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Observation of Coral Reef and Macroalgae Competition in the Sempu Strait, Malang

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ABSTRACT

Competition for space between coral reefs and macroalgae has a significant impact on coral cover and, consequently, on the sustainability of coastal ecosystems. This study aimed to ascertain the Sempu Strait's substrate coverage, dominant coral reef lifeform, coral-macroalgae competition, and water quality. The Underwater Photo Transect method and the CPCe software are used to monitor coral reefs. The condition of the approximately 11.5% of living corals was deemed to be substandard. The western portion of the Sempu Strait is dominated by encrusting, branching, and massive corals, whereas the eastern portion is dominated by Acropora corals. Temperature varied between 26 and 35 °C, salinity varied between 17 and 35 ppt, pH varied between 7 and 8, water clarity varied between 2.25 and 2.73 m, and dissolved oxygen varied between 6.28 and 6.71 mg/L. Competition between corals and macroalgae is observed at multiple stations, including Banyu Tawar, Waru-Waru, and WatuMeja. This phenomenon can be attributed to the presence of suitable substrates such as sand, rubble, and pebbles, as well as favorable seasonal conditions and water quality that promote the growth of macroalgae. Essentially, macroalgae grow more rapidly than corals, resulting in competition for growing space.

Keyword: CPCe software, underwater photo transect, water quality of coral reef habitat, coral reef life forms, macroalgae monitoring, coral reef monitoring, suitable substrate for macroalgae, macroalgae growth.

INTRODUCTION

coral cover decreases due to natural and anthropogenic environmental change (farid et al., 2018, manlea et al., 2016). land clearing, agricultural fertilization, and herbivore mortality due to overexploitation or heat stress can disrupt the natural balance, reducing coral reefs and increasing macroalgal cover. Increased coral-macroalgae competition may degrade coral reefs. Macroalgae and coral interactions are becoming important due to rapidly changing coral reef ecosystem dynamics

(Brown et al., 2020). Coral-macroalgae interactions vary by coral species and are dynamic. To understand long-term macroalgae impacts, seasonal changes must be considered (Fong & Todd, 2021).

Sempu Island, which has a diverse coral reef ecosystem, nevertheless has some of these threatening activities (Febryana, 2014). Sempu Island is a protected natural reserve (Purnomo et al., 2013). Due to its location across from the Archipelago Fishing Port Pondokdadap (Marhaendra et al., 2021), the main fishing port in southern East Java, Sempu Strait's great coral diversity is under danger. Tourism, capture fisheries, unmanaged household waste, and land reclamation sedimentation also contribute to coral reef loss (Luthfi et al., 2018a). Coastal population growth also increases pollution (Tanjung et al., 2019b).

The percentage of coral cover in the Sempu Strait decreased from 23.3% in 2016 to 20% in 2018 (Luthfi, 2017; Luthfi et al., 2018b; Luthfi, 2019), with Dead Coral Algae covering 19.17% and Coral Foliose covering 13.51% (Ramadhan, 2018). The high percentage of Dead Coral Algae may imply that reefs will shift from live coral to dead coral overgrown with algae (Donner et al., 2007). Turf algae of the genus Laurencia, less than 3 cm in size, dominate the coral sections in the seas of the Sempu Island Nature Reserve (Ramadhan, 2018). Turf algae, the juvenile phase of macroalgae, is found as algae assemblages (AA) in coral reefs (Littler and Littler, 2013). The average AA coverage percentage is 0.98%, and the macroalgae area ranges from 68.91 cm^2 to 785.23 cm^2 with percentages of 26.61% and 34.88%, respectively (Ramadhan, 2018). Barott et al. (2012) state that macroalgae will overcome hard corals in waters near settlements.

Coral reef deterioration affects Sempu Strait communities' economies. Traditional fishing communities depend on coral, which has many high-value fish and other species (Jubaedah & Anas, 2019). Based on the background and the fact that coral cover has decreased, it is necessary to monitor coral reefs in the Sempu Strait waters based on coral cover, lifeforms, space competition between corals and macroalgae, and water parameters.

