Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(4): 3373 – 3391 (2025)
www.ejabf.journals.ekb.eg

Status Assessment of Coral Reefs in the Banda Sea Marine Conservation Area

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ARTICLE INFO

Article History:
Received: June 1, 2025
Accepted: Aug. 5, 2025
Online: Aug. 30, 2025

Keywords:
BMCA,
Coral cover assessment,
Coral reef distribution,
Reef health status,
Water quality analysis

ABSTRACT

Coral reefs are vital marine ecosystems that support biodiversity and provide ecological services, yet they face increasing threats from environmental and anthropogenic pressures. This study aimed to map the distribution and spatial extent of live coral, dead coral, and sandy substrates, determine the percentage of coral cover, assess coral reef conditions, and analyze water quality parameters in the Banda Marine Conservation Area, Central Maluku Province, Indonesia. Data on coral reef distribution were collected using manual on-screen digitization based on high-resolution satellite imagery, based on the Lyzenga model combined with field verification using the Underwater Photo Transect (UPT) method. Coral reef mapping covered four islands: Gunung Api, Neira, Banda Besar, and Pisang. Results showed live coral coverage of 1.41 hectares, dead coral of 0.12 hectares, and sand of 0.01 hectares. The benthic composition of BMCA reefs is dominated by live hard corals (53.67%–70.47%), with moderate abiotic substrates (19.8%–31.01%), low biotic non-coral cover (2.13%–20.13%), and minimal dead coral presence (<1%). Live coral cover percentages were 58.47, 53.67, 70.47, and 61.93% for stations 1 through 4, respectively, with an average live coral cover of 61.13%, categorized as 'good' condition. Water quality parameters measured at four stations indicated a mean temperature of 28°C, salinity between 30 and 31ppt, pH values ranging from 6 to 8, and varying current velocity and water clarity consistent with typical reef environments. These findings highlight the relatively healthy status of coral reefs at all stations in the Banda Marine Conservation Area and provide baseline data essential for conservation and sustainable management efforts.

INTRODUCTION

Coral reefs are marine invertebrates classified within the phylum Cnidaria and class Anthozoa, characterized by their calcium carbonate structures. They are among the most biologically diverse and ecologically significant marine ecosystems, providing vital services such as coastal protection, fisheries habitat, and sources of livelihood for coastal communities **(Hughes *et al.*, 2017)**. Although coral reefs occupy only 0.1% of the global ocean surface, remarkably, they support approximately 25% of all marine life. These ecosystems host diverse organisms, including fish, mollusks, annelids, crustaceans, echinoderms, sponges, ascidians, and other cnidarians. As essential habitats, coral reefs provide shelter, feeding grounds, spawning sites, and nurseries for many marine species. Additionally, reefs function as natural coastal barriers, contribute to biopharmaceutical discovery, support recreational tourism, and provide critical resources for research and education **(Utami & Anggoro, 2021)**.

Globally, coral reefs are recognized as biodiversity hotspots and play a crucial role in maintaining the ecological balance of marine environments. Healthy and productive reef systems are vital for ensuring the sustainability of marine ecosystems, supporting fishery resources, promoting tourism, and conserving marine biodiversity. To achieve sustainable management of coral reef resources, it is essential to understand their spatial distribution and coverage conditions in specific regions **(Permatasari *et al.*, 2023)**. However, coral reef ecosystems worldwide face severe threats from global stressors such as climate change and ocean acidification, as well as local pressures including overfishing, coastal development, and pollution **(Eddy *et al.*, 2021)**.

In Indonesia, the Coral Triangle region harbors one of the world's highest concentrations of coral biodiversity, making it a priority for marine conservation initiatives. As the world's largest archipelagic nation, Indonesia possesses immense biodiversity, particularly in its coastal and marine areas. Coral reefs form one of the most ecologically significant ecosystems in the region, offering vital protection to shorelines against wave and current forces **(Indrabudi & Alik, 2017)**. Furthermore, these reefs provide multiple ecosystem services, including spawning, nursery, feeding, and rearing grounds for many marine species **(Dasmasela *et al.*, 2019)**.

Specifically, the Banda Islands in Maluku Province contain approximately 15 hectares of coral reef resources, predominantly consisting of fringing reef formations. Despite their relatively limited area, these reefs support over 300 recorded species of hard corals, meeting high global diversity standards **(Lestaluhu & Wasahua, 2014)**. Coral morphology in this region exhibits wide variation, including globose, branching, digitate plate, compound plate, fragile branching, encrusting plate, foliate, and micro-atoll forms **(Barus *et al.*, 2018)**. These diverse growth forms are strongly influenced by environmental factors such as light availability and wave pressure **(Schalaefer *et al.*, 2021)**. Despite the ecological significance of the Banda reefs, scientific assessments of their condition remain limited, particularly studies integrating spatial analysis and *in situ* ecological data. Recent advancements in remote sensing and reef classification techniques have enhanced the capacity to monitor coral reef distribution and health over broad spatial scales **(Hedley *et al.*, 2016)**. Combined with direct field observations, these tools provide valuable insights for assessing reef conditions and guiding management priorities.

