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Original research article

Community Structure of Transplanted Corals by Shelf Method at Bangsring Beach, Banyuwangi

Pratama Diffi Samuel[1], Anisa Dwi Riskiani Utomo[2], Rio Christy Handziko[3*], Citra Satrya Utama Dewi[2]

[1]*Aquatic resources management study program, Universitas Brawijaya, Malang*
[2]*Marine science study program, Universitas Brawijaya, Malang*
[3]*Ecology and Environment Laboratory, Biology Education Department, Universitas Negeri Yogyakarta, Yogyakarta*

*Corresponding author
Email: handziko@uny.ac.id
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Abstract

Coral reef ecosystems that have been damaged require restoration actions. The study's goal was to identify transplanted coral species on Bangsring Beach, as well as to assess the importance of community structure and local community role on coral transplantation activities. Location is determined through purposive sampling-divided into five blocks and direct data capture. Descriptive data analysis, including the diversity index, uniformity, and dominance. The community's part was determined through interviews and questionnaires distributed to the residents of Bangsring. Corals transplanted at Bangsring Banyuwangi Beach include 12 genera and 30 species of coral. The Acropora genera includes Favia, Merulina, Pavona, Pocillopora, Porites, Stylophora, Turbinaria, Nepthea, Tubipora, and Hetroxenia. Block 4 has the greatest diversity index (2.75), followed by blocks 3, 2, 5, and 1. Coral species diversity was relatively high throughout all blocks, with no dominant species. The role of local communities cannot be ruled out in the sustainability of coral reef conservation activities. The community's and managers' active participation in coral transplantation at Bangsring Beach is critical to its success. The transplanted corals at the Bangsring Beach area are monitored on a regular basis to observe changes in the coral community structure.

1. INTRODUCTION

Coral reefs are tropical marine ecosystems rich in biodiversity. They play a vital role in preserving the balance of marine ecosystems, protecting beaches, and supporting the community's economy [1]. Indonesia, a country positioned in the center of the world's coral triangle, has very high coral reef riches [2], [3]. However, several concerns such as climate change and human activities have caused the degradation of coral reefs [4]. The current status of coral reefs in Indonesia is still classified as poor to moderate. 1,067 research stations around the coastal areas of Indonesia reveal 36.18% in poor condition, 34.3% in moderate condition, 22.96% in good, and 6.56% in highly good condition [1].

Damage to coral reef ecosystems necessitates rehabilitation initiatives to restore their ecological functions and environmental benefits [5], [6]. Coral transplantation is a type of rehabilitation in which live corals are grafted or fragmented and then planted in damaged regions [7], [8]. This strategy has proven to be useful in repairing coral reef ecosystems, as was successfully carried out in Bangsring Beach, while also giving advantages to the environment and local populations [9]. Almost of the local communities informed that shelf method is the most succesful method for coral transplantation in Bangsring. The community's role is an effort to participate in a collaborative activity, demonstrated by the deliberate participation of a person or group of individuals [10], [11], [12].

Coral reef communities are composed of populations of numerous species living in a specific area. Community structure can be classified depending on the form or major structural properties [13]. Community structure can be measured by diversity, uniformity, and dominance [14]. Community structure and environmental carrying capacity have a substantial impact on ecosystem dynamics, influencing species interactions and ecosystem balance. The species level, as the smallest unit, plays a vital role in the creation of populations, which eventually constitute the overall community [15].

Bangsring Beach is a located-on Java Island's eastern tip, specifically in Bangsring Village, Wongsorejo District, and Banyuwangi Regency. Bangsring has a tourism community that emphasizes the health of coral reefs [16], [17]. Bangsring Beach has 596 meters of beachfront and lies between -8.049611°N and 114.430222°E in the north and -8.054747°N and 114.431086°E in the south. Bangsring Beach is a coral reef protection area governed by local regulations. This region is designated as a Joint Protection Zone (JPZ), with a total area of approximately 15 hectares. This region is separated into two sections: a 1-hectare core area and a 14-hectare buffer zone. The management of this protected area is legally based on Bangsring village and the regulations numbered 02/429.205.01/2009 [18].