MATERIALS AND METHODS

Study area

This study was conducted in the Sempu Strait waters in August, October, and December of 2021. Five stations with distinct water characteristics (WatuMeja-WM, Waru-waru-WW, Banyu Tawar-BT, Jetty-JT, RumahApung-RA). WatuMeja is a station located at the entrance of the strait that is surrounded by natural conditions and is remote from human activities. Waru-waru is a station that represents Sempu Strait tourism

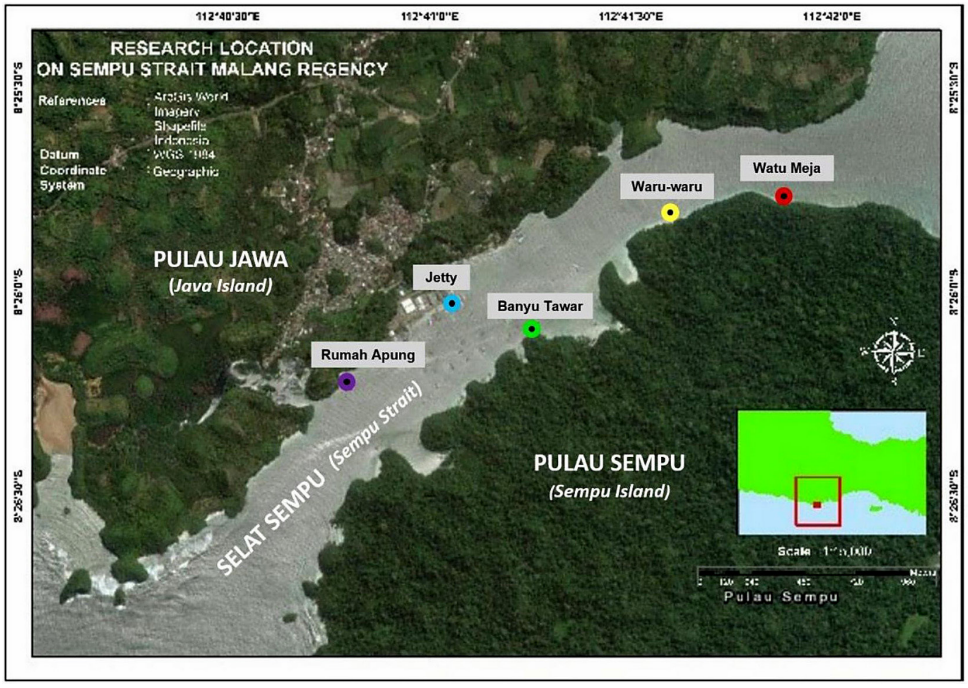


Figure 1. Research site map

destinations. Banyu Tawar was selected because it has the characteristics of waters with low salinity values, as there are river mouths in these waters. Jetty is a highly active port area where fish are loaded and unloaded. Lastly, the station selected is RumahApung due to its proximity to residential areas. Determination of the research site was using the method of purposive sampling. Following is a map of the research site (Figure 1).

Data Collection

The collection of coral data was conducted at five stations, with a total of five points at each station, at depths ranging from 2-6 meters. These five sites were randomly selected and marked with a 1x1 m quadrant transect (Figure 2A). The placement of the transect quadrant at 10 meter intervals in a serpentine pattern, with 10 meters on the left, 20 meters on the right, etc. (Figure 2B). The UPT (Underwater Photo Transect) method was used to capture coral reef data in accordance with the Coremap-CTI LIPI Coral Reef Health Monitoring Guidelines 2014 (Giyanto et al., 2014).

Data analysis

Based on the Decree of the Minister of Environment of Republic Indonesia No. 4 of 2001, data on the condition of coral reefs were analyzed, ranging from damaged to very excellent conditions (Table 1).

Percentage of coral cover calculated using CPCe and Microsoft Excel. Based on the following formula, CPCe software is used to rapidly and accurately calculate coral cover in a given area (Kohler & Gill, 2006; Giyanto et al., 2014).

