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Monitoring of Coral Reef Cover in The Waters of Bunaken National Park, Popareng Village, South Minahasan Regency, North Sulawesi Province

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ABSTRACT

Coral reefs are one of the coastal ecosystems, which consist of hard coral (cnidarians), and have important roles as a place to look for food, shelter, and breeding grounds for others biota. Natural phenomena and various anthropogenic activities threaten the health and existence of coral reefs in the waters of Bunaken National Park, Popareng Village. This study aims to determine the condition of coral reefs in the waters of Bunaken National Park, Popareng Village. CPCe (Coral Points Count with Excel extension) is used to observe or monitor reef ecosystems. The photos taken using Underwater Photo Transect (UPT) method from three observation sites in Popareng's Waters were used as database. Photos consisted of 50 slides per Site were taken to represent Popareng's waters. Each photo was processed in the CPCe by using 30 random points. The condition of coral reefs in Popareng was moderate. Coral reef health conditions at three sites in Popareng revealed as poor (21.67%) in site 1; good (54.53%) in site 2; and moderate (32.37%) in site 3.

Keywords*: Coral Reefs; Underwater Photo Transect*; *Coral Points Count with Excel extension; Bunaken National Park*

INTRODUCTIONS

Coral reefs are the benthic colonies of invertebrates belonging to the phylum Cnidaria. Corals deposit hard structure from calcium carbonate ($CaCO_3$) on the seabed. These become a very high dynamic ecosystem in the sea (Mellawati, 2012; Papu, 2011). As a high diversity of marine life and it is an important ecosystem for coral-dwelling biota associated in the ecosystem. Coral reefs also perform feeding areas, breeding, nurturing, and protection for several species of marine life (Kambey, 2014).

Indonesia's coral reefs rank among the world's top coral reefs in terms of area and species with more than 75,000 km2 or 14% of the world's total coral reef area. Coral reefs are one of the coastal ecosystems with the highest level of diversity with approximately one million species worldwide (Reaka-Kudla, 1997). The level of coral reef diversity in this area is also quite high, where more than 80 genus and 596 coral species can be found in this area (Suharsono, 2008; Giyanto et al., 2017).

Coral reef ecosystems are vulnerable to environmental change due to the people exploitation exceeding its ability to recover, and the pressures they experience are increasing along with the increase in population and community activities in coastal areas. In addition to the relatively slow growth and recovery of coral reefs, human activities that tend to be destructive exacerbate the condition of coral reefs (Farsia, 2014). It also occurs in Bunaken National Park (BNP), where a part of this conservation area includes utilisation zones where there are certain areas that are still used by the community for their lives.

Bunaken National Park (BNP) is a marine conservation area located in North Sulawesi. Popareng village, located in Tatapana sub-district of the South Minahasa district, is included in the Bunaken National Park area. As one of the conservation areas, Popareng Village is promoted as one of the utilisation zones, namely as a

nature tourism area by boasting its coral reef potential. The utilisation of this area must be monitored by controlling the level of coral cover to analyse the health of the coral reef periodically. However, the last available data is in 2015.

It is necessary to re-monitor after the last result in eight years ago. Therefore, this study aims to monitor the coral reef coverage condition in Popareng coral reefs area, Bunaken National Park, North Sulawesi.

METHODS

This research was conducted from March to May 2023 in Popareng coral reefs, Bunaken National Park, South Minahasa District, North Sulawesi. In detail, three sites were chosen. Each coordinate was placed at N 01°17'29.39" E 124°31'33.05", N 01°17'35.78" E 124°30'52.212", and N 01°17'39.94" E 124°30'53.83" (**Figure 1**)

