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Assessment of Reef Fish Biomass in Sibuguey Bay: Visual Census Insights from Roseller T. Lim, Zamboanga Sibugay

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ABSTRACT

This study assessed the species composition, abundance, fish biomass, and ecological status of Roseller T. Lim marine area in Zamboanga Sibugay, Philippines. Using the Underwater Fish Visual Census method, three 50-meter belt transects per station were surveyed in selected reef sites (inside and outside Marine Protected Areas) through a stratified stop-count approach. A total of 639 individual fishes were recorded, including 23 commercially important target species and 616 habitat indicator species across five families. Target species accounted for only 4% of the population, suggesting high fishing pressure and limited enforcement. In contrast, habitat indicators dominated, with Pomacentridae as the most abundant, reflecting relatively stable reef conditions. Estimated fish biomass was 45.2 metric tons per square kilometer, indicating productive reef habitats. However, low species diversity (Shannon-Wiener Index = 0.36) and evenness (0.21) pointed to ecological imbalance. To address these issues, the study recommends strengthening enforcement and monitoring, promoting sustainable fisheries management, and implementing coral reef restoration efforts. These actions are essential to improve MPA effectiveness, restore target species populations, and support long-term marine biodiversity conservation and sustainable livelihoods, in alignment with Sustainable Development Goal 14 (Life Below Water).

Keywords: reef fish biomass, visual census, marine protected area, Sibuguey Bay, target species, habitat indicators.

1 INTRODUCTION

Coral reef ecosystems are among the most ecologically significant and biologically diverse marine habitats on Earth. Despite covering less than 1% of the ocean floor, they support approximately 25% of all marine species, underscoring their critical role in global biodiversity (Hughes et al., 2003). Reef fishes are central to the ecological integrity of coral reefs, contributing to key ecosystem functions such as nutrient cycling, algal control, and the maintenance of biodiversity (Bellwood et al., 2004). Their adaptations—including cryptic coloration and defensive spines—enable them to thrive in structurally complex reef environments (Lieske & Myers, 2001), reinforcing the resilience and stability of these ecosystems.

The extraordinary species richness of reef fishes, with an estimated one-third of the world's marine fish species inhabiting coral reefs, continues to fuel scientific inquiry into the mechanisms of biodiversity generation and maintenance (Spalding & Grenfell, 1997; Hilomen et al., 1999). Their high dispersal capacity through planktonic larval stages facilitates genetic connectivity across vast ocean expanses, especially in tropical seas where geographic barriers are minimal (Mora & Sale, 2002; Rocha et al., 2007). However, despite their ecological importance, reef fish populations are increasingly threatened by overfishing, habitat degradation, and the effects of climate change, raising concerns about the long-term sustainability of reef ecosystems.

Understanding the spatial patterns and biomass distribution of reef fish communities is crucial for evaluating reef health and informing adaptive management strategies. This study assessed the species composition, abundance, and biomass of reef fishes in Sibuguey Bay, particularly within and outside the Marine Protected Area (MPA) of Roseller T. Lim, Zamboanga Sibugay. It aimed to quantify fish community structure using visual census methods, analyze ecological indicators such as diversity and evenness, and determine the conservation status of observed species based on IUCN criteria. By identifying dominant species, assessing biomass across size classes, and comparing fish populations inside and outside the MPA, the study offers insights into the effectiveness of existing protection measures and highlights areas for improvement.

Moreover, this research contributes to national and global sustainability goals. It supports the United Nations Sustainable Development Goals (SDGs), notably SDG 14 (Life Below Water), by promoting marine conservation and the sustainable use of coastal resources; SDG 13 (Climate Action), through ecosystem monitoring that informs resilience-building; and SDG 15 (Life on Land), by emphasizing biodiversity preservation in coastal zones. The findings provide a scientific foundation for marine spatial planning, community-based conservation, and fisheries policy in Zamboanga Sibugay and beyond. Additionally, the data generated serve as a valuable baseline for monitoring trends, guiding local governments and agencies like DA-BFAR and DENR in managing coastal resources. Ultimately, this study supports the broader mission of Mindanao State University – Buug in advancing environmental research, community engagement, and sustainable development.