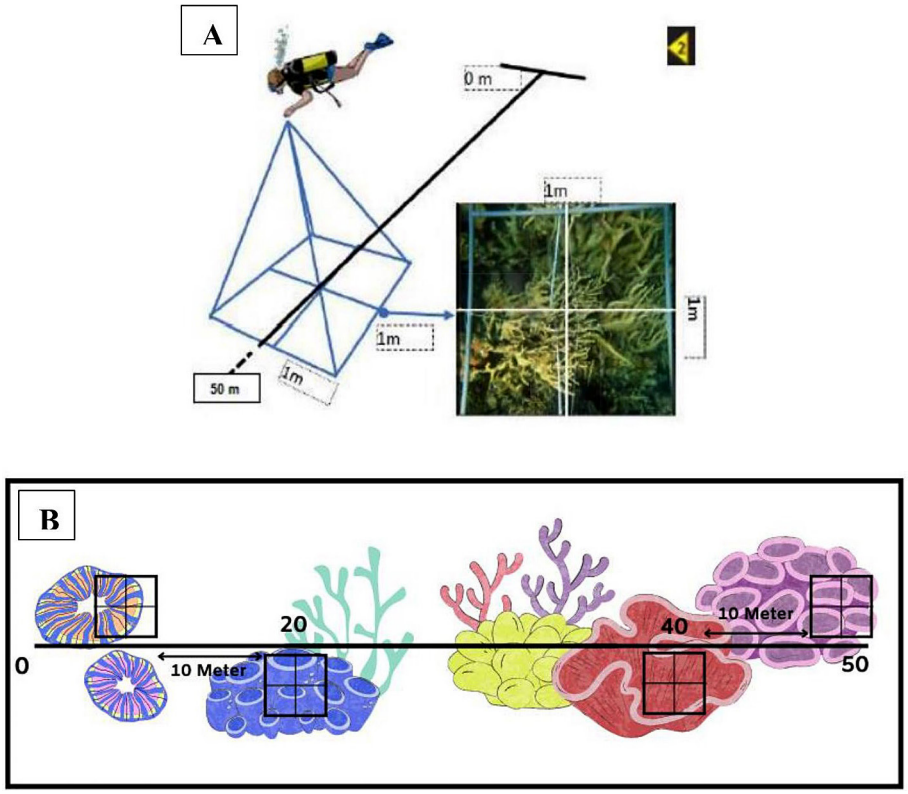


Figure 2.UPT Methods: (A) quadrant transect 1x1 m; and (B) UPT method ilustration

Table 1. Table of criteria for percentage of coral cover

Parameters	Coral reef damage standard criteria (%)		
Percentage of live coral cover	Damaged	Bad damaged	0–24.9
		Medium damaged	25–49.9
	Good	Good	50–74.9
		Very good	75–100

Decree of Minister of Environment Decree No. 4/2001

Table 2. Table of water quality standard

Parameters	Standart value
Temperature (° C)	28 – 30
Salinity (‰)	33 – 34
pH	7 – 8.5
Water clarity (%)	100
DO (mg/L)	>5

Decree of Minister of Environment Decree No. 51/2004

$$Percentage\ of\ Coral\ Cover = \\ = \frac{Total\ point\ of\ category}{Total\ of\ random\ point} \times 100 \quad (1)$$

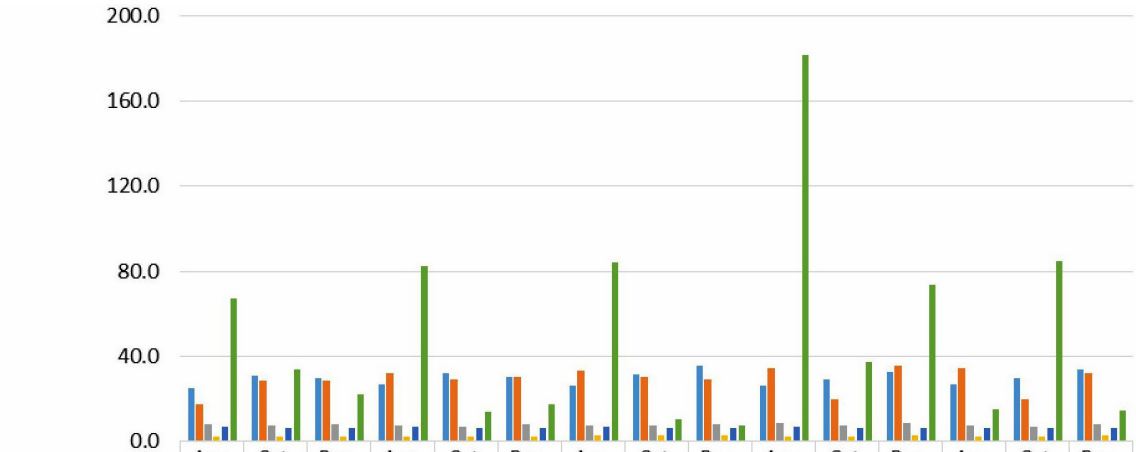
The obtained water quality result is then compared to quality standards (Table 2) to determine whether the waters are conducive to the development of coral reefs.

RESULTS AND DISCUSSION

Water quality parameters

Sea water has the role of supporting good conditions for the development of marine life (Apriani et al., 2018). In addition to the type of substrate, other environmental factors such as temperature, pH, DO, salinity, water clarity, and sedimentation rate influence the growth of coral reefs. Figure 3 depicts the environmental parameters measured during the study.

