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Article

Comparative Analysis of Coral Cover Percentage and Species Diversity in Karanrang Island, Balang Lompo Island, Badi Island, and Lumu-Lumu Island Using the Underwater Photo Transect (UPT) Method

Gracella[1], Nita Rukminasari[1*], Jamaluddin Fitrah Alam[1], Sri Wahyuni Rahim[1]

[1]Department of Fisheries, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, Makassar, Indonesia

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Abstract. Coral reefs are vital ecosystems providing high ecological and economic value, yet in the Spermonde Islands, they are increasingly threatened by anthropogenic and environmental pressures. This study assessed live coral cover and coral genus diversity across Karanrang Island, Balang Lompo Island, Badi Island, and Lumu-Lumu Island. Data collection was conducted at 12 observation stations (depth ±5 m) using the Underwater Photo Transect (UPT) method in April 2025. Photo analysis with CPCe 4.1 software was used to calculate the percentage of live coral cover, while the diversity index was calculated using the Shannon-Wiener formula (H'). The findings revealed that Badi Island exhibited the highest live coral cover (32.31–45.03%), whereas Lumu-Lumu Island demonstrated the lowest condition (10.60–24.97%). The highest diversity index was recorded on Balang Lompo Island (H' = 2.53) and the lowest on Karanrang Island (H' = 0.83). Badi Island is predominantly composed of *Porites* sp. and *Acropora* sp., suggesting ecosystem stability and a high potential for regeneration, while Karanrang and Balang Lompo Islands display moderate conditions with a prevalence of adaptive massive corals. These results show variations in coral cover and diversity between islands due to differences in environmental pressures and the ecological characteristics specific. These findings emphasize the need for location-based management to maintain the ecological functions and restoration potential of coral reefs ecosystem in the Spermonde Islands.

Corresponding Author :
Nita Rukminasari
Department of Fisheries, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia
Email : nita.r@unhas.ac.id

1. Introduction

Coral reefs, composed of calcium carbonate ($CaCO_3$) produced by coral polyps, repsesent one of the most complex marine ecosystems [1]. These ecosystems are highly significant, particularly for maritime nations, as they offer critical ecological and economic benefits, supporting fisheries, tourism, and biodiversity [2]. In particular, coral reef ecosystems protect coastlines from erosion and support a wide range of marine species [3].

Indonesia, located within the coral triangle, is a maritime nation of exceptional coral diversity. It hosts approximately 569 species and 83 genera, representing about 69% of global coral species and 76% of coral genera worldwide [4]. With the highest coral biodiversity worlwide, Indonesian reefs serve as a focal point for research, conservation, and management [5]. However, the condition of these reefs has substantially, with most now classified as degraded due to declining live coral cover [6]. It was reported that animals are highly sensitive to disturbances, and that excessive exploitation combined with human pressures accelerates reef degradation [7]. A representative example of this degradation can be observed in the Spermonde Islands, one of Indonesia's most important coral reef systems.

The Spermonde Islands, located off the coast of South Sulawesi represent encompasses extensive fringing and barrier reefs, forming one of the largest coral reef systems in eastern Indonesia [8]. It was reported that 310 species from 62 genera were identified, with an average live coral cover of about 33% across the Spermonde region [9-10]. It was reported that between 2015 and 2018, the decline mainly occurred due to high sedimentation, shipping activities, and destructive fishing practices such as blast fishing [5]. This degradation highlights increasing anthropogenic pressure on the Spermonde reef system. Subsequent coastal reclamation for port and residential development has further accelerated reef degradation.

Human activities in both marine and terrestrial environments, including unsustainable fishing practices, sedimentation, and coastal development, exert continuous pressure on coral reef ecosystem, leadinreg to reduced diversityand accelerating degradation [5], [11]. It was reported that the hard coral communities in the Spermonde Archipelago remain relatively stable and resilient, showing high diversity and a low dominance index [9]. Such resilience is partly attributed to coral adaptations to continuous natural disturbances, which help ensure their survival. Various methodologies have evolved and diversified to monitor and evaluate coral reef conditions, one of which is underwater photo transect (UPT) method, is employed to assess live coral cover [12]. Among various monitoring techniques, the Underwater Photo Transect (UPT) method has proven reliable for assessing live coral cover and benthic composition across different spatial and temporal scales [4-5], [13]. It was reported that the use of UPT improved identification accuracy, as field data could be reanalyzed from photographs, enabling verification by coral taxonomy experts [12].

