

Biodiversity of coral reefs ecosystem at Tunda Island, Banten, Indonesia

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Abstract: Coral reef ecosystems play a crucial role in marine biodiversity, providing habitat, food, and ecological stability. However, increasing anthropogenic pressures and environmental changes threaten their sustainability, necessitating research to inform conservation efforts. This study examines the biodiversity of coral reefs around Tunda Island, Banten Province, Indonesia, with a focus on the diversity of corals and reef fishes to support conservation efforts. Fieldwork was conducted in November 2019 across six stations using scuba diving. Data collection involved the belt transect method to assess coral community structures and the Underwater Visual Census method to evaluate reef fish populations. The study recorded 25 coral genera, with *Porites* being the most dominant. Omnivorous fish constituted the highest biomass, while herbivorous fish, particularly *Caesio* *cuning*, indicated significant fisheries potential. The station located farthest from the community and adjacent to seagrass and mangrove ecosystems exhibited the best overall ecological condition. The findings highlight the ecological significance of Tunda Island's coral reef ecosystem and underscore the importance of adjacent habitats in maintaining biodiversity. Conservation efforts should focus on protecting areas with high biodiversity and promoting sustainable fisheries management.

1. Introduction

As an archipelagic country with the second longest coastline in the world, Indonesia spans more than 95,000 km². Over 60% or two-thirds of its territory is the ocean, extending from Sabang to Merauke. Its geographic location between the Indian and Pacific Oceans creates a rich and diverse marine biodiversity. This region, often referred to as the "Amazon of the Seas," harbours approximately 30% of the world's coral reefs and supports 75% of known coral species (Burke et al., 2012). [1] Fertile tropical marine areas with a climate suitable for the growth of various marine biota have enhanced the potential of Indonesia's marine and coastal resources [2].

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Coral reefs are shallow marine ecosystems composed of calcium carbonate (CaCO_3) structures produced by marine organisms, such as corals and algae [3]. These highly productive ecosystems thrive in tropical marine waters and support a wide range of marine life due to their complex physical structure, which includes branching formations, crevices, and tunnels. Such intricate habitats offer shelter, feeding grounds, and breeding sites for numerous marine biota, including reef fish species, which rely on coral reefs for survival [4] [5]

Tunda Island, located in Banten, Indonesia, is recognized for its natural potential, featuring an extensive sea area, white sandy beaches, beautiful underwater biota, and various species of ornamental fish, coral reefs, and seagrass beds [6]. However, despite its ecological richness, the coral reef ecosystem around Tunda Island has experienced degradation. The high level of sand mining activity around the waters of Tunda Island puts pressure on coral reef ecosystems [7]. This ongoing pressure has led to a continuous decline in coral reef conditions around Tunda Island, thereby reducing the overall health and resilience of the ecosystem. The live coral cover in the waters surrounding Tunda Island is reported to range between 8% and 42%, classifying it as poor to moderate conditions [8]. Such low coral cover reduces habitat availability for reef-associated species, diminishes reef productivity, and alters the species composition. As specialized reef-dependent organisms decline, opportunistic species may dominate, leading to an imbalance in the ecosystem. Furthermore, reefs with poor to moderate coral cover are more susceptible to further degradation by environmental stressors, weakening their overall resilience.

The decline in coral cover not only affects the ecological balance but also poses a significant threat to the long-term sustainability of marine biodiversity on Tunda Island. This shift in species composition and habitat degradation underscores the urgent need for conservation efforts. Given these challenges, this research aims to identify the biodiversity conditions of coral reefs, reef-associated fish species, and reef fishes on Tunda Island. By understanding the current state of marine biodiversity, this study contributes to conservation efforts and informs sustainable management strategies for coral reef ecosystems on islands.

2. Methods

2.1. Study Site

The study was conducted from 29-30 November 2019. It is located in the waters of Tunda Island, Serang Regency, Banten Province. The observation stations were spread over six stations in the coral reef ecosystem areas. Scuba diving equipment was used to collect data at depth of 5-7 m. Figure 1 shows the detailed point locations of the survey area.