Coral reefs still grow in the Sempu Strait, according to research site environmental characteristics. According to Decree of Minister of Environment Decree of Republic of Indonesia No. 51 of 2004, coral reef growth is best around 26 to 32 °C. Coral grows at 20–36 °C and 36–40 °C, coral reefs grow at current temperatures (Nybakken,1992; Kepel & Abrar, 2013; Wiguna et al., 2018). According to Table 2, the Sempu Strait exhibits a pH range of 7-8 and a water clarity ranging from 2.25 to 2.73 meters. Additionally, it is seen that optimal coral growth occurs at salinity levels of approximately 33-34 parts per thousand (ppt). The graph shows that the salinity is below the optimal threshold. Temperature changes of 2 °C and seasonal salinity variations of 5% are usually allowed (Tanjung et al., 2019a). During the three-month monitoring period, the DOconcentrations in the Sempu Strait waters ranged from 6.28 to 6.71 mg/l, appropriate for coral reef growth (Connel & Miller, 1995). Water mass dissolved oxygen is usually 6–14 mg/l. Algutomo et al., (2002) report that sea surface layer dissolved oxygen averages 5.8–8.4 mg/l.



	Aug.	Oct.	Dec.	Aug.	Oct.	Dec.	Aug.	Oct.	Dec.	Aug.	Oct.	Dec.	Aug.	Oct.	Dec.
	WM			WW			BT			JT			RA		
Temp. (° C)	25.3	31.1	29.7	26.8	32.0	30.5	26.0	31.5	35.8	26.3	29.1	32.6	26.8	29.8	33.9
Sal. (‰)	17.5	28.4	28.7	32.3	29.4	30.2	33.3	30.4	29.0	34.6	20.0	35.7	34.6	20.0	32.1
pH	7.81	7.68	8.12	7.3	7.02	7.9	7.27	7.34	8.04	8.67	7.78	8.58	7.3	6.73	8.18
Water Clarity (m)	2.02	2.15	2.3	2.1	2.37	2.3	2.95	2.81	2.9	2.1	2.5	3.05	2.1	2.3	3.08
DO (mg/L)	6.95	6.59	6.43	6.85	6.37	6.33	6.64	6.46	6.21	6.64	6.5	6.29	6.47	6.51	6.15
SR (mg/cm²/hari)	67.3	33.7	22.2	82.7	13.9	17.7	84.3	10.6	7.8	181.5	37.7	73.8	15.2	84.8	14.3

Figure 3. Water quality parameters in the Sempu Strait in August, October, and December (2021). Watu Meja (WM), Waru-Waru (WW), Banyu Tawar (BT), Jetty (JT), and Rumah Apung (RA)

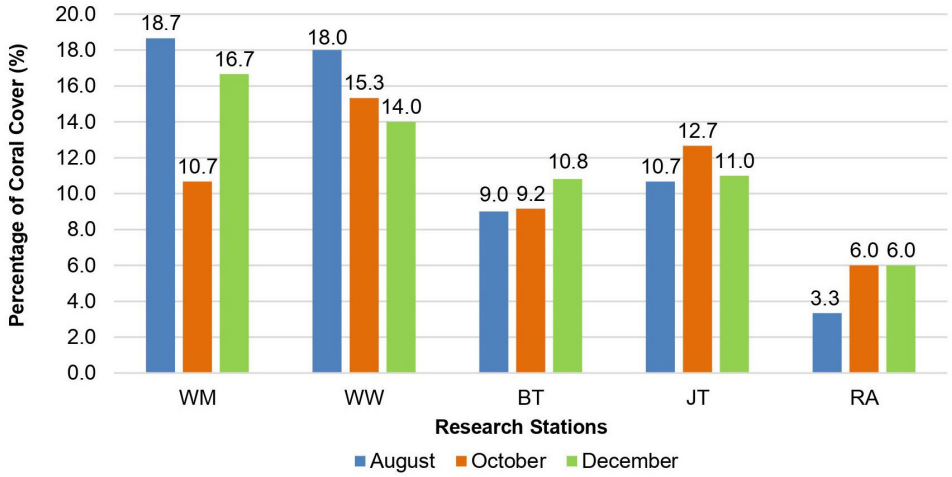


Figure 4. Percentage of coral cover (Watu Meja (WM), Waru-waru (WW), Banyu Tawar (BT), Jetty (JT), and Rumah Apung (RA))

