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Assessing the relationship between coral cover and coral recruitment in the degraded ecosystems of Sempu Nature Reserve, East Java, Indonesia

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Abstract. *Isdianto A, Wibowo RA, Kudrati AV, Aliviyanti D, Asadi MA, Dewi CSU, Setyanto A, Lelono TD, Tumulyadi A, Hidayah LN, Fathah AL, Putri BM, Wardana NK, Supriyadi, Luthfi OM. 2024. Assessing the relationship between coral cover and coral recruitment in the degraded ecosystems of Sempu Nature Reserve, East Java, Indonesia. Biodiversitas 25: 3075-3083.* The long-term survival of coral ecosystems requires the existence of coral recruitment variables that function as agents for future coral generations. The efficacy of this recruitment is crucial for the coral ecology in Sempu Waters, which is renowned for its ongoing loss in coverage. This research aims to determine hard coral cover, the number of coral recruits, and the correlation between hard coral cover and the number of coral recruits. Data was collected using the underwater photo transect method, a widely accepted and reliable technique for assessing coral cover and diversity, at five research stations during 3 observation periods (December 2022, February 2023, and April 2023) and then analyzed using pearson correlation to determine the relationship between the percentage of coral cover and the number of coral recruits. The results show that the coral cover of the Sempu Strait is classified as damaged and has decreased for 3 consecutive months, namely 14.28, 13.92, and 12.57%, and only 22 coral recruits were found in total with 6 identified genera, including *Seriatopora*, *Porites*, *Pocillopora*, *Goniastrea*, *Pavona*, and *Acropora*. The correlation between hard coral cover and coral recruits shows a positive relationship and a fragile level of closeness (r = 0.1119). The availability of stable substrates for recruitment, such as Dead Coral with Algae (DCA), Dead Coral (DC), and Rock (RK), can increase the potential for successful recruitment. However, coral recruits in the Sempu Strait also face competition from other biota, such as macroalgae and adult corals themselves.

Keywords: Coral ecology, coral larval settlement, coral reef monitoring, pearson correlation analysis, underwater photo transect method

INTRODUCTION

Coral reef sustainability is intricately tied to the recruitment process of coral larvae, from settlement to the formation of a skeleton on the substrate. This process is crucial for the survival and resilience of coral reefs, especially in the face of challenges like climate change, pollution, and sedimentation (Hoegh-Guldberg et al. 2018; Mujahidah et al. 2023). Settlement of coral larvae and successful post-attachment survival are two key steps for successful coral recruitment (Elmer et al. 2018; Aunurrahman et al. 2024). Coral recruitment is a critical factor in controlling coral reef population dynamics and plays an important in the recovery of coral reefs following disturbances (Holbrook et al. 2018; Oetama et al. 2024). Declining recruitment rates in coral reefs have been observed to coincide with changes in recruit assemblage compositions (Hughes et al. 2019). Research has demonstrated that enhancing coral recruitment is vital for reef recovery. For example, providing high densities of mass-cultured larvae to artificial reef substrata resulted in significantly increased coral settlement compared to the natural larval supply (Cameron and Harrison 2020; Putri et al. 2024).

Sempu Island is one of the conservation areas in East Java which is included in the nature reserve category, located in Tambakrejo Village, Malang District, East Java. Corals in the Sempu Strait Waters, on average, live at a depth of 1-7 m (Luthfi et al. 2018; Isdianto et al. 2024). Sempu Island is directly connected to the Indian Ocean, making the waters of this island, especially its coral reef

ecosystem, directly affected by physical and chemical factors from the Indian Ocean. Several coral ecosystem challenges are faced in these waters, and it is known that the condition of coral cover continues to decline (Wibawa and Luthfi 2017). The coral cover in Sempu Strait Waters was found to be 50% in 2006 and 2013 but later decreased to 36% from the average percentage for each station (Luthfi and Jauhari 2016). From 2006 to 2009, a reclamation project involving 2.6 hectares was initiated with the purpose of constructing a fishing port. This reclamation activity resulted in sedimentation, hence impacting the overall condition of the coral ecosystem. Consequently, by 2014, the coral cover in the waters of the Sempu Strait had declined to 24.1% (Luthfi et al. 2018). Moreover, there were fluctuations observed in the years 2016, 2017, and 2018. Specifically, there was an increase in the poor category during the period of 2016-2017, followed by a significant decrease in 2018. These fluctuations were observed at three specific stations, namely Teluk Semut, Watu Meja, and Waru-Waru. According to recent research conducted in 2023, the average coral cover in the Sempu Strait is approximately 11.47%, indicating a classification as poor (Isdianto et al. 2023).

