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Research Article

The potential of coral reefs at Penambulai Island, Aru Islands Regency

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ABSTRACT

Penambulai Island, one of the 676 islands in the Aru Islands Regency, is one of Indonesia's outermost small islands and has the status of a Certain National Strategic Area. The coral reefs on this island have been under pressure from human activities and climate influences. Research in the waters of Penambulai aims to analyze the potential of coral reefs. The research was conducted in August 2023. Data collection used the LIT method and data analysis used the English (1997) percent cover formula and the Standard criteria for coral reef damage and condition. The coral reefs around Penambulai Island are extensive, covering over 1,000 hectares. The majority of the reef area (73.76%) comprises living organisms, which is a good sign. Hard corals, a crucial reef-building organism, have a significant presence (42.04%). The reef exhibits high species diversity with 51 hard coral species belonging to various families and genera. Despite these positive aspects, the overall health of the coral reefs is considered "moderate" due to natural stressors.

Keywords: cover, biotic, abiotic, life form, coral status

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INTRODUCTION

The district of Kepulauan Aru, one of the regions in Maluku Province with the highest number of islands, has 676 islands. One of these islands is Penambulai, which has an area of 1,059.52 hectares. The island has the status of an Outermost Small Islands (*Pulau-Pulau Kecil Terluar, PPKT*) based on Presidential Regulation Number 6 of 2016 concerning the Determination of Outermost Small Islands. It is also included in Certain National Strategic Areas (*Kawasan Strategis Nasional Tertentu, KSNT*) as stipulated in Presidential Regulation Number 26 of 2021 concerning the Determination of Certain National Strategic Areas. Its designation as a PPKT has several objectives, including: 1) strengthening and securing national maritime territory; 2) enhancing the economic potential and natural resources of outermost small islands; 3) improving the welfare of communities in outermost small islands; and 4) preserving the environmental sustainability of outermost small islands.

Identifying of issues on Penambulai Island, one of which is environmental conservation issues, especially in one of its main habitats, the coral reef. Several coral reef issues on this island include human activities that produce household waste (especially plastic waste) and oil, which can affect the existence of coral reefs (Ouédraogo et al. 2021). Damaged coral reefs can be caused by high human activity in coral reef areas such as ship anchorages, destructive fishing practices, marine tourism, and other activities.

On the other hand, fishing activities have been damaging (Isdianto et al. 2022), sedimentation and erosion (Faizal and Yuanita, 2017; Prasetyo et al. 2018; Kjerfye et al. 2021; Isdianto, 2022), and the effects of climate change that can cause coral bleaching and coral mortality. The reduction in live coral coverage leads to an increase in dead coral coverage (Muhaemin et al. 2022). Coral bleaching is a natural response to pressure exerted on corals due to extreme environmental conditions and human activities that cause coral stress (Setiawan et al., 2017), loss of Symbiodinium populations (zooxanthellae algae) or coral polyp habitats (Westmacott et al. 2000; Muhaemin et al. 2022).

Several studies on coral reefs in Maluku Province highlight ecosystem management in the region, focusing on the impacts of human activities and natural factors on this vulnerable marine habitat. Research conducted in the area reveals that coral reefs in Maluku are threatened by anthropogenic activities and other environmental factors, underscoring the urgent need for conservation efforts to protect this vital ecosystem. Studies on coral reef biodiversity in Southeast Maluku show a high diversity of megabenthos and coral fish at various research stations, indicating rich marine life in the region.

Specifically, studies on coral reefs in the Aru Islands focus on the importance of conservation and ecosystem management within the region to combat the impacts of overfishing and climate change. Research also examines the socio-economic aspects of local communities in the Aru Islands and their interactions with coral reef ecosystems. Furthermore, the effects of traditional and modern management practices on the sustainability of marine resources in the area are investigated. Studies in the Aru Islands reveal high biodiversity levels in coral reef ecosystems. While the reefs show significant diversity, they are under pressure from various environmental stressors and human activities.

The status of coral reefs in the Aru Islands is assessed through analysis of coral cover, composition, megabenthos density, and coral fish populations at several research stations in the region. This assessment helps understand the health and dynamics of coral reef ecosystems in the area. The research underscores the urgent need for conservation efforts in the Aru Islands to protect and preserve the rich biodiversity of coral reefs. It highlights the importance of sustainable management practices and effective conservation measures to safeguard this vital marine ecosystem for future generations.

Addressing coral reef issues on Penambulai Island can be effectively reduced through research into its potential, similar to other areas in Maluku and the Aru Islands. The results can serve as a basis for developing well-managed strategies. Specifically, studying the potential of coral reefs in remote island areas like Penambulai Island is crucial for sustainable management of the environment, resources, and community welfare.

