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RESEARCH ARTICLE

Distribution and Diversity of Coral Growth Forms at Different Depths in Badi Island, South Sulawesi, Indonesia

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Abstract. Coral reefs are marine ecosystems composed primarily of calcium carbonate and characterized by diverse growth forms that reflect environmental conditions. Physicochemical factors, including water temperature, depth, and salinity, may influence coral growth and community distribution. This study aimed to analyze the distribution and diversity of coral growth forms and the physicochemical characteristics of the waters surrounding Badi Island, Pangkajene and Islands Regency, South Sulawesi, as baseline information for the inventory and assessment of coral reef ecosystem conditions. Data were collected in February 2019 at four stations established according to the cardinal directions at depths of 3 m and 10 m using the *Line Intercept Transect* (LIT) method. Benthic cover consisted of live hard corals (LHC), abiotic components, dead corals, and other fauna. Live hard corals were the dominant cover category, accounting for 59.38%, and were classified as good according to Decree of the Minister of Environment No. 4 of 2001. The most frequently observed coral growth forms at both depths were *Acropora encrusting*, *Coral massive*, and *Coral encrusting*. Coral growth-form diversity was classified as moderate, with H′ values ranging from 1.72 to 2.01, whereas the evenness index ranged from 0.44 to 0.52, indicating low evenness at three stations and moderate evenness at one station. Water quality was measured once at the surface layer at each station; therefore, the measurements represent conditions at the time of observation and do not capture temporal variability.
Keywords: coral growth forms, physicochemical characteristics, depth, LIT, Badi Island, coral reefs.

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INTRODUCTION

Research on coral reef conditions in the Spermonde Archipelago has expanded in recent years. However, recent studies have increasingly focused on large-scale and long-term monitoring using remote sensing approaches. Nurdin *et al.* (2024), for example, mapped reductions in live coral cover across eight Spermonde islands from 1990 to 2022 using multidecadal satellite imagery, whereas Nurdin *et al.* (2021) compared reef conditions between inhabited and uninhabited islands within the same archipelago using Landsat image classification. These approaches are effective for describing broad and consistent trends in coral reef degradation over time. However, they provide limited information on the detailed composition of coral growth forms at specific stations and depths. Such information is important for understanding how coral communities respond to local environmental pressures, including wave exposure, sedimentation, and current patterns. Differences in ecological conditions among islands in the Spermonde Archipelago, influenced by variations in protection status, fishing practices, and sediment and nutrient loads, also indicate that reef conditions cannot necessarily be generalized from one island to another. Therefore, site-specific information on coral growth forms, such as that from Badi Island, remains relevant for documenting local reef conditions.

Coral reef ecosystems also provide important benefits to coastal communities by supporting fisheries resources, protecting shorelines, and contributing to marine-based economic activities (NOAA, 2024). Coral reefs support the availability of fisheries resources for surrounding communities, dissipate wave energy and thereby reduce the risk of coastal erosion, and provide an important foundation for marine tourism development. Therefore, continuous monitoring and effective management of these ecosystems are necessary because reef degradation affects not only marine organisms but also economic activities and the livelihoods of communities that depend on coastal resources.

From a methodological perspective, the *Line Intercept Transect* (LIT) method used in this study has increasingly been compared with newer approaches, such as underwater transect photography and Structure-from-Motion photogrammetry. These approaches have been reported to reduce observer bias and improve the efficiency of data processing (Urbina-Barreto *et al.*, 2021). Recent research has also indicated that underwater photogrammetry can provide greater accuracy in describing coral reef structures than conventional LIT and may be more efficient for monitoring at different spatial scales (Muhsoni *et al.*, 2026). Nevertheless, LIT remains relevant for long-term monitoring because it is relatively simple to implement in the field and is compatible with existing historical datasets.

Based on these considerations, the research gap is the limited availability of baseline data derived from direct field observations on the spatial distribution of coral growth forms across specific depths and cardinal-direction zones on Badi Island. This gap is particularly relevant given the increasing use of large-scale remote sensing approaches in coral reef research within the Spermonde Archipelago. This study addresses this gap by providing detailed information on coral growth forms at the station and depth levels, together with a description of the local physicochemical characteristics of the waters. The data were collected in February 2019 and are therefore not intended to represent current reef conditions. Instead, they serve as a historical baseline dataset that can be used as a reference for subsequent monitoring activities. The importance of continuous coral reef monitoring is also emphasized by the International Coral Reef Initiative (ICRI, 2024), which highlights the need for long-term observational data to understand changes in reef conditions, identify the effects of environmental disturbances, and assess ecosystem recovery.

Badi Island is administratively located in Mattiro Deceng Village, Liukang Tupabbiring District, Pangkajene and Islands Regency, South Sulawesi Province, and is one of the islands within the Spermonde Archipelago. The island is approximately circular in shape and is located about 18 km from Makassar City, with a travel time of approximately 1.5 hours from central Makassar (Rahman, 2024). Rahman (2024) reported that the coral reef condition of Badi Island was relatively good. However, information on the distribution of coral growth forms according to depth and *windward–leeward* zonation, together with the physicochemical characteristics of the surrounding waters, remains limited.

Therefore, this study aimed to determine the percentage cover and diversity and evenness indices of live hard coral growth forms at four stations and two depths (3 and 10 m) in the waters surrounding Badi Island, South Sulawesi, assess their distribution patterns according to depth and *windward–leeward* zonation, and describe the physicochemical characteristics of the waters during the observation period.