A healthy coral population plays a crucial role in influencing its reproductive rate. Research by Hartmann et al. (2018) states that populations with higher coral cover will produce more larvae per unit of coral surface area compared to populations that experience a decrease. These findings highlight how important coral cover is as a determining factor in larval production, which in turn promotes coral recovery. Some concerns are that the decline in coral coverage within the Sempu Strait may result in a drop in the population of coral larvae. This research aims to determine the general condition of water quality, the condition of hard coral cover and substrate, the number of coral recruits and their genus, and to analyze the relationship between hard coral cover and the number of recruits at the research location.

Against the background of the increasingly deteriorating condition of the coral ecosystem in the Sempu Strait, this research is important to provide a deeper understanding of the dynamics of coral recruitment in degraded waters. In addition, it is hoped that the results of this research can contribute to the development of more effective conservation strategies, especially in coral reef restoration efforts in conservation areas such as Sempu Island. The methodological approach used in this research is expected to produce accurate and reliable data to identify factors that influence coral recruitment and provide recommendations for better coral reef management in the future.

MATERIALS AND METHODS

A research study was conducted on Sempu Island, Malang District, East Java, Indonesia at five locations during December, February, and April 2023. The research addressed several stations, namely Watu Meja (WM), Waru-waru (WW), Banyu Tawar (BT), Rumah Apung (RA), and Jetty (JT) in Figure 1. Each stations characteristic describes in Table 1.

Table 1. Stations description

Station	Coordinates	Description
Watu Meja	8°25'45.13"S, 112°41'49.65"E	Located at the strait's mouth and is far from the impact of human activity and tourists.
Waru-waru	8°25'50.14"S, 112°41'32.94"E	The popular tourist destination, frequently visited by visitors for activities such as snorkeling and swimming.
Banyu Tawar	8°26'5.85"S, 112°41'14.78"E	The salinity conditions of this station have been suggested to be influenced by the freshwater input from the estuary.
Jetty Port	8°26'1.57"S, 112°41'3.21"E	This location directly influenced by several activities, including fisheries and harbor activities.
Rumah Apung	8°26'13.56"S, 112°40'48.01"E	Located near the residential area and affected by the presence of domestic waste.

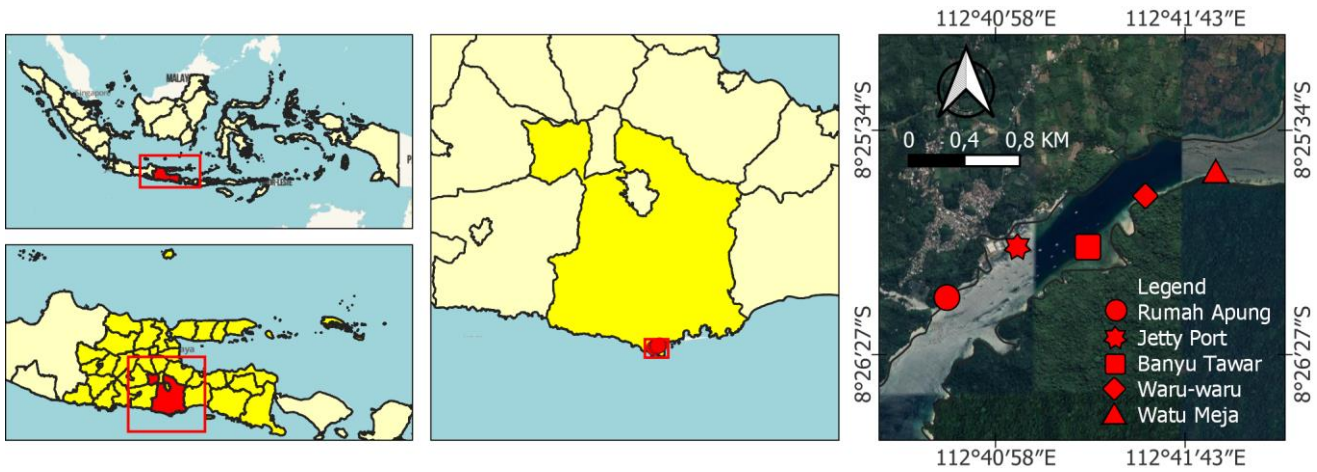

Figure 1. Research map on Sempu Island, Malang, East Java, Indonesia

Observation of coral cover

The research was conducted over 3 observation periods starting from December 2022, February 2023, and April 2023. As a focus for observing coral condition data, the underwater photo transect method was used. This method involves the use of semi-permanent transects tied with ropes and markers to ensure consistent positions at each observation period. Ten semi-permanent transects using pegs and ropes measuring 1x1 m (Figure 3) were carried out at each research station. The distance between semi-permanent transects is approximately 10 meters, and the placement is adjusted to the substrate conditions and coral distribution at each research station. Each transect is tagged to facilitate the periodic identification process.

