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Original research article

The Reef Fish Community Structure in Penyusuk Waters, Bangka Regency, Indonesia (Case Study of Artificial Reef in PT. Artha Cipta Langgeng)

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ABSTRACT

Reef fishes are important components of a healthy coral ecosystem. However, when coral reefs are degraded, reef fishes also lose their habitat resulting in a decline in reef fish production and sustainable livelihood for the communities depending on it. In this study, we determined the status of reef fish communities in an artificial reef at PT Artha Cipta Langgeng in the Penyusuk waters of Bangka Regency, Indonesia. Data on reef fish communities were collected using the underwater visual census (UVC) method, including in situ and ex situ environmental parameters. A total of 2,987 individuals belonging to 12 reef fish species and five families were recorded across three stations. The abundance of reef fish ranges from 45 to 60 ind/m², categorized as highly abundant. Diversity, evenness, and dominance indices were calculated at 1.18-1.49, 0.56-0.65, and 0.26 -0.36, respectively which are categorized as low to moderate. The environmental parameters in the artificial reef are still within the standard limit for a reef ecosystem. The study emphasizes the importance of artificial reefs as an alternative to a degraded coral reef ecosystem in supporting the thriving existence of reef fishes in the Penyusuk waters.

Introduction

Bangka Belitung Islands province is endowed with both biological and non-biological resources. One of the non-biological resources derived from the Bangka Belitung Islands province is the mineral resource known as tin. Tin mining has been conducted for a long time both on land and at sea. The tin mining activities have led to changes in the landscape and environmental damage. The environmental damage is a result of irresponsible human activities, necessitating the need for restoration. One of the damaged ecosystems in the sea is the coral reef ecosystem. Coral reefs are essential ecosystems in marine waters that play a crucial role in the survival of marine life, such as fish and other organisms (Oktarina et al., 2014).

Due to several anthropogenic and climatic stressors, many of the coral reefs throughout the world are already

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imperiled and warrant active restoration (Hoegh-Guldber 2011). However, coral restoration projects require a high investment of time, money, and effort on the part of concerned stakeholders (e.g., government agency, fisherfolks, etc.). Similarly, the long-term benefits of any restoration activities are usually noticed 10-20 years after its first establishment and requires alternative livelihood for affected coastal communities (Gonzales & Dolorosa 2017). Aside from restoration, restoring the lost functioning and reconnecting the reef ecosystem to its vital components with the aid of rehabilitation techniques and technologies are also needed. Examples of rehabilitation technologies or techniques include artificial reefs (ARs), coral transplantation or coral gardens, and sea ranching (Guntur, 2011; Gonzales & Dolorosa, 2017). These rehabilitation technologies or techniques can assist and accelerate the recovery of damaged coral reefs which involve enhancing or facilitating the natural recovery processes of the corals. The ARs are man-made reefs that are commonly used to restore coral ecosystems and also serve as additional protection against wave erosion or abrasion of the coastal environment (Watanuki & Gonzales 2006). They are constructed in the sea and placed in the unproductive seabed, imitating some characteristics of natural reefs (Directorate General of Marine Affairs, Coastal Areas, and Small Islands et al., 2005). Aside from increasing fisheries productivity, ARs can also be used for recreational diving which can contribute to the local economy through sustainable tourism (Baine 2001). Because of its perceived advantage, reef rehabilitation using ARs has been implemented to restore the coral ecosystem in Artha Cipta Langgeng (ACL), Pensuyuk waters.

Several marine biota are vital components and associated with a healthy coral reef ecosystem including reef fishes, benthic macroinvertebrates, and megafaunas. Most of the reef fishes are dependent on the coral reefs for their habitat and consider it as their feeding, nursery, and feeding grounds (Nontji, 2007). Any damage to the coral reefs has a profound effect on the diversity and abundance of reef fishes. Thus, monitoring of reef fauna surrounding ARs is necessary to measure the success of any restoration efforts. In this study, we determined the status (diversity, abundance, uniformity) of reef fish communities in the artificial reefs of PT Artha Cipta Langgeng (ACL) in Penyusuk, Bangka Regency, Indonesia. The provided information will help future activities (e.g., monitoring of reef fish communities) and serve as a basis for comparison with research for the management of marine resources in the waters of Penyusuk, Bangka Regency.

Materials and Methods

Study Location

The study was conducted in May 2023 in the waters of Penyusuk, Bangka Regency, Indonesia (Figure 1).