METHODS

The research began in August 2023, in the coral reef waters of Penambulai Island, South Central Aru District, Aru Islands Regency (Figure 1).

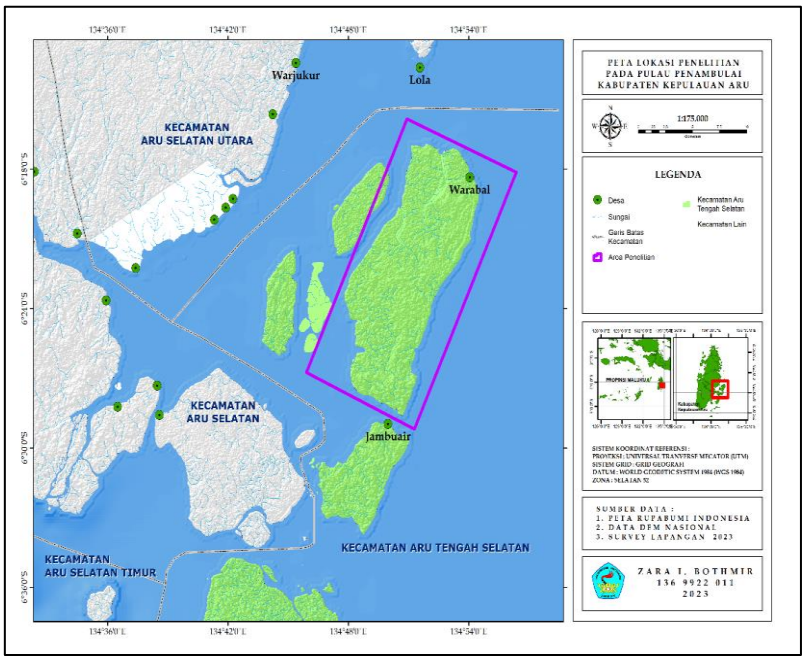

Figure 1. Research location map

The data on coral species richness and coral reef components at each study site to analyze the potential and condition of the coral reefs are obtained using the Line Intercept Transect (LIT) method or line-intercept method according to English et al. (1997) and Sahetapy (2015). Data on coral species, the length of intercepts of these coral colony types, and other benthic growth forms along 50 m transect lines are collected using the Photo Transect Method. The lengths of biotic and abiotic component intercepts are recorded. Coral species along and around the transect line are photographed and collected for taxonomic analysis of coral composition at each research station.

The coral species are identified and classified using identification books by Veron (1986; 2002), Allen and Steene (2002), and Suharsono (2008). Echinoderm species are identified using the identification keys by Clark and Rowe (1971), and Cannon and Silver (1987). In addition, mollusk species are identified using identification keys from Dance (1990), Dharma (1992), and Kenneth (2000). Anthipatharian species, anemones, soft corals, and crustaceans are identified following the guidelines provided by Allen and Steene (2002).

The lengths of intercepts of coral reef component elements are tabulated by the research station in Excel format. Through analysis using Excel, the percentage coverage of coral reef substrate by hard coral life forms, other benthic biota, and abiotic components is calculated using the formulas proposed by English et al. (1997) and Sahetapy (2015):

$$Pt = \frac{Pjc}{Pjt} x100$$

Explanation: P*t* = cover presentage; P*jc* = length category; Pjt = transect length

The condition of the coral reefs in the coastal waters of Parang Island is determined based on the percentage cover of hard corals obtained and the Standard Criteria for Coral Reef Damage (Minister of Environment Decree No. 4, 2001), as shown in Table 1.

Table 1. Standard criteria for coral reef damage and condition

No.	Condition	Criteria	Cover Percentage (%)
1.	GOOD	Excellent	75 – 100
2.		Good	50 – 74,9
3.	BAD	Fair	25 – 49,9
4.		Bad	0 – 24,9

Source : Minister of Environment Decree Number 4 of 2001

RESULTS AND DISCUSSION

Coral reefs are found to grow and develop well in the mid-reef to reef edge zones. The distribution conditions of coral reefs in this study area are consistent with Setaiwan (2017), stating that coral reefs generally grow in more open waters or facing the sea. This is likely due to better oxygen availability from continuous seawater movement, more nutrients, stable temperature and salinity, and lower sedimentation.

Analysis of Sentinel satellite imagery data verified with field measurements provides information on coral reef areas (Figure 2). The total area of coral reefs in the coastal waters of Penambulai Island and its surroundings reaches 1,059.52 hectares.