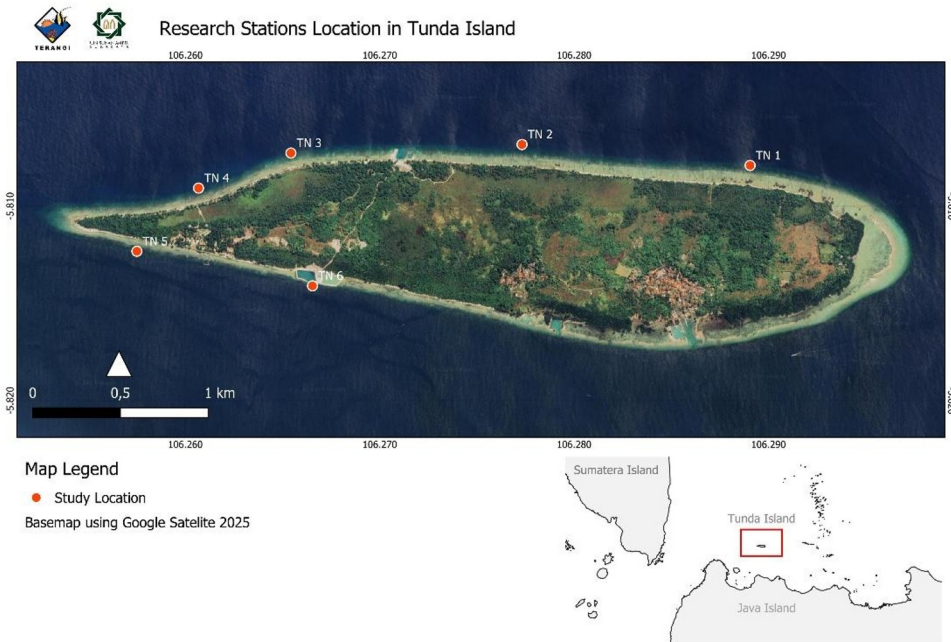


Fig 1. Map of research station location in Tunda Island

2.2. Data Collection

2.2.1. Coral Community Structure

Data were collected using the Belt Transect method with a transect length of 50×1 m [9]. This method allowed for the systematic recording of coral genera, colony sizes, and their abundances to assess the coral reef ecological index. Coral identification followed the taxonomic classifications established by [3] and [10] to ensure accuracy in genus identification. To ensure consistency in the classification, a ruler was used to measure the maximum diameter of each coral colony within the belt transect. Colony size was categorized into three classes: small (<5 cm), medium (5-25 cm), and large (>25 cm), following established studies on coral population structure and ecological resilience [11]. This classification provides a standardized approach for evaluating coral reef health and demographic trends across different reef ecosystems. Due to technical errors, only data from four of the six surveyed locations were suitable for further analysis of the coral community structure.

2.2.2. Reef fishes community structure

Data collection was conducted using the Underwater Visual Census (UVC) method, a widely used nondestructive survey technique in marine research for assessing reef fish diversity, distribution, and abundance. The transect was laid out along a 50-meter line parallel to the coastline, with observers recording fish species within a 5-meter wide belt (2.5 meters on either side of the transect line). Fish length estimation followed the methodology described in [12], which estimates fish length and categorizes them into predefined size classes. To enhance accuracy, divers were calibrated using reference objects before the field surveys, and size estimation was standardized into 5 cm interval classes. Observers also utilized known-size objects, such as rulers or fixed markers, to improve measurement reliability. Identification of reef fish species was based on [13] ensuring

precise taxonomic classification, and data collection was conducted using the Underwater Visual Census (UVC) method. UVC is a survey technique that is used in marine research to gather data on the diversity, distribution, and abundance of underwater organisms. The transect was laid out along a 50 meter line parallel to the coastline. Observers surveyed the fish 2.5 meters to the left and 2.5 meters to the right of the transect line.