METHODS

The study was conducted in the waters surrounding Badi Island, Pangkajene and Islands Regency, South Sulawesi. Data on coral growth forms and the physical and chemical parameters of the waters were collected in February 2019 at four stations representing the cardinal directions. Station 1 represented the northern part, Station 2 the western part, Station 3 the southern part, and Station 4 the eastern part of Badi

Island. Stations 1 and 2 faced the Makassar Strait, whereas Stations 3 and 4 faced the mainland of Sulawesi. The *windward* and *leeward* zones were determined based on the geographic position of each station relative to the prevailing direction of wind and wave exposure. The side facing the Makassar Strait was considered the exposed side, whereas the opposite side was considered the sheltered side. Wind direction and speed, as well as wave height, were not measured directly during the study. Therefore, the classification of the *windward* and *leeward* zones represents a geographic approximation and constitutes one of the limitations of the study. The study area is presented in Figure 1.

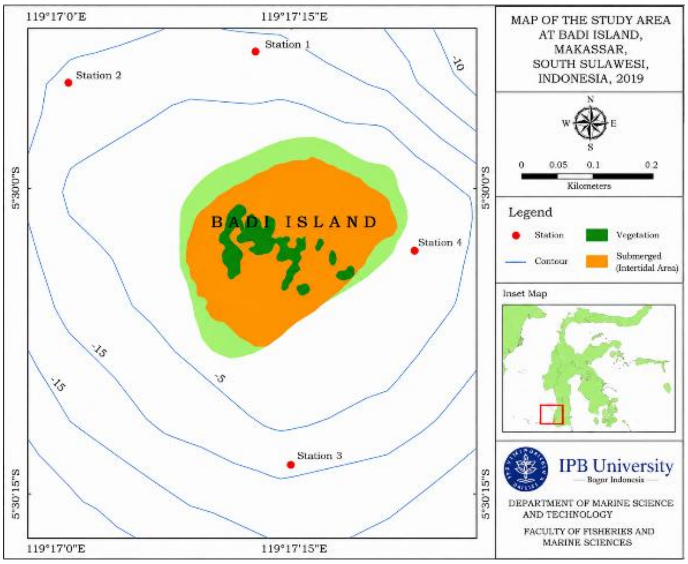

Figure 1. Map of the Study Area

Environmental parameters were measured *in situ* at the four sampling stations. Water quality data were collected once at each station under clear-weather conditions (Figure 2). Measurements were conducted at the surface layer of the water column. Therefore, the recorded values represent a single *snapshot* and do not capture daily or seasonal variations in dynamic parameters such as temperature, pH, and dissolved oxygen. In addition, the measurements do not represent the conditions at the 3 m and 10 m depths where coral observations were conducted. This limitation means that the water quality data were used only to provide a general description of the environmental conditions at the time of observation and were not used to explain differences in coral conditions among stations or depths. The environmental water parameters measured and the instruments used for their measurement are presented in Table 1.

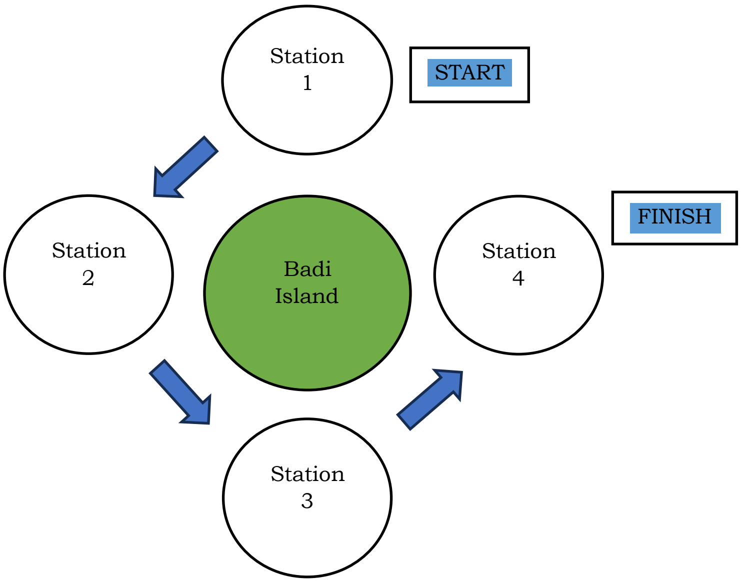

Figure 2. Environmental Data Collection Procedure

Table 1. Water Quality Parameters

Parameter	Unit	Measurement Instrument	Measurement Method
Temperature	°C	Thermometer	*In situ*
Salinity	ppt (‰)	Refractometer	*In situ*
pH	–	Water Quality Checker	*In situ*
Dissolved Oxygen (DO)	mg/L	Water Quality Checker	*In situ*

Coral reefs were surveyed using the Line Intercept Transect (LIT) method, with three replicate transects established at each sampling station at depths of 3 m and 10 m. A 25-m transect was established at each depth, as shown in Figure 3. Data from the three replicate transects at each station and depth were combined, resulting in a total transect length of 75 m for each station–depth combination as the analytical unit. Coral growth-form data were collected by positioning the transects parallel to the reef edge. After the transects were established using a roll meter, observations were conducted progressively along the transect line while recording all live hard coral growth forms located directly beneath the transect line. Measurements were recorded with a precision of approximately 1 cm.