Components of reef substrate and substrate cover

Analysis of the coral reef components of Penambulai Island shows that biotic components dominate the reef substrate. The biotic component cover percentage is higher than the abiotic (Table 2). The reef substrate is dominated by biotic components (73.76%). The remaining 26.24% of the substrate is made up of abiotic components, which are mainly dead coral fragments, sand, and dead coral covered with algae. This indicates a healthy and diverse reef ecosystem with a thriving population of organisms.

Table 2. Biotic and abiotic component cover of coral reefs in Penambulai Island Waters

Components of reef substrate	*Substrate Cover (%)*
Biotic	**73,76**
Hard Corals:	42,04
- *Acropora*	2,48
- *Non Acropora*	39,56
Non-Coral Biota:	31,72
- *Sponge*	14,38
- *Coraline algae*	12,22
- *Turf algae*	5,12
Abiotic	**26,24**
Dead Coral Fragments	3,52
Dead Coral covered with Algae	8,34
Sand	14,38

Source: Field Data (2023)

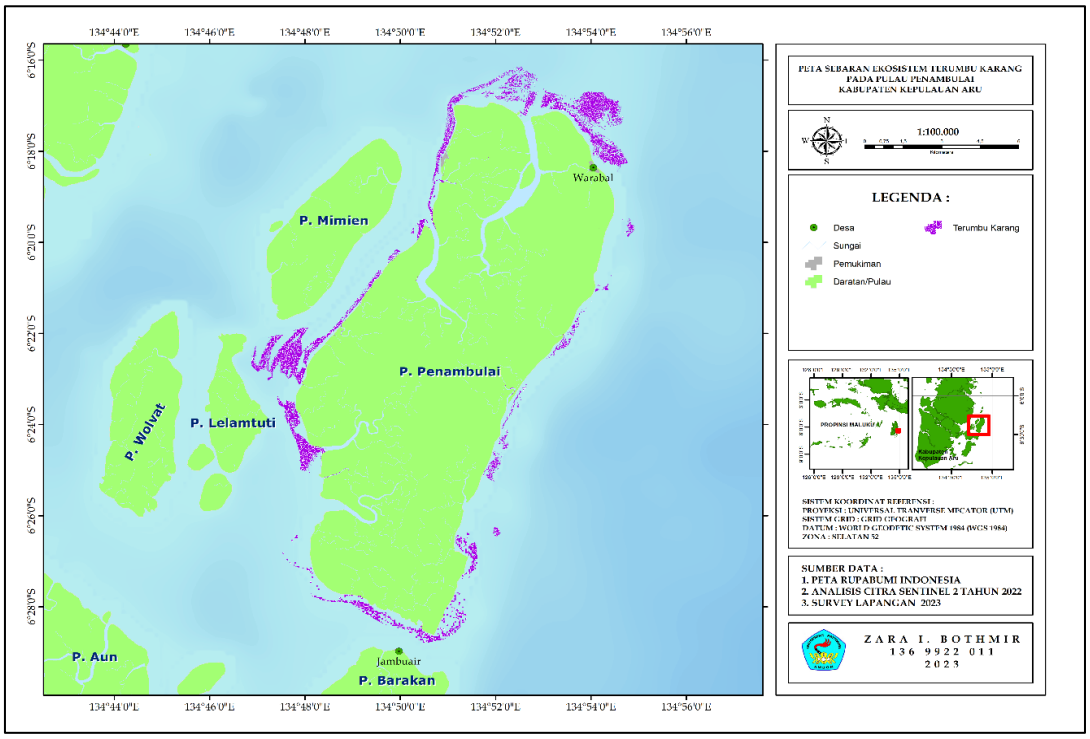

Figure 2. Map of coral reef distribution in Penambulai Island

Hard corals (42.04%) make up a significant portion of the living organisms, which is a positive indicator of a healthy reef. However, there seems to be a lower abundance of Acropora corals (2.48%) compared to non-Acropora corals (39.56%). Acropora corals are generally fast-growing and more susceptible to environmental stressors. Their lower abundance might be a cause for concern and could require further investigation. Non-coral biota (31.72%) contributes significantly to the reef's biodiversity. This category includes: Sponges (14.38%), Coralline algae (12.22%), and Turf algae (5.12%).

These results indicate that the coral reefs on this small island are still in good condition despite the hard coral cover percentage. Hard corals comprise 42.04% of the total substrate cover, suggesting a good presence of these reef-building organisms. Non-Acropora corals (39.56%) are more abundant than Acropora corals (2.48%). Acropora corals are generally considered fast-growing and sensitive to environmental changes. Their lower abundance might be due to various factors.

Non-coral Biota is the most abundant component within the biotic category (31.72%), highlighting the presence of a rich variety of organisms besides hard corals. Turf algae (12.22%) and coralline algae (14.38%) are the most common types of non-coral biota, indicating a diverse algal community. Sponges (5.12%) also contribute to the reef's biodiversity.