Hard coral data was observed using the underwater photo transect method (Figure 2), where the image is taken as perpendicular as possible to the object of observation. Photos are taken perpendicular to the object of observation using an underwater camera. Each image focuses on details in one small quadrant and also covers the large quadrant as a whole. This approach was taken to ensure accurate substrate identification within the transect.

The resulting photos were then processed using CPCe (Coral Point Count with Excel extensions) software, which allows analysis of coral cover based on 50 random points on each transect. Calculation of coral cover is carried out using the formula:

$$Category\ \%cover = \frac{number\ of\ category\ points}{random\ number\ of\ points} \times 100\%$$

The coral cover values obtained were then categorized according to Giyanto et al. (2014). Many criteria, namely the poor category (0-25%), medium category (26-50%), good category (51-75%), and very good cover (76-100%). Identification of the benthic substrate category refers to the Survey Manual for Tropical Marine Resource 2nd Edition and Coral Reef Health Monitoring Guide (Giyanto et al. 2014).

Observation of coral recruits

Coral recruitment was observed in a 1x1 meter transect quadrant area and repeated ten times at the same depth (Figure 3). Documentation was carried out perpendicular to the transect quadrant for five repetitions in each box on the transect. The size of coral recruits was measured directly using calipers. The documentation results were then processed using Image-J software to cross-check the size of the recruits (the determined size of the recruits was >5-<10 cm). The recruits found were identified based on their morphology by referring to Babcock et al. (2003) and English et al. (1997). The abundance of coral recruits in the transects was captured for further statistical data analysis.

Correlation analysis

Therefore, to determine the relationship between hard coral cover and the number of coral recruits, a pearson correlation test (r) was carried out. Pearson correlation analysis was used to evaluate the degree of linear relationship between two variables, in this case, between the percentage of hard coral cover and the number of coral recruits. This analysis is carried out by calculating the correlation coefficient value, which shows the strength and direction of the relationship between the two variables. Interpretation of the correlation coefficient is carried out based on the intervals in Table 2.

The analysis process begins with collecting data on coral cover and the number of coral recruits from each transect. After the data was collected, a normality test was carried out to ensure the data met the normality assumptions required in the pearson correlation test. Next, the data was analyzed to see the strength of the relationship between coral cover and recruitment, which was represented by the correlation coefficient (r). The relationship between these two variables was then analyzed further to provide an interpretation regarding the factors that influence the level of coral recruitment at the research location.

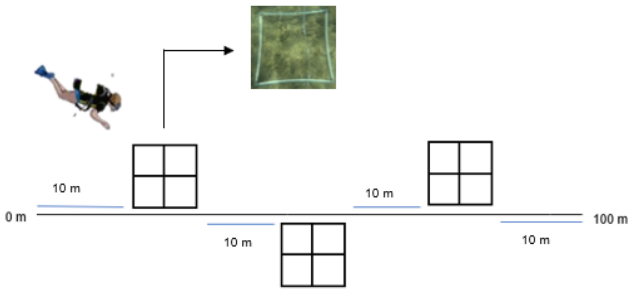

Figure 2. Underwater photo transect method (Giyanto et al. 2014)

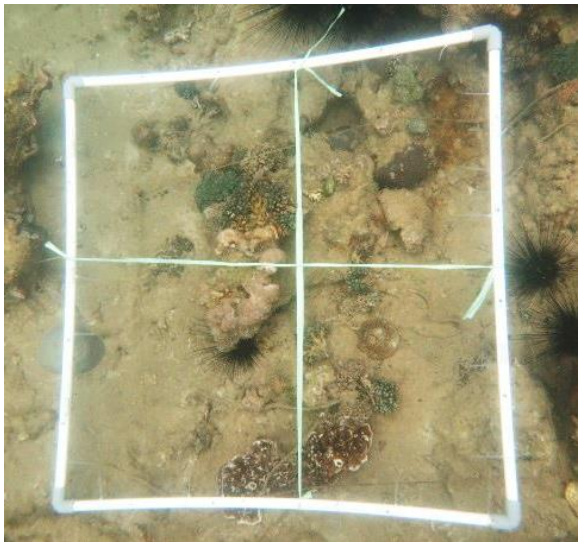

Figure 3. Use of quadrant transect as a tool for analysis of area

Table 2. Correlation level

Coefficient interval	Correlation value
0.00-0.19	Very weak
0.20-0.39	Weak
0.40-0.59	Moderate
0.60-0.79	Strong
0.80-1.00	Very strong

RESULTS AND DISCUSSION

Water quality

The water quality parameters collected included temperature, salinity, pH, brightness, dissolved oxygen (DO), depth, waves, currents, nitrate, phosphate, and sedimentation rate. Parameters were measured using a secchi disk to measure brightness, AAQ Rinko 1183s-F for salinity, temperature, and pH, a scale staff for waves, and a sediment trap for sedimentation rate. Table 3 shows the following parameter measurement results.