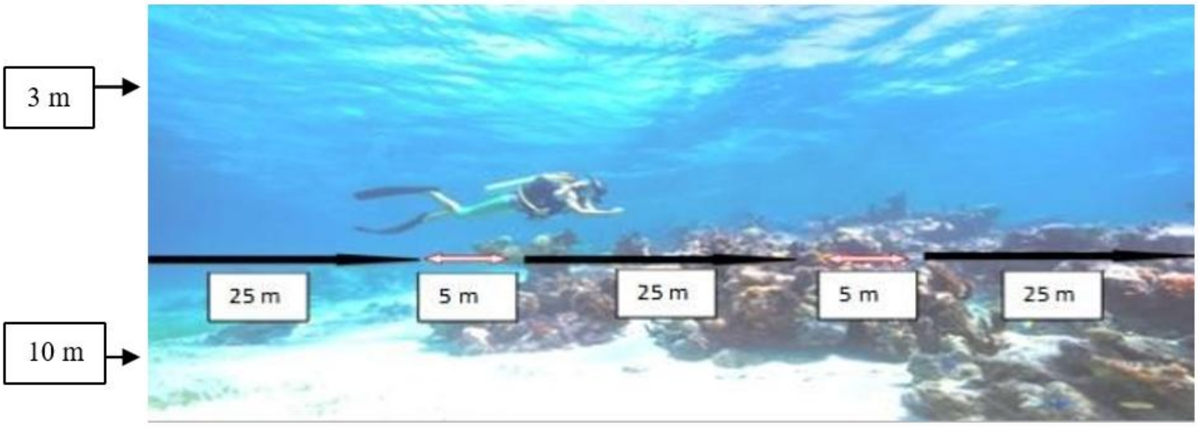

Figure 3. Schematic Diagram of Coral Reef Data Collection at 3m and 10m Depths

Environmental characteristics of the waters were analyzed descriptively based on measurements obtained from the four sampling stations and presented in tabular form. Data analysis was performed using Microsoft Excel 2013.

The diversity of coral growth forms was analyzed using the Shannon–Wiener diversity index (H′) and the evenness index (E). The diversity index was calculated using the following formula (Abdullah *et al.*, 2023):

$$H' = -\Sigma P_i \ln P_i \text{ dengan } P_i = \frac{n_i}{N}$$

Where:
H′ : Shannon–Wiener diversity index
n_i : Total length of the *i*th growth form (cm)
N : Total length of all coral growth forms (cm)

In this calculation, P_i represents the proportion of the intercept length of the *i*th growth form relative to the total intercept length of all growth forms recorded along the transect, rather than the frequency of occurrence. Values of H′ > 3 indicate high diversity, values of 1–3 indicate moderate diversity, and values of H′ < 1 indicate low diversity (Abdullah *et al.*, 2023). The evenness index was then calculated using the following formula (Abdullah *et al.*, 2023):

$$E = \frac{H'}{H_{max}} = \frac{H'}{\log_2 S}$$

Where:
E : Evenness index
H′ : Shannon–Wiener diversity index
S : Number of coral growth forms recorded

The evenness of coral growth forms (E) was analyzed based on the relationship between the Shannon–Wiener diversity index (H′) and its maximum possible value (H_{max}). An E value of 0–0.50 indicates low evenness, >0.50–0.75 indicates moderate evenness, and >0.75–1.00 indicates high evenness (Abdullah *et al.*, 2023).

The distribution of coral growth forms was analyzed based on the percentage cover of each growth form by comparing the total intercept length of each coral growth form with the total transect length using the following formula (Abdullah *et al.*, 2023):

$$C = \frac{N_i}{L} \times 100\%$$

Where:
C : Percentage cover of the coral growth form
n_i : Total intercept length of the *i*th coral growth form (cm)
L : Total transect length (75 m)

The percentage cover values were subsequently used to determine reef condition based on the criteria established by Decree of the Minister of Environment (Kepmen LH) No. 4 of 2001, namely poor (0–24.9%), moderate (25–49.9%), good (50–74.9%), and very good (75–100%).

The relationship between coral growth forms and depth was analyzed using Correspondence Analysis (CA) with the assistance of XLSTAT 2016 software. Correspondence analysis is a factorial analysis that groups statistical units into homogeneous groups based on a set of variables or characteristics. The CA method is descriptive because no variable is assigned greater importance than another. The variables examined in the CA were coral growth forms and depth (Abdullah *et al.*, 2023). The CA results were interpreted based on the percentage of inertia explained by axes F1 and F2, as well as the proximity between coral growth-form categories and station–depth combinations on the factorial plane.

RESULTS AND DISCUSSION

There were four benthic cover categories: live hard coral (LHC), abiotic substrate, dead coral, and other fauna. The abiotic category included non-living materials recorded along the transects, such as sand, coral transplantation racks, and other non-living objects. The dead coral category comprised coral rubble and dead coral with algae. The other fauna category included soft corals, sponges, and other organisms recorded within the observation transects (Abdullah *et al.*, 2023). The total cover of each benthic category is presented in Figure 4. Live hard coral was the dominant benthic category, accounting for 59.38% of the total cover, followed by abiotic substrate (21.63%), dead coral (18.97%), and other fauna (0.02%). At Station 1, live hard coral had the highest cover at a depth of 3 m, whereas dead coral had the highest cover at 10 m. At Station 2, the highest cover at 3 m was represented by abiotic substrate, while live hard coral had the highest cover at 10 m. At Stations 3 and 4, live hard coral had the highest cover at both depths.

The dominance of dead coral at Station 1 at a depth of 10 m was presumably associated with disturbances affecting the reef, either natural or anthropogenic, given that dead coral represents formerly living hard coral colonies that have undergone mortality. Human activities around the station were not directly assessed in this study; therefore, a causal relationship cannot be established (Ginting, 2023). According to the literature, such disturbances may be associated with fishing practices involving chemicals, explosives, or entangled fishing nets, which can damage coral reefs that serve as habitat for fish and other marine organisms. Blast fishing has also been reported in the waters of Makassar, where explosive materials remain available (Ginting, 2023; Fadly *et al.*, 2023).