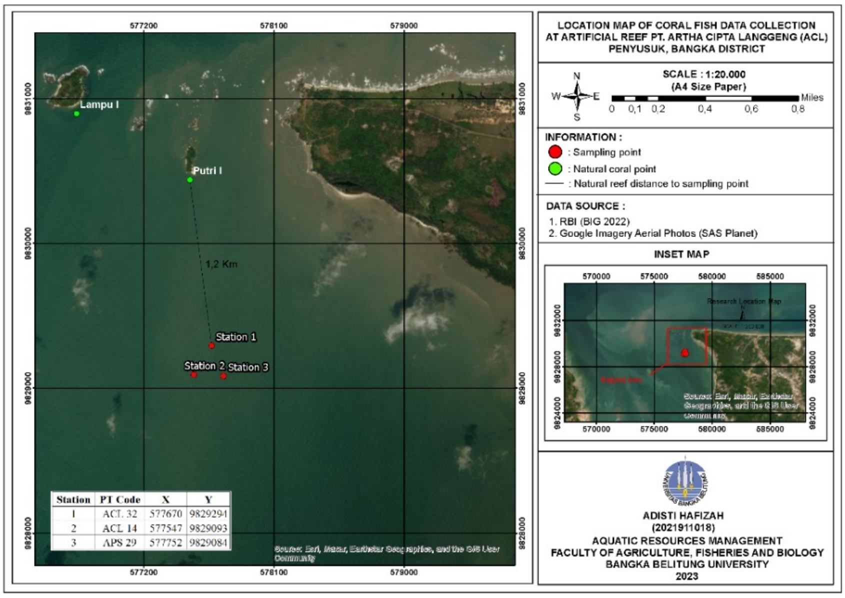

Figure 1. Location of the artificial reefs in PT Artha Cipta Langgeng (ACL) in the waters of Penyusuk, Bangka Regency, Indonesia.

Tools and Materials

The tools and materials used include SCUBA set, GPS, roll meter, underwater camera, Sechi disk, thermometer, refractometer, pH meter, current kite, stopwatch, dive slate, boat, TSS sample bottle, and coral fish identification book.

Data Collection Method

Environmental parameters were also measured both *in situ* and ex-situ. The total suspended solids (TSS) samples were collected using sampling bottles and tested at the Laboratory of the Provincial Health Office of the Bangka Belitung Islands using the gravimetric method following the SNI (06-6989.3-2004) protocol.

Reef fish communities were assessed using the underwater visual census (UVC) method and an underwater camera (Andrian et al., 2020). The UVC surveys were conducted at 3-6 m depth. The observer made a stop in the modules of each station of the AR, identified, and counted the reef fishes within each station. Aside from the observer, an underwater camera was also used to document reef fishes in each station (Figure 2). Most of the fishes were identified *in situ,* while unidentified species were verified from photos and videos taken by the underwater camera. Fish were identified down to the lowest possible taxon using Allen (2000) and Kuiter and Tonozuka (2001a,b,c) as references. We also classified the fish as "target" (moderate to high commercial importance) or "major" (non to low commercial importance).

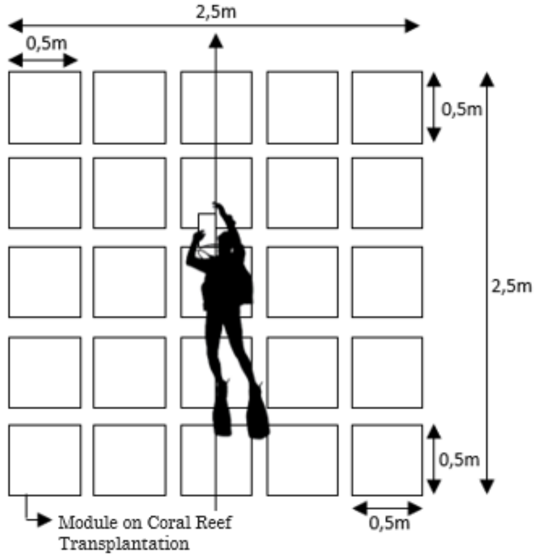

Figure 2. An illustration of reef fish community data collection using the underwater visual census (UVC) method in each artificial reef.