2. MATERIALS AND METHODS

From March to May 2024, the research was carried out at Bangsring Beach in Banyuwangi, East Java. The investigation was carried out at coral transplantation sites on Bangsring Beach. The transplantation site was divided into five blocks, as indicated in Figure 1.

Waters parameters that had been taken are current velocity, brightness, salinity, temperature and pH. All those waters paramaters taken at the site of coral in each observed blocks. All parameters measured in average as a main results.

The instruments and supplies used in this research data collection include a SCUBA gear, sabak (a plate that use to writing under the water), underwater camera, pencil, coral identification book, laptop, and transplanted corals as the research object.

To determine the site of data collection, this study used the purposive sampling method. Data on transplanted coral reefs were collected by SCUBA dives in five selected transplanting blocks. The belt transect method was used to make dives at depths ranging from 4 to 8 meters. Data were obtained immediately through recording and underwater documentation. The data were evaluated using the Coral Finder Toolkit, as well as references from the book "Corals of the World" by [19] and “Types of Corals in Indonesia” written by [20]. Analysis was conducted to obtain transplanted coral species.

Data on the role of the community gathered through interviews and questionnaires were evaluated descriptively. Descriptive analysis is used to collect basic data that just provides an explanation rather than generating predictions [21]. The interview results provide information on the community's role in coral transplantation initiatives conducted in the Bangsring Beach area.

This study examined the abundance of transplanted coral colonies on Bangsring Beach. Each transplant shelf measured 1x1 meter, with 9 pieces in each quadrant and evenly distributed around the space. The data were gathered by counting the number of colonies on each shelf.

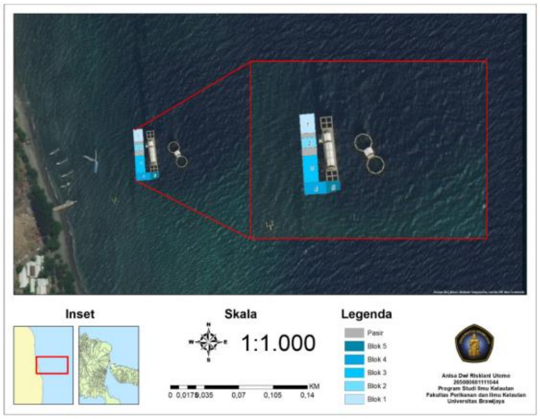


Figure 1. Research Site

The results of this calculation are then used to compute the average number of colonies in each location or observation block.

The value of community structure is obtained from calculating the abundance of coral individuals, calculating diversity, uniformity and dominance indices. Calculation of colony abundance was done with the formula [22]:

$$\textbf{Coral abundances} = \frac{\textit{Total of coral colonies}}{\textit{Total observation area}}$$

Calculation of Shannon-Wiener species diversity index [23] was calculated by:

$$H' = -\sum_{i=1}^{s} pi \; ln \; pi \quad ....\ (2)$$

Description:
H' = Shanon – Wiener Biodiversity Index
Pi = Total individual in each species
S = Summary of all individuals

Range score categories [24]:

- H'<1 = Low diversity index
- 1<H'<3 = Moderate diversity index
- H'>3 = High diversity index

The similarity index assesses the degree of similarity in the number of individuals from various species within a group. The higher the homogeneity index, the more unstable the ecosystem's balance [25].

$$E = \frac{H'}{Ln\ S} \quad ....(3)$$

Description:
H' = Diversity index
S = Species total
E = Similarity index

Range score categories [26]:

- E < 0,4 = Low similarity, Stresses community
- E 0,4 - 0,6 = Moderate similarity, Fragile community
- E > 0,6 = High Similarity, Stable community