The average temperature and salinity values for water quality in the Sempu Strait are 29.6°C and 32.2 ppt; these values are still considered optimal. Salinity and temperature are important factors that have a significant impact on coral survival (Isdianto et al. 2020). Low salinity combined with high temperatures can cause a stress response in corals, thereby affecting their growth, survival, and photosynthetic efficiency (Ding et al. 2022; Patthanasiri et al. 2022). Temperature is a crucial factor affecting coral reproductive success, influencing gametogenic and spawning cycles (Leinbach et al. 2021; Carlson et al. 2022). Studies have demonstrated that elevated temperatures can expedite gametogenesis, impact the timing of planulae release, and decrease reproductive efficiency in corals (Airi et al. 2014; Galanto et al. 2022). Meanwhile, salinity values that are too low can affect coral's resistance to high temperatures (Giyanto et al. 2017; Wibawa and Luthfi 2017).

The current speed value in Sempu Waters has an average of 0.46 m/s and is categorized as medium (Ramlah et al. 2015). The growth of coral is influenced by various hydrodynamic processes, particularly those associated with sediment transport. This is significant as sediment has the potential to impact the overall health of coral (Silaban and Kadmaer 2020). Moderate currents, waves, and tides play a crucial role in supporting coral recruitment and growth. These natural processes help in the transportation of coral larvae, removal of sediments, and creation of suitable conditions for coral settlement and development (Foley et al. 2014). Optimal water motion levels are essential for facilitating sediment removal and promoting coral recruitment and growth (Stender et al. 2021). In low wave exposure environments, herbivores can promote the growth of coralline algae while limiting turf and encrusting fleshy algae, creating microhabitats conducive to coral recruitment (Doropoulos et al. 2016).

The sedimentation rate in the waters of the Sempu Strait is in the catastrophic category, with a value of 73.7 mg/cm/day >50 mg/cm/day (Pastorok and Bilyard 1985). Sedimentation greatly affects fauna communities physically as well as through changes in sediment composition, organic matter, and nutrient input. The study conducted by Chou et al. (2014) shows a strong correlation between changes in benthic communities and the amount of clay/silt fractions in sediments. Sedimentation poses a significant threat to coral reefs by disrupting coral photosynthesis through various mechanisms. Sediment deposition on coral polyps can lead to smothering, preventing tentacles from feeding and reducing light availability for photosynthesis (Tuttle and Donahue 2022). Not only for adult corals, sedimentation is also a stressor for corals that are just starting to settle on the substrate (Moeller et al. 2017). Sedimentation damage to coral reefs in the waters of the Sempu Strait occurs due to high anthropogenic activities and river flows, which increase the rate of sedimentation in the waters. Sedimentation leads to coral death, which is eventually overgrown by algae (Isdianto et al. 2024).

Substrate cover percentage

The average coral cover (Figure 4.A) classification at 5 stations was damaged with a range from 10.28 to 18.30% (Isdianto et al. 2024). The percentage value of coral cover from December 2022, February, and April 2023 decreased every month, with average values of 14.28, 13.92, and 12.57%, which were included in the damaged category. The lowest cover was at WM station, with an average of 10.28%, and the highest was at RA station, with an average of 18.36%.

Table 3. Water quality in Sempu Strait, Malang, East Java, Indonesia

Parameter	Unit	Station					Average	Quality standards
		WM	WW	BT	RA	JT		
Temperature	°C	29.39-29.45	29.68-29.95	29.67-29.78	29.67-29.73	29.51-29.62	29.6	28-30[a]
Salinity	‰	32.32-32.40	32.35-32.52	32.09-32.13	32.12-32.19	32.01-32.10	32.2	33-34 [a]
pH	-	8.10-8.48	8.0-8.22	8.22-8.26	8-8.08	8.10-8,42	8.2	7-8.5 [a]
DO	mg/L	6.36-6.38	6.32-6.34	6.32-6.34	6.35-6.37	6.37-6.39	6.4	>5 [a]
Current	m/s	0.05-1.18	0.07-1.15	0.12-1.06	0.19-0.86	0.13-0.82	0.46	Slow: 0-0.25b m/s[b] Moderate: 0.25-0.50 m/s Fast: 0.50-1 m/s Very fast: >100 m/s
Sedimentation	mg/cm/day	72.5-113	70.2-73	34.8-76.4	45-68.8	74-98.5	73.73	1-10 slight-moderate[c] 10-50 moderate-severe >50 severe-catastrophic

Source: [a] Government Regulation of Indonesia 2021, [b]Ramlah et al. 2015, [c]Pastorok and Bilyard 1985