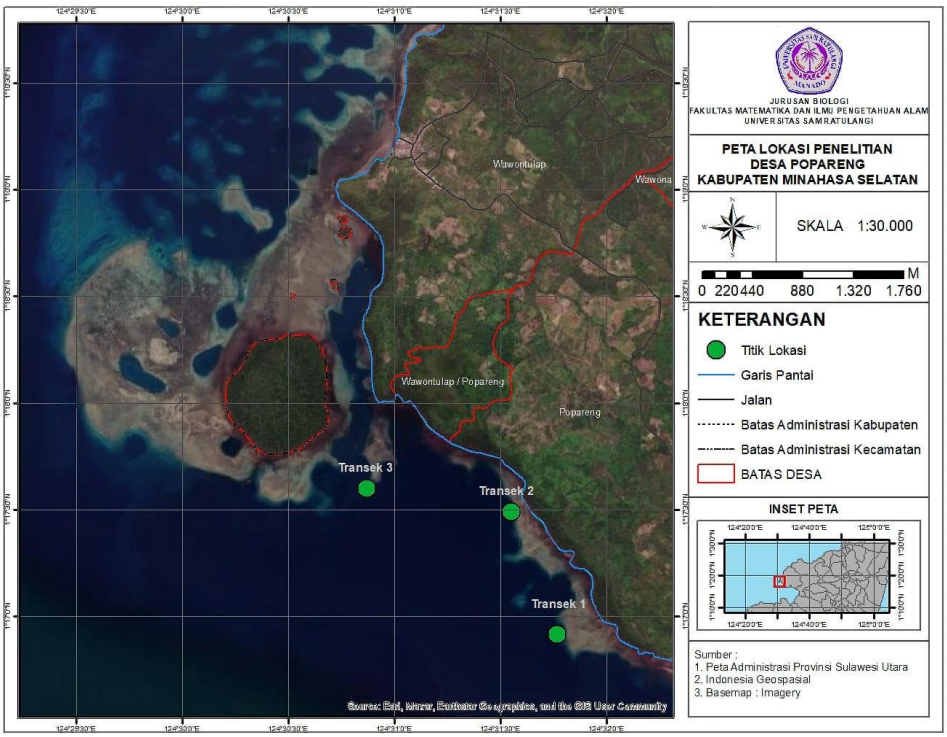

Figure 1. Sampling location in Popareng coral reef. Green dots represent three locations.

Coral was assigned from transect photographs at every meter, using a frame with a size of 58 cm × 44 cm along a 50 m transect line (**Figure 2**). Data were determined by using CPCe (Coral Point Count with Excel extension) method in analysing underwater photos to determine the coral coverage (Kohler & Gill, 2005). CPCe is used in counting the number of points per life form category per 30 random points that are considered representative to estimate the percentage cover of the category. The data used was obtained from underwater photographs taken using the Underwater Photo Transect (UPT) method (Giyanto et al., 2014).

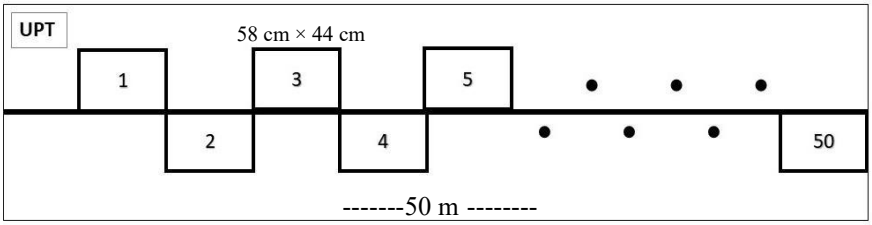

Figure 2. Illustration of the underwater sampling. A number of 50 points were placed along the 50 m transect line.

The photo analysis process was carried out on each frame of photos taken. The percentage value of category cover for each frame obtained automatically through the application, which is basically calculated by the following formula (Giyanto et al., 2014):

$$L = \frac{\Sigma Li}{N} x100\%$$

Where are:
L = Precentage of substrate coverage (%).
Li = Number of points in those categories.
N = Number of random points.

The percentage of coral reef coverage is then categorised based on the quality standards of Minister of Environtment Decree KepMen LH No. 4/ 2001 with criteria as described in **Table 1**.

Table 1. Coral reef cover index

Condition	Category
Bad	0 – 24,9%
Moderate	25 – 49,9%
Good	50 – 74,9%
Very good	>75%

RESULTS AND DISCUSSIONS

Coral cover percentage values at three sites varied, between 21.67% - 54.53%. These numbers indicate poor to good in terms of coral cover condition (**Table 2**). However, in general, the coral cover depicting Popareng Village is included in the moderate category with a value of 36.19%. The percentage value of coral cover obtained is a combination of the hard corals *Acropora* and Non-*Acropora* group species which are divided into life form coral growth forms in subcategories (**Figure 3**).