The dominance index (C) measures how much one group of biota dominates another. A large enough dominance will result in a labile or depressed community [27].

$$C = \sum \left(\frac{ni}{N}\right)^2 \quad ....(4)$$

Description:
C = Dominance index
Ni = Number of i-th individuals
N = Total number of individuals
Range score categories [27]:
0 < C < 0,5 = Low Dominance
0,5 < C ≤ 0,75 = Moderate Dominance
0,75 < C ≤ 1 = High Dominance

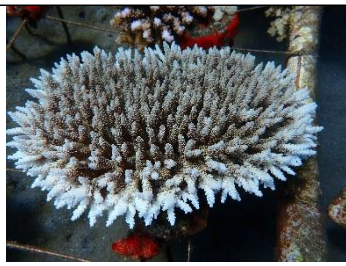
3. RESULTS and DISCUSSION

Types of Transplanted Corals

The Observations result from coral transplants that have been carried out in the Bangsring Beach area have found 30 species of coral from 12 genera. There are 9 hard coral genera and 3 soft coral genera. Hard coral genera are *Acropora*, *Favia*, *Merulina*, *Pavona*, *Porites*, *Montipora*, *Pocillopora*, *Stylophora*, and *Turbinaria*. Soft coral genera are *Nepthea*, *Tubipora*, and *Hetoroxenia*.

The Acropora genus had the majority of coral species, with 15 identified. Identification to get coral species is matched to the features of transplanted corals, which are described in references [19]. The identified transplanted coral species are shown in Figure 2 below.

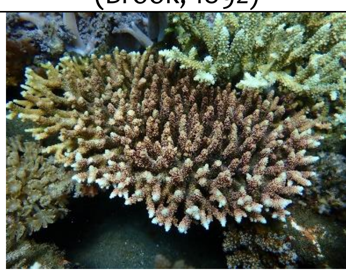
Bangsring Beach Transplanted Coral Species



Acropora latistella (Brook, 1892)

Acropora muricata (Linnaeus, 1758)

Acropora parahemprichii (Veron, 2000)



Acropora millepora (Ehrenberg, 1834)

Acropora cervicornis (Lamarck, 1816)

Acropora parapharaonis (Veron, 2000)

Bangsring Beach Transplanted Coral Species

Acropora nasuta (Dana, 1846)

Acropora copiosa (Nemenzo, 1967)

Acropora samoensis (Brook, 1892)

Acropora paniculata (Verril, 1902)

Acropora divaricata (Dana, 1846)

Acropora valenciennesi (Milne Edwards, 1860)

Acropora plana (Nemenzo, 1967)

Acropora intermedia (Brook, 1891)

Acropora vaughani (Wells, 1954)

Pavona venosa (Ehnrenberg 1834)

Montipora verrucosa (Lamarck,1816)

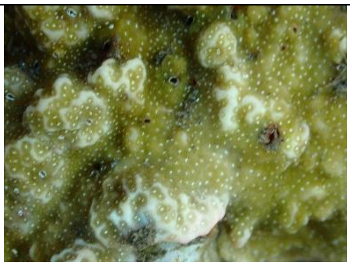
Montipora porites (Veron, 2000)

Favia laddi (Wells, 1954)

Pocillopora verrucosa (Ellis and Solander, 1786)

Pocillopora damicornis (Linnaeus 1758)