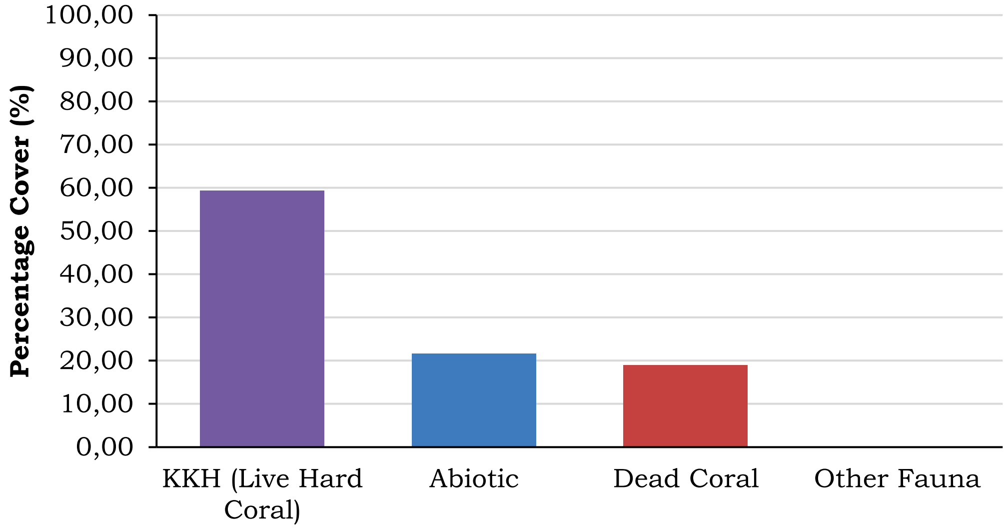

Figure 4. Percentage Cover of Total Benthic Categories Across All Stations

The dominance of abiotic substrate at Station 2 at a depth of 3 m was presumably related to relatively greater sedimentation pressure compared with the other stations, as high sedimentation can increase the dominance of abiotic substrate relative to live coral cover (Abdullah *et al.*, 2023; Kolibongso *et al.*, 2024). Sedimentation rates were not measured in this study; therefore, this interpretation is based only on comparison with findings from previous studies. A similar phenomenon has been reported in coral reef ecosystems exposed to sedimentation pressure, where sediment accumulation on coral surfaces can adversely affect habitat conditions and contribute to declining coral health. Such conditions have been reported on Bangka Island, where sedimentation associated with mining activities has covered coral surfaces and constituted one of the pressures affecting the sustainability of coral reef ecosystems (Ismi, 2024). The benthic cover at each station is presented in Figure 5.

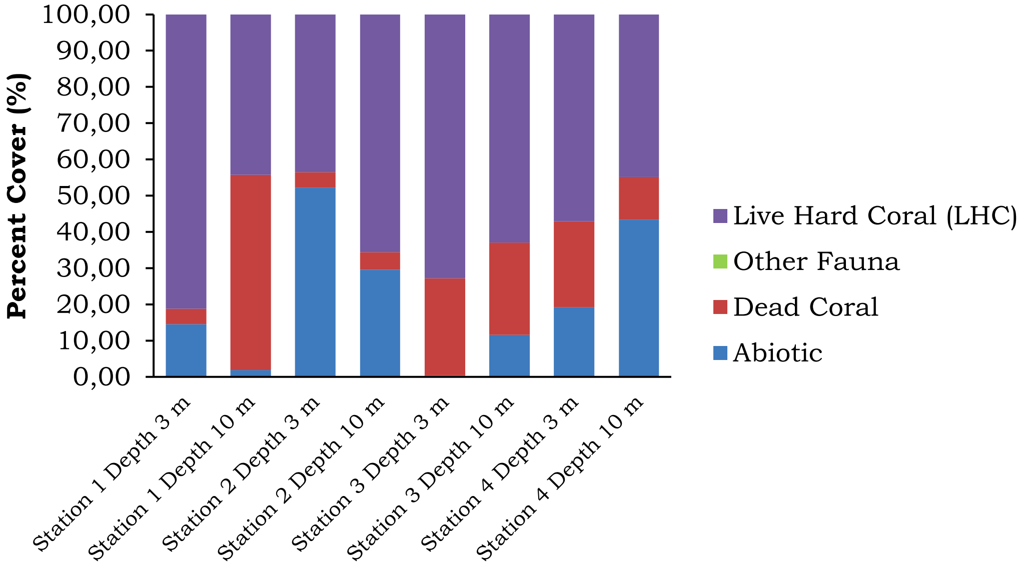

Figure 5. Percentage of Benthic Cover at Each Stations

The coral growth-form data collected in this study, particularly for live hard corals, comprised the *Acropora* and *non-Acropora* groups. The *Acropora* group included branching *Acropora* (ACB), tabulate *Acropora* (ACT), encrusting *Acropora* (ACE), submassive *Acropora* (ACS), and digitate *Acropora* (ACD). The *non-Acropora* group comprised branching coral (CB), digitate coral (CD), massive coral (CM), encrusting coral (CE), submassive coral (CS), foliose coral (CF), and mushroom coral (CMR). The results showed that diverse coral growth forms were present at both 3 m and 10 m depths based on their percentage cover. The highest total cover among the coral growth forms was recorded for massive coral (CM), at 29.32%. Massive coral growth forms are generally common in waters exposed to relatively high wave action, turbidity, and sedimentation because they have greater adaptive capacity and resistance to environmental stress than other growth forms (Abdullah *et al.*, 2023; Cahyani *et al.*, 2025; Pradana *et al.*, 2025; Permatasari *et al.*, 2023). The total cover of live hard coral growth forms across the four sampling stations at depths of 3 m and 10 m is presented in Figure 6.