Coral distribution across the Indonesian archipelago is uneven. While some regions show stunted reef development, areas around Sulawesi, Maluku, Sorong, West Nusa Tenggara, and East Nusa Tenggara are recognized as optimal zones for coral growth **(Ceccarelli *et al.*, 2022)**. The seas surrounding Sulawesi, in particular, are considered the global center of coral diversity and are believed to be among the evolutionary origins of modern coral species **(Perenden et al., 2023)**.

Coral reefs are an invaluable national marine resource given their ecological and economic importance. Therefore, accurate coral reef distribution and extent mapping are imperative to inform marine spatial planning and conservation strategies. Indonesia hosts an estimated 2.5 million hectares of coral reefs, accounting for approximately 14% of the world's total reef area **(Irawan *et al.*, 2017)**. Nonetheless, coral reef ecosystems face escalating threats, including thermal stress and widespread bleaching events driven by global climate change **(Sinaga *et al.*, 2023)**. A 2018 survey by the Indonesian Institute of Sciences (LIPI) monitoring 1,067 reef sites reported that 36.18% were classified as poor, 34.3% as fair, 22.96% as good, and only 6.56% as excellent **(Taofiqurohman *et al.*, 2021)**.

Both anthropogenic and natural factors have contributed significantly to the decline of coral reef health throughout Indonesia **(Najmi *et al.*, 2021)**. In response, advanced technologies such as remote sensing and satellite imagery have become essential for assessing reef distribution and condition. These technologies enable efficient, large-scale monitoring of coral reef ecosystems, especially in remote conservation areas such as the Banda Marine Conservation Area **(Pratama, 2024)**. Accordingly, this study aimed to analyze the spatial distribution and condition of coral reefs in the Banda Marine Conservation Area, Central Maluku Regency, by employing remote sensing techniques to provide comprehensive baseline data for marine resource management and conservation planning.

MATERIALS AND METHODS

1. Study sites and field data collection

Field data collection was conducted at four reef stations in the Banda Sea Conservation Area (Fig. 1). Station 1: Mangkubatu Beach, Rajawali Village (4°30'31.5"S, 129°54'30.3"E); Station 2: Batu Panjang Beach, Kampung Baru (4°30'56.8"S, 129°54'39.0"E); Station 3: Walang Spanciby Village (4°32'45.7"S, 129°54'20.4"E); and Station 4: Gunung Api Island (4°32'06.4"S, 129°53'27.7"E). Coral reef mapping covered four islands: Gunung Api, Neira, Banda Besar, and Pisang, also known as Syahrir.