Table 2. The Percentage of benthic coral cover in Popareng and the Three Sites

Categories	Location			
	Site 1	Site 2	Site 3	Popareng
Coral cover (%)	**21.67**	**54.53**	**32.37**	**36.19**
Recent Dead Coral (DC)	3.07	2.53	7.29	4.30
Dead Coral With Algae (DCA)	29.46	28.77	17.8	25.34
Soft Coral (SC)	4.54	2.00	0.53	2.36
Sponge (SP)	5.67	6.95	6.47	6.36
Fleshy seaweed (FS)	0.27	0.13	0.73	0.38

Categories	Location			
	Site 1	Site 2	Site 3	Popareng
Other biota (OT)	1.33	1.20	1.56	1.36
Rubble (R)	13.40	2.87	18.00	11.42
Sand (S)	19.20	1.00	12.87	11.02
Silt (SI)	1.40	0.00	2.35	1.25
ROCK (RK)	0.00	0.00	0.00	0.00
Coral reef Condition	**Bad**	**Good**	**Moderate**	**Moderate**

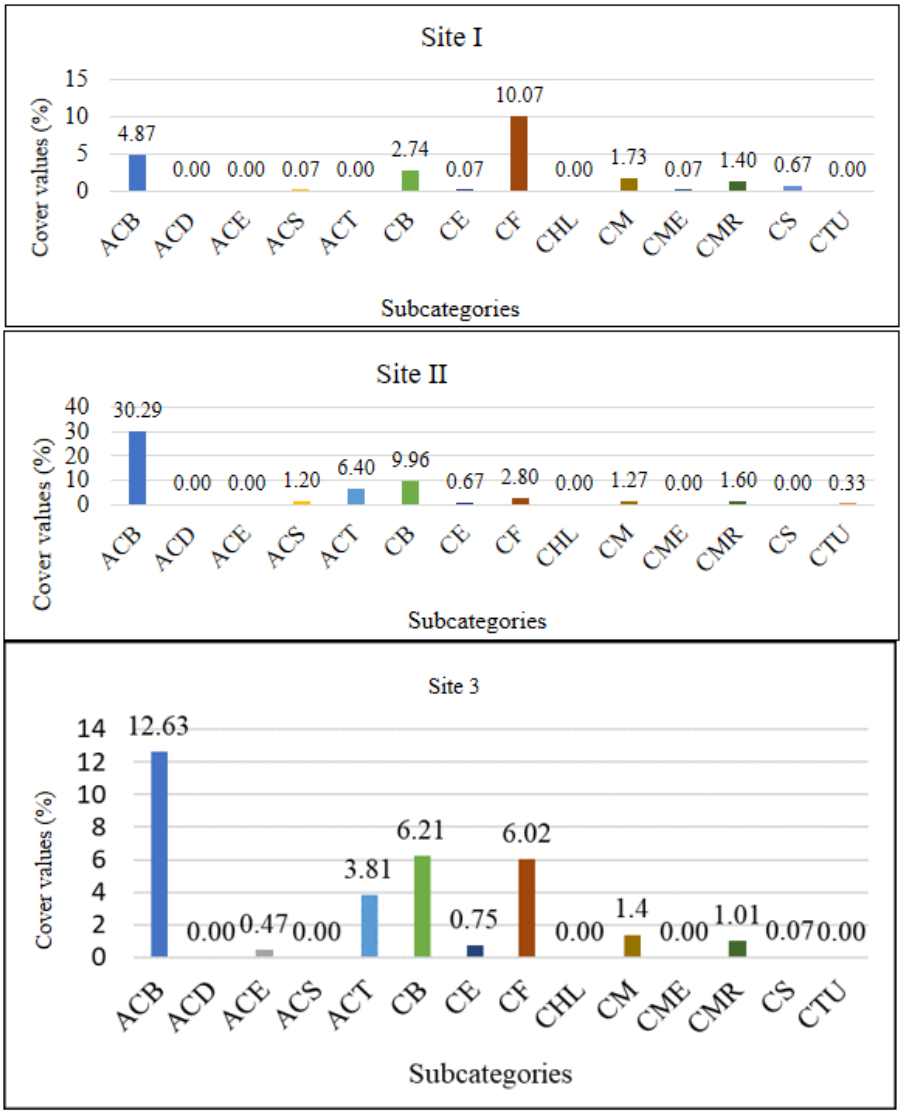

Figure 3. Coral Cover Values from these three sites based on the growth forms: *Acropora Branching* (ACB); *Acropora Digitate* (ACD); *Acropora Encrusting* (ACE); *Acropora Submassive* (ACS); *Acropora Tabulate* (ACT); *Coral Branching* (CB); *Coral Encrusting* (CE); *Coral Foliose* (CF); *Coral Heliopora* (CHL); *Coral Massive* (CM); *Coral Millepora* (CME); *Coral Mushroom* (CMR); *Coral Submassive* (CS); *Coral Tubipora* (CTU)

Coral reef conditions at Site 1 reveal a coverage level of 21.67%. Total coverage is divided into 3.07% dead coral, 4.54% soft coral, 13.40% coral rubble, and 1.42% other biota. The life corals category was dominated by CF with a value of 10.07% (**Figure 4**). Meanwhile, Acropora Encrusting (ACE), Acropora Tubulate (ACT), Coral Heliopora (CHL) and Coral Tubipora (CTU) are not found at the site. The most dominant substrate is dead coral with algae (DCA) with a coverage total of 29.46%. The high value of DCA compared to hard corals at Site 1 indicates past bleaching, which was largely influenced by human activities (Afni, 2017). This research site is adjacent to the anchor boats and ships, the place for fishermen to drop anchors. This can damage coral reefs, and turn the reefs to coral rubble (Thovyan et al., 2017). Activities such as dropping anchors and fishing in unsustainable environments cause coral to break and die. Therefore, it is causing coral damage. Furthermore, fish bombing in this location can also cause the high percentage of presence of (DCA). Thus, contribute to the poor condition.