The condition of the coral reef ecosystem in a body of water can be seen from the percentage of live coral cover. Physical, biological, and human environmental pressure that occurs on coral reef ecosystems, especially from increasingly dense and high levels of human activity, includes pollutants originating from the land, such as dirty waste from fishing ports, ship passageways, and fish waste Tourist activities also influence the changes in the coral reef ecosystem (Wibawa and Luthfi 2017). The decline is marked by the large number of dead corals that algae have overgrown (Isdianto et al. 2023). Apart from that, it is also influenced by the presence of the South Java Current (SJC) along the coastline of South Java, which changes over time, causing sediment to move up from the bottom of the waters, resulting in disruption to coral life on this area (Luthfi and Jauhari 2016). The low value of coral cover in the waters of the Sempu Strait is predicted by the high percentage of sand and silt at several stations; this can support the reason that the sedimentation rate is relatively high (Isdianto et al. 2023).

The results of the overall benthic substrate cover are shown in Figure 4.B. Sempu Strait consists of an overall 10 substrate types, which include Hard Coral (HC), Dead Coral (DC), Dead Coral with Algae (DCA), Rubbles (R), Rocks (RK), Sand (S), Silt (SI), Macroalgae (MA), Turf Algae (TA) and Others (OT). The figure provides insight into a substrate that is suitable for successful recruitment due to its high stability. Examples of such substrates include Dead Coral with Algae (DCA), Dead Coral (DC), and Rocks (RK). According to research by Munasik et al. (2021) in Pulau Panjang, coral recruits prefer stable, rough, sediment-free surfaces like Dead Coral with Algae (DCA), particularly in higher regions sheltered from sediment resuspension. Coral larvae are more likely to cling to and develop on textured and complex surfaces. The high level substrate of the Artificial Patch Reefs (APR) had the highest density of coral recruits, reaching 129.2 individuals per square metre, showing that this substrate is better suited for coral growth than the lower level substrate, which is exposed to significant sedimentation. The stability of DCA is considered to be as beneficial; nevertheless, the recruitment process of coral recruits may be hindered by the presence of algae that covers the surface of dead coral Giyanto et al. (2023). Meanwhile, research by Lubis et al. (2018) at Gosong Pramuka, Seribu Islands, shows that hard substrates, such as rocks, are ideal for coral recruitment, especially by the genera Acropora and Porites. The rough surface of this substrate provides stability and protection to coral larvae. Exposure station I had the highest recruitment density (0.22 colonies/m²), with lower densities in wave-protected stations. The abundance of room on the substrate also promoted coral recruitment.

Recruitment

Total coral recruits found

A total of 22 coral recruits (Figure 5) were found at the five stations during 3 months of observation, and their numbers increased or remained constant. The highest number of recruits was at the WM station, with a total of 8 recruits in the whole month. In December, no recruits at the WM station were found in the transects during observations, but in the following months, namely February and April, 8 recruits were found in each month.

Coral recruitment in WM was found most often attached to parts of dead Coral Covered in Algae (DCA) (Figure 4.B) because this substrate is stable and has many crevices, making the recruitment process easier. These findings could be used to inform coral reef restoration efforts, suggesting that using dead coral covered in algae as a substrate could enhance coral recruitment. Even though they are in large numbers, their existence is threatened by the coral recruits at this station because they are thought to be competing for space with algae, which simultaneously grow on the surface of dead coral (Webster et al. 2015). The station with the second highest total recruitment was JT with a total of 6 recruits. Even though the silt substrate cover is quite high, this station provides the highest stable and Gapped Rock (RK) substrate compared to other stations for the recruitment process. The lowest number of recruits was at WW station with 2 recruits. The few coral recruits found in WW were thought to be due to the limited availability of stable substrates for coral recruitment, such as rocks and dead coral. The WW station is dominated by silt compared to other stations, which increases the risk of coral being covered by sediment, resulting in death due to the lightness of the silt substrate particles (Miller et al. 2016).