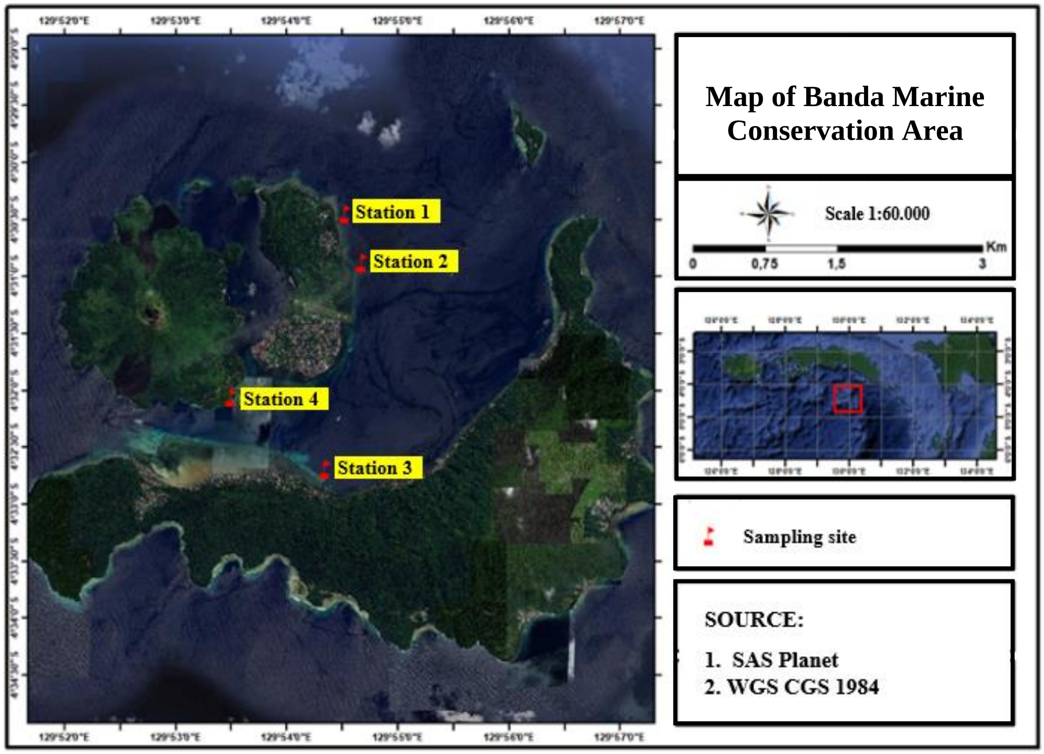

Fig. 1. Study site of the research

The underwater photo transect (UPT) method was used for coral reef assessment, utilizing underwater photography supported by a digital camera with waterproof housing **(Daud *et al.*, 2021)**. Supporting tools included scuba equipment, a 50-meter transect tape, a rectangular photo quadrat frame measuring 58 × 44cm (dimension refers to the inner frame excluding the PVC pipe thickness), and an underwater camera, as shown in Fig. (2). A rectangular rather than a square frame was used because it provided a suitable aspect ratio for underwater photography, maximizing coral coverage in each image while remaining manageable for divers underwater. At each station, the transect tape was deployed parallel to the coastline at depths ranging from 5 to 7 meters. Photographs were taken perpendicular to the seabed at 1-meter intervals. Odd-meter marks were photographed from the left side, and even-meter marks from the right **(Erwin, 2023)**.

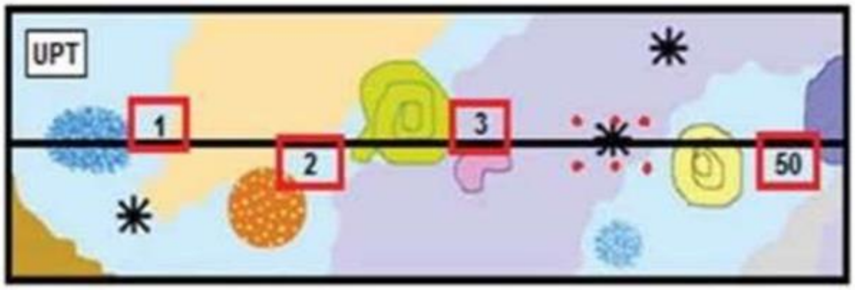

Fig. 2. Sampling illustration using the UPT method

2. Satellite image acquisition and preprocessing

Satellite imagery used to map the spatial distribution of coral reefs was obtained from the SAS Planet application, which functions as a free platform to access and download publicly available basemaps from various providers. For this study, high-resolution ESRI ArcGIS Clarity imagery (zoom level 16) was retrieved in enhanced compression wavelet (ECW) format. Although the imagery is limited to true-color (RGB) bands, corresponding to the red, green, and blue spectral ranges, these bands (2, 3, and 4 in the ESRI basemap nomenclature) are commonly employed for marine habitat analysis where higher-resolution multispectral satellite data are unavailable. Image preprocessing involved geometric correction, sharpening, and water column correction using the Lyzenga method **(Pratama, 2024)**. The corrected imagery was then imported into ArcMap version 10.5 for further spatial analysis.

3. Reef mapping and field validation

Reef habitats were mapped using manual on-screen digitization based on high-resolution satellite imagery, complemented by *in situ* field observations to ensure accuracy. Areas identified in the field, but not clearly visible in the imagery, were digitized manually to capture all reef features **(Rizal *et al.*, 2022)**. The spatial extent of each habitat class (live coral, dead coral, sand) was calculated from the resulting polygons. This approach combines satellite interpretation with field validation, providing an accurate representation of reef distribution while avoiding over-reliance on automated classification algorithms.

4. Image analysis and coral reef mapping

The coral reef distribution maps were produced using ArcMap 10.5 (ESRI, licensed to Bone Polytechnic of Marine and Fisheries), following a multi-step process that included the importation of preprocessed satellite imagery, supervised classification with training data, manual corrections based on field data, and vector map generation of coral reef areas. This approach enabled efficient identification of coral reef extent and supported integration with geographic and ecological layers for further interpretation **(Widhiatmoko *et al.*, 2020)**. The steps are detailed in Fig. (3).