Percentage of coral cover based on coral lifeform on CPCe

Coral reefs are destroyed (Kepmen LH No. 4 of 2001) based on data from five sites in the Sempu Strait in August, October, and December 2021 (Figure 4). Sempu Straits has just 3.3–18.7% corals. Watu Meja has the highest proportion because of the lowest anthropogenic activity and its strong currents, pure water, and low sedimentation rate. Because it faces the Pacific Ocean and is far from the bay, Luthfi et al. (2019) found that Watu Meja has a sloped water topography and strong currents. The Rumah Apung has the lowest cover, 3.3–6%. Data collection on the reef slopes with moderate currents, moderately turbid water, and a high sedimentation rate because deep currents are low enough to allow sedimentation (Isdianto et al., 2022b) caused low coral cover in the Rumah Apung (Figure 4). The Rumah Apung's corals develop more in shallow, sloping sections near the shore, hence the transect has few corals since they are hidden on the slopes.

In October coral cover decreased at Watu Meja and Waru-Waru stations. October closures increased at Banyu Tawar, RumahApung, and Jetty. In December, Watu Meja and Banyu Tawar stations increased their percentages, Waru-Waru and Jetty stations decreased, and Rumah Apung remained the same.The optimal coral growth temperature of 28 to 30 °C at Banyu Tawar, Jetty, and Rumah Apung increased coral cover. August also improves water clarity at the three stations. A temperature increases of 2–30 °C causes coral bleaching, which leads to death if it lasts for several weeks (Giyanto et al., 2017; Luthfi et al., 2018a). The Coral cover in Waru-Waru and Jetty dropped in December affected by temperature and sedimentation rates. Waru-Waru is a tourist destination, and the jetty is near the port, so anthropogenic activity affects coral growth at these two sites. The percentage increase at Watu Meja and Banyu Tawar stations was affected by temperature, sedimentation rates, salinity, and human activities like fishing and ship activities.

Using 2016 study, the average coral cover in the Sempu Strait was 23.3% (Luthfi, 2017). In 2017, the Sempu Strait coral cover increased to 39.3% (Luthfi et al., 2018b), but in 2018, it declined to 20% (Luthfi, 2019). In 2021 observations lowered coral cover to 11.5%. This reveals that coral reef cover in the Sempu Strait is gradually declining, hence comprehensive and consistent measurements are needed.

Lifeform dominance

In the discussion of lifeform dominance, it is divided into two sections: the eastern station, which includes waru-waru and Watu Meja, and the western station, which includes Banyu Tawar, Jetty, and Rumah Apung.

Figure 5 shows that Waru-waru is dominated by Coral Branching, Acropora Branching, and Acropora SubMassive, with the dominant non-biological substrate being sand. Coral Branching grows in calm, protected seas like Waru-waru (Thovyan et al., 2017). Other sources suggest this submassive growth represents an adjustment to protected areas (Nusaputro et al., 2019).

At Watu Meja, Acropora Branching lifeforms prevailed and the same non-living substrate,

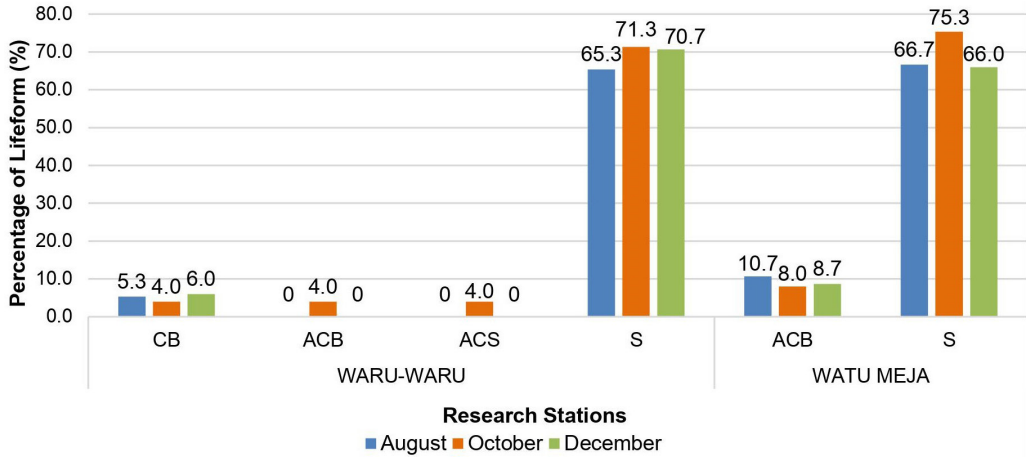


Figure 5. Dominance of coral lifeforms at the east station: Waru Waru, and Watu Meja (Coral Branching (CB), Acropora Branching (ACB), Acropora SubMassive (ACS), and Sand (S))