However, most previous studies remain localized and have not compared coral reef conditions among islands within the same archipelago. Addressing this limitation, the present study provides a comparative assessment across multiple islands in the Spermonde Archipelago. This study aims to assess live coral cover and genus level diversity across four islands in the Spermonde Archipelago, Karanrang Island, Balang Lompo Island, Badi Island, and Lumu-Lumu Island using the UPT method, to reveal spatial variations in live coral cover and coral diversity among these islands. The findings are expected to support evidence-based coral reef conservation and management in the Spermonde region and contribute to broader understanding of tropical marine ecosystem dynamics.

2. Experimental Section

2.1. Research Location

The study was conducted on April 12-13, 2025, at four islands within the Spermonde Archipelago, South Sulawesi, Indonesia: Karanrang Island, Mattiro Bulu Village, North Liukang Tupabbiring Subdistrict; Balang Lompo Island, Mattiro Sompe Village, Liukang Tupabbiring District; Badi Island, Mattiro Deceng Village, Liukang Tupabbiring District, Pangkajene and Islands Regency; and Lumu-Lumu Island, Barrang Caddi Village, Sangkarrang Islands District (Figure 1). Observations of coral reefs were carried out at 12 designated station points. Sampling locations were selected purposively to represent variations in anthropogenic pressure, sedimentation exposure, and accessibility. The general characteristics of each station, including coordinates, observation depth, and the number of photographs collected, are summarized in figure 1.