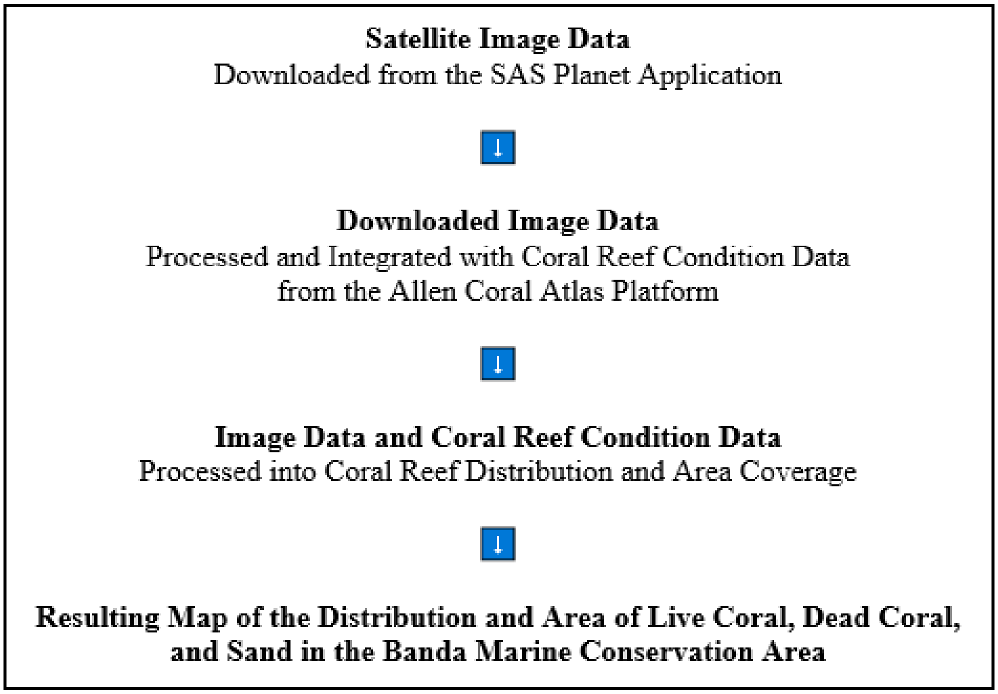

Fig. 3. Steps for mapping the distribution of coral reefs

5. Coral Cover Analysis Using CPCe

Quantitative analysis of coral cover was performed using Coral Point Count with Excel extensions (CPCe), a software tool developed for analyzing benthic images **(Kohler & Gill, 2006; Kase *et al.*, 2019)**. A total of 30 random points per image frame were selected for analysis. Each point was categorized based on the benthic component (live coral, dead coral, rubble, algae, sand, etc.) directly beneath it **(Sagai *et al.*, 2017)**. The coral cover percentage was calculated using the formula:

$$\text{Coral cover percentage} = \frac{\text{points in category number}}{\text{points number}} \text{X } 100$$

6. Coral condition assessment criteria

Coral reef conditions were evaluated based on live coral cover percentages and were categorized following the Indonesian Ministry of Environment Decree No. 04/2001 **(Utami & Anggoro, 2021)**, as presented in Table (1).

Table 1. Criteria for determining coral reef conditions

Coral Cover (%)	**Condition Category**
0 – 25	Poor
25 – 49.9	Fair
50 – 74.9	Good
75 – 100	Excellent

7. Water quality sampling and field procedures

Water quality was measured at each station using simple, low-cost, field methods that can be replicated. At every station, measurements were taken at the surface (0– 0.5m) during daytime and outside of rain events. All instruments were rinsed with site water before use, and values were recorded after readings stabilized.

a) **pH and temperature.** A handheld multiparameter meter measured pH and temperature. The pH sensor was calibrated daily using two-point buffer solutions (pH 7.00 and 4.00; checked with pH 10.00. The temperature probe was factory-calibrated and was allowed to equilibrate for 60s before logging.
b) **Salinity.** Salinity (ppt) was obtained from a handheld salinity/conductivity meter. The probe was checked with a standard solution (e.g., 35 ppt) at the start of each field day. Readings were taken after stabilization (30–60 s) with the probe fully submerged.
c) **Current velocity.** Current was estimated using a float-and-stopwatch method along a measured transect (10 m). A neutrally buoyant float was released at the upstream marker; travel time to the downstream marker was recorded with a stopwatch. Velocity (m/s) was computed as distance/time and corrected by a factor of 0.85 to approximate subsurface flow. Each station had three releases; the mean was used as the station value.
d) **Water clarity.** Secchi disk depth (m) was measured on the shaded side of the boat/platform. The disk was lowered until it disappeared, then raised until it reappeared; the average of the two depths was recorded as the Secchi depth. Measurements were avoided near noon glare and intense wave action.
e) **Replication and QA/QC.** At each station, duplicate readings were taken for pH, temperature, and salinity; if duplicates differed by >0.1 pH units, >0.5 °C, or >1 ppt, a third reading was taken and the median reported. Currently, three float trials have been performed, as noted above. One station per day was repeated as a field duplicate; relative percent difference <10% (physicochemical) and <20% (current) was deemed acceptable. All data were logged with station ID, date/time, GPS, and operator initials.
f) **Data handling.** For each station, the reported value is the mean of replicate measurements (current = mean of three trials; clarity = average of disappearance/reappearance). Units are pH (dimensionless), temperature (°C), salinity (ppt), current ($m\ s^{-1}$), and clarity (m).

RESULTS AND DISCUSSIONS

1. Coral reef distribution

The spatial distribution of coral reefs in the Banda Marine Conservation Area (BMCA) was mapped through manual on-screen digitization of high-resolution satellite imagery, guided by *in situ* field observations to ensure accuracy. Distinct zonation patterns influenced by natural and anthropogenic factors are visible in the resulting map (Fig. 4). The classification delineated three primary reef categories, including live coral, dead coral, and sand, with live coral dominating a total area of approximately 1.41 hectares, followed by dead coral (0.12 ha) and sand (0.01 ha). Live coral formations were predominantly distributed offshore, while dead coral zones were concentrated closer to the shoreline. This nearshore degradation pattern aligns with previous findings that attribute coral mortality in such areas to anthropogenic disturbances such as anchoring, fishing, and sedimentation **(Alamsyah *et al.*, 2019)**.