Sand (S), was identified as at Waru-Waru. In substrates with lots of sand and gravel, Acropora can adapt and recover. Figure 5 shows that the lower the amount of sand in Watu Meja, the higher the percentage of Acropora branches, and vice versa. The sand substrate is coral pieces carried by ocean currents (Prasetyo et al., 2018). Due to fast currents, clean water, and low sedimentation rates, branching dominates the east stations. According to Luthfi et al. (2014), hard corals in the Sempu Strait reflect their surroundings. Acropora Branching dominates eastern coral reefs with stronger currents and relatively clear water.

Figure 6 shows several dominant lifeforms. Coral massive is the highest living form in Banyu Tawar, and rubble is the main substrate. October had more debris than December. Strong currents and many boats devastated the coral reefs in Banyu Tawar. The local populace will fish at this station when the water recedes, trampling coral reefs. However, excessive sedimentation and turbid waters have increased huge coral cover, such as at Banyu Tawar.

The jetty is dominated by submassive and encrusting coral, with silt as the dominant non-living substrate. Coral encrusting was only observed during the months of August and October because subsequent transect observations revealed an abundance of fauna, namely sea urchins, which obscured coral encrusting. In December, coral submassive was still present due to its upward growth, indicating that the abundance of sea urchins did not inhibit its development. The high proportion of silt at the Jetty is a result of the intense sedimentation caused by the construction work surrounding the station. The Rumah Apung Station is dominated by coral encrusting and coral massive due to the powerful currents and relatively low water clarity of the surrounding waters.

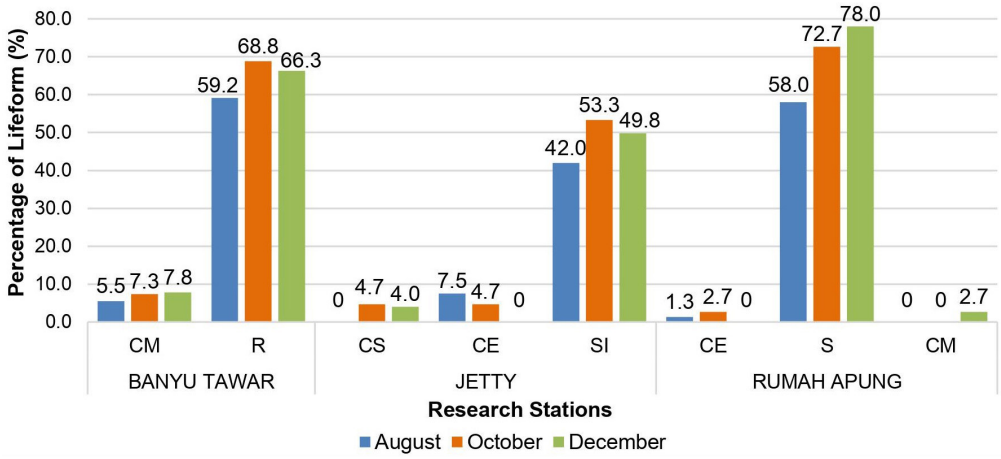


Figure 6. Dominance of coral lifeforms at the west station: Banyu Tawar, Jetty, Rumah Apung (Coral Massive (CM), Coral Submassive (CS), Coral Encrusting (CE), Rubble (R), Silt (SI), and Sand (S))

The prevalent lifeforms at the three stations west of the Sempu Strait are coral massive, encrusting, and submassive. This type of coral growth is an adaptation to water conditions. This is consistent with the findings of Luthfi et al. (2014), who found that the station to the west is dominated by branching and massive coral, which characterizes water conditions that are subject to natural pressures such as low sedimentation and clarity.

Lifeforms

Figure 7 shows some of the most common life forms found in Sempu Strait waters in 2021. The life forms found at the west station are Coral Massive, Coral encrusting, and Coral Submassive. As for the station located in the eastern part, Acropora Branching, Coral Branching, and Acropora Submassive lifeforms were found.

Coral and macroalgae competition

Human activities are degrading tropical coral reefs, leading to a decline in reef-building corals and an increase in macroalgae (Brown et al., 2018). In general, macroalgae grow more rapidly than coral animals. The presence of other biota, such as macroalgae, inhibit coral growth (Wijaya et al., 2017). The distribution of coral and algae in the water is inversely proportional; when the proportion of coral is high, the proportion of algae is low, and vice versa. This indicates that corals and algae are in competition in space (Nugraha et al., 2016).