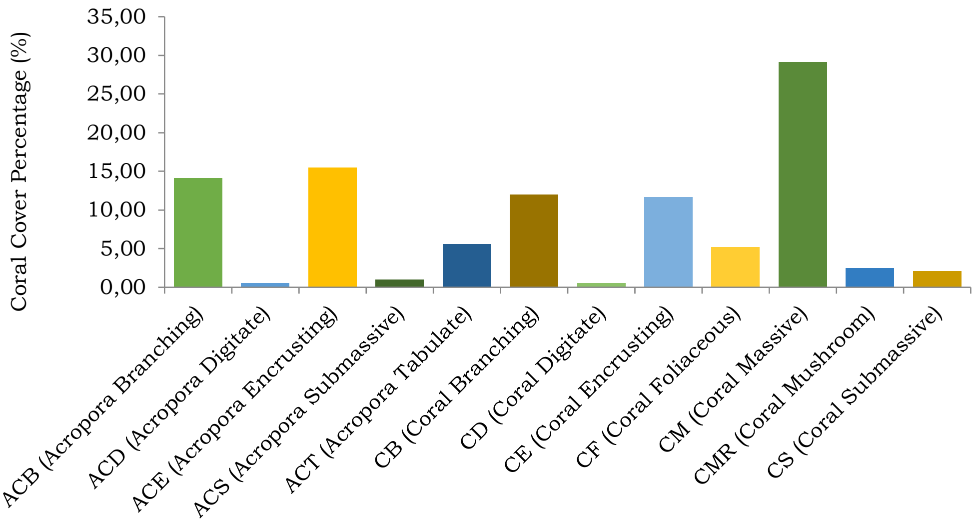

Figure 6. Percentage of Total Live Hard Coral Cover at Each Stations

The percentage cover of coral growth forms at each station is presented in Figure 7. At Station 1 at a depth of 3 m, the highest cover was recorded for branching *Acropora* (ACB), at 31.74%, whereas the lowest cover was recorded for mushroom coral (CMR), at 0.33%. At 10 m, the highest cover shifted to branching coral (CB), at 30.56%, while the lowest cover was recorded for digitate *Acropora* (ACD), at 1.85%. At Station 2, massive coral (CM) had the highest cover at both depths, reaching 36.14% at 3 m and 33.33% at 10 m, whereas submassive coral (CS) had the lowest cover, at 1.56% and 0.41%, respectively. At Station 3, branching *Acropora* (ACB) had the highest cover at 3 m, reaching 38.19%, while mushroom coral (CMR) had the lowest cover, at 0.95%. At 10 m, encrusting coral (CE) had the highest cover, at 22.54%, whereas digitate *Acropora* (ACD) had the lowest cover, at 1.02%. At Station 4, massive coral (CM) again had the highest cover, reaching 46.54% at 3 m and 42.92% at 10 m. The lowest cover was recorded for foliose coral (CF) and branching coral (CB) at 3 m, at 1.38%, and for mushroom coral (CMR) at 10 m, at 0.87%.

Overall, the *non-Acropora* group accounted for approximately 63% of the total live hard coral cover, whereas the *Acropora* group accounted for approximately 37% (Figure 6). This dominance was primarily contributed by massive coral (CM), which accounted for 29.32% of the total cover, while within the *Acropora* group, the highest cover was recorded for encrusting *Acropora* (ACE) and branching *Acropora* (ACB). The *non-Acropora* group also had the highest cover in six of the eight station–depth combinations (Figure 7). This pattern was presumably associated with relatively turbid water conditions, as these coral groups have relatively large and short polyps that may provide greater tolerance to turbidity associated with sedimentation (Abdullah *et al.*, 2023).

An increasingly healthy coral reef ecosystem is generally characterized by a higher percentage of live coral cover than abiotic cover. Based on the total coral cover, the waters within the study area were classified as being in good condition (59.38%) according to the criteria established by Kepmen LH No. 4 of 2001. Nevertheless, variations in coral cover among stations and depths may still be influenced by current and wave dynamics, substrate characteristics, and habitat conditions, which can act as limiting factors for coral growth and reef persistence (Ginting, 2023; Lalang *et al.*, 2025; Sallata *et al.*, 2022). Current dynamics in the waters surrounding Badi Island are influenced by the circulation of the Makassar Strait, which receives its primary water mass input from the Sulawesi Sea (Pacific Ocean), with current velocity at the study site reaching approximately 0.3 m/s (Rahman, 2024). Other factors that may influence coral reef conditions include human activities such as fishing using chemicals or explosives and damage caused by boat anchors, although these activities were not directly assessed in the present study (Ginting, 2023).