2.3. Data analysis

The Community structure of coral and reef fishes was analyzed to provide information about Richness, Diversity Index, Evenness, Dominance Index, and Abundance.

- A. Diversity Index using Shannon-Wiener (H') [14]

$$H' = - \sum P_i \ln P_i$$

P_i = proportion abundance of species

- B. Evenness (E) [14]

$$E = H' / H_{\max}$$

$H_{\max} = H' / \ln S$ (S for species richness)

- C. Dominance (D) [14]

$$D = - \sum P_i^2$$

- D. Abundance (N) [14]

$$N = \sum n_i / A$$

n_i = sum of each species

A = survey area

Reef fish biomass was analyzed using an allometric Length-Weight (L-W) relationship that estimated biomass from the weight (W) data of a species.

$$W = a L^b$$

W = weight a and b = constant

L = fork length

3. Result and discussion

3.1. Coral community structure

The total number of coral genera found on Tunda Island was 25, with *Porites* having the highest density of 57 colonies per 50 m² (Figure 2). *Porites* are known for their slow growth, but are more resistant to thermal-induced bleaching [15]. Additionally, *Porites* can grow in various environments, including both coral reef-dominated and sandy areas [16]. The dominance of *Porites* coral abundance is attributed to high sedimentation, as Tunda Island is geographically close to the northern Java mainland, which contains several river estuaries. The dominance of *Porites* coral has also been recorded in other locations with extreme wave conditions, such as Sabu Raijua and Rote in the East Nusa Tenggara [17] [18]. Therefore, the presence of *Porites* coral on Tunda Island is crucial for enhancing the resilience of coral reef ecosystems to the threats posed by climate change and extreme environmental shifts.

The diversity index (H') provides an overview of coral community diversity based on the number of genera and abundance of colonies within each species (Table 1). According to the data, Station 3 had the lowest diversity index (3.25), whereas Station 4 had the highest diversity index (4.46). As shown in Table 1, all stations fell into the high-diversity category ($H' \geq 3$). In terms of evenness, the highest index was found at Station 1 (1.82), and the lowest at Station 3 (1.23). The evenness (E) values for all stations were categorized as fairly

high, whereas the dominance index values were classified as low. The highest dominance (C) index was at Station 3 (0.06) compared to other station. (Table 1)

Based on Figure 3, there are contrasting values between TN 1 and TN 5: TN 1 had the lowest coral richness but higher abundance, whereas TN 5 had the lowest abundance but greater richness. This was due to the dominance of the coral genera *Montipora* and *Porites* in TN 1, with values of 94 and 48 colonies per 50 m², respectively. Maintaining both the abundance and diversity of corals is crucial for preserving the ecological functions of coral reef ecosystems. Diverse coral communities enhance reef resilience, support a wide array of marine life, and contribute to the overall health of the ocean. For instance, a study from [19] emphasizes that corals provide complex habitats that support fish and macroinvertebrate diversity, thereby playing a vital role in maintaining ecosystem stability. The highest genera richness was observed in TN 6, with 22 genera, while the lowest was observed in TN 1, with 10 genera. Regarding coral colony abundance, TN 3 and TN 6 had the highest at 369 colonies per 50 m², whereas TN 5 had the lowest at 53 individuals per 50 m². Therefore, TN 3 and TN 6 play a more crucial role in supporting ecological processes because of their high diversity of coral species and colony abundance compared to the other sites.

Table 1. Community Structure of Coral Population

Station	H	E	C
TN 1	4.20	1.82	0.02
TN 3	4.40	1.91	0.02
TN 5	3.25	1.41	0.06
TN 6	4.46	1.94	0.02