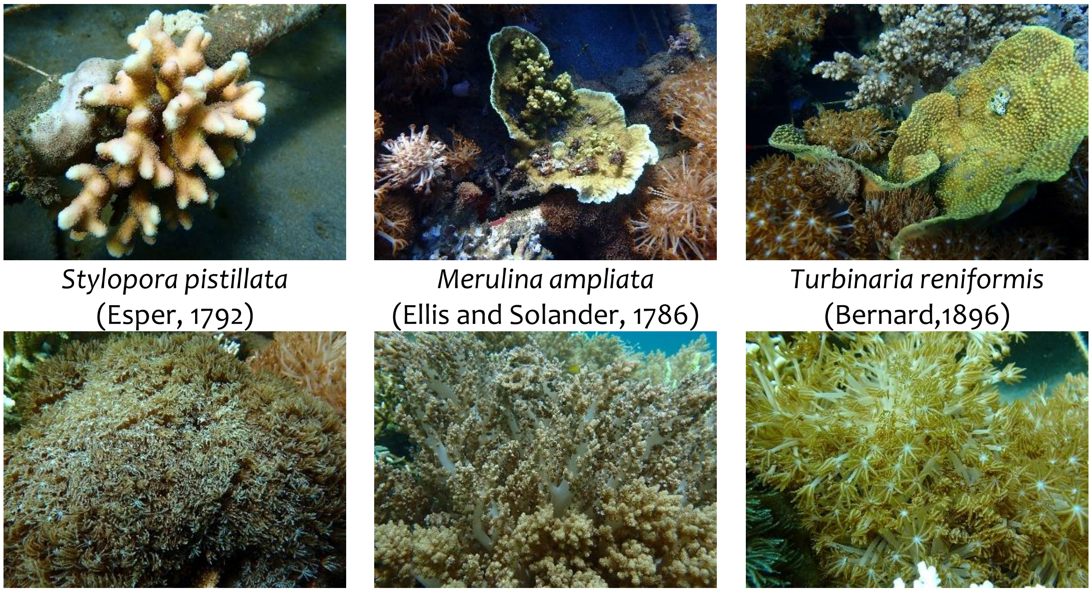
Bangsring Beach Transplanted Coral Species



Porites rus (Forskål, 1775)

Porites lutea (Milne Edwars,1860)

Porites murrayensis (Vaughan, 1918)



Stylopora pistillata (Esper, 1792) | *Merulina ampliata* (Ellis and Solander, 1786) | *Turbinaria reniformis* (Bernard,1896)

Tubipora musica (Linnaeus, 1758) | *Nepthea* (Audouin, 1828) | *Heteroxenia fuscescens* (Ehrenberg, 1834)

Figure 2. Bangsring beach transplanted coral species (*Resources: Research documentations 2024 and Coral of The World 2024*).

Waters parameters

These are the results of measurements of physical and chemical properties of water taken in the Bangsring Beach region. Measurements were taken prior to coral data collection. Current, brightness, salinity, temperature, and pH are among the parameters monitored. These measures are used to assess the water quality at the research location and compare it to quality standard of requirements by Ministry of Marine Affairs and Fisheries. All the waters parameters are depicted in table 1.

Table 1. Result of water parameters measurement

No	Water parameter	Measurement result	Quality standard
1	Current	0,06m/s	0,05 – 0,08 m/s
2	Brightness	9,5m	>5m
3	Salinity	30 ppt	30-35 ppt
4	Temperature	28,4°C	28-30°C
5	pH	8,09	7- 8,5

4. Discussion

Coral colony abudance

Based on the transplanted coral notes and calculations for each block. The transplanted rack measures 1 × 1 meter and has 9 segments for fragment coral planting. There is a tabulation of information regarding the transplatation rack, the total number of living colonies, and the average colony per square meter for each block. Colony of coral in each block at the observed site had been collected in the table2.

Table 2. Coral colony abudance

Research site	Number of racks	Colony total	Colony abundance/ Kuadrat (m^2)	Abudance percentages/m^2
Blok 1	156	1133	6/m^2	66.67%
Blok 2	121	744	6/m^2	66.67%
Blok 3	250	1588	7/m^2	77.78%
Blok 4	126	899	7/m^2	77.78%
Blok 5	98	656	7/m^2	77.78%

Block 1 had 156 transplant shelves, 1,133 living colonies, and an average density of 7 colonies per m^2. Block 2 includes 121 shelves with 744 live colonies at an average density of 6 colonies/m^2. Block 3 comprised 250 transplant shelves, 1,588 living colonies, and an average density of 6 colonies/m^2. Block 4 has 126 shelves, 899 living colonies, and an average value of 7 colonies/m^2. Block 5 had 98 shelves, 656 living colonies, and an average value of 7 colonies/m^2. According to KEPMEN LH No.4 of 2001, the percentage of coral abundance in each quadrant in all blocks ranged from 66.67% to 77.78% living colonies/m^2, which met the good standards [28].