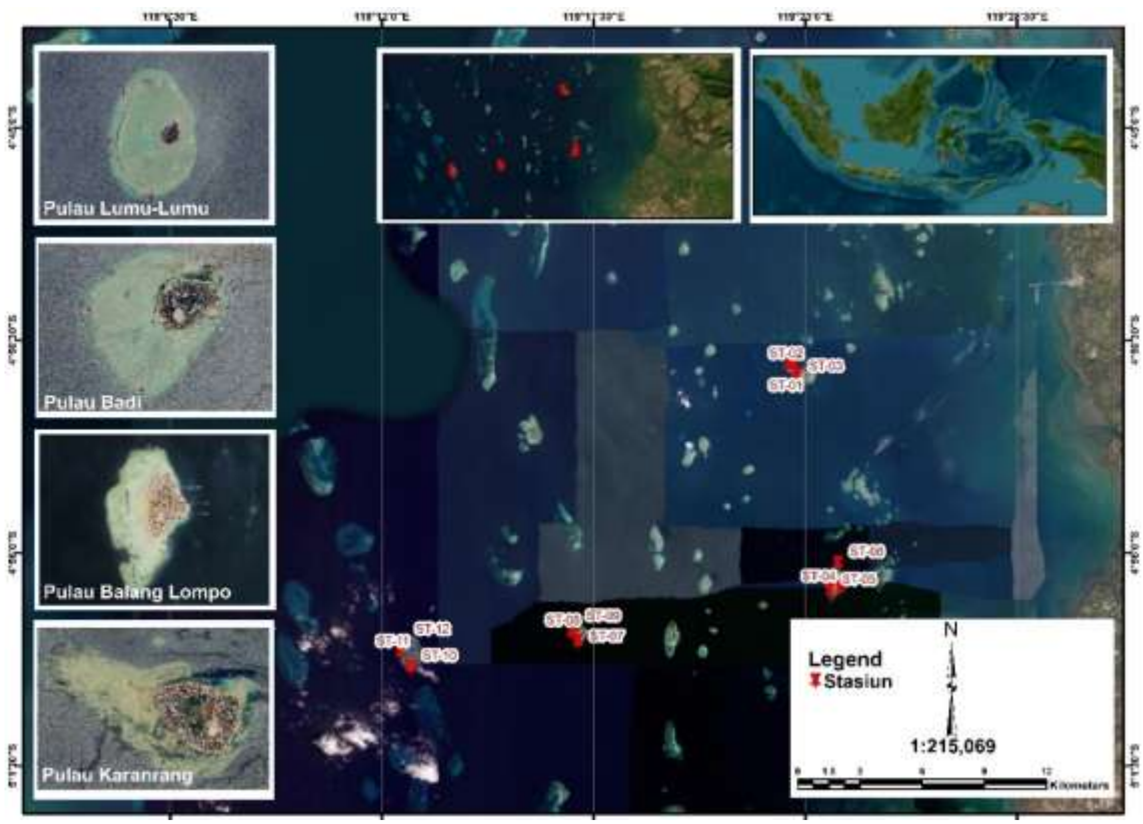


Figure 1. Research Location

2.2. Materials and Methods

2.2.1 Equipment

The equipment utilized in this study comprised SCUBA (self-contained underwater breathing apparatus) sets and diving tanks for underwater observation, GPS (global positioning system) for station positioning, a 50-meter measuring tape for line placement, a 58×44 cm quadrat frame for photographic sampling, and an underwater camera (GoPro 10) for image capture. Image analysis was conducted using CPCe 4.1 software (Coral Point Count with Excel extensions) to calculate coral cover and genus composition.

2.2.2. Location Determination

It was stated that the observation sites were determined using purposive sampling [14]. This method involves selecting a location based on survey results, with the assumption that the characteristics and sample population can adequately represent the coral reef ecosystem at the research site, varying levels of anthropogenic pressure (e.g., proximity to settlements or fishing grounds), differing sedimentation and water clarity conditions; and accessibility and safety for SCUBA-based surveys. This approach ensured that the selected stations represented a gradient of environmental and human impacts within the Spermonde Archipelago.

2.3. Data Collection and Data Analysis

The processed transect data were subsequently analyzed in Microsoft Excel to visualize live coral cover and diversity index values at each observation station [12-13]. The percentage of live coral cover was calculated using the following formula [8]:

$$\text{Percentage coverage category} = \frac{\text{Number of category points}}{\text{Number of random points}} \times 100\%$$

Based on the percentage of live coral cover, the condition of coral reefs can be determined, as classified by the Oceanographic Research Center-Indonesian Institute of Sciences (Puslit Oceanografi-LIPI), as presented in Table 1 [5]

Table 1. Classification of coral reef conditions based on the percentage of live coral cover

Live coral cover (%)	Assesment criteria
75-100	Very Good
50 – 74.9	Good
25 – 49.9	Fair
0 – 24.9	Not Good

Coral diversity index(H’) was analyzed to assess species abundance and evenness within each community; higher H’ values indicate greater ecological diversity. Diversity index (H’) can be calculated using the Shannon-Weaver formula [13] as follows:

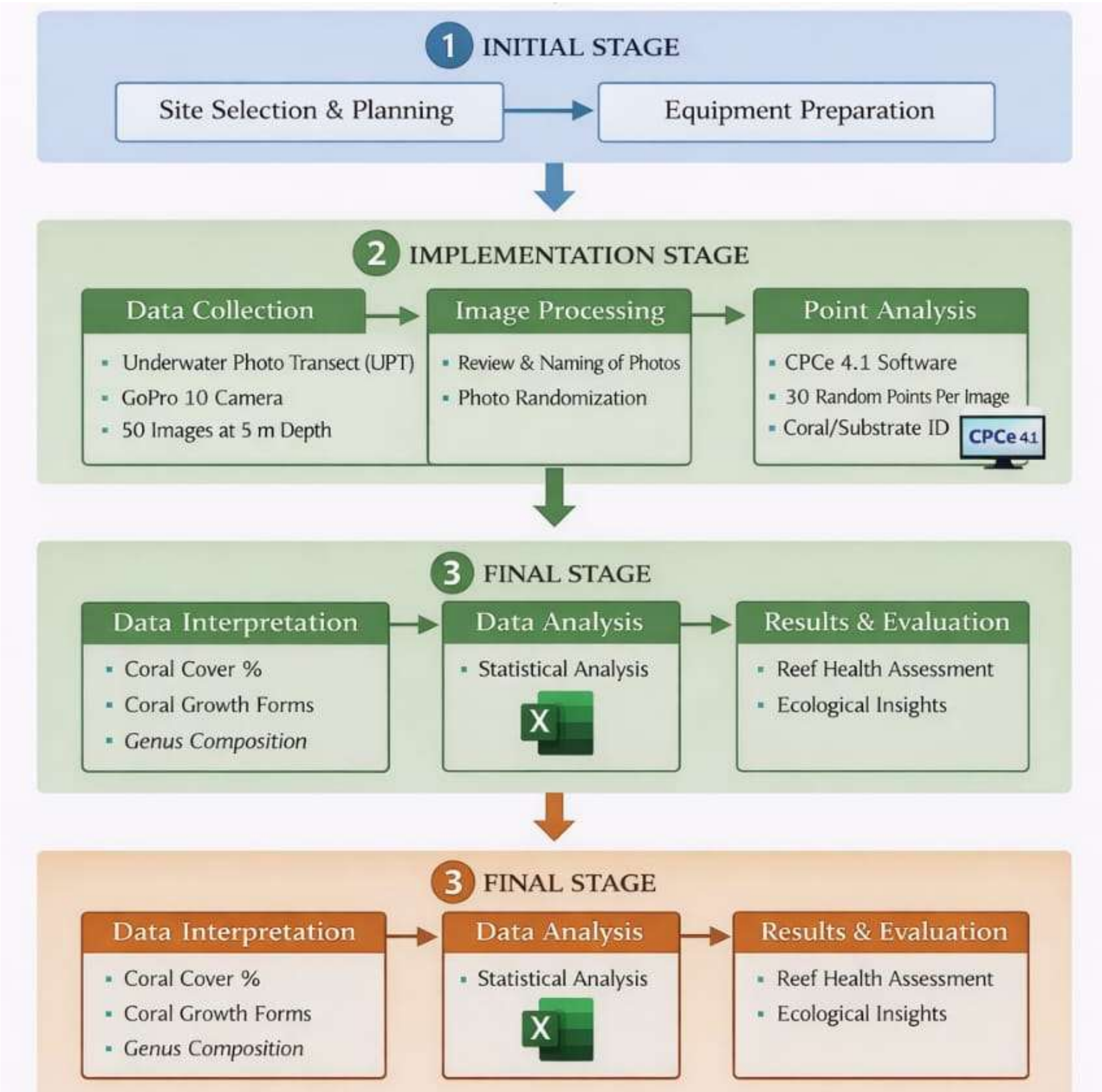
$$H' = -\Sigma i_{i=1}^{i} \text{ pi} \ln \text{pi}$$

$$pi = \frac{ni}{n}$$

H’ = Diversity index
ni = Number of individuals of species-i
N = Total number of individuals

The criteria for analyzing diversity data (H’) [10] are as follows:

H’<1 : Low diversity
1<H’<3 : Moderate diversity
H’>3 : High diversity



3. Results and Discussion

The analysis of coral cover percentages from four islands; Karanrang Island, Balang Lompo Island, Badi Island, and Lumu-Lumu Island each assessed at three observation stations, reveals significant variability in the coral reef ecosystem's condition. The components evaluated include live coral, dead coral, biotic elements (excludin live coral), and abiotic substrates (non-biological) (Figure 2).