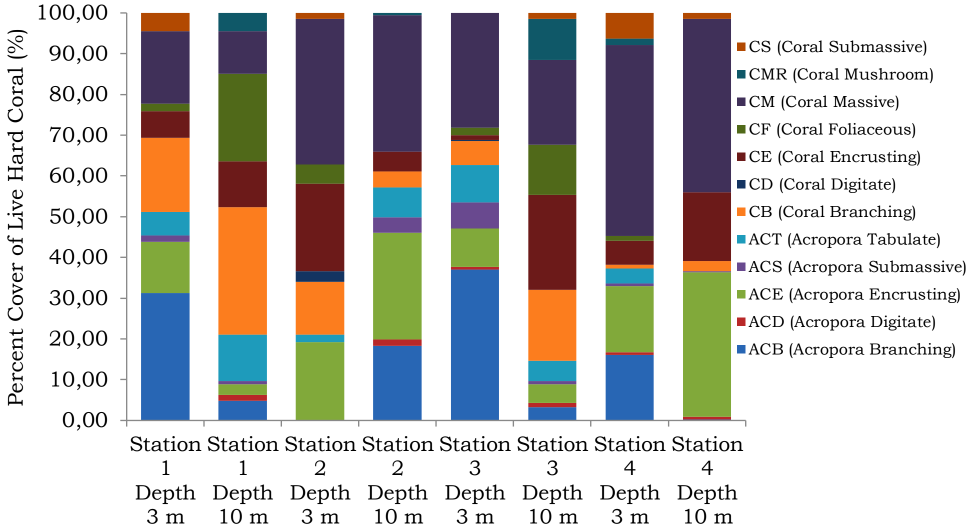

Figure 7. Percentage of Live Hard Coral Cover at Each Sampling Stations

The Shannon–Wiener diversity index (H′) at all four sampling stations was classified as moderate, with values ranging from 1.72 to 2.01 (Table 2). The evenness index (E) ranged from 0.44 to 0.52, with three stations (E = 0.48, 0.45, and 0.44) classified as having low evenness and one station (E = 0.52) classified as having moderate evenness. Based on the Shannon–Wiener diversity index, all four stations were categorized as having moderate diversity. This condition indicates that no single coral growth form strongly dominated the community, although the evenness among growth forms remained relatively low at most stations. These values indicate that the coral community at the study site exhibited moderate diversity at the time of observation, reflecting a relatively favorable community condition (Haris & Rani, 2023; Lestari *et al.*, 2025). Because the study was based on a single observation, conclusions regarding the temporal stability of the coral community cannot be drawn from these data.

Table 2. Diversity and Evenness Indices of Coral Growth Forms

Station	**Diversity Index (H′)**	**Evenness Index (E)**
1	1.87	0.48
2	1.75	0.45
3	2.01	0.52
4	1.72	0.44

Environmental parameters were measured at four stations at the surface layer of the seawater. The environmental parameters measured at the study stations included temperature, salinity, dissolved oxygen (DO), and pH, as presented in Table 3.

Table 3. Physicochemical Characteristics of the Water at Each Sampling Station

No.	Parameter	Unit	Station 1	Station 2	Station 3	Station 4
1	Water Temperature	°C	28.56	28.00	27.26	28.66
2	Salinity	ppt	30	30	30	30
3	pH	–	9.51	9.44	9.42	9.60
4	Dissolved Oxygen (DO)	mg/L	8.86	8.29	8.89	8.46

The temperature measurements at the four stations ranged from 27.26°C to 28.66°C. These values remained within the optimal temperature range for coral reef waters, which is 23°C–30°C. Temperature measurements are highly dependent on the time and weather conditions during data collection. Corals can tolerate temperatures of up to approximately 36°C–40°C (Haris & Rani, 2023). However, increases in sea surface temperature may induce coral bleaching, which occurs as a physiological response to environmental changes that causes zooxanthellae to be expelled from coral tissues and reduces coral pigmentation under thermal stress. Prolonged thermal stress may subsequently compromise coral reef ecosystem health (Hidayah *et al.*, 2024; HS, 2024). This is consistent with the explanation provided by WWF that elevated water temperatures can cause corals to become stressed and expel the zooxanthellae living symbiotically within their tissues. If high temperatures persist for a sufficiently long period, corals may undergo bleaching and become vulnerable to mortality (Hancock, 2025). The effect of decreased temperature on zooxanthellae survival was considered to have no direct effect at the time of the study (Hidayah *et al.*, 2024). Overall, the temperature range recorded at the four stations indicated conditions that supported coral survival at the time of observation.

The salinity recorded at all four stations was consistent at 30 ppt. Based on Kepmen LH No. 51 of 2004, which specifies a range of 33–34 ppt, the salinity at the study site was classified as relatively low. Several ranges have been reported as suitable for coral growth. Rahman (2024) stated that suitable salinity for coral reefs is above 30 ppt and below 35 ppt, whereas Haris and Rani (2023) reported that corals can tolerate salinities ranging from 27 to 40 ppt. The optimal salinity range for coral growth has also been reported to be 30–37 ppt (Hanafi *et al.*, 2024). Salinity may vary due to changes in the amount of water resulting from evaporation and precipitation (Hidayah *et al.*, 2024). Thus, despite being relatively low according to the referenced water-quality standard, the salinity recorded at the four stations remained within a range considered suitable for coral survival.

The pH measurements at the four stations ranged from 9.42 to 9.60. These values exceeded the marine biota water-quality standard established by Kepmen LH No. 51 of 2004, which specifies a pH range of 7.0–8.5, and were also considerably higher than the typical seawater pH range of 7.5–8.4 (Yolanda, 2023). pH can be influenced by photosynthetic activity, industrial discharges, and domestic wastewater (Yolanda, 2023). It also plays an important role in biochemical processes occurring in aquatic environments (Yolanda, 2023). The magnitude of the deviation suggests that the recorded pH values may have been affected by technical measurement conditions, including instrument calibration status, measurements conducted during daytime, and the measurement procedure used at the surface layer. The calibration records and raw field data could no longer be verified because the measurements were conducted in 2019. Therefore, the pH values are reported as recorded but were not used as a basis for assessing the suitability of the waters for coral survival and are treated as a limitation of the study. Repeated pH measurements using a calibrated probe, together with explicit documentation of measurement times, are strongly recommended for subsequent monitoring to enable a more reliable assessment of the chemical characteristics of the waters surrounding Badi Island.

The dissolved oxygen (DO) concentrations recorded at the study site ranged from 8.29 to 8.89 mg/L. These values indicate that DO concentrations in the study area were within a favorable range, as the water-quality standard for marine biota specified by Kepmen LH No. 51 of 2004 is >5 mg/L. Dissolved oxygen is essential for aquatic organisms, and its transfer into the water is influenced by several factors, including temperature, salinity, water and air movement, and overall water quality (Yusal & Hasyim, 2022; Indriyani *et al.*, 2026).