Diversity index, similarity and dominance

Based on the recording and computation of transplanted coral fragments at Bangsring Beach in blocks 1, 2, 3, 4, and 5. The findings of the calculation of the index value of diversity (H'), uniformity (E), and dominance (C) in each block are as follows at the table 3.

Table 3. Diversity index, similarity, and dominance

Site of observation	(H)	Category	(E)	Category	(C)	Category
Blok 1	2,25	Moderate	0,66	High	0,15	Low
Blok 2	2,72	High	0,80	High	0,09	Low
Blok 3	2,73	High	0,80	High	0,09	Low
Blok 4	2,75	High	0,82	High	0,10	Low
Blok 5	2,50	High	0,74	High	0,11	Low

Based on the table above, it is clear that the diversity index (H') value varies over observation blocks. The diversity index values in all observation locations are moderate to high, ranging from 2.25 in block 1 to 2.75 in block 4. The value in block 1 (2.25), which has a moderate diversity value as the lowest value of all blocks, could be attributed to a lack of diversity of coral species planted during the early stages of transplantation. Block 4 has the greatest rating (2.75), suggesting that it has the highest species diversity value when compared to other places. The great value of diversity in block 4 can be attributed to corals planted in diverse varieties and equal volumes.

The observed uniformity values (E) ranged from 0.66 to 0.82, indicating that the distribution of individuals of each species at both sites is relatively even and steady. This signifies that no single species has a dominant position in the population. The dominance index values at all sites were low, ranging from 0.09 to 0.15, indicating high uniformity values. Block 5 had the lowest value (0.09), indicating that no single species dominated all locations.

The presence of sufficient resources and the absence of environmental disturbance offer excellent circumstances for the environment and interactions between species at this site, allowing the creation of a stable and balanced community.

Role of local community.

Based on the results of data gathering through interviews and questionnaires to with 15 respondents from the community near Bangsring Beach on coral transplantation activities. The results of the answers to the 10 questions are presented in the percentage chart of respondents' answers, as follows:

1. When did coral transplantation activities in Bangsring start?

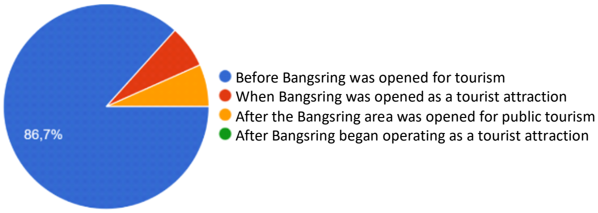


Figure 3. Early transplantation

Based on the percentage of responses in figure 3, it is clear that the community was involved in coral transplantation operations long before the Bangsring area was classified as a tourist destination. This suggests that the community's endeavor to restore coral reefs has been in the works for quite some time.

2. Since what year has the pipe rack of coral transplantation been conducted in Bangsring

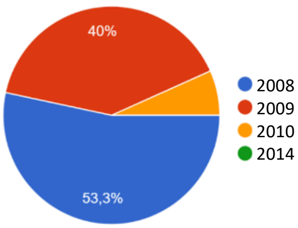


Figure 4. Initial official year of transplantation

More than half of the responders claimed that coral reef transplantation activities in Bangsring have been ongoing since 2008, it can be seen at figure 4. Coral transplantation initiatives in Bangsring Beach have been a key part of attempts to preserve marine ecosystems in the area, long before Bangsring Beach became known as a marine tourism destination.

