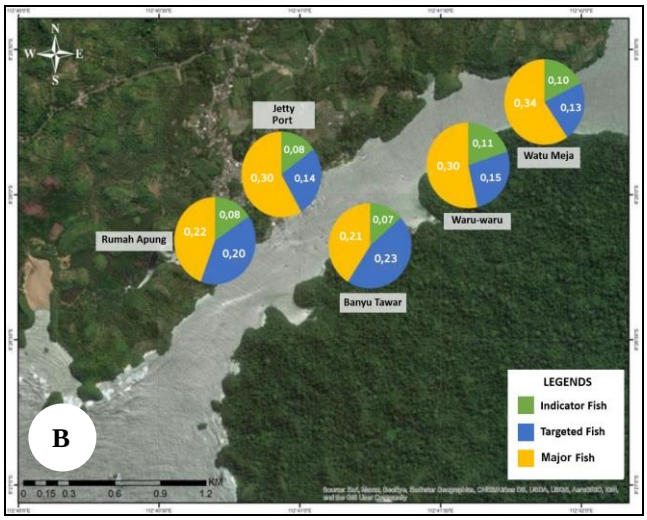

Figure 6. Map of The abundance of reef fish in Sempu Strait, February 2022

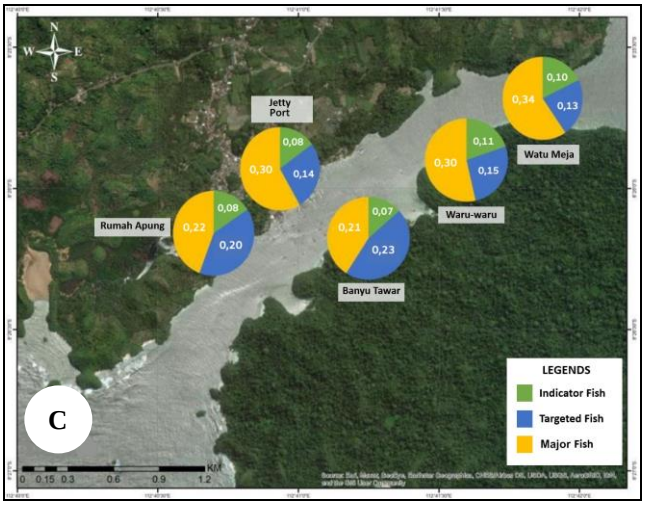

Figure 5. Map of The abundance of reef fish in Sempu Strait, December 2021

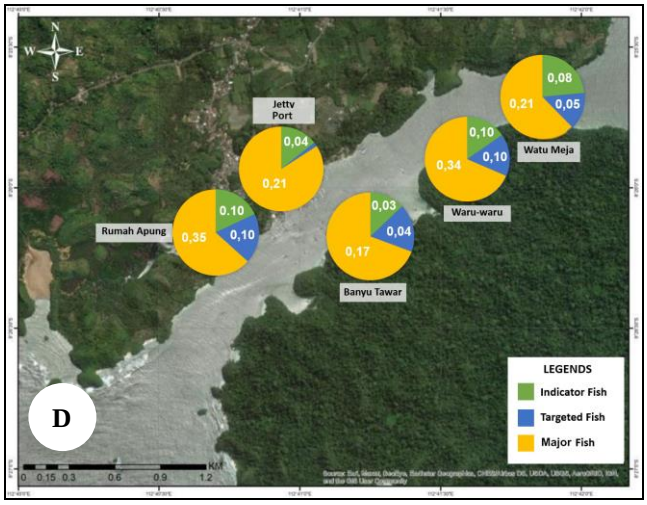

Figure 7. Map of The abundance of reef fish in Sempu Strait, May 2022

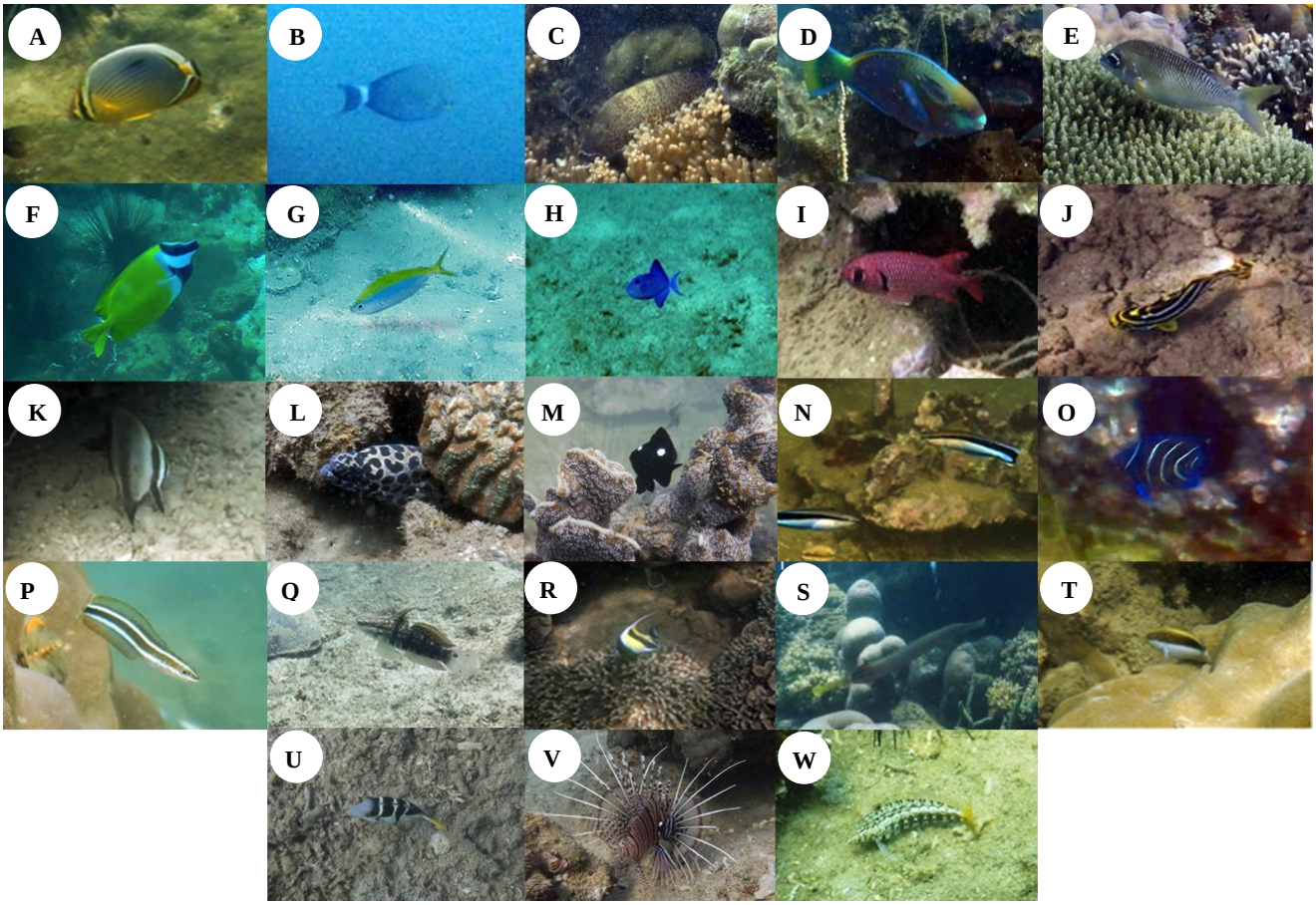

Figure 8. Families of reef fish in Sempu Strait. A. Chaetodonidae, B. Acanthuridae, C. Serranidae, D. Scaridae, E. Nemiptidae, F. Siganidae, G. Caesionidae, H. Balistidae, I. Holocentridae, J. Haemullidae, K. Ephipidane, L. Muraenidae, M. Pomacantridae, N. Labridae, O. Pomacanthidae, P. Blennidae, Q. Gobidae, R. Zanclidae, S. Aulosttomodonidae, T. Cirhitidae, U. Tetratoidae, V. Scorpionidae, and W. Pingupidae

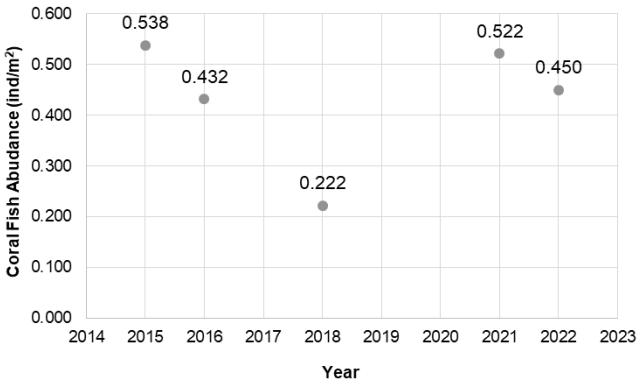

Figure 9. Reef fish abundance fluctuations in Sempu Strait from 2015 to 2022

The average abundance in 2021 was taken in October and December 2021 and was 0.522 individuals/m^2. In October 2021, the average abundance was 0.516 individuals/m^2, and in December 2021, it was 0.516 individuals/m^2. Data were taken from 5 stations, namely Watu Meja, Waru-Waru, Banyu Tawar, Jetty, and Rumah Apung, with 3 categories: indicator, major, and target fish.