The reef distribution also reflects the geomorphological and hydrodynamic features of the Banda Islands, a volcanic archipelago characterized by steep bathymetric gradients. The dominant reef morphologies observed, fringing reefs and patch reefs, are typical of island systems where coral growth occurs along the periphery of volcanic landmasses **(Harris *et al.*, 2018)**. Fringing reefs in the BMCA tend to develop parallel to the shoreline, especially on the islands' eastern (leeward) side, where reduced wave energy creates favorable conditions for larval settlement and coral recruitment.

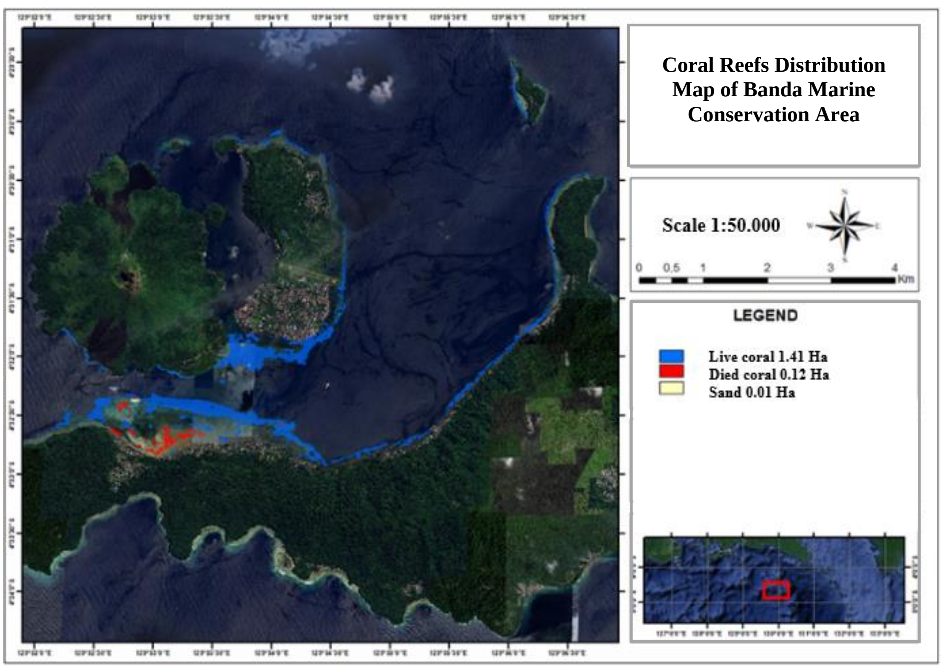

Fig. 4. Coral reef distribution map

Hydrodynamic conditions play a critical role in structuring reef distribution by affecting several ecological parameters, including coral cover, species diversity, recruitment success, and benthic community composition. Coral communities on the leeward side of islands often experience lower current velocities, which promote higher coral cover, increased species richness, and successful settlement of juvenile corals **(Qamarina *et al.*, 2025)**. Conversely, windward zones with stronger currents and elevated sediment transport may reduce coral recruitment, limit growth rates, and decrease overall biodiversity. Field observations confirmed that areas near river mouths or those experiencing sediment influx showed reduced coral cover or signs of partial degradation, highlighting the importance of managing land-based sources of pollution **(De Clippele *et al.*, 2023)**.

Despite the observed spatial variation in reef health, the overall condition of coral ecosystems in the BMCA remains relatively intact. The limited coastal development and low human population in the Banda region may have played a role in mitigating widespread degradation. However, even in these remote systems, cumulative stressors such as climate-induced bleaching, illegal fishing, and maritime traffic could pose future threats if not effectively managed. Therefore, integrating geospatial mapping with ongoing ecological monitoring is vital for informed conservation strategies. Incorporating land-sea planning approaches will help protect upstream watersheds while sustaining marine biodiversity **(Carter *et al.*, 2020)**.

2. Coral composition and ecological structure

The spatial variability in coral reef composition across the four monitoring stations in the BMCA reflects differences in ecological structure, coral morphotypes, and potential disturbance history (Fig. 5). The percentage of live coral cover across survey stations varied significantly, reflecting the heterogeneity of reef health throughout the conservation area. Apparently, coral reefs at each station are shown in Fig. (6).