Correspondence analysis produced two principal axes, explaining 46.30% of the total inertia for F1 and 19.29% for F2. Collectively, these two axes explained 65.59% of the variation in the association between coral growth forms and the station–depth combinations (Figure 8). Axis F1 separated station–depth combinations associated with branching, tabulate, massive, and foliose growth forms (ACB, ACT, CM, and CF) on the positive side from those associated with submassive, digitate, and encrusting growth forms (ACS, ACD, ACE, CS, and CMR) on the negative side. Axis F2 further separated submassive and digitate *Acropora* (ACS and ACD), which occurred at positive values, from encrusting, encrusting/branching, and branching coral growth forms (ACE, CE, and CB), which occurred at negative values. Based on the proximity of points, three major associations were identified: (1) Station 3 and Station 4 at 3 m, together with Station 2 at 10 m, were associated with ACS and ACD; (2) Station 4 at 10 m was associated with ACE, while Station 1 at 10 m was located close to CS and CMR; and (3) Station 2 at 3 m was associated with CB and CE. Station 1 at 3 m and Station 3 at 10 m were located on the positive side of F1 and were positioned close to ACB, ACT, CM, and CF. The categories located farthest from the origin, namely CF, ACS, ACD, and CB, contributed most strongly to the formation of the two axes, whereas categories located close to the origin, namely CS and CMR, had distribution profiles relatively close to the overall average of all station–depth combinations. Positions on the factorial plane represent relative associations with the average profile rather than absolute dominance. Therefore, a growth form may have a high percentage cover at a particular station without necessarily being positioned close to that station in the factorial plot.

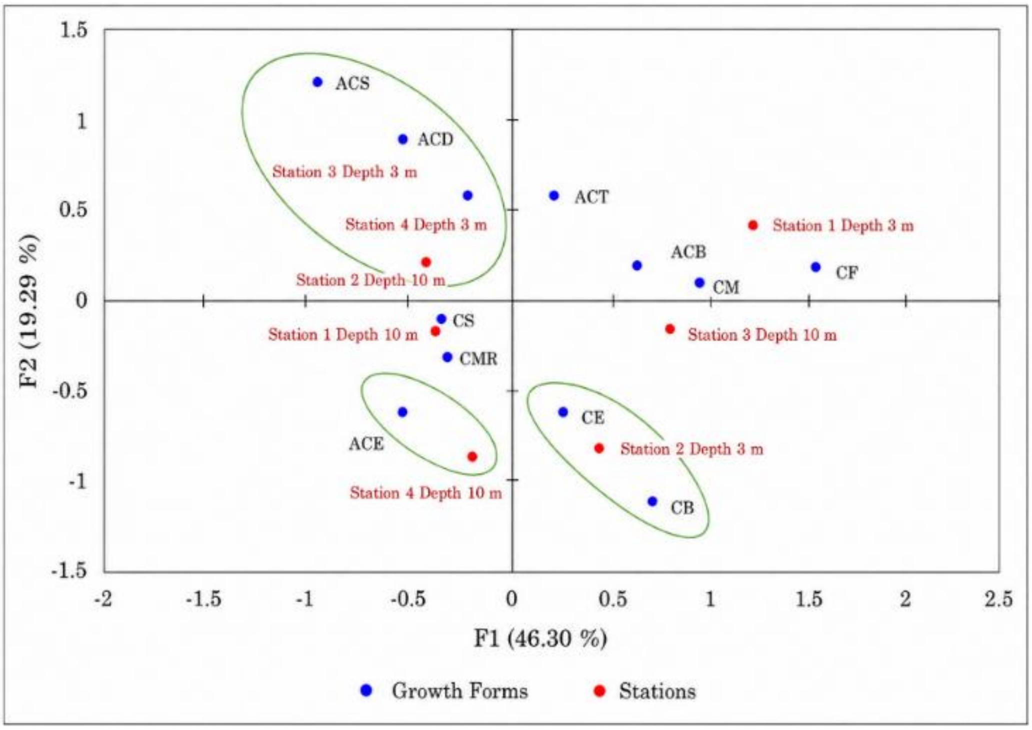

Figure 8. Correspondence Analysis of Coral Growth Forms and Depth

Stations 1 and 2 were located on the side of Badi Island facing the Makassar Strait. The results suggest that coral growth forms at these stations tended to be shorter, more robust, and encrusting, presumably because they were exposed to stronger wave action and represented the *windward* zone. Stations 3 and 4 were located in relatively sheltered areas with lower wave exposure and represented the *leeward* zone, where more slender and elongated coral growth forms were observed (Abdullah *et al.*, 2023). The *windward* and *leeward* directions can be determined based on the prevailing wind direction, with the *windward* zone referring to the side facing the incoming wind and the *leeward* zone referring to the side sheltered from the prevailing wind. Consequently, *windward* zones tend to have greater proportions of rubble and sand than *leeward* zones. The *windward* and *leeward* zones of Badi Island are presented in Figure 9. The reef zonation according to the *windward* and *leeward* directions, based on vertical and horizontal cross-sections of Badi Island, is presented in Figure 10 and 11. The association of massive coral, submassive coral, and encrusting *Acropora* with the 10 m depth suggests a reef-slope zone, whereas the association of branching *Acropora*, submassive *Acropora*, and digitate *Acropora* with the 3 m depth suggests a reef-flat zone.