2 Methodology

2.1 Location of the Study

This study was conducted in Roseller T. Lim, Zamboanga Sibugay, focusing on both the interior and exterior zones of the established Marine Protected Area (MPA) to assess reef fish biomass. The dual-site approach allowed for comparative analysis of fish populations within protected versus non-protected reef zones, providing insights into the effectiveness of MPA management.

To ensure accurate spatial representation, QGIS Desktop Version 3.26.3 and Google Earth were utilized for mapping and geospatial analysis. Additionally, the GPS Status & Toolbox mobile application was employed to obtain precise geographic coordinates of survey sites. The central reference point of the study area was located at 7.635564° N latitude and 122.490696° E longitude, covering reef habitats known to support a variety of reef-associated fish species (Fig. 1). This geospatial data was essential for documenting survey locations and ensuring replicability in future monitoring efforts.

Fieldwork for this research took place on May 23-24, 2024. Prior to the commencement of the study, the necessary research permit was secured from the Municipality of Roseller T. Lim, Zamboanga Sibugay, ensuring compliance with local regulations governing research activities within the MPA.

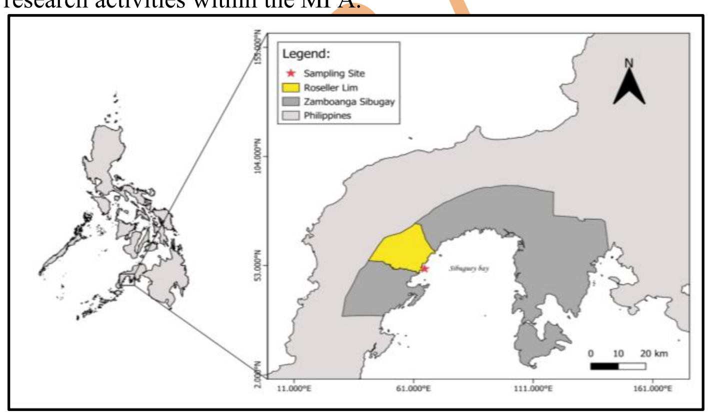


Fig. 1. The Map of the Location of the Study, Sibuguey Bay, Zamboanga Sibugay, Philippines, 7.635564° N and 122.490696° E

2.2 Collection of data

The Underwater Fish Visual Census (UFVC) was conducted based on the standardized protocol of Hilomen et al. (1999), with methodological enhancements to improve data accuracy and minimize observer bias. Surveys were implemented using a 50-meter transect line, with fish observations conducted at 10-meter intervals along the transect (Fig. 2). At each station—both inside and outside the Marine Protected Area (MPA)—three replicate belt transects were laid parallel to the shoreline to capture spatial variability in fish distribution.

Fish species identification and size estimation were performed using high-resolution GoPro cameras, allowing for detailed post-survey video analysis and reducing in situ observational errors. To avoid disturbing fish behavior and ensure natural activity patterns, divers paused for five minutes before each assessment point. This acclimation period enabled fish to reoccupy the survey area, improving the accuracy of species identification and size classification. The modified approach strengthened the reliability of biomass estimates and provided robust baseline data for assessing fish community structure in the study area.

Fig. 2. Transect line laid out during Underwater Fish Visual Census (UFVC)

2.3 Fish composition and identification

Fish species observed along the transects were identified using high-resolution underwater images captured during preliminary dives. Species-level identification was performed by referencing authoritative taxonomic sources, including FishBase (Froese & Pauly, 2017) and A Field Guide to Tropical Reef Fishes of the Indo-Pacific by Allen (2020). These references provided morphological descriptions and identification keys essential for verifying species observed in situ.

All fish encountered during the surveys were visually counted and categorized into three size classes based on estimated total length: small (≤10 cm), medium (11–20 cm), and large (21–30 cm). This size-based classification facilitated subsequent analyses of fish biomass and community structure, allowing for assessment of population dynamics and functional roles within the reef ecosystem.