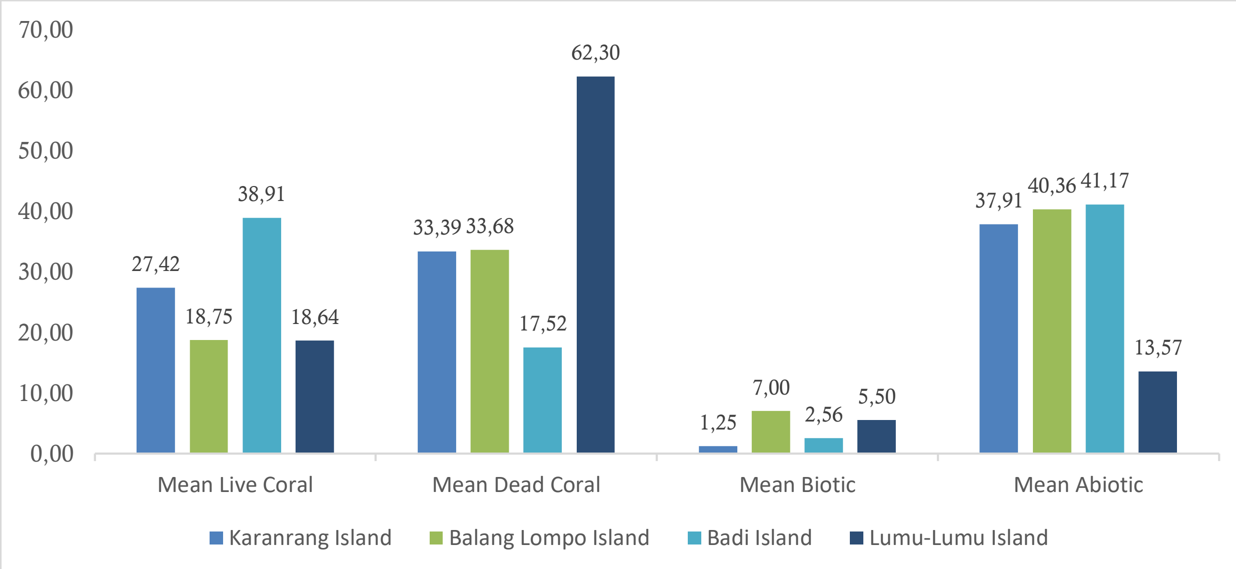


Figure 2. Graph of coral cover percentage

Based on live coral cover observations and the coral reef condition assessment criteria (Table 1) conducted at a uniform depth (±5 m), coral reef conditions across the four study islands showed clear spatial variation, indicating that the observed differences were driven primarily by local environmental conditions and anthropogenic pressures rather than depth-related factors. Based on the Oceanography Research Center–LIPI live coral cover criteria (Table 1), reef conditions at Badi Island (38.91%) and Karanrang Island (27.42%) are classified as fair, whereas Balang Lompo (18.75%) and Lumu-Lumu Islands (18.64%) fall into the poor category. Although both Badi and Karanrang Islands are classified within the same category, the substantially higher live coral cover at Badi Island (>35%) indicates minimal environmental stress and high potential for natural reef regeneration [15].

It was reported that the coastline of Badi Island has been designated as a marine protected area, and the high percentage of live coral indicates strong ecological stability and the ecosystem's natural ability to recover from disturbances [16]. This is supported by coral transplantation activities carried out by the Marine Engineering Department's Community Service Team together with the South Sulawesi Provincial Tourism Office, the Mattiro Deceng Village Government, and the youth organization [17]. This study indicates that management effectiveness particularly marine protection status combined with active restoration has a stronger influence on coral reef resilience and recovery than environmental setting alone, highlighting management based interventions as a key strategy for improving reef conditions in the Spermonde Archipelago.

The highest percentage of dead coral was recorded on Lumu-Lumu Island (mean 62.30%), followed by Karanrang Island (mean 33.39%) and Balang Lompo Island (mean 33.68%), while Badi Island exhibited the lowest value (mean 17.52%), indicating a clear gradient of degradation intensity across the study sites. The high proportion of dead coral on Lumu-Lumu Island indicates long-term environmental stress influenced by both anthropogenic and natural factors, such as sedimentation from coastal activities, destructive fishing, and frequent boat traffic along shipping routes [1-3]. The dominance of algae over coral rubble further supports the notion of reef stress, as elevated algal growth often occurs when coral mortality increases and open substrates become available [18].

In such conditions, alga proliferation suppresses coral larval settlement and recovery, leading to continued declines in live coral cover, a pattern that contrasts with sites experiencing lower dead coral cover and reduced anthropogenic pressure, and is consistent with the geomorphological and socio-economic characteristics of Lumu-Lumu Island as a small, densely populated island surrounded by shallow sandy habitats intensively used for fishing and transportation zones [19-20]. Intensive fishing pressure and limited management regulation exacerbate habitat disturbance, making Lumu-Lumu the most vulnerable among the observed islands [5]. These findings demonstrate that the interaction between high local human pressure and unfavorable geomorphological settings accelerates coral mortality, highlighting the urgent need for site-specific management interventions to prevent further reef degradation in the Spermonde Archipelago.

Biotic components other than hard corals (e.g., algae and sessile invertebrates) accounted for a small proportion across all islands, ranging from 1.25% on Karanrang to 7.00% on Balang Lompo, indicating that benthic communities remain coral-dominated; however, higher values on Balang Lompo (7.00%) and Lumu-Lumu Islands (5.50%) suggest early ecological imbalance. Recent studies show that increased algal and invertebrate abundance reduces coral competitiveness and inhibits reef recovery under prolonged disturbance [21-22]. This pattern represents an early warning signal of potential reef degradation, highlighting the need for timely, site-specific management to maintain coral-dominated reef conditions.