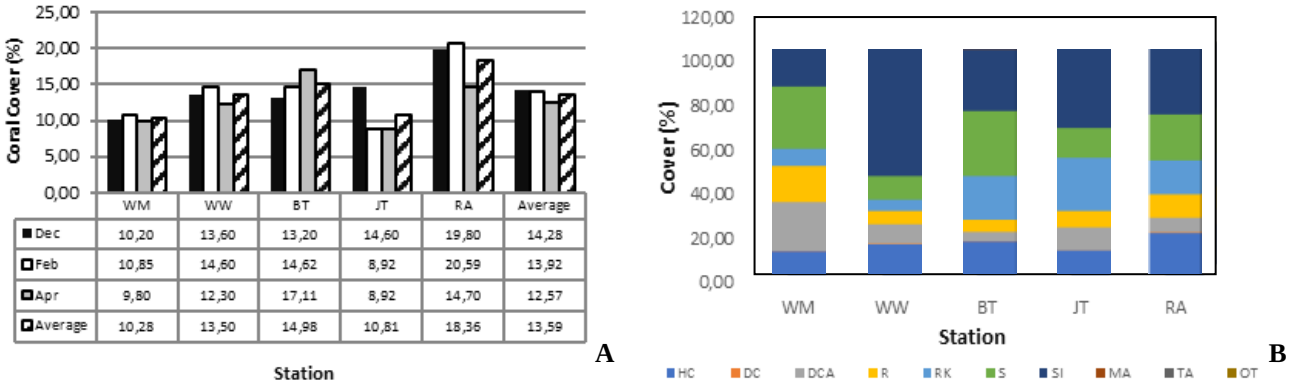

Figure 4. A. Average percentage of coral cover at each station; B. Benthic cover in Sempu Strait, Malang, East Java, Indonesia

The benthic substrate is very important in the continuity of coral recruitment. The basic substrate type of the Sempu Strait is dominated by silt, which, due to its low mass, has the potential to clog coral polyps. Studies have shown that most coral recruits prefer attaching to surfaces with crevices rather than smooth ones, which provides shelter and protection for young coral recruits (Doropoulos et al. 2016). Coral recruits are also often found on stable substrates such as dead coral and rocks compared to coral fragments and sand substrates (Oli et al. 2022). Unstable substrates, such as rubble, can hinder recruitment by killing coral recruits and impeding the binding processes necessary for creating a stable substrate (Kenyon et al. 2023). Stabilizing substrates through physical and biological processes can enhance the suitability of the substrate for successful coral recruitment, such as the role of Crustose Coralline Algae as "natural glue" for young corals (Crook et al. 2016; Johns et al. 2018). In conclusion, coral recruitment is a complex process influenced by various factors such as substrate composition, benthic community structure, larval density, and environmental conditions.

The genus of coral recruits

According to the results, it was found that 6 genera of coral recruits (**Error! Reference source not found.** and 7) in the waters of Sempu Island, namely *Seriatopora*, *Porites*, *Pocillopora*, *Goniastrea*, *Pavona*, and *Acropora*. The most common coral recruitment genera found at sizes <5 cm were *Pocillopora* and *Goniastrea*. *Pocillopora* corals exhibit morphological variations in response to different flow conditions, with branches being thicker and more compact in high-flow habitats and thinner and wider in low-flow environments (Paz-García et al. 2015). Different coral species exhibit plasticity in growth morphology in response to local environmental conditions (Cresswell et al. 2017). These branching colonies of *Pocillopora* corals are abundant and serve as key bio-constructors in coral reef ecosystems across the Indo-Pacific and the Red Sea (Oury et al. 2022). *Pocillopora* is known to have fast growth, high survival rate, and high abundance, especially in the Indo-Pacific region, so this species is suitable for transplantation to conserve coral reefs (Rivest and Hofmann 2014; Li et al. 2020).

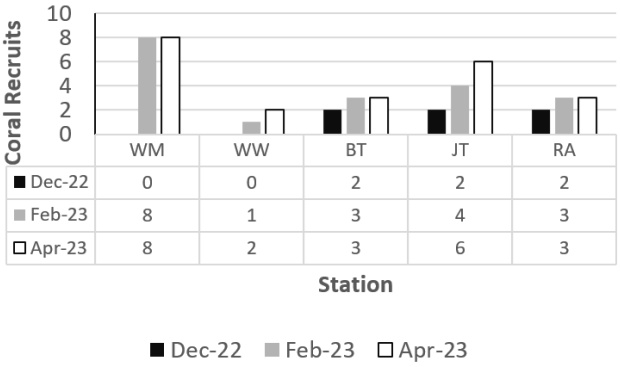

Figure 5. Total coral recruits found in Sempu Strait, Malang, East Java, Indonesia