Live coral cover at Site 2 is the highest cover value of all sites with the total percentage of 55.53%. It is considered to be in good condition. All substrate coverage in this site is divided to 2.53% death coral (DC), 28.77% death coral with alge (DCA), 2.87% broken coral (R), and 1.20% other biota (OT). Life corals in Site 2 are dominated by Acropora branching (ACB) at 30.29%. Other growth coral forms include Acropora Tubulate (ACT), Acropora Submassive (ACS), Coral Foliose (CF), and Coral Massive (CM) are found at Site 2. High percent cover of ACB retrieve the topography of this site as a fringing reefs or top slopes that performs as a barrier from the waves (Barus, 2018). This type of coral is commonly used by fish and marine invertebrates as shelter due to the branches can protect them from the predators. The percentage of Rubble (R) or known coral breaks is 2.87% in this Site. This value is smaller than the other 2 sites. A high percentage of ACB and the presence of coral fractures indicate this Site has a high level of resilience. It is the level of coral reefs to be able to adapt or survive disturbances that threaten their growth (Giyanto et al., 2017).

Site 3 has 32.37% of life coral cover, and it is categorized as moderate. Other substrate categories are divided into 7.29% death coral (DC), 18.00% broken coral (R), and 1.56% other biota (OT). Life corals are dominated by Acropora Branching (ACB) by 12. 63% and followed by other growth forms, include Coral Branching (CB) by, Coral Foliose (CF), Acropora Tubulate (ACT), Coral Massive (CM), Coral Mushroom (CMR), Coral Encrusting (CE), Acropora Encrusting (ACE) and Coral Submassive (CS). The high substrate cover in the form of coral Rubble (R) affects the coral reef condition. The percentage of coral rubbles are the highest of the other 2 sites. The more coral fragments (R) found, the lower the potential for recovery of coral reef ecosystems from damage (Giyanto, 2017). Unstable rubble structure are not a good option for the coral larvae to attach into. Rubble also very difficult to recover directly to the coral reef (Giyanto et al., 2014). However, coral rubble naturally by will break and become sand. Some bigger rubble also by the wave stably embedded and become an alternative substrate for algae, sponges, and coralline algae. Thus, the rubble become a new habitat for microba and other life form. In underline, it takes long time and it need natural biology, chemical and physic processes (Godbold et al., 2025, Sánchez-Quinto & Falcón, 2019, Ceccarelli et al., 2020).