2.4 Fish species diversity, density, biomass status and data analysis

Fish biomass was estimated using the standard length–weight relationship equation: $W = aL^b$, where W is the estimated body weight (in grams), L is the total length of the fish (in centimeters), and a and b are species-specific Bayesian parameters obtained from validated sources such as FishBase and peer-reviewed literature. These parameters were selected based on the closest matching family-body shape models to ensure accurate and representative biomass estimations.

Fish density was calculated as the number of individuals per unit area (ind/m²), serving as a direct measure of fish abundance across surveyed transects (Penczak, 2013). Estimating fish biomass and density is critical in evaluating reef health, informing resource management, and guiding conservation strategies. Biomass estimates, in particular, provide valuable insights into population structure, trophic dynamics, and the potential productivity of reef-associated fish communities (Keezhedathu et al., 2023).

For analysis, observed fish species were categorized into two functional groups based on ecological and fishery relevance, adapted from previous reef fish assessments (Muallil et al., 2019; Abesamis et al., 2022):

Target species: Commercially exploited reef fishes typically sought after by local fisheries, including members of the families Caesionidae (fusiliers), Labridae (wrasses), Haemulidae (sweetlips), and others known for their market value.

Habitat indicator species: Non-target reef fishes that serve as indicators of coral reef health and ecological stability. These include small-bodied species primarily from the families Pomacentridae (damselfishes) and Chaetodontidae (butterflyfishes), which have strong associations with live coral habitats.

Biodiversity metrics such as the Shannon-Wiener Diversity Index, Pielou's Evenness Index, and Simpson's Dominance Index were calculated to assess community structure and ecological status. This classification and analytical approach allowed for a nuanced understanding of the reef fish assemblage, enabling the evaluation of MPA effectiveness and broader ecosystem integrity within the study area.

Table 1. Status categories of fish species, density, and biomass (adapted from Hilomen et al., (1999).

Fish Density (species/1000m²)				
Very poor	Poor	Moderate	High	Very High
0 – 201	202-676	677-2,267	2,268-7,592	>7,592

Biomass Status (individuals/1000m²)				
Very poor	Poor	Moderate	High	Very High
<5.0	5.1-20.0	20.1-35.0	35.1-75.0	>75

2.4.1 Diversity Indices

Shannon-Weiner Index of diversity, H' (Odum,1971)

Diversity index (H') states the circumstances of the organism's population mathematically to analyze the number of individuals in each growth step or genus in a habitat community. The most commonly used diversity index is the Shannon-Weiner index (Odum, 1971).

$$H' = -\sum_{i=1}^{s} Pi \ln Pi$$

non-Weiner index; $Pi = ni/N$; ni = Number of individual species; N = Total individuals of all species.

Table 2. Categories of fish Diversity (Odum,1971).

Species Diversity Index (Odum, 1971)		
Low Diversity	Moderate Diversity	High Diversity
0 – 1	1 – 3	≥ 3

Evenness Index, E (Odum, 1971)

E (Odum, 1971) The evenness index E describes the number of individuals between species in a fish community (Odum, 1971). The more evenly distributed between species, the more balanced the ecosystem will be. The index shows the distribution of the number of individuals of each species. If there is no similarity, there is tendency for one species to dominate.

$$E = \frac{H'}{H'max}$$

ness index; H' = Diversity index; $H'max$ = ln$S$; S = es found.

The Evenness index value ranges from (0-1). The smaller the evenness index, the population uniformity is smaller as well. The index value is based on (Kreb, 1989).

Table 3. Categories of fish Evenness (Kreb, 1989).