Fish abundance in 2022 was measured at five stations: Watu Meja, Waru-Waru, Banyu Tawar, Jetty, and Rumah Apung in February 2022 and May 2022. The average fish abundance in 2022 is 0.450 individuals/m^2. There are 3 categories, namely indicator fish (Chaetodontidae family), major (Acanthuridae family) and target fish (Pomacantridae family).

The proportion of coral cover

Coral reef data were processed on the CPCe software to obtain the proportion of coral cover based on the lifeform category (

Figure **10**). Based on the proportion of coral cover standards from Minister of Environment Decree No. 04 of 2001, Republic of Indonesia, coral cover in the Sempu Strait is in the "low" category (Table 3) with a range from 6% to 21.3%. There are differences in monthly coral reef cover at the five stations. In October, the highest was at the Waru-Waru station (15.3%), and the lowest was at the Banyu Tawar (6%). In December, the highest was at the Watu Meja (16.7%), and the lowest was at the Rumah Apung (6%). In February, the highest was at the Banyu Tawar (21.3%), and the lowest was at the Rumah Apung (7.3%). Finally, in May, the highest was at the Waru-Waru

station (15.3%), and the lowest was at the Rumah Apung (6%).

Watu Meja has the highest proportion of coral cover compared to other stations due to the condition of its waters, which have a fairly strong current, clear water, and a fairly low sedimentation rate. Luthfi et al. (2019) stated in their research that the Watu Meja station has a sloped water topography and strong currents because it is far from the bay and faces directly on the Pacific Ocean. Overall, Rumah Apung has the lowest percentage of cover at 4 observations. The low coral cover at Rumah Apung is due to a reef slope section with moderate currents, quite cloudy water, and quite high sedimentation. Water conditions cause the low value of coral cover at Rumah Apung. Sedimentation can be stressful for corals that are just starting recruitment (Moeller et al. 2017). In addition, sedimentation causes water turbidity, which leads to coral bleaching (Jones et al. 2020) and also affect reef fishes biodiversity (Madduppa et al. 2013). In addition, the coral at Rumah Apung itself grows more in the shallow, sloping part that approaches the beach, so there are very few corals in the transect due to the planting location on the slope. Another possible cause of low coral cover comes from human activity that damages coral, such as fishing, that is not environmentally friendly, shipping, the effects of tourism, and housing activities. Water quality also influences how coral reefs live, grow, and develop, as well as the varied flora and animals that inhabit them (Isdianto et al. 2021). In addition, the loss of favorite coral species could have profound effects on reef fish biodiversity, more so than declining coral cover (Komyakova et al. 2018). Controlled area management results in better abundance and biomass of reef fish than open areas (Rudi et al. 2009).

The relationship between coral reef cover-reef fish abundance

After analyzing the linear regression statistics, the correlation value (R) was 0.462. The correlation value obtained is in the moderate category (0.40-0.59) (Figure 11). Then we obtained a coefficient of determination (R^2) of 0.214, or 21.4%. This value indicates that 21.4% of reef fish abundance is influenced by coral cover, while the remaining 78.6% is influenced by other factors outside the test variables.

A constant value (a) of 0.240 is obtained, while the value of coral cover (b/regression coefficient) is 0.021, so that the regression equation can be written:

$$Y = 0.240 + 0.021X$$

The regression coefficient X of 0.021 states that for every 1% addition of coral cover (X), the abundance of fish (Y) will increase by 0.021. The regression coefficient is positive, meaning that the direction of X's influence on Y is positive.

Discussion

According to the findings of four observations carried out in October 2021, December 2021, February 2022, and May 2022, the abundance of reef fish across all stations falls into the "low" category. The abundance of reef fish was measured to be between 0.55 and 1.54 individuals per square meter. This was also related with the discovery of the presence of reef fish around the observed coral reefs, which demonstrated that the indicator fish of the Chaetodontidae family had a lower abundance and fewer different species when compared to other groups of organisms. This is pertinent to the explanation provided by Tony et al. (2020), which claims that not all members of the Chaetodontidae family acquire the majority of their sustenance from coral polyps. This information can be found in the previous referenced article. The low population of these fish is an indicator, according to the findings of research conducted on coral reefs that belong to the damaged group, that the condition of the coral reefs in these seas is poor or that they have been damaged. It is common knowledge that coral reefs play a significant role in defining the distribution as well as the richness of fish communities.

The average proportion of live coral cover as a whole at the five study locations for 4 months belongs to the low category with a range from 6-21.3%. Based on visual observations, it was found that there were many dead corals covered with algae and coral rubble in the study area. A healthy coral reef can be determined to be in good condition by the presence of a large number of fish belonging to the family Chaetodontidae as an indicator fish. This is consistent with the viewpoint presented by Luthfi et al. (2016), which states high live coral cover is positively related to the number of fish that can be found in an environment. Furthermore, the targeted fish have characteristics that are intertwined with the state of the coral reefs in the waters where they live (Luthfi et al. 2019). These findings can be explained by the presence of anthropogenic activities in the waters of the Sempu Strait. These activities include fishing auctions, activities that take place on ships and in ports, and tourism. These activities have a very close relationship with fishing grounds and have a significant direct impact on the aquatic ecology, including the ecology of coral reefs (Luthfi et al. 2017).