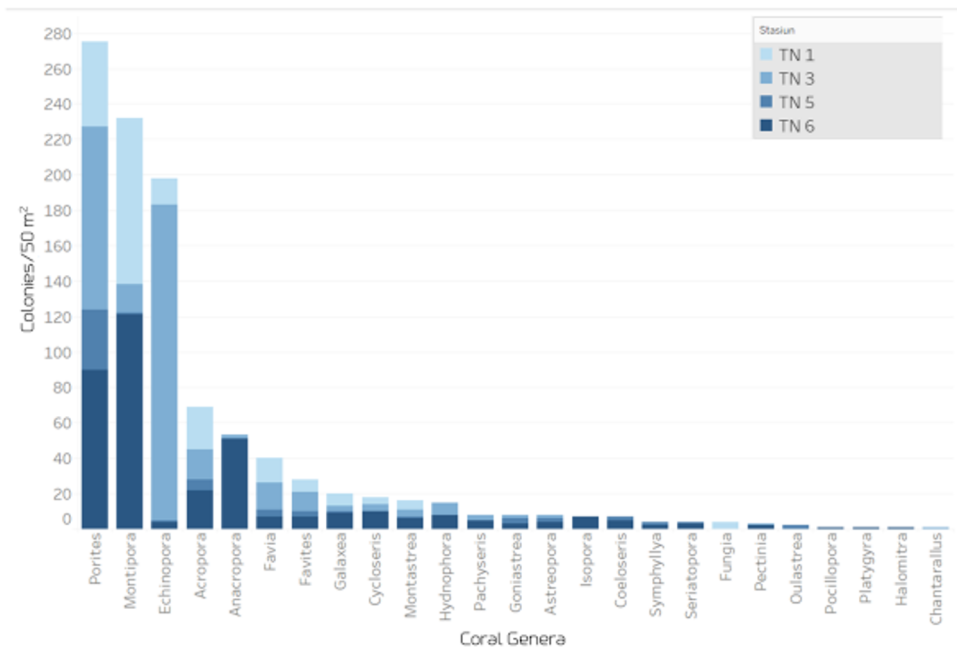


Fig 2. Abundance of coral genera recorded in each station

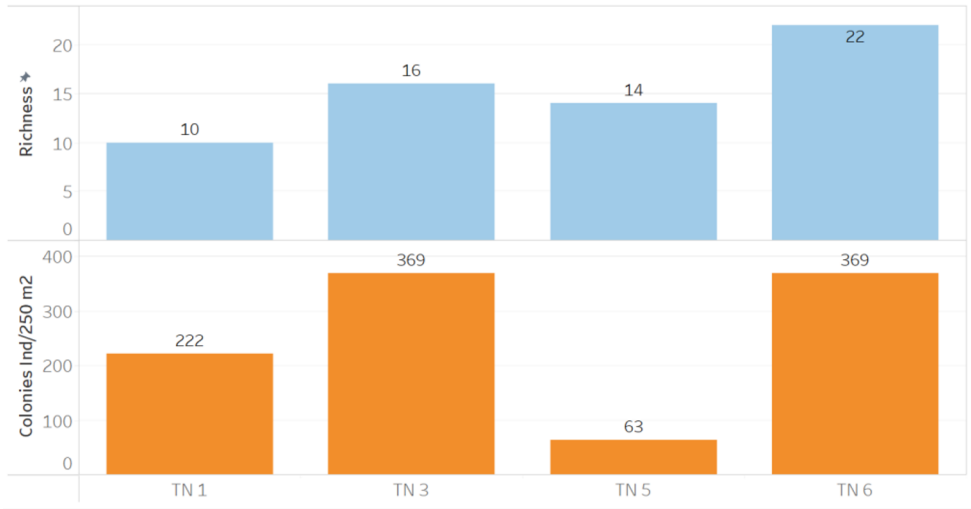


Fig 3. Richness genus and colonies abundance for each stations

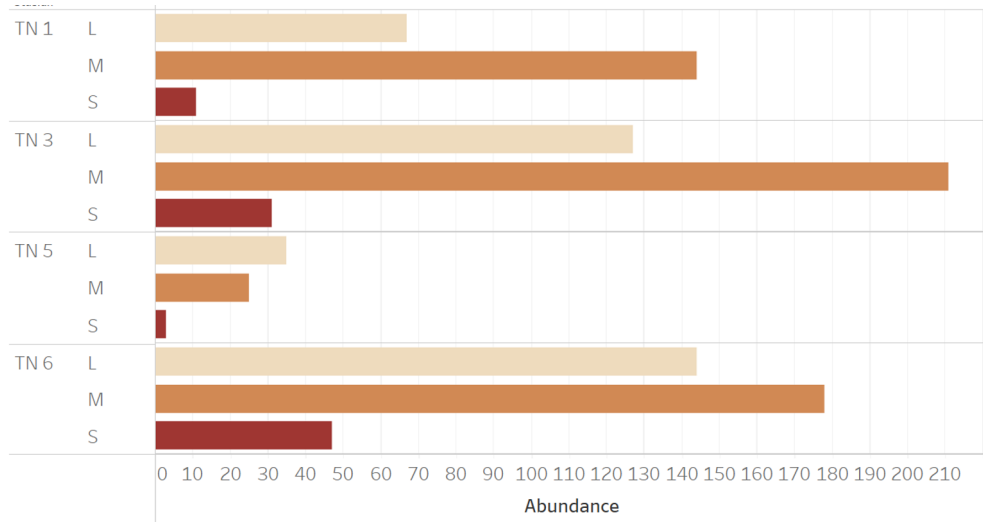


Fig 4. Size of coral population

The results of observations on Tunda Island show that medium-sized (M) coral colonies dominate all locations except TN 5 (Figure 4). These data indicate that coral colonies on Tunda Island are predominantly between 5-25 cm in size. Given the dominance of the *Porites* genus, it can be concluded that the age of coral reefs on Tunda Island ranges from 5 to 10 years. The presence of medium (M) and large (L) corals is crucial for enhancing ecosystem resilience to environmental pressure. Small-sized (S) corals, which are juveniles or recruits, play a crucial role in the attachment and sustainability of coral populations. Corals measuring up to 5 cm in length are considered juveniles, typically indicating that the corals are approximately three years old [20]. From the data in Figure 4, we can see that the abundance of coral recruits averaged 23 colonies at each observation station. TN 6 had the highest recruitment abundance, with 46 colonies, whereas TN 5 had the smallest abundance, with three colonies. The low number of coral recruits in TN 5 indicates that the coral population in this location is more vulnerable than that in other areas.

Based on the abundance, richness, and recruitment of the coral reef community, TN 6 exhibits the best values compared to the other locations. This superior performance is likely due to the presence of well-preserved mangrove and seagrass ecosystems in the surrounding areas. These ecosystems provide essential nursery habitats, reduce sedimentation, and offer protection against coastal erosion, thereby supporting coral health and diversity. Furthermore, the relative isolation of TN 6, which is far