Evenness Index (Kreb, 1989)		
Depressed Community	Unstable Community	Stable Community
0 – 0.5	0.5 – 0.75	0.75 – 1

Simpson Dominance Index, C (Odum, 1971)

The Simpson dominance index quantifies the dominance of one or few species in a community (Odum,1971). The greater the value, the higher the dominance of the species.

$$C = -\sum_{i=1}^{s} Pi^2$$

nance index; Pi = the proportion of individuals in ..., n. Index values range from 0-1 by the following categories

Table 4. Categories of Fish Dominance (Odum, 1971)

Low Dominance	Moderate Dominance	High Dominance
0 – 0.5	0.5 - 0. 75	0.75 – 1

3 Results And Discussion

3.1 Species composition and IUCN Conservation Status

A total of 639 individuals were recorded in the survey, with species classified into two categories: target species and habitat indicator species (Table 5). Among them, 23 individuals were identified as target species, falling within the "very poor" category (0 to 201 individuals). These were distributed across three primary families: Caesionidae, Haemulidae, and Labridae. Notably, these families are often the primary targets of fishers due to their commercial value, particularly within coastal communities near Marine Protected Areas (MPAs) (Muallil et al., 2013).

Table 5. Species composition by category and family frequency and IUCN STATUS.

Category	Family	Scientific Name	Common name	T1	T2	T3	Total	IUCN
Target species	Caesionidae	*Pterocaesio pisang.*	Bana fusilier	9	4	5	18	LC
	Haemulidae	*Plectorhinchus sp.*	Yellow-striped sweetlips.	0	3	0	3	LC
	Labridae	*Thalassoma lunare*	Crescent wrasse	1	1	0	2	LC
		Subt-total		10	8	5	23 (4%)	
Habitat Indicator	Pomacentridae	*Amblyglyphidodon ternatensis*	Staghorn Damsel	2	0	3	5	LC
		Amblyglyphidodon curacao	Staghorn damselfish	1	2	0	3	LC
		Chrysiptera brownrigii	Surge damselfish	0	4	2	6	LC
		Amblyglyphidon batunai	Batuna Damsel,	21	339	211	571	LC

Chaetodontidae	*Chaetodon octofasciatus*	Eightband butterflyfish	0	4	0	4	LC
	Chaetodon modestus	Gold barred butterflyfish	3	0	1	4	LC
	Sub-total		27	349	217	616 (96%)	
	Total		37	357	222	639	

Legend: LC= Least Concern

In contrast, 616 individuals were classified as habitat indicator species, representing six species from the families Pomacentridae and Chaetodontidae. Unlike target species, these fish are not commonly harvested but serve as essential indicators of reef health. The presence and abundance of habitat indicator species are often closely linked to the structural complexity and ecological stability of coral reefs. For example, the family Pomacentridae has a well-documented association with branching corals, particularly those from the genus Acropora (Allen & Erdmann, 2012). Similar dominance by damselfish species has been reported in other Philippine MPAs where coral cover remains relatively intact (Abesamis et al., 2022).

All recorded species in the survey were classified as Least Concern (LC), indicating they are widely distributed, abundant, and currently not subject to significant extinction risk, as defined by the IUCN Red List (IUCN, 2023). While this classification is encouraging, it should not overshadow the vulnerability of local populations to overexploitation and habitat degradation. The resilience of reef fish populations is closely linked to the health of coral reefs, which are increasingly threatened by climate change, ocean acidification, and destructive human activities.

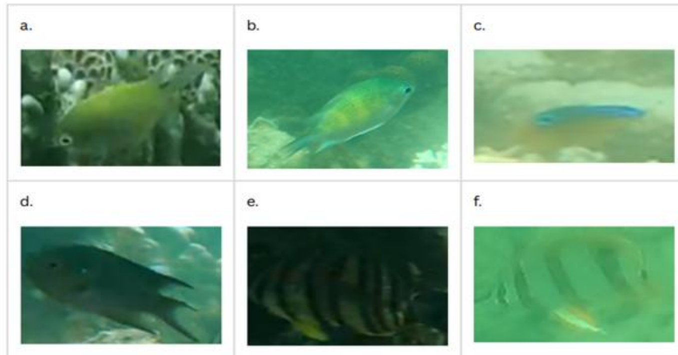
Protected areas with high species richness and balanced community structures have been associated with greater resilience to climate-driven stressors (Duffy et al., 2016), underscoring the importance of maintaining both commercially important and ecologically significant species. Continued protection of habitat indicator species—especially those reliant on live coral—remains critical. The establishment of coral restoration initiatives and the promotion of sustainable fishing practices are recommended to preserve the ecological integrity and long-term effectiveness of the MPA.