Data Analysis

Abundance

Coral fish abundance is the number of fish found in the observation location per unit area of the observation transect. The abundance index can be calculated using the formula (Labrosse, 2002):

$$K = \frac{ni}{A} \quad \text{..................(1)}$$

Where:

K = Coral fish abundance (ind/m$^{2)}$

ni = Number of coral fish at observation station 1 (ind)

A = Area of the observation transect (m^2)

Diversity Index

The diversity index (H') was calculated using the Shannon-Wiener equation (Setyobudiandi et al., 2009):

$$H' = -\{\Sigma pi \text{ In } pi\} \quad \text{..................(2)}$$

$$Pi = \frac{ni}{N} \text{..............................(3)}$$

Where:

H' = Shannon-Wiener Index

n_i = Number of individual (i)

N = Total number of individual

According to Mason (1981), the grouping of fish diversity index in a community is expressed in the following categories of values:

H<1 = Low diversity

1≤H<3 = Moderate diversity

H>3 = High diversity

Evenness Index

The evenness index (E) is used to determine the distribution of the number of individuals for each coralfish species. It was calculated using the formula:

$$E = \frac{H'}{Hmaks} \longrightarrow Hmaks = InS \text{ ....(4)}$$

Where:

E = Diversity Index

H' = Shannon-Wiener Diversity Index

H_{maks} = Maximum Diversity

S = Number of Spesies

According to Krebs (1989), the categorization of the uniformity index of fish in a community is expressed in the following value categories:

E<1 = High evenness

0,4<E<0,6 = Moderate evenness

E > 0,4 = Low evenness

Dominance Index

The dominance index (C) is used to determine the dominant coral fish species in the waters. The extent of dominance can lead to a community's condition becoming unstable or stressed (Choat and Bellwood, 1991). The dominance value was calculated following the formula used by Odum (1971):

$$C = \sum_{i=1}^{n} P_i^2$$

Where:

C = Dominance Index

P_i = Prportion of the number of individualis in the *i*th coral fish spesies

According to Odum (1971), the classification of fish groups based on dominance index in a community is expressed in the following categories:

0<C=0,3 = Low dominance
0,3<C=0,6 = Moderate dominance
0,6<C=1 = High dominance

Result and Discussion

Results

Environmental Parameters

The environmental parameters collected in this study are presented in Table 1. Most of the parameters, such as water clarity (29.27 – 40.57%), water current (0.51 m/s), pH (7.3-7.4), water depth (3.9 to 5.3 m), and salinity (30 and 35 ppt) are within the limit, while temperature (31 and 32°C) and TSS (12-38.5 mg/l) are mostly over the standard limit.

Table 1. Environmental parameters collected from the three stations in the artificial reefs of PT. Artha Cipta Langgeng, Penyusuk Waters, Bangka Regency, Indonesia

Parameter	Average value	Standar Limit	Source
Temperature (^{O}C)	31,33	28-30	Government Regulation No. 22 of 2021
Brightness (%)	36,10	-	-
Depth (m)	4,67	>5	Government Regulation No. 22 of 2021
Current (m/s)	0,50	0.1-0.76	Adrian *et al.* (2020)
Salinity (ppt)	31,67	33-34	Government Regulation No. 22 of 2021
pH	7,33	7.0-8.5	Government Regulation No. 22 of 2021
TSS (mg/1)	23,57	20	Government Regulation No. 22 of 2021

Spesies Diversity and Abudance

A total of 12 species from five fish families were recorded in this study. Among the families, Lutjanidae (4 species) and Serranidae (3 species) are the most speciose groups. There are six target species and another six major species. The complete list of fish recorded in the study can be found in Table 2.

The mean abundance (±SE) of reef fishes in all stations was calculated at 995.7 (±5.1) individuals Among the three stations, Station harbored the most number of fishes recorded with 1,131 (mean±SE, 113.1±7.8) individuals, followed by Station 2 at 1,017 (145.3±10.3) individuals, and Station 1 at 839 (93±8.5) individuals. In terms of species (number of individuals±SE), *Lutjanus lutjanus* (326.7±2.7), *Lutjanus ehrenbergii* (266.7±15.3) and *Zoramia perlita* (263.3±7.5) were the most abundant species (Table 2).

Table 2. Species composition of reef fishes recorded frfom three stations in an artifixial reef of PT. Artha Cipta Langgeng, Penyusuk Waters, Bangka Regency, Indonesia.

No	Category	Family	Species	Station (ST) 1	2	3	Mean (±SE)
1	Target Fish	Lutjanidae	*Lutjanus lutjanus*	300	300	380	326.7 (±2.7)
2		Lutjanidae	*Lutjanus ehrenbergii*	100	400	300	266.7 (±15.3)
3		Lutjanidae	*Lutjanus malabaricus*	-	-	22	-
4		Lutjanidae	*Lutjanus biguttatus*	22	6	-	14.0 (±2.4)
5		Serranidea	*Epinephilus bleekeri*	6	4	4	4.7 (±0.5)
6		Serranidea	*Epinephilus sexfaciatus*	2	6	6	4.7 (±0.5)
7		Serranidea	*Epinephilus coioides*	-	-	10	-
8		Serranidea	*Siganus javus*	8	-	8	8.0
9	Major Fish	Tetraodontidae	*Arothron stellatus*	1	1	1	1.0
10		Leiognathanidae	*Photopectoralis bindus*	-	-	300	-
11		Apogonidae	*Zoramia perlita*	390	300	100	263.3 (±7.5)
12		Pornacentriade	*Pomacentrus nigromarginatus*	10	-	-	-
		Total (ind)		839	1017	1131	995.7 (±5.1)
		Abundance (ind/m^2)		45	54	60	