Figure 8, shows how coral reefs and macroalgae have competed in the past, but not at all

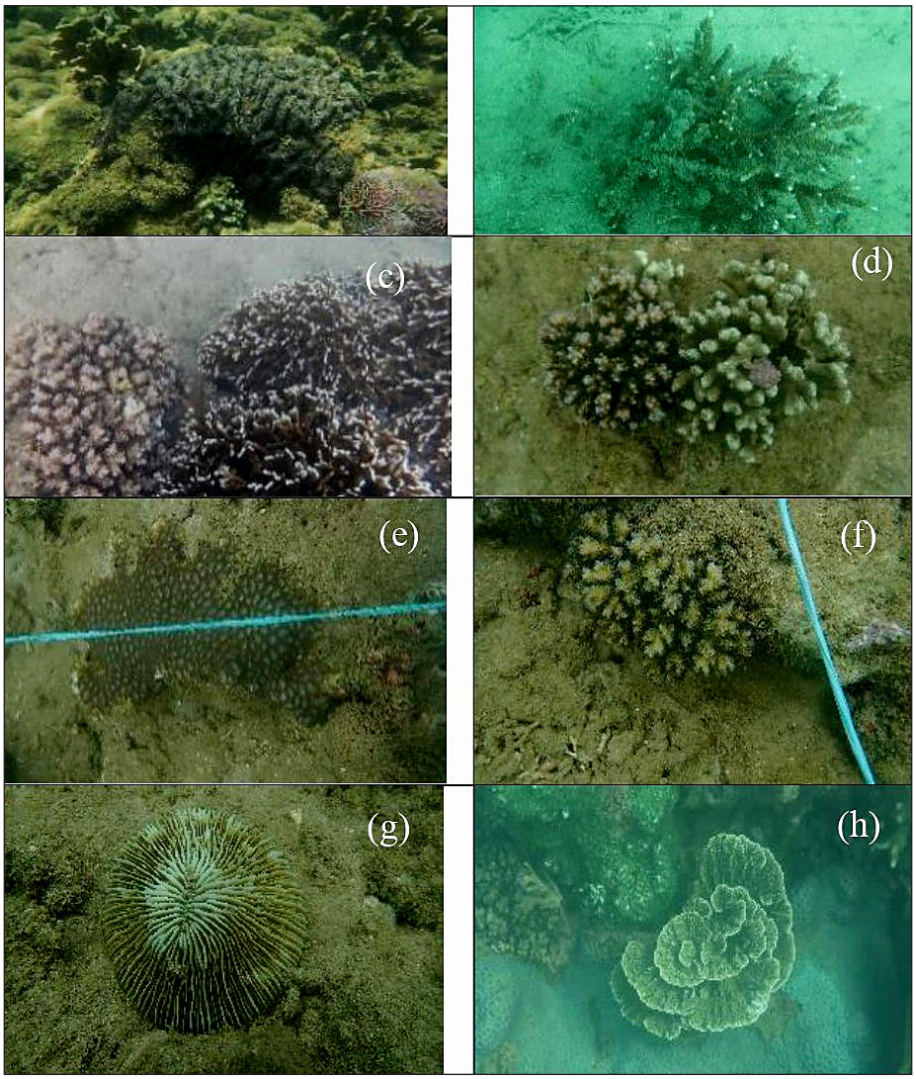


Figure 7. Lifeform of corals found in the waters of the Sempu Strait: (a) Coral Massive; (b) Acropora Branching (c) Coral Millepora (d) Coral Submassive (e) Coral Encrusting (f) Coral Submassive; (g) Coral Mushroom; (h) Coral Foliose