3. Who is the first initiator for coral transplantation in Bangsring?

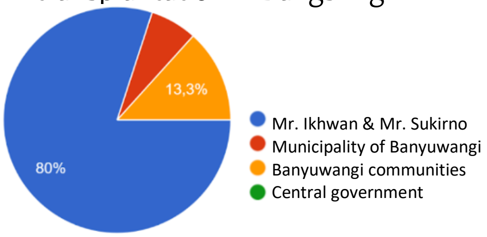


Figure 5. Coral transplant initiator

According to the poll results in figure 5, most respondents (80%) believed that Mr. Ikhwan and Mr. Sukirno were the primary initiators of coral transplantation activities at Bangsring Beach. However, the success of this activity is dependent on effective coordination among the community, government, and different associated parties. They were able to make their dream of a healthy and sustainable marine ecology a reality via collaborative efforts.

4. Do transplantation activities get assistance and funding from partners or CSR?

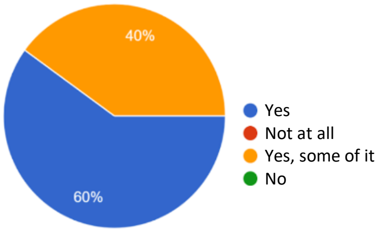


Figure 6. Support and funding

The responses gained demonstrate in figure 6 that coral reef transplanting initiatives in Bangsring have gotten quite a lot of support, both technically and financially.

5. Who are the parties that have worked to transplant corals at Bangsring Beach?

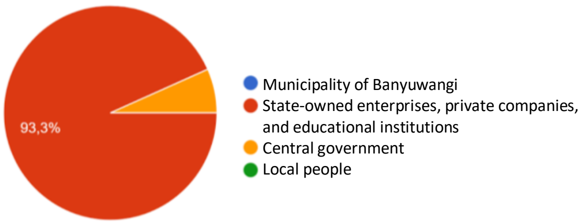


Figure 7. Networking

At the figure 7, many coral transplantation initiatives are undeniably supported by institutions ranging from state-owned corporations to private companies and educational institutions. In addition to local fishing organizations, active support from CSR companies, the Indonesian Navy, and other commercial companies has contributed to coral reef conservation initiatives at Bangsring Beach.

7. How is the collaboration procedure with partners/CSR for transplantation activities at Bangsring Beach?

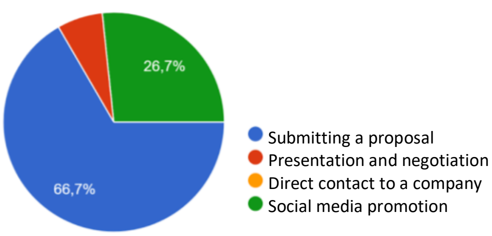


Figure 8. Networking progress

Figure 8 illustrates that submission of activity proposals is the most typical technique used by Bangsring Beach management staff. Others remarked that social media is a promotional tool that helps to increase awareness of Bangsring Beach. Furthermore, 6.7% of respondents said that cooperation with partners occurred through presentations and talks between management and partners who agreed to collaborate. Partner participation contributes significantly to the activity program's long-term success.

8. What are the hurdles that occur in the process of coral transplantation using the shelf method from the beginning to today?

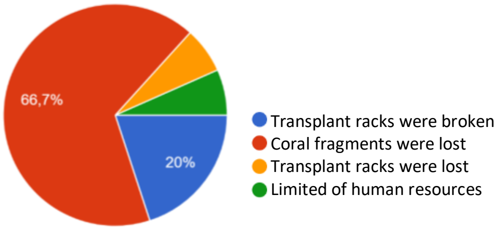


Figure 9. Transplant obstacles

Coral fragments that had been transplanted were lost over time. This is most likely the result of strong ocean currents and water column movement. This can be averted by strengthening the transplanted corals' bonds. It been depicted in figure 9.