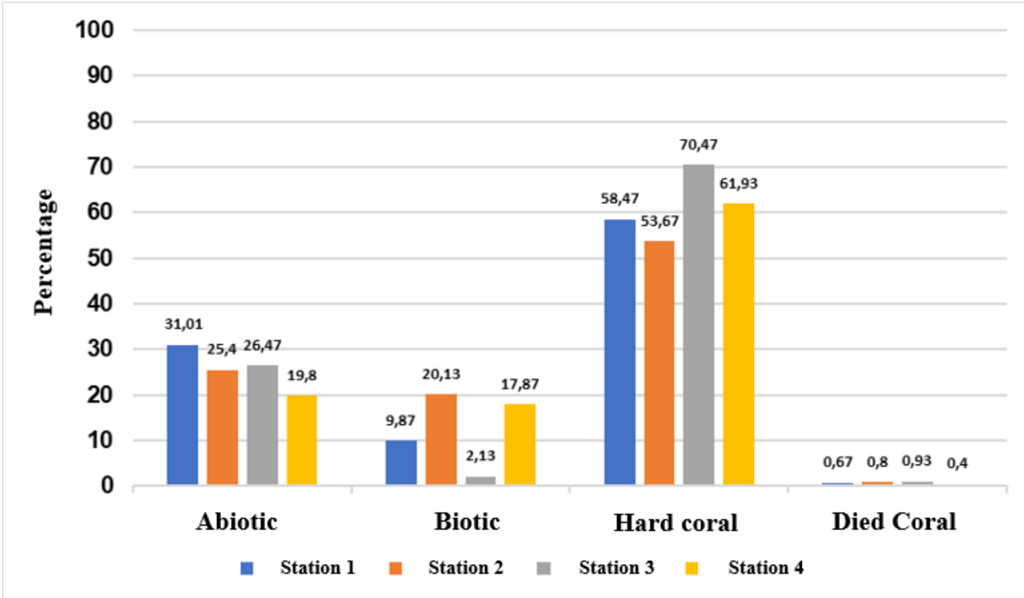

Fig. 5. Coral cover percentage at each station

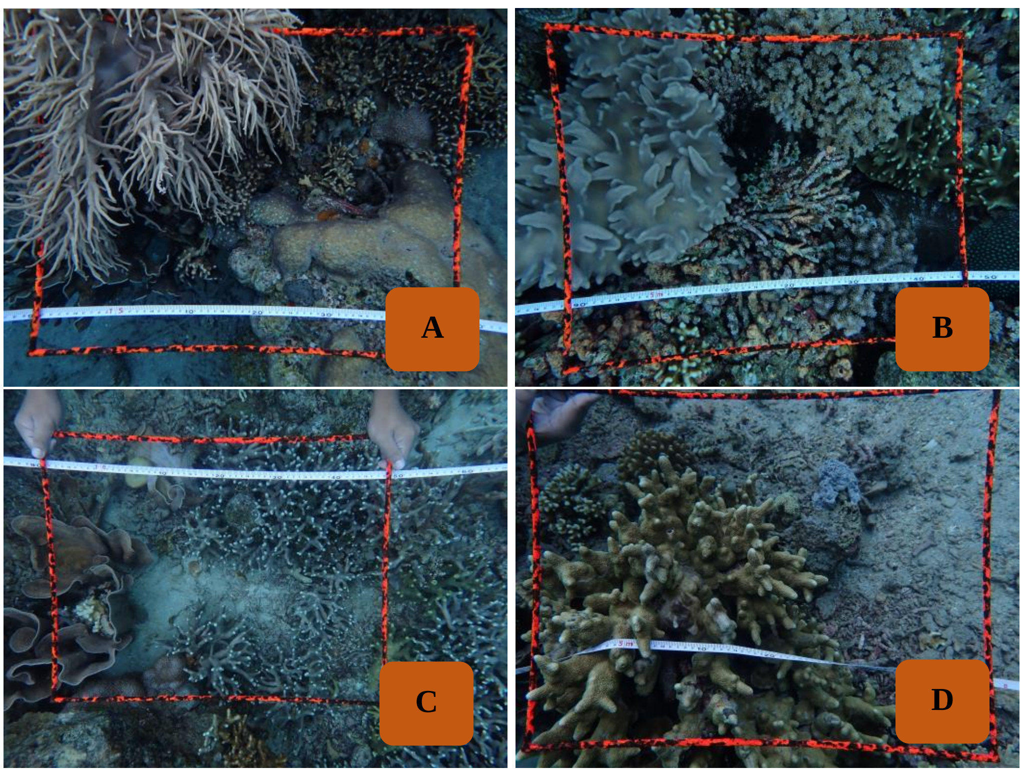

Fig. 6. Visual of coral across the stations. A) Station 1; B) Station 2; C) Station 3; and D) Station 4.

At Station 1, live coral cover reached 58.47%, with a notable dominance of mushroom corals (22.73%), a group typically associated with moderately disturbed reef environments and high sedimentation tolerance **(Hoeksema *et al.*, 2019)**. The presence of rare taxa such as *Heliopora coerulea* (blue coral), albeit at low cover (0.53%), suggests limited representation of ancient reef-building species, which are often indicators of stable, low-stress environments **(Reaka-Kudla, 2001)**. The relatively high proportion of abiotic components (31.01%), primarily sand, and 9.87% biotic non-coral components (sponges, soft corals), may indicate patchy substrate conditions and intermediate reef maturity.