from the village, minimizes human interaction and direct community intervention, reducing anthropogenic stressors, such as pollution, overfishing, and physical damage. This combination of natural protection and limited human impact makes coral recruitment in TN 6 a vital and resilient part of the coral reef ecosystem on Tunda Island, highlighting the importance of preserving adjacent ecosystems and maintaining a low human impact for coral conservation.

3.2. Reef fishes community structure

Observations of coral fish conditions across six locations on Tunda Island have recorded a total of 86 species. It's quite low if compare to other location such as Lembeh Island 342 species and Raja Ampat 197 species [21] [22]. Among these locations, TN 4 had the highest species richness with 48 species, whereas TN 2 had the lowest speceis richness 14 species (Figure 5). Variations in the number of species and fish abundance among these locations can be attributed to several environmental factors. However, [11] highlighted that a decline in coral cover is the primary cause of loss of fish biodiversity. The fish diversity index ranged from 2.1 (low) to 3.6 (high), indicating that fish communities were under pressure to maintain stable conditions (Tabel 2). The dominance index ranged from low to moderate, reflecting varying degrees of dominance by certain species (Tabel 2).

High dominance values can affect the stability and diversity of the fish communities [14]. The average fish abundance across all observation stations was 674 individuals per 250 m², with TN 4 showing the highest abundance at 2.517 individuals per 250 m² and TN 3 the lowest at 163 individuals per 250 m² (Figure 5). A previous study in 2017 showed that the average abundance of fish on Tunda Island was 176 individuals per 250 m² [8]. This value indicates that there has been an increase in the average abundance of fish on Tunda Island over the past two years.