Abiotic substrates such as sand, rubble, and rock fragments dominated several sites, particularly on Badi, Balang Lompo, and Karanrang Islands (>37%), indicating extensive coral degradation that increased substrate exposure. Although abiotic substrates may provide potential surfaces for coral larval settlement under improved environmental conditions [23-25], such substrates can originate both from natural reef erosion and from terrestrial runoff, depending on the geomorphological characteristics of the surrounding islands [26]. The dominance of abiotic components in these areas suggests a shift in benthic composition following coral degradation, where the loss of living coral increases substrate exposure and sediment accumulation [27-28]. If such conditions persist, coral recruitment potential may decline due to reduced substrate stability and increased sediment resuspension [29-31].

This interaction between increased abiotic substrate and algal proliferation indicates a feedback mechanism in which reduced coral cover facilitates algal expansion, further inhibiting coral recruitment and slowing overall reef recovery [32-33]. The persistence of abiotic-dominated substrates, coupled with algal proliferation and reduced coral recruitment, indicates an unstable post degradation reef state in which local management effectiveness particularly sediment and algal control becomes a decisive factor for restoring coral dominance and long-term reef resilience in the Spermonde Archipelago.

Overall, the results demonstrate that Badi Island represents the most stable coral reef ecosystem among the four islands, as reflected by high live coral cover and low dead coral proportions, whereas Lumu-Lumu Island exhibits the most degraded condition characterized by extensive coral mortality and limited recovery potential. These contrasting patterns indicate that local anthropogenic pressure and management effectiveness, rather than environmental setting alone, are the primary drivers shaping coral reef condition across the study area.

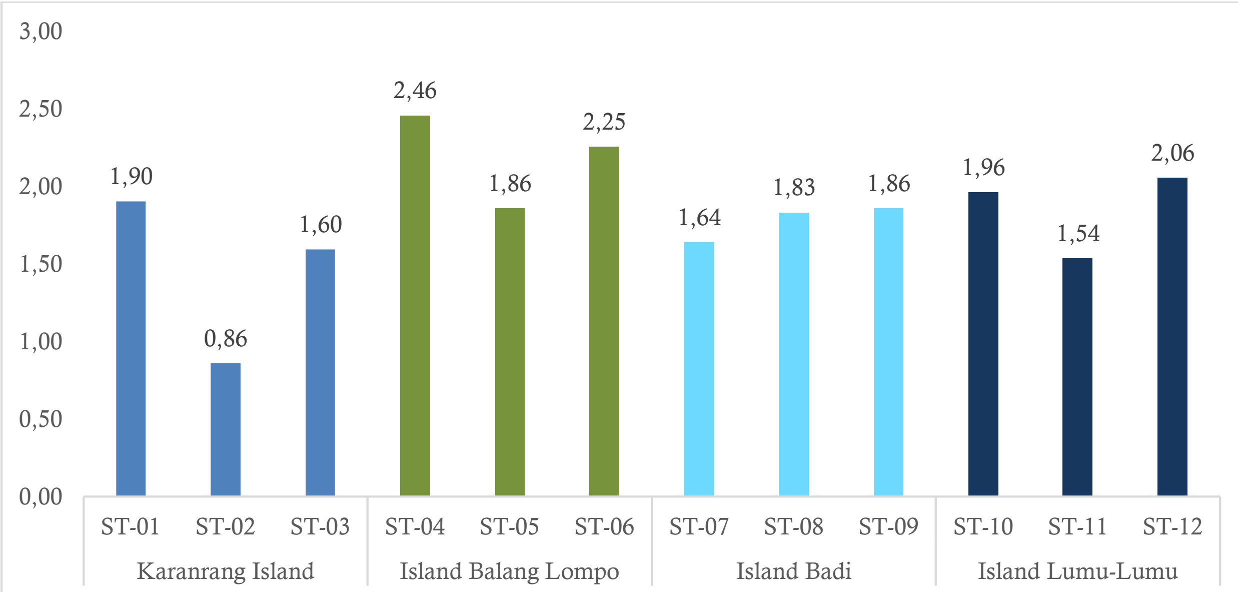


Figure 3. Graph of the diversity index calculation results for Karanrang Island, Balang Lompo Island, Badi Island, and Lumu Lumu Island