Diversity, Evenness, and Dominance

The diversity index in each station was calculated at 1.18-1.49 (low to moderate), with Station 2 having the lowest (1.18) and Station 3 having the highest diversity index (1.49). The evenness in each station did not vary significantly (056-0.65). Station 1 recorded an evenness of 0.56 and stations 2 and 3 recorded 0.65 evenness, all categorized as moderate. On the other hand, the dominance index was calculated at 0.26-0.36 (moderate) with Station 3 recording 0.26 and stations 2 and 3 recording 0.33 and 0.36, respectively (Table 3).

Table 3. Computed fish diversity, evenness, and dominance indices of three stations in the artificial reefs of PT. Artha Cipta Langgeng, Penyusuk Waters, Bangka Regency, Indonesia

Index	ST1	ST2	ST3	Categories
H'	1.24	1.18	1.49	Low to Moderate
E	0.56	0.65	0.65	Moderate
C	0.36	0.33	0.26	Moderate

Discussion

Environmental Parameters

The temperature measured in the waters of Penyusuk in all stations slightly differs from one another (31-32°C). According to Government Regulation No. 22 of 2021 concerning the water temperature standards for marine biota (including coral reefs), the standard limit is set between 28-30°C, with an allowable of up to 2°C from the natural temperature. The measured temperature is within the suitable temperature for tropical fish (25-32°C) and does not pose any threat to the reef ecosystem (Yanuar, 2015). However, most tropical fishes are stenothermic (viz., narrow tolerance to temperature) and any increase in ambient temperature is detrimental to their reproduction and survival (Donelson et al. 2010).

The obtained brightness in surveyed stations was calculated at 29-41%, and the water depths of ARs ranged from 3 to 6 m. The ideal depth of any reef surveys must be conducted with at least 5 m depth to avoid any potential damage to coral reefs during the monsoon season when waves are relatively higher and accompanied by strong winds (Government Regulation No. 22). The study of Andian et al. (2020) in Bangka Regency recorded higher brightness (85-100%), with a similar depth range in this study. The value is related to the availability of light and the water's brightness level limits the growth of associated biota (e.g., zooxanthellae) which depends on the intensity of sunlight for *photosynthesis* (Sulistiawati *et al.* 2020).

The current measured in each station ranged between 0.50 and 0.51 m/s. According to Asrul (2021), water currents are categorized as very fast (>1 m/s), fast (0.5-1 m/s), moderate (0.25-0.5 m/s), slow (0.1-0.2 m/s), and very slow (<0.1 m/s). In a similar study, water currents ranged between 0.10 and 0.76 m/s in Bangka Regency (Andrian et al., 2020). Ocean currents play a crucial role in the distribution of turbidity in the water column, as the speed and direction of water currents can affect the dispersion of suspended solids (Yonar et al., 2021).

In terms of salinity measurement, this study obtained a salinity of 30-35 ppt. The standard salinity for coral reefs ranges between 33 and 34 ppt, and a change of up to 5% from the seasonal average salinity is allowed (Government Regulation No. 22 of 2021). Coral fish are stenohaline (viz., have a limited ability to tolerate changes in salinity) and can only tolerate a salinity range of 25-40 ppt (Armanto et al., 2022). The influence of salinity on the life of coral-associated biota varies significantly depending on the conditions of the local marine environment. The salinity in the research stations is considered suitable as Indonesian waters typically have a salinity range of 30-35 ppt (Yanuar, 2015).

The measured pH levels in each station were at 7.3-7.4. According to Government Regulation No. 22, the standard range for water pH should be at 7.0-8.5. The general pH measured in this study (7.3-7.4) is within the common pH conditions in Indonesian (tropical) waters (Barus et al., 2018). This is consistent with the study of Corvianawatie and Abrar (2018) who stated that the optimum pH value for marine biota is between 6.5 and 8.5. Thus, the pH obtained at the research station is suitable for coral fish life.