3.2.1 Species Composition by Category and Family

The target species consisted of three distinct species, with a total of 23 individuals recorded (Fig. 3). These included: a) *Pterocaesio pisang* (Dalagang Bukid) from the family Caesionidae (18 individuals); b) *Plectorhinchus* sp. (Yellow-striped Sweetlips) from the family Haemulidae (3 individuals); c) *Thalassoma lunare* (Crescent Wrasse) from the family Labridae (2 individuals).

Institute, 2020). Their low abundance suggests potential fishing pressure or environmental stressors.

The habitat indicator species were represented by six species, accounting for 96% of the total fish population (616 individuals) (Fig. 4). These included: a) *Amblyglyphidodon ternatensis* (Staghorn Damsel); b) *Amblyglyphidodon curacao* (Staghorn Damselfish); c) *Chrysiptera brownrigii* (Surge Damselfish); d) *Amblyglyphidodon batunai* (Batuna Damsel); e) *Chaetodon octofasciatus* (Eightband Butterflyfish); and f) *Chaetodon modestus* (Gold-barred Butterflyfish).



Species

As shown in Fig. 5, the target species accounted for only 4% of the total fish population, while habitat indicator species made up 96%. This disproportion suggests that target species are under greater fishing pressure, leading to reduced abundance. Overfishing, habitat degradation, and climate change-induced stressors may have contributed to the depletion of these commercially valuable species (Russ & Alcala, 1989). Conversely, the high abundance of habitat indicator species, particularly Pomacentridae, is a positive indicator of a thriving coral reef ecosystem. Their prevalence signifies a stable habitat with adequate coral cover and low predation pressure, fostering fish recruitment and growth.

on of target species and habitat indicator

rget species, making up only 4% of the ignificant fishing pressure, potentially and habitat degradation. Target species, ng (Bana fusilier), *Plectorhinchus* sp. and *Thalassoma lunare* (Crescent aluable and frequently harvested by local fishers (Muallil et al., 2013). Their reduced presence highlights the need for stronger MPA enforcement and stricter regulations to reduce fishing pressure. The potential effects of illegal fishing within the MPA or inadequate management measures may also contribute to their decline. Additionally, the concept of spillover, where fish migrate from protected areas to adjacent fishing zones, may explain the absence of larger fish within the MPA boundaries (Silva et al., 2015).

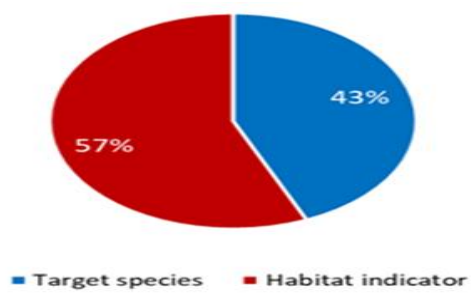
Conversely, habitat indicator species accounted for 96% of the fish population, with a significant contribution from the family Pomacentridae, particularly *Amblyglyphidodon batunai*. Their abundance suggests a relatively healthy reef ecosystem, as these species are closely associated with coral habitats. Studies have demonstrated that Pomacentridae, as coral dwellers, are indicative of reef health and structural complexity (Allen & Erdmann, 2012). The high presence of Chaetodontidae, including species such as *Chaetodon octofasciatus* (Eightband Butterflyfish) and *Chaetodon modestus* (Gold-barred Butterflyfish), further supports the ecological stability of the reef. These species are known corallivores, and their presence indicates the availability of live coral, a crucial factor for reef resilience (Reese, 1993).