9. What factors should be considered while deciding where the transplant shelf will be located?

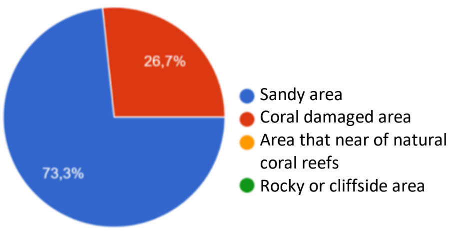


Figure 10. Positioning transplant shelf

On the figure 10, there were differing perspectives on the best place for coral transplantation. Approximately three-quarters of respondents said that coral transplants should be placed in sandy areas. The remaining respondents believed that transplantation should occur in regions where coral reefs were degraded

10. What are the most widely used transplant methods?

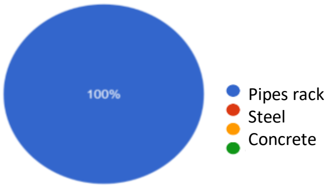


Figure 11. Transplant method

It shown on the figure 11, based on questionnaire and interview results, 100% of respondents believed that pipe racks were utilized for transplantation. However, in the future, several measures will be utilized in the Bangsring Beach region, including concrete, iron, and nets. Coral transplants have been placed in a variety of locations, including vacant sand areas. This even distribution demonstrates a genuine attempt to restore the coral reef ecosystem at Bangsring Beach.

11. Who is involved in the implementation, maintenance, and monitoring of coral transplanting at Bangsring Beach?

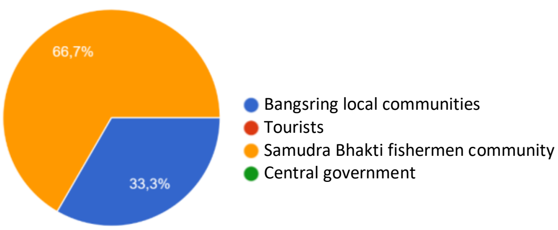


Figure 12. Implementator and supervisor

Figure 12 illustrates the results of questionnaires and interviews, 66.7% of respondents feel the Samudra Bhakti fishermen organization is responsible for initiating, sustaining, and supervising coral transplantation initiatives. As many as 33.3% believed that individuals participating as managers, maintenance, and supervisors represented the entire Bangsring community. The effectiveness of coral transplantation initiatives at Bangsring Beach is inextricably linked to the active participation of the local community and area managers, particularly the Samudra Bhakti fishermen organization. Starting with preparation and progressing to post-transplant maintenance.

5. Conclusion

Based on the findings of the research, it can be inferred that transplanted coral species in the Bangsring Beach area include 30 species from 12 genera. It consists of nine hard coral genera and three soft coral genera. The number of live colonies in coral transplants varied among five blocks, with an average of 6-7 colonies per m^2. Block 4 has the greatest diversity index (2.75), followed by blocks 3, 2, 5, and 1.

Coral species diversity was rather high throughout all blocks, with no single species dominating. These findings show that transplantation was effective in enhancing coral variety across the site, with Block 4 producing the best results because to the even distribution of species. The percentage of living coral abundance in each block varied from 66.67% to 77.78%m^2.

Waters parameters were measured in Bangsring waters at the coral reef planting site are still within the optimal range for coral reef growth, based on ministry of marine affairs and fisheries.

The community's active engagement and manage collaboration with partners / CSR are inextricably linked to the success of coral transplantation at Bangsring Beach. For the next training session, the local community's competency related to coral reef transplantation is training to monitor and evaluate coral reef growth on a regular basis. The purpose of this training is to ensure that the transplanted coral reefs can grow well.

6. Acknowledgement

The success of this project was a direct result of strong partnerships with local communities. We are deeply grateful to the fishermen of the Bangsring, named Kelompok Nelayan Samudera Bhakti for their local knowledge, assistance with site selection, and continued support for our conservation efforts. We also thank the Bangsring Underwater Community for granting the necessary permits and for their valuable insights into marine protected area management.

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