Abiotic components make up the remaining 26.24%, consisting mainly of dead coral fragments, dead coral covered with algae, and sand. Sand (14.38%) is the most prevalent abiotic component, indicating the presence of

sandy areas within the reef system. Sand is the most common abiotic component, indicating the presence of sandy areas within the reef system.

Dead coral fragments (3.52%) and dead coral covered with algae (8.34%) suggest some coral mortality has occurred. However, the relatively low percentage of dead coral compared to live coral suggests the reef is in a good state overall. Dead coral fragments and dead coral covered with algae suggest some degree of coral mortality has occurred in the past. However, the relatively low percentage of dead coral compared to live coral suggests the reef is in a good state overall.

The high percentage of live coral cover (both hard and soft corals) and the presence of diverse non-coral biota suggest a generally healthy reef ecosystem. The presence of dead coral indicates some past stress or mortality events, but the relatively low amount suggests these events were not widespread and the reef is recovering. The specific composition of the non-coral biota (algae and sponges) might provide further insights into the reef's health and environmental conditions. For instance, a high abundance of turf algae might indicate nutrient enrichment in the water.

The high combined cover percentage of reef-forming biota (coralline algae and turf algae) suggests that Penambulai Island's coral reefs are in the process of developing into an ideal and robust reef. The notable abiotic component is sand, followed by dead coral covered with algae and dead coral fragments, with relatively small substrate cover percentages.

Hard Coral Cover and Number of Species

The data suggests that Acropora corals are the dominant coral life form in the area. This could be due to various factors such as suitable environmental conditions or historical dominance. Based on the percentage of reef substrate cover by hard corals according to colony life forms (Table 3), it turns out that only Acropora hard coral life forms are present, accounting for 2.48%. The tabulate or table life form (ACT) has a low percentage of substrate cover in the reef area of Penambulai Island, while other colony life forms were not found.

Table 3. Hard coral cover and number of species according to colony life forms in the coastal waters of Penambulai Island

Life Forms Category	*Percent (%)*	*Number of Species*
Acropora	**2,48**	**7**
Acropora branching (ACB)	-	3
Acropora digitate (ACD)	-	1
Acropora tabulate (ACT)	2,48	2
Acropora encrusting (ACE)	-	-
Acropora sub massive (ACS)	-	1
Non Acropora	39,56	44
Coral branching (CB)	2,40	4
Coral encrusting (CE)	2,00	1
Coral foliose (CF)	0,76	2
Coral massive (CM)	25,14	28
Coral *Milepora* (CME)	-	1
Coral sub massive (CS)	0,58	3
Coral mushroom	-	4
Coral *Heliopora* (CHE)	8,68	1
Total	**42,04**	**51**

Source: Field Data Lapangan (2023)

For the hard coral category Non-Acropora, it turns out that the massive life form (CM) has a higher percentage of substrate coverage compared to other Non-Acropora hard coral life forms in the coastal reef area of this small island. The hard coral life forms in the Non-Acropora category are more varied compared to the Acropora category.

The coral reef of Penambulai Island has a total of 51 species of hard coral, all belonging to 22 genera and 10 families. The family with the highest number of coral species is Faviidae (18 species), followed by Poritidae with five species. The families Helioporidae and Oculinidae have the lowest number of species, each with only one coral species. The richness or variety of coral species in the reef area of Penambulai Island is considered quite good and is likely to continue to increase as the reef formation process continues to provide an ideal substrate for young coral juveniles.

The coral reefs in Penambulai are classified as "moderate" based on standard criteria for coral reef damage. This means that the coral cover is not as high as it could be, but it is not yet in a critical state (Sahetapy,

2003; Sahetapy & Far-Far, 2008). Data from 1993 to 2001 shows that the overall condition of coral reefs in Indonesia has been declining, with a decrease in the percentage of reefs categorized as "very good" and "good" (Susanto et al., 2015). Natural factors such as sedimentation and anthropogenic pressures such as pollution and overfishing can negatively impact coral reef health.

In line with these opinions, the coral reefs in the Penambulai waters have a "moderate" standard due to pressure from natural factors (Sahetapy et al. 2021). Sedimentation issues and anthropogenic pressure are related to the dynamic water conditions around the coral reefs (Sahetapy et al. 2018).

CONCLUSION

The coral reefs around Penambulai Island are extensive, covering over 1,000 hectares. The majority of the reef area (73.76%) comprises living organisms, which is a good sign. Hard corals, a crucial reef-building organism, have a significant presence (42.04%). The reef exhibits high species diversity with 51 hard coral species belonging to various families and genera. Despite these positive aspects, the overall health of the coral reefs is considered "moderate" due to natural stressors.

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