Comparison of Coral Reefs in Popareng and several other areas in Sulawesi, including within Bunaken National Park

The percentage of coral cover in areas of TNB ranged from 28-52%, indicating that coral cover was in the moderate to good range (**Figure 4**). Good coral cover is found on Bunaken Island, while moderate conditions are found in the other seven areas measured. The coral cover of Siladen Island, although in the moderate condition category, tends to be good. The high value of coral cover condition in Bunaken Island can be supported by the presence of coral reef core zones.

Data from several famous dive sites and coral reef conservation sites in Sulawesi were also used for comparison (**Figure 5**). Popareng itself is essentially part of the BNP. Although data is analysed as an independent main data in this study. Figure 5 recognises Takabonerate National Park as the best category in coral cover level. Popareng coral reef has the lowest score compared to other conservation areas due to Popareng itself being included in the traditional zone, where this zone can be utilised by residents traditionally, due to the fact that historically, the lives of local residents have long depended on this area before the establishment of the national park zone. Moreover, Popareng is still used daily as a place to anchor boats and fish.

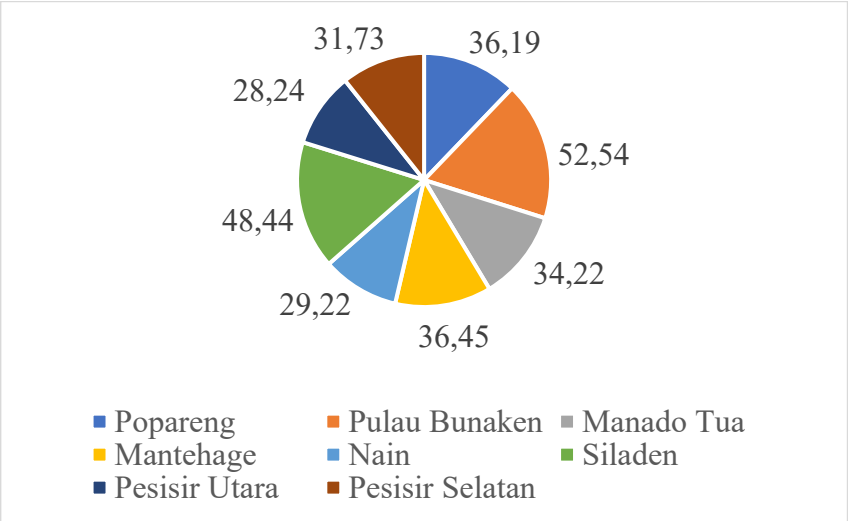

Figure 4. Coral coverage comparison within other areas in Bunaken National Park

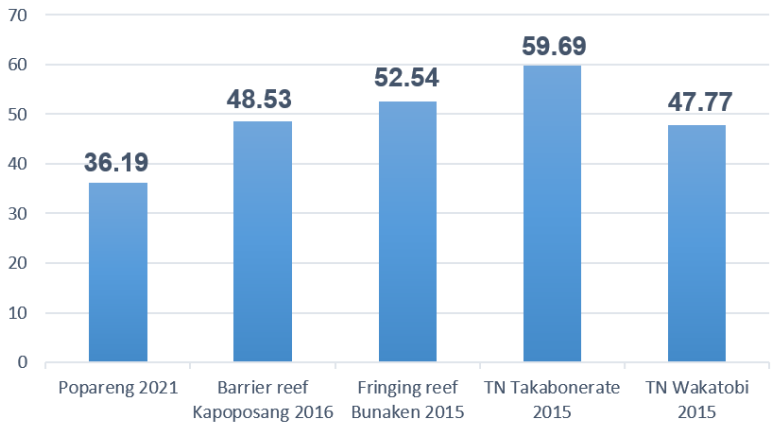

Figure 5. Coral cover percentage comparison between Popareng and areas in Sulawesi

CONCLUSIONS

The condition of coral reef cover of Popareng, South Minahasa Regency, is at a moderate level, represented of 36.19% live coral coverage. This is related to the condition of Popareng conservation area as a utilisation area. Popareng coral reefs are still very close to humans in utilisation.

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