Figure 6 shows the top ten families of reef fishes with the highest richness based on family and abundance based on species. Among these, the Pomacentridae family exhibited the highest number of species, with a total of 65 species per 1,500 m². Frequently recorded Pomacentridae species during data collection included *Cirrhilabrus cyanopleura* 480 and *Caesio cuning* 130 individuals from the six observation areas. The Pomacentridae family was evenly distributed across all observation stations, with the highest abundance observed at TN 4, where 1,948 individuals per 250 m² were recorded. This widespread distribution and high abundance underscores the ecological significance and adaptability of the Pomacentridae family in the coral reef ecosystems of Tunda Island. Generally, Pomacentridae fish are known for their attractiveness, bright coloration, distinctive body shapes, and agile movements [23]. Furthermore, the coral fish populations on Tunda Island, particularly in TN 4, have significant economic potential through ornamental fish trade owing to these appealing characteristics.

Table 2. Community Structure of Reef Fishes

No.	Location	Diversity Index (H')	Evenness (E)	Dominance Index (D)
1.	TN 1	3,0	1,2	0,07
2.	TN 2	2,1	0,7	0,05
3.	TN 3	2,6	0,9	0,09

No.	Location	Diversity Index (H')	Evenness (E)	Dominance Index (D)
4.	TN 4	3,6	1,06	0,03
5.	TN 5	2,4	0,9	0,15
6.	TN 6	2,4	1,19	0,11

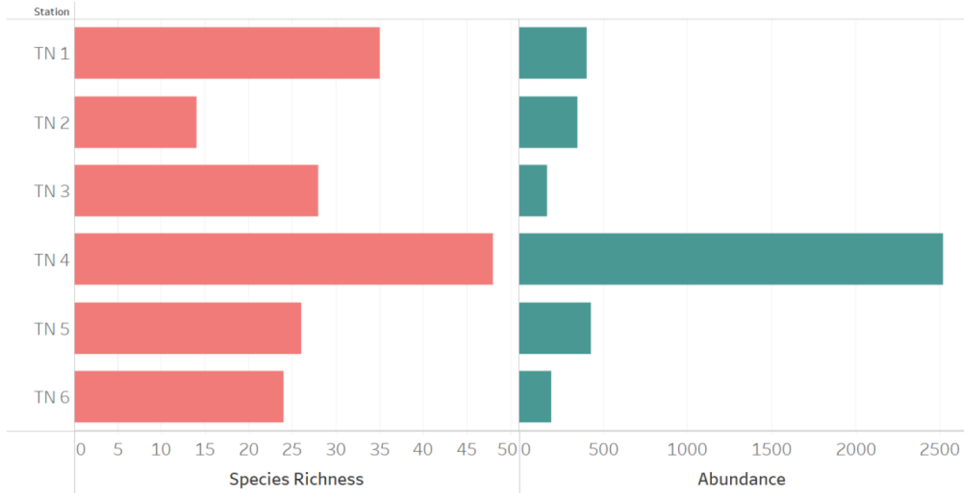


Fig 5. Species richness and abundance in each station (individuals per 250 m²)