Station 2 recorded a slightly lower live coral cover (53.67%) with dominance by *Acropora digitata* (16.53%), a fast-growing branching coral often associated with early successional stages or post-disturbance recovery zones **(Darling *et al.*, 2012)**. The high contribution of biotic components (20.13%), more than double that at Station 1, suggests a more complex benthic community structure, possibly linked to niche availability or lower coral competition. The low representation of *Heliopora* (0.13%) and substantial abiotic fraction (25.4%) again indicates a habitat still undergoing colonization and consolidation.

In contrast, Station 3 showed the highest live coral cover (70.47%), dominated by foliose coral morphotypes (41.13%), which typically thrive under conditions of moderate light and water movement and often provide high habitat complexity for reef-associated fauna. The minimal presence of *A. digitata* (0.2%) may reflect competitive exclusion or substrate preferences. Notably, this station had the lowest proportion of biotic components (2.13%), possibly due to space occupation by live scleractinian colonies, and an abiotic component of 26.47% (mainly rubble), which may result from historical breakage events or storm impacts **(Erftemeijer *et al.*, 2012)**.

Station 4, with a live coral cover of 61.93%, was primarily dominated by submassive *Acropora* (18.67%), suggesting structural resilience and adaptation to moderate wave exposure **(Veron, 2000)**. However, this station also exhibited very low percentages of branching and tabulate *Acropora* (0.07% each), which are typically more sensitive to physical damage and bleaching **(Loya *et al.*, 2001)**. The presence of biotic components (17.87%) and abiotic substrate (19.8%, mostly rubble) points toward a moderately complex and recovering benthic landscape. The biotic community also benefited from the use of coral substrates, as these created favorable conditions that attracted a greater diversity and abundance of coral biota **(Faizal *et al.*, 2025)**.

These patterns reflect site-specific environmental conditions and potentially different disturbance histories. The observed diversity in morphotypes (branching, foliose, submassive, and mushroom corals) across stations suggests that BMCA supports a heterogeneous reef system with high ecological value. According to **Rogers *et al.* (2014)**, such structural diversity enhances reef resilience by supporting a wider range of functional groups and ecological niches.

Furthermore, the varying proportions of dead coral with algae (ranging from 0.4% to 0.93%) remain low at all stations, indicating limited recent mortality and low macroalgal overgrowth, two critical indicators of reef degradation **(McClanahan *et al.*, 2019)**. This reinforces the earlier conclusion that reefs within the BMCA are in relatively healthy condition, likely due to reduced anthropogenic pressure and possible enforcement of marine protected area regulations.

3. Coral reef condition assessment

The condition of coral reefs was assessed using live coral cover percentages and classified according to the Ministry of Environment Decree No. 04/2001, as detailed in Table (2). The results indicate that the coral reef cover at all four Banda Marine Conservation Area monitoring stations falls into the "good" category, with live coral cover percentages ranging from 53.67 to 70.47%. Station 3 recorded the highest cover at 70.47%, followed by Station 4 (61.93%), Station 1 (58.47%), and Station 2 (53.67%). According to the coral reef health classification by **Edinger and Jisk (2000)**, live coral cover between 50 and 75% indicates a healthy or "good" reef condition. These findings suggest that the coral reefs in this region remain relatively intact and ecologically functional.

The relatively high live coral cover is particularly significant given the broader context of coral reef degradation in many parts of Indonesia. Studies by **Razak *et al.* (2022)** have emphasized that many reef areas in western and central Indonesia exhibit coral cover below 50% due to anthropogenic pressures such as overfishing, coastal development, and destructive fishing practices. In contrast, the Banda Sea region, including the Banda Islands and Lucipara Islands, has consistently demonstrated healthier reef ecosystems. Research by **Limmon *et al.* (2023)** reported that reefs in the Lucipara Islands showed medium to high coral cover and substantial fish biomass, attributing this to the relative isolation of the area and low human impact.

Table 2. Coral reef condition by station according to AIMS (2021)

Station	Live coral cover (%)	Condition
1	58.47	Good
2	53.67	Good
3	70.47	Good
4	61.93	Good
Mean	61.13	Good

Moreover, coral reef health in remote eastern Indonesia is increasingly recognized as critical to regional biodiversity conservation. A study by **Novriansyah *et al.* (2023)** emphasized that the reefs of the Banda Sea are part of a biodiversity hotspot within the Coral Triangle and serve as critical refugia for coral and fish species under climate stress. This study's relatively high coral cover supports the notion that the BMCA functions as an ecologically important and resilient marine ecosystem.

Live coral cover is also a key indicator of reef resilience, particularly in the face of increasing sea surface temperatures and coral bleaching events. According to studies by **Hughes *et al.* (2018)**, reefs with higher initial coral cover and structural complexity tend to exhibit greater recovery potential following bleaching or disturbance events. Therefore, the current status of coral reefs in the BMCA represents a valuable natural capital that must be prioritized for protection and adaptive management.