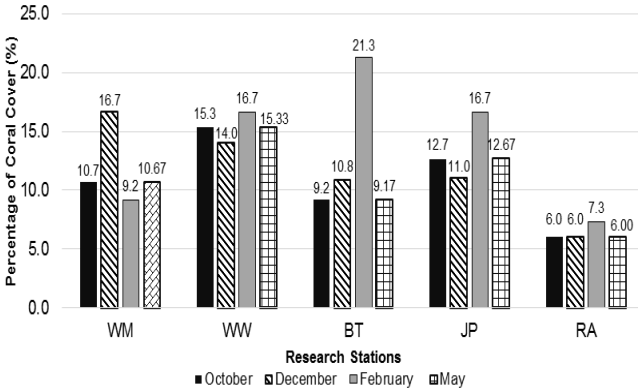

Figure 10. Proportion of coral cover in the Sempu Strait. Note: WM: Watu Meja, WW: Waru-Waru, BT: Banyu Tawar, JP: Jetty Pelabuhan, and RA: Rumah Apung

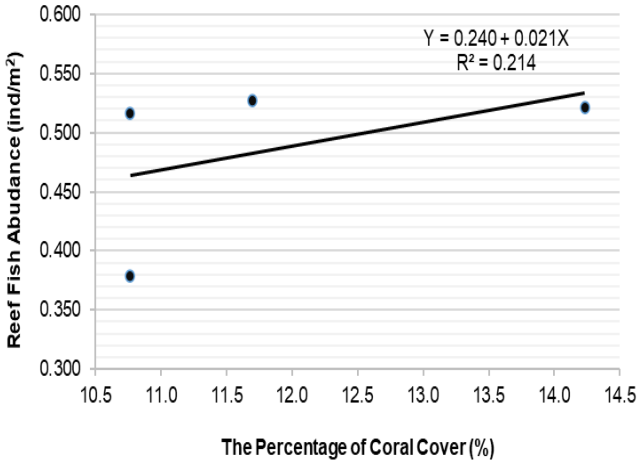

Figure 11. Simple linear regression graph

It has been demonstrated that the variation in environmental conditions has a significant effect on species composition (Utama et al. 2022), particularly on species that are associated with aquatic physico-chemical parameters (Herawati et al. 2021), depth, and benthic complexity (Wulandari et al. 2022). This is demonstrated by the findings of the study that analyzed the relationship between the abundance of coral reefs and the quantity of fish, which found that 78.6% of the relationship is influenced by other factors that are not included in the test variables. According to Yuspriadipura et al. (2014), the relationship between bottom substrate and reef fish can generally be seen in the behavior of reef fish. For example, reef fish tend to favor sandy or granular substrates since these bottom types provide a location for reef fish to thrive. Other studies have indicated that the availability and diversity of feed have an effect on the quantity and diversity of reef fish, particularly corallivora fish, which are affected by coral cover. According to Harahap et al. (2019), corallivore fish, which belong to the family Chaetodontidae, have a high correlation value with coral cover. This is due to the fact that these fish prefer corals that are in healthy condition and have a high cover of algae and food. Other factors such as food availability, safe shelter and lack of predators in coral reef areas also determine the high distribution of coral reefs, which is associated with high coral cover (Rosdianto et al. 2021a). According to Hadi et al. (2023), branching coral life forms show a significant correlation with herbivorous fish because they provide protection from predators. On the other hand, Ernaningsih et al. (2022) found that the presence of live coral cover had a negative correlation with the number of fish and the variety of species. It was also stated in Fatimah et al. (2018) that research findings at two distinct depths, specifically 3 and 10 meters, exhibited contrasting outcomes. The observed correlation between the abundance of reef fish and coral cover percentage exhibits a negative coefficient at a depth of 3 meters and a positive at a depth of 10 meters. It is hypothesized that this phenomenon can be attributed to oceanographic factors that induce instability in aquatic environments.

The condition of reef fish and coral reefs in the waters of the Sempu Strait can be effectively characterized by the changes in population size that can also be linked to true natural selection. Regardless of any continuing conservation efforts or potential classification of the area as a protected coral reef zone, it is anticipated that this development will have significant biological repercussions on the coastal area of Sempu. These repercussions are predicted to be enormous. This project's mission is to conduct research and provide policymakers with insights, with the end goal of enabling them to establish appropriate policies for the conservation of coastal ecology, with a particular emphasis on the coral reef ecosystems that are found in the waters surrounding Sempu.

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