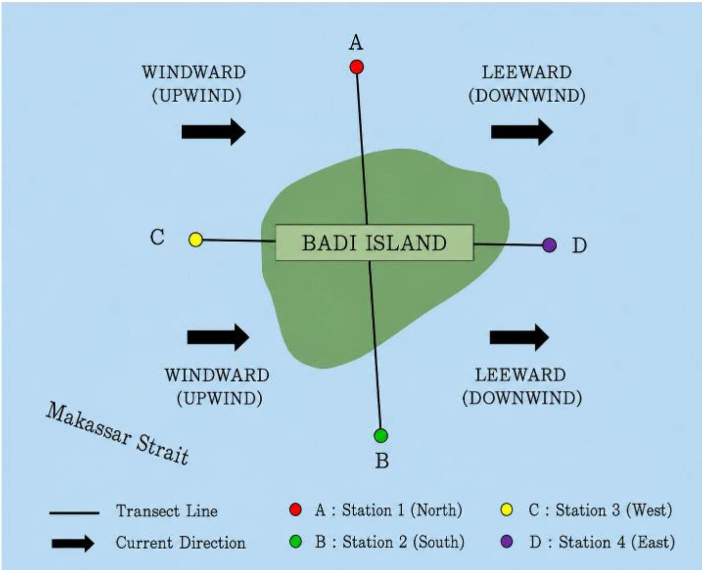

Figure 9. Leeward and Windward Directions around Badi Island

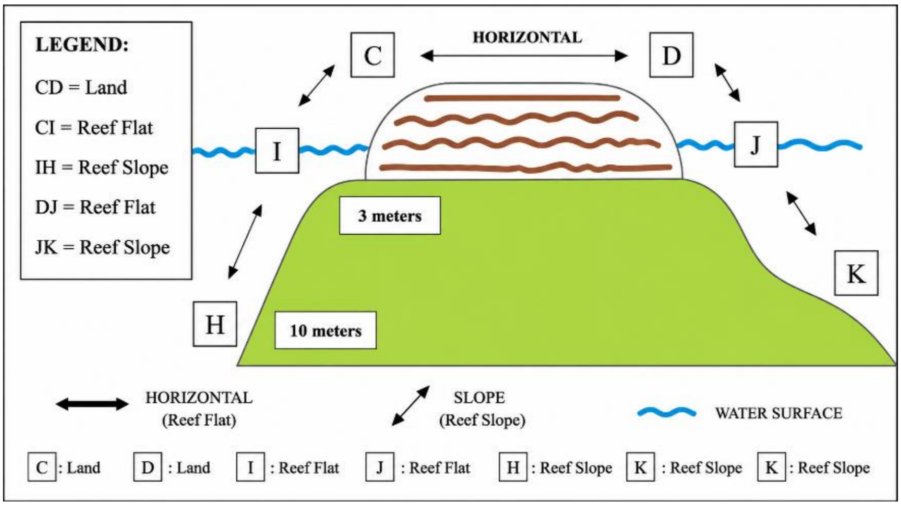

Figure 10. Coral Reef Zonation along the Horizontal Transect at Badi Island

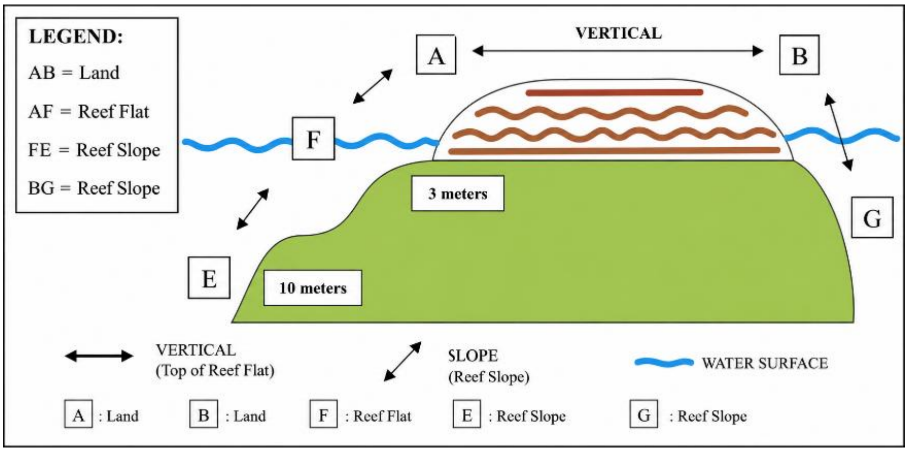

Figure 11. Coral Reef Zonation along the Vertical Transect at Badi Island

CONCLUSION

The distribution of coral growth forms was observed at both 3 m and 10 m depths, with the most frequently encountered growth forms being *encrusting Acropora*, *massive coral*, and *encrusting coral*. Based on the Correspondence Analysis, the 3 m depth was associated with *branching Acropora*, *submassive Acropora*, and *digitate Acropora*, whereas the 10 m depth was associated with *massive coral*, *submassive coral*, and *encrusting Acropora*. Coral growth-form diversity in the study area was classified as moderate, while evenness was classified as low at three stations and moderate at one station. At the time of observation, temperature (27.26–28.66°C) and dissolved oxygen (8.29–8.89 mg/L) were within ranges considered supportive of coral survival, whereas salinity (30 ppt) was slightly below the standard specified by Kepmen LH No. 51 of 2004. The measured pH values (9.42–9.60) exceeded the standard range of 7.0–8.5 and deviated from the typical pH range of seawater. Therefore, pH was not used as a basis for assessing water conditions in this study and should be remeasured using calibrated equipment during subsequent monitoring.

AUTHOR CONTRIBUTIONS STATEMENT

The author contributed fully to all stages of the research, including research design, data collection, data analysis and interpretation, preparation of the initial manuscript, and review and finalization of the manuscript

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest with any party regarding the publication of this article.

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