Continued monitoring and improved spatial data integration are essential to ensure long-term sustainability. Recent advancements in remote sensing and machine learning offer promising tools for large-scale coral monitoring **(Trudeau *et al.*, 2025)**. These tools can enhance the precision of reef mapping and allow for early detection of degradation trends. However, ecological data must be complemented by governance and community engagement to support effective conservation strategies.

4. Water quality parameters

Water quality plays a vital role in determining coral reef ecosystems' health, resilience, and growth potential. Table (3) summarizes the water quality parameters measured at four Banda Marine Conservation Area (BMCA) stations, including pH, temperature, salinity, current velocity, and water transparency.

Table 3. Water quality parameters at each station

Station	pH	Temperature °C	Salinity (ppt)	Current (m/s)	Clarity (m)
1	6	28	30	0.15	5
2	6	28	30	0.10	5
3	7	28	31	0.05	5
4	8	28	30	0.12	6

Salinity values across the stations ranged from 30 to 31ppt, slightly below the optimal range for coral reef development, typically 32– 35ppt **(Lyu *et al.*, 2024)**. The observed lower salinity levels may be attributed to recent rainfall events, increased freshwater input, wave dynamics, and wind-driven surface currents that alter local salinity profiles **(Pratama, 2024)**. Nevertheless, corals tolerate a wider salinity range between 25– 40ppt, and such conditions can still support coral growth and the survival of other marine organisms **(Patty & Akbar, 2018)**. The recorded pH levels ranged between 6 and 8, indicating station variability. Although some values fall slightly below the typical range for seawater (7.5–8.4), especially in offshore environments **(Hamuna *et al.*, 2018)**, the general pH conditions remain tolerable for coral health. Acidic or basic conditions may negatively affect marine organisms by interfering with metabolic and respiratory functions. However, a pH range of 7 to 8.5 is still acceptable for sustaining coral reef ecosystems and does not indicate acute stress.

Water temperature at all four stations was consistent at 28°C, which falls within the optimal thermal range for coral growth, namely 27– 29°C **(Supriyadi *et al*, 2020)**. **Rashad *et al.* (2025)** reveal that temperature plays a crucial role in regulating the spawning timing of corals such as *Acropora digitifera* and *Acropora gemmifera*, with coral reefs being highly sensitive to thermal fluctuations that, when prolonged, can trigger bleaching events. However, the current readings suggest thermally stable conditions that support coral calcification and physiological processes. **Hamuna *et al.* (2018)** state that average sea surface temperatures in tropical coral reef zones typically range from 28 to 31°C. Current velocities varied between 0.05 and 0.15 m/s. These values fall within the optimal range for coral development, estimated at 0.01– 0.33m/ s **(Pratama, 2024)**. Moderate water movement facilitates nutrient exchange, sediment clearance, and oxygenation, which are crucial for coral health. On the other hand, powerful currents may cause physical damage, whereas stagnant conditions may promote sediment accumulation and stress.

Water clarity, or Secchi depth, ranged from 5 to 6 meters, meeting the Indonesian marine water quality standard for coral reef waters, which requires a minimum transparency of more than 5 meters **(Mandey *et al.*, 2022; Minister of Environment Decree No. 51/2004)**. Sufficient light penetration is critical for coral symbiotic algae (zooxanthellae) to conduct photosynthesis. Reduced water clarity often correlates with increased turbidity, nutrient loading, or sediment resuspension, negatively impacting coral health and recruitment. Water quality conditions observed at the monitoring stations in the BMCA were within acceptable and supportive ranges for coral reef growth. Despite slight deviations in salinity and pH at some stations, the combination of stable temperatures, adequate light penetration, and favorable current speeds suggests that the physical environment remains conducive to maintaining a healthy coral reef ecosystem.

CONCLUSION

The coral reefs within the Banda Marine Conservation Area are distributed across four major islands: Neira, Banda Besar, Gunung Api, and Pisang. Remote sensing analysis supported by field observations confirmed the presence of extensive live coral formations, with minor areas of degraded reefs and sandy substrates. Overall, the spatial distribution and composition of benthic habitats reflect a predominantly healthy reef system. Field assessments indicated that coral reef conditions across multiple monitoring stations fall within a favorable ecological category, characterized by substantial live coral cover and relatively low signs of physical or biological degradation. These conditions suggest that the coral reefs in the area remain ecologically functional and resilient, with limited anthropogenic disturbance. The prevailing oceanographic parameters, including temperature, salinity, pH, and current velocity, were within the optimal range for coral reef development as defined by national seawater quality standards. These environmental conditions contribute positively to the region's health and the sustainability of the coral reef ecosystems. Maintaining such ecological integrity is essential for sustaining coral reefs' biodiversity and ecosystem services. Continued protection and adaptive management strategies are crucial to ensure the long-term resilience of the Banda Marine Conservation Area, particularly in the face of climate variability and increasing human pressures.

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