On the other hand, the TSS in the waters of monitoring stations ranged between 12 and 38.5 mg/l with only Station 1 (12.0 mg/l) having the optimum TSS level according to the standard limit promulgated by Government Regulation No. 22. The high TSS value at Station 3 is associated to mining activities near the station. Similarly, data was collected after rainfall which could have also affected the TSS reading. The result is consistent with Adibrata et al. (2023) who stated that high TSS is usually associated with human activities exploiting coastal resources. The concentration of TSS in the study sites of Yonar et al. (2021) ranged from 0 to 176 mg/l and was also influenced by tides, currents, and rainfall. This aligns with Winnartsih et al. (2016) that when a station is farther than the source of pollution (e.g., mining, rivers), lower TSS is observed as TSS is easily diluted and washed away by the currents and the vastness of the sea.

Species Composition and Abundance

The number of species (12) recorded in this study is low compared to other studies also utilizing ARs and reef balls (RBs) (Cardoso et al. 2020; Prabowo et al. 2021). The lower number of species could be attributed to the size and age of the ARs, wherein larger ARs can attract many nearby species (especially the predators) and the species composition of older ARs (>20 years) may resemble natural reefs (NRs) (Perkol-Finkel et al. 2007).

The abundance of reef fishes of the ARs in Station 1 consists of six families and nine species, with a total of 45 ind./m². At Station 2, four families and seven species with 54 ind./m² being recorded, while Station 3, comprises four families and 10 with a total of 60 ind./m². The abundance of coral fish is classified into categories, such as very abundant (>50 ind./m²), abundant (20-50 ind./m²), less abundant (10-20 ind./m²), rare (5-10 ind./m²), and very rare (1-5 ind./m²) (Djamali and Darsono 2005). Using the said categories, the number of individuals in each station (45-60 ind./m²) are classified as very abundant and abundant.

Among the families, the highest abundance was observed in Lutjanidae or snappers (a target group). Snappers are a migratory fish that moves between habitats looking for food. According to Sulardiono et al. (2022), some snappers migrate to shallow waters (e.g., estuaries and mangroves) to feed in groups when they are juveniles, and as adults, they move to deeper waters. Snappers requires the availability of food such as small fish and crustaceans (Syaputra et al. 2009). The abundance of carnivorous fish (such as snappers) in an area is influenced by several factors, such as the physical condition or topography of the area, food availability, and fishing pressure (Andrimida and Hardiyah 2022).

Diversity, Evenness, and Dominance

The diversity indices of reef fish in the ARs in Penyusuk Waters ranged between 1.18 and 1.49 (categorized as low to moderate). According to Mason (1981), the diversity index is considered low ($H < 1$), moderate ($1 \leq H < 3$), and high ($H > 3$). In a similar study, Anastion et al. (2018) recorded a moderate diversity index at their study sites in North Moramo Regency, and they attributed it to the low number of observed species, resulting in normal conditions and stability in the community, both in ARs and NRs.

In terms of the evenness index, the values obtained from the present study fall between 0.56 and 0.65, categorized as moderate. Evenness values are categorized as high ($E < 1$), moderate ($0.4 < E < 0.6$), and low ($E < 0.4$) (Krebs, 1989), The evenness index of fish ranges from 0 to 1, and the smaller the evenness value, the lower the evenness in the community (Armanto et al. 2022). In an ecosystem with an optimum condition, the evenness index is computed at 1.0 (or approaches 1) (Mujiyanto and Sugianti 2007).

The dominance index value of reef fishes in the monitored stations was computed at 0.33-0.36, categorized as moderate. Odum (1971) categorized the dominance index as low ($0 < C = 0.3$), moderate ($0.3 < C = 0.6$) category, and high ($0.6 < C = 1$) c. A similar study by Anastion et al. (2018) recorded a low dominance (0.12 to 0.27) which indicates that there are no dominant species in their surveyed sites.

Conclusion

The water quality conditions (i.e., temperature, brightness, current, salinity, pH, and TSS) in the artificial reefs of PT. Artha Cipta Langgeng Penyusuk Waters are still within the environmental carrying capacity limits based on Government Regulation No. 22. The low number of species recorded could be attributed to the size and age of the ARs. The high abundance of target species offers a long-term potential for maintaining ARs for scientific and recreational activities. Both diversity, evenness, and dominance index are categorized as low to moderate which supports the low species composition and no species dominated in the ARs. Increasing the size or number of ARs and annual monitoring will help us understand the dynamics of reef fishes within ARs. Long-term monitoring will also help us determine the benefits of establishing ARs in the tropical region which is being challenged by man-made activities and the impeding effects of climate change.

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