Based on the Shannon–Wiener diversity index (H'), coral diversity across the four study islands ranged from 0.83 to 2.46, indicating low to moderate diversity according to established criteria (H' < 1 = low; 1 < H' < 3 = moderate). The highest diversity values were recorded on Balang Lompo Island, particularly at stations ST-04 (H' = 2.46) and ST-06 (H' = 2.25), followed by ST-12 on Lumu-Lumu Island (H' = 2.06), suggesting relatively balanced coral community structures. In contrast, the lowest diversity occurred at station ST-02 on Karanrang Island (H' = 0.83), reflecting reduced ecological stability and higher environmental pressure.

Moderate diversity observed on Balang Lompo and Badi Island (H' up to 1.86) indicates comparatively stable reef conditions supported by higher live coral cover and structural complexity [34-35]. Although some stations on Lumu-Lumu Island exhibited moderate diversity values (H'=2.06), overall coral communities showed clear signs of stress related to sediment accumulation and intense human activity near coastal settlements, where sediment deposition suppresses coral growth and calcification while increasing susceptibility to bleaching, disease, and physical damage [36]. This condition is further exacerbated by the island's small size and dense fishing community, where intensive use of surrounding waters for fishing without effective management policies increases ecological pressure and limits coral recovery capacity [5]. The observed spatial variation in coral diversity suggests that moderate diversity values reflect transitional or stressed reef states rather than stable ecosystems, underscoring the critical role of local environmental management and fishing regulation in sustaining coral diversity and long-term reef resilience in the Spermonde Archipelago.

Genus level identification revealed clear spatial variation in coral assemblages across the four study islands. Badi Island exhibited the highest genus richness (32 genera), dominated by *Porites* (44.07%) with a substantial contribution from *Acropora* (17.40%), reflecting a more balanced coral community structure in which branching *Acropora* enhances habitat complexity and promotes faster reef accretion under favorable water clarity and current flow [16]. Balang Lompo Island hosted 25 coral genera, with *Porites* (32.56%) as the dominant genus accompanied by intermediate proportions of *Montipora, Fungia,* and *Favia*, indicating moderate ecological stability.

In contrast, Karanrang Island (21 genera) was strongly dominated by stress tolerant taxa, particularly *Porites* (48.97%) and *Fungia* (25.04%), suggesting adaptive responses to sedimentation and variable water quality, as massive corals such as *Porites* are known for their resistance to environmental stress and persistence in turbid, shallow environments [37-39]. Similarly, the high abundance of *Fungia* on Karanrang and Lumu-Lumu Islands suggests adaptation to unstable substrates, as this free-living coral genus tolerates sediment disturbance and can reposition itself after burial [40]. By comparison, the dominance of *Seriatopora* and *Fungia* on Lumu-Lumu Island indicates a shift toward opportunistic and sediment-tolerant genera, consistent with higher anthropogenic disturbance and reduced reef stability [41].

The dominance of massive and free-living corals on Karanrang and Lumu-Lumu contrasts with the coexistence of massive and branching forms on Badi Island, highlighting a gradient of ecological resilience shaped by local geomorphology and human disturbance. Overall, these genus-level patterns indicate that coral communities within the Spermonde Archipelago respond strongly to localized environmental stress, where dominance by stress-tolerant taxa reflects degraded or transitional reef states, emphasizing the importance of genus-level monitoring for detecting early ecological change and guiding site-specific reef management.

4. Conclusion

This study demonstrates clear spatial heterogeneity in coral reef conditions across the Spermonde Archipelago driven by localized environmental dynamics and anthropogenic pressures. Badi Island represents the most resilient reef system, characterized by higher live coral cover, relatively stable diversity, and a balanced genus composition, whereas Lumu-Lumu and Karanrang Islands exhibit degraded conditions associated with sedimentation, intensive human activity, and dominance of stress-tolerant taxa. The integration of live coral cover, diversity indices, and genus-level composition provides a robust ecological baseline for site-specific reef management. Strengthening community-based management, reducing land-based sediment inputs, and implementing continuous ecological monitoring are essential to support coral recovery. Future research should focus on long term temporal monitoring of coral recruitment and community dynamics to evaluate the effectiveness of conservation and restoration efforts under changing environmental pressures.

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