3.3 Fish Biomass

Fish biomass was estimated using the Bayesian Length-Weight parameters obtained from FishBase.org (Froese & Pauly, 2017). The total fish biomass was calculated at 17,110.33 g per 375 m^2, equivalent to 45.2 metric tons per square kilometer (mt/km^2). According to the classification by Hilomen et al. (1999), this value falls within the "high" category, which ranges from 35.1 to 75.0 mt/km^2. Biomass by Category (Fig. 6) shows that habitat indicator species contributed 57% of the total biomass (39 mt/km^2) while target species accounted for 43% of the biomass (30.2 mt/km^2)

Despite their lower abundance, target species maintained a significant biomass contribution, emphasizing their larger body size and commercial value. In contrast, the smaller-bodied habitat indicator species exhibited higher population densities, contributing substantially to the total biomass.

Fig. 6. Biomass distribution between habitat indicator and target fish species.



The estimated total fish biomass of 45.2 mt/km^2 places the MPA within the high biomass range (Hilomen et al., 1999). Habitat indicator species contributed 57% of the biomass, demonstrating the importance of coral reef-associated species in supporting trophic stability. In contrast, the lower biomass contribution from target species (43%) reflects ongoing fishing pressures and the absence of apex predators. This trophic imbalance may lead to ecological disruptions, including the overgrowth of macroalgae due to a lack of herbivorous control (Boaden & Kingsford, 2015). Restoring predator populations and promoting sustainable fishing practices could mitigate these imbalances and enhance ecosystem resilience.

3.4 Fish Diversity, Evenness, and Dominance

Biodiversity indices provide insights into the ecological health of coral reefs fishes. The following indices were calculated as shown in Table 6. The Shannon-Weiner Diversity Index (0.36) indicated low species diversity in the marine areas, with a few species dominating the fish community. The Evenness Index (0.21) further classified the reef ecosystem as a depressed community, where certain species thrive while others remain underrepresented. The low Simpson Dominance Index (0.20) suggests that the ecosystem is heavily influenced by a small number of species. Such low diversity and uneven species distribution often reflect ongoing environmental stressors, including overfishing and habitat degradation (Ulfa et al., 2019). Enhancing habitat restoration efforts and reducing fishing pressure will be critical in improving species diversity and fostering ecological balance.

Table 6. Diversity indices of reef fishes in Roseller T. Lim, Zamboanga Sibugay

Diversity Indices	Result	Remarks
Shannon-Weiner Diversity Index	0.36	Low Diversity
Evenness Index	0.21	Depressed Community
Simpson Dominance Index	0.20	Low Dominance

The low diversity and evenness suggest that a few species dominate the reef ecosystem, while others are scarce. The presence of habitat indicator species further indicates that while the reef may appear structurally intact, the absence of target species signals potential ecological imbalance. Continuous monitoring and adaptive management will be necessary to restore species diversity and ecosystem stability.

Conclusion

This study demonstrated that the RT Lim Marine Protected Area (MPA) offers moderate conservation benefits, particularly for non-target habitat indicator species such as Pomacentridae, which showed high biomass and abundance. These findings suggest a level of ecological resilience and underscore the role of MPAs in providing refuge for reef-associated fish. However, the consistently low abundance of commercially important target species, coupled with reduced species diversity and dominance of a few taxa, points to potential shortcomings in enforcement or spatial design. Such imbalances highlight the need for strengthened management to ensure both biodiversity conservation and fishery sustainability.

To improve the long-term ecological effectiveness of the MPA, enhanced enforcement and community-based monitoring are essential to curb illegal and unsustainable fishing practices. Integrating science-based fisheries management—such as buffer zone delineation, seasonal closures, and gear restrictions—can help rebuild overexploited populations. Furthermore, implementing habitat restoration measures, including coral transplantation and artificial reef deployment, can enhance structural complexity and ecological resilience. These adaptive strategies are critical to securing the RT Lim MPA's role in conserving marine biodiversity and supporting sustainable fisheries.

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