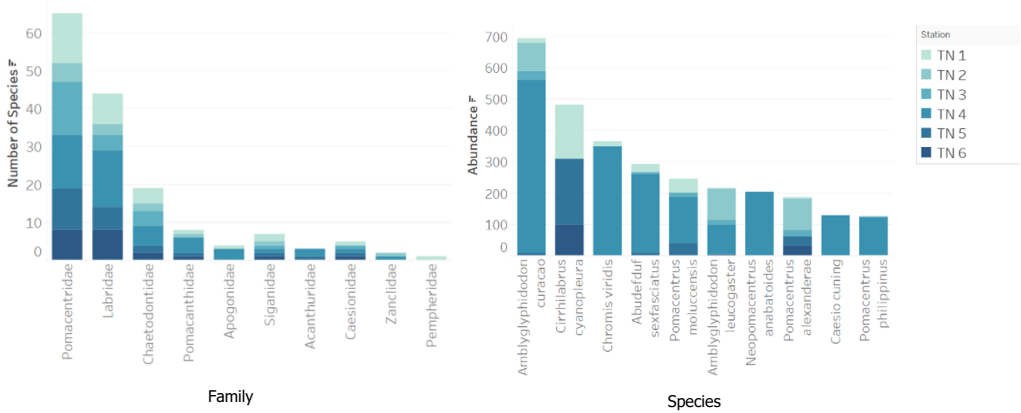


Fig 6. Top 10 Richness species based on family (left) and total abundance based on Species (right) (individuals per 1,500 m²)

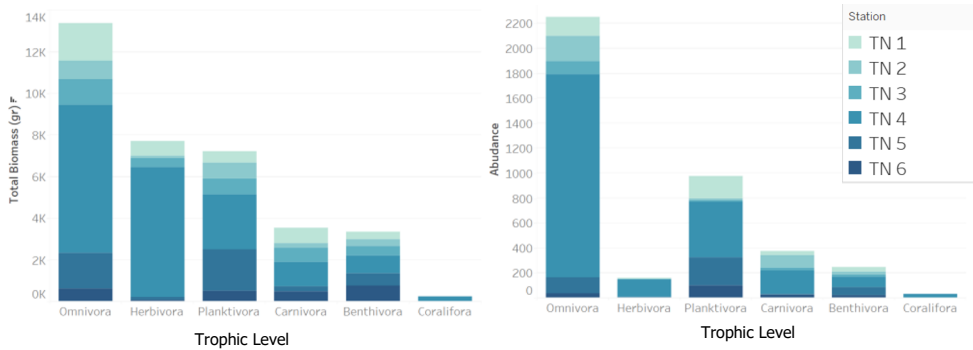


Fig 7. Total biomass gr (left) and abundance individuals (right) based on trophic level (per 1,500 m²)

The results based on Fig 7 shows the biomass and abundance data based on trophic levels found that omnivores had the highest values compared to other trophic levels. This distribution indicates that omnivorous fish, which have a more varied diet, dominate the biomass on Tunda Island, whereas corallivorous fish, which feed specifically on corals, are less prevalent. Interestingly, the biomass data of herbivorous fish showed a significant inverse relationship with their abundance. Despite their small numbers (139 individuals per 1500 m²), herbivorous fish exhibit a substantial biomass of 7,705 g per 1500 m². This indicates that herbivorous fish on Tunda Island are larger than those at other trophic levels. Notably, 80% of the herbivorous fish species were represented by *Caesio cuning*. These findings indicate that Tunda Island has significant fishery potential because of the large size of the recorded *Caesio cuning* fish.

4. Conclusion

The study results indicate that Tunda Island's coral reef ecosystem exhibits diverse biodiversity, with *Porites* being the dominant coral genus owing to its resilience against environmental stressors and high sedimentation levels. Variations in coral richness and abundance among observation stations suggest the localized impacts of environmental conditions and human activities. The presence of well-preserved mangrove and seagrass ecosystems near TN 6 supports higher coral recruitment and fish diversity, highlighting the importance of adjacent habitats for reef resilience. Reef fish diversity was high, with the Pomacentridae family being the most abundant, reinforcing its adaptability to various reef conditions. The dominance of omnivorous fish suggests shifts in trophic dynamics, potentially indicating changes in the ecosystem stability. Encouragingly, the increased abundance of reef-associated fish compared with previous studies suggests positive trends, but continued conservation efforts are essential. Strengthening habitat protection, minimizing human impact, and promoting sustainable fisheries and ecotourism will be critical for ensuring the long-term health and biodiversity of coral reefs on Tunda Island. Future research should focus on the long-term monitoring of coral recruitment and fish population dynamics to better understand the resilience of ecosystems under changing environmental conditions.

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