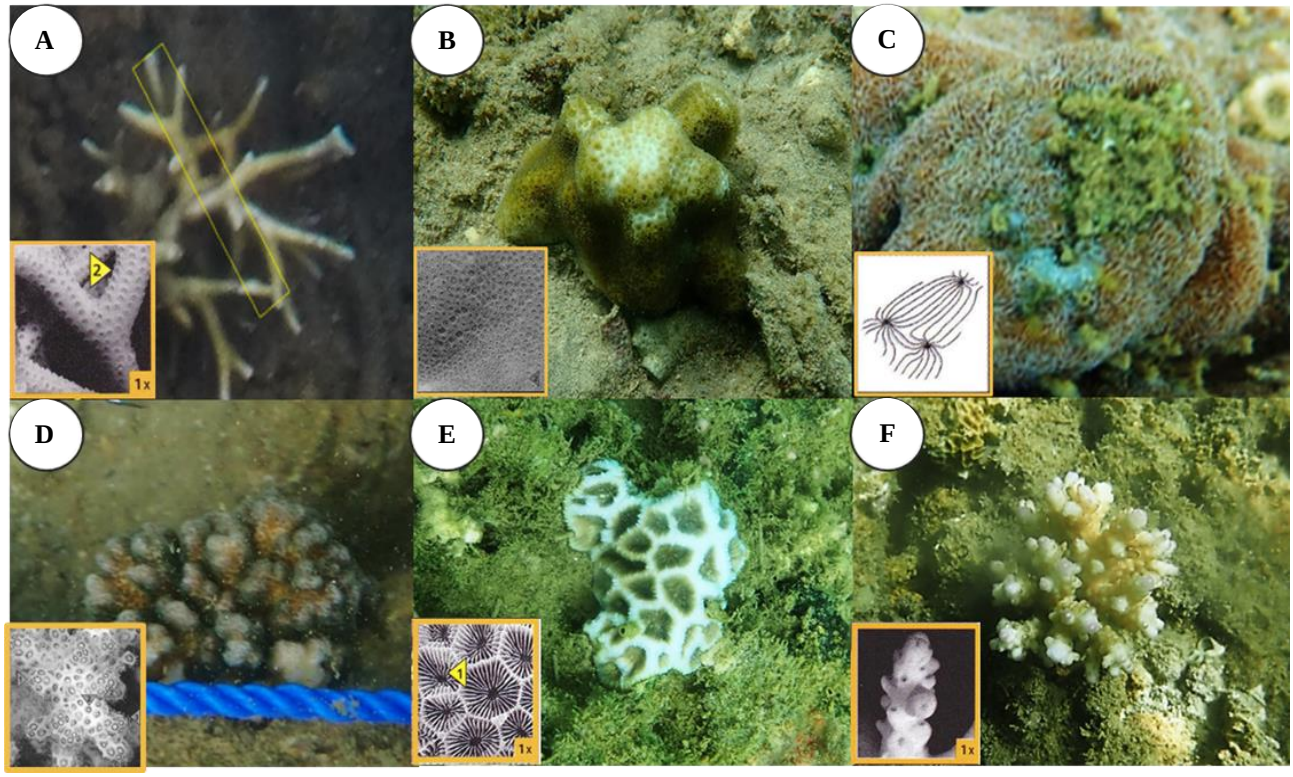

Figure 6. Juveniles found in research area along with corallite form in scaled (Kelley 2012). A. Seriatopora; B. Porites, C. Pavona; D. Pocillopora; E. Goniastrea; F. Acropora