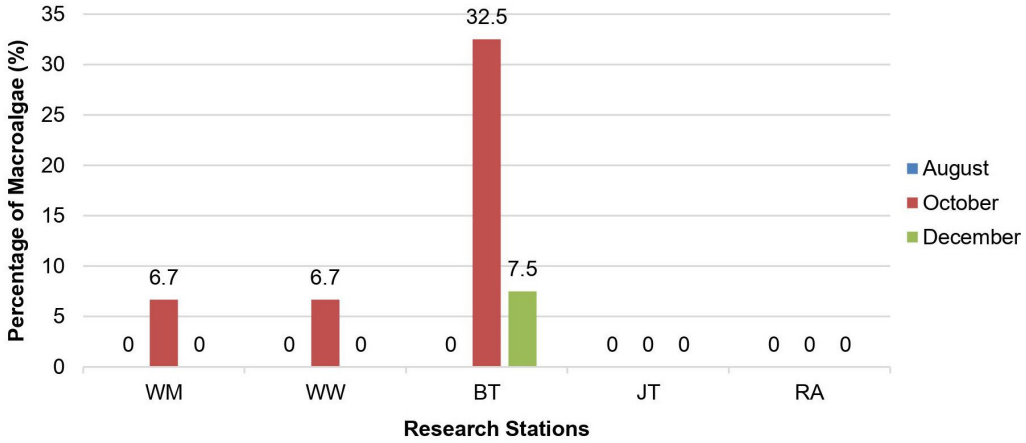


Figure 8. Coral and macroalgae competition (Watu Meja (WM), Waru-waru (WW), Banyu Tawar (BT), Jetty (JT), and Rumah Apung (RA))

research stations. During the observation period, only Banyu Tawar, Waru-waru, and WatuMeja hosted competitions, while RumahApung and Jetty were devoid of competitions. In WatuMeja and Waru-waru, the competition occurs only in October, whereas in Banyu Tawar, the competition occurs in October and the percentage declines in December.

The underlying substrate is the initial source of competition between coral reefs and macroalgae. On hard substrates such as sand, dead coral, debris, or shells, macroalgae stick by themselves. The substrates of the Waru-Waru, Watu Meja, and Banyu Tawar stations consist of sand, rubble, and rocks, making them ideal for macroalgae growth (Fitria et al., 2019). Beaches usually have a diverse substrate, which consists mostly of sand. However, if the substrate is composed of a mixture of rocks, various types of macroalgae will develop. Other stations, including Rumah Apung and Jetty, have a substrate consisting of silt, which makes them less suitable for macroalgae growth.

The influence of the season also contributes to the occurrence of competition. In Waru-waru, Watu Meja, and Banyu Tawar during the months of October and December (east season and transition 1), the water's nutrient content is still high, making it ideal for the growth of macroalgae. In order to survive, macroalgae absorb nutrients from the water and undergo photosynthesis (Rugebregt et al., 2020). Seasons are known to affect the frequency of coral and macroalgae competition, with temperature and light variations playing a crucial role in the abundance of tropical macroalgae (Brown et al., 2018).

Water quality has an immediate impact on macroalgal communities. The growth factors for macroalgae are highly complex and interconnected between physical and chemical factors such as temperature, salinity, pH, and concentrated substances such as nitrogen and phosphate. According to Dawes (1991), the optimal temperature range for macroalgal growth is between 25 and 35 °C. In October and December, competition between macroalgae and coral reefs increases, as depicted in Figure 8. Figure 3 shows a temperature increase every two months from August to December 2021, which has the effect of slowing photosynthesis and destroying pigments. At the Banyu Tawar station, the temperature rose from 26 °C in August to 31.5 °C in October and 35.8 °C in December 2021. Both positive and negative relationships exist between the species diversity of macroalgae and water quality parameters. The diversity of macroalgae increased as phosphate, nitrate, pH, and salinity concentrations rose. In contrast, increases in temperature, salinity, and ammonia reduce macroalgal diversity (Rugebregt et al., 2020).

CONCLUSIONS

Based on observations taken bimonthly from August to December 2021, it was determined that the condition of coral reefs in the waters of the Sempu Strait was "poor" because the percentage of coral cover ranged from 5.3% to 18.7%, with an average of 11.5%. This value decreased significantly in comparison to 2016 (23.3%), 2017 (39.3%), and 2018 (20%) research. In addition, it was discovered that the dominant life forms at the

west station were Coral Encrusting, Massive, and Submassive, whereas the dominant life forms at the east station were Acropora Branching, Coral Branching, and Acropora Submassive. Temperature ranged from26 to 35 °C, salinity ranged from 17 to 35 ppt, pH ranged from 7 to 8, water clarity ranged from 2.25 to 2.73 meters, and DO ranged from6.28 to 6.71 mg/L.Four of the five parameters have optimal values, while salinity is below the optimal value and therefore detrimental to coral reef growth. It was also identified that there was competition between corals and macroalgae at several stations, namely only at Banyu Tawar, Waru-Waru, and Watu Meja stations, because the suitable substrate was sand, coral rubble, and rocks. Another factor is due to the season and water quality that support the growth of macroalgae. Basically, macroalgae grow faster than corals, resulting in competition for space to grow.

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