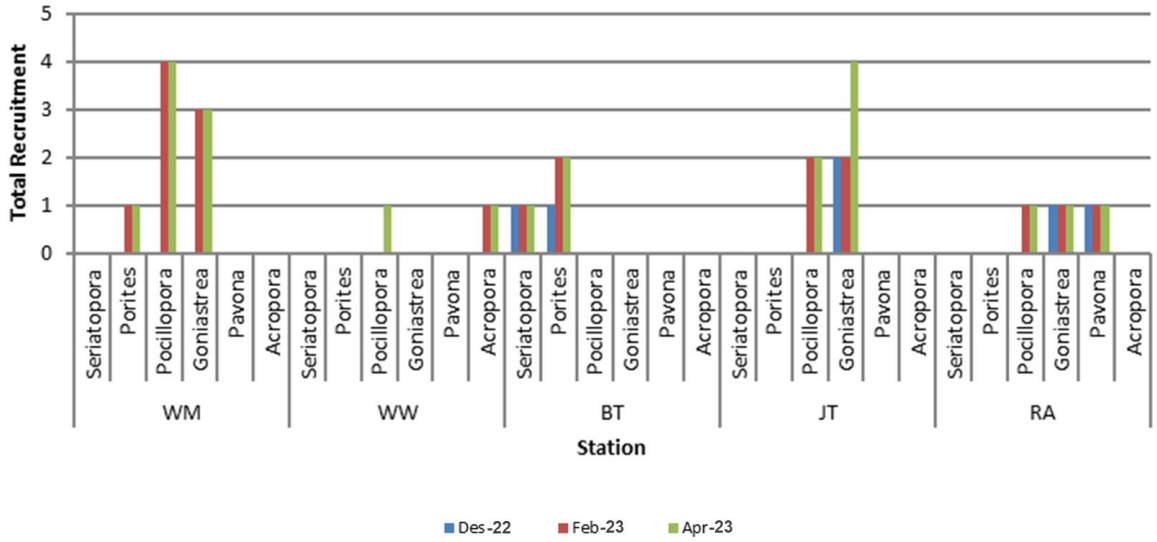

Figure 7. The corals recruit genus in Sempu Strait, Malang, East Java, Indonesia

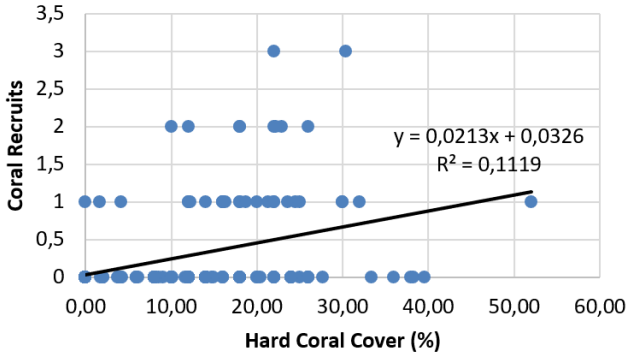

Figure 8. Correlation between coral cover and coral recruitment

Meanwhile, the genus *Goniastrea* has a massive growth or rock form. Studies have shown that these coral groups, characterized by their large and robust structures, can dominate reef ecosystems even in conditions of increased water turbidity (Sosdian et al. 2024). Furthermore, the survival rates of encrusting and massive corals have been reported to be higher compared to branching corals, indicating their resilience in different environmental conditions (Frias-Torres et al. 2023). Massive and submassive coral groups have coral characteristics that can survive and are often found in murky waters (Barus et al. 2018). This is in accordance with the five research stations that have high sedimentation rates (Pastorok and Bilyard 1985), so it is more many coral recruits were found in submassive and massive growth forms.

Some of the findings of this study are in accordance with research conducted by Asadi et al. (2022) in a similar location. All corals measuring <4 cm were referred to as juvenile. Several genera of juvenile corals discovered at five sites differed according on local conditions. Acropora and Montipora are two genera found in Waru-Waru. Montipora, Porites, and Pocillopora were the dominant genera in Teluk Semut. Tiga Warna Station (TW) also has an abundance of Acropora, Montipora, and Porites. Meanwhile, in Kondang Merak (KM) and Jembatan Panjang Tanjung Sirap (JPTS), the genera Porites, Goniastrea, and Favites were detected more frequently. This distribution is influenced by environmental factors like currents and sedimentation.

Correlation of coral cover and coral recruits

Statistical analysis of the correlation-regression test between the percentage of live coral cover and the number of coral recruits obtained a correlation coefficient of 0.1119. This value can be interpreted as meaning that the percentage of live coral cover has a very weak level of relationship to the amount of coral recruitment. The pattern of relationship between these two variables can be described with the equation y=-0.0213x + 0.0326, where x is coral cover and y is coral recruitment (Figure 8).

There was a clear positive correlation between the percentage of live coral cover and the density of coral juveniles; several studies support this relationship. Edmunds et al. (2015) found a positive association between coral cover and juvenile density, indicating strong recruitment and growth favoring the presence of juvenile corals in the adult population. This study also provides other results that the density of coral juveniles is more common in dead coral than in live coral; this is because dead coral is a stable substrate, so it is suitable for the coral recruitment process (Elmer 2017). There are different levels of correlation between the percentage of hard coral cover and the number of coral recruits at each location, indicating that coral recruitment is not the only factor in supporting an increase in coral cover in an area. Research by Giyanto et al. (2023) provides another perception that high hard coral cover also has the potential to increase competition in terms of getting space and nutrients, thereby

inhabiting the recruitment process of young corals. This gap shows the need to emphasize the complexity of factors that influence coral recruitment, thus requiring further research to understand the specific conditions under which hard coral cover can positively impact coral recruitment (Holbrook et al. 2018).

Adult coral colonies play an important role in producing coral larvae, but not all larvae produced will be successful in the recruitment process. Genetic diversity and the adaptability of parent corals have an impact on larval dispersal and settlement, thereby influencing recruitment success (Leite et al. 2017). Other factors such as competition with algae and other biotas (Cortés-useche et al. 2019), water quality, and human activities also influence recruitment success. However, efforts to increase the number of recruits through restoration initiatives have become important in the sustainability of coral ecosystems. Several conservation activities, such as coral propagation, large-scale restoration, selective breeding of heat-tolerant corals, and marine protected areas, can contribute significantly to increasing coral recruitment and increasing the natural recovery process (Maya et al. 2016; Cunning et al. 2021).

In general, the findings of this study indicate that although there is a very weak positive correlation between coral cover and coral recruitment in the Sempu Strait, deteriorating environmental conditions, such as high levels of sedimentation in the waters and competition between corals and macroalgae, are one of the main factors contributing to low levels of coral recruitment. Therefore, to mitigate this, conservation efforts are needed that concentrate on reducing sedimentation levels and regulating macroalgae, which is absolutely necessary to increase the possibility of coral recruitment and restore the condition of the coral reef ecosystem in this area.

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