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Community Structure of Benthic Macroinvertebrates in Jose Abad Santos, Davao Occidental, Philippines

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ABSTRACT

Macroinvertebrates play a vital role in energy transfer and nutrient cycling in marine ecosystems and serve as important sources of food and livelihood for coastal communities. However, these critical resources are currently under threat due to uncontrolled harvesting and habitat degradation. This study aimed to provide valuable information on the community structure of benthic macroinvertebrates within the marine protected area (MPA) of Butulan and the open-access area of Balangonan in Jose Abad Santos, Davao Occidental. Sampling was conducted using the belt transect method. A total of 749 individuals, representing 27 species were recorded across the two sites, with gastropods comprising the majority of species. The mean (± SE) population density was significantly higher in Butulan, at 3,540 ± 701.52 ind ha^{-1}, compared to 1,560 ± 246.36 ind ha^{-1} in Balangonan (t = 3.25, P = 0.02). Diversity index results indicated significantly higher species diversity in Butulan (H' = 3.04, H_{max} = 3.30) than in Balangonan (H' = 2.45, H_{max} = 2.64) (t = 4.65, P = 0.001), with species evenly distributed and no single species dominating both sites. The higher density and diversity of benthic macroinvertebrates in Butulan may be attributed to the strict protection of the MPA by the local government. In contrast, unregulated collection in the open-access area of Balangonan likely contributed to its lower diversity and density. Regulatory measures such as catch limits, size quotas, restrictions on harvesting juveniles and gravid individuals, and stock enhancement should be implemented to ensure the sustainable use of this important resource.

Keywords: Diversity, macroinvertebrate, management, marine protected area, open access.

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INTRODUCTION

Benthic macroinvertebrates are essential components of benthic ecosystems, playing critical ecological and economic roles. Ecologically, they contribute significantly to the structure and function of aquatic communities. Their roles include the mineralization and decomposition of organic matter, sediment mixing, oxygen flux into sediments, and the overall cycling of nutrients (George et al., 2009). As direct consumers, benthic macroinvertebrates serve as a crucial food source for many aquatic organisms, thereby facilitating energy transfer and nutrient regeneration within aquatic ecosystems (van Houte-Howes et al., 2004).

From an economic standpoint, benthic macroinvertebrates play a vital role in supporting the livelihoods and food security of many coastal communities in the Philippines. They are traditionally harvested through gleaning—a low-cost, small-scale fishing method involving handpicking on reef flats, or wading and raking sediments in shallow-water habitats. This practice contributes significantly to the daily sustenance and income of small-scale fishers (del Norte-Campos et al., 2005; de Guzman et al., 2019). In the Albay side of Lagonoy Gulf, for instance, gleaning activities yield an estimated annual production of 296 metric tons, valued at approximately php 5,920,000. This translates to an average annual income of around php 20,600 per gleaner (Nieves et al., 2010). Similarly, in Banate Bay, located on the eastern side of Panay Island, the annual catch in this area ranges from 20,988.7 to 43,527.6 kilogram (kg), generating an estimated total value of php 421,047.1 when sold in local markets. This value can increase significantly—up to php 897,140.0—when the harvested macroinvertebrates are sold in urban markets, where prices are comparatively higher (del Norte-Campos et al., 2005). Beyond their role as food sources, benthic macroinvertebrates are also collected for various non-traditional uses. These include souvenir items, components of handicrafts and decorative pieces, jewelry, carving tools, and other artisanal products (Jontila et al., 2014; Mecha and Dolorosa, 2020).

Currently, the diversity of benthic macroinvertebrates is in decline due to various anthropogenic activities occurring within intertidal zones. These activities include coastal housing development, intensive fishing practices, pollution, and unregulated tourism. Such disturbances have a direct impact on macroinvertebrate populations, particularly because their limited mobility within benthic habitats reduces their ability to escape environmental stressors (Sahidin et al., 2019). In open-access areas, overharvesting has emerged as a significant concern. Due to the slow-moving nature of most macroinvertebrate species, they are especially vulnerable to overharvesting, resulting in notable population declines (Nieves et al., 2010; Szabó and Amesbury, 2011). If left unmanaged, the unregulated exploitation of marine macroinvertebrate resources can lead to overexploitation, threatening species sustainability and contributing to the further degradation of their habitats (de Guzman et al., 2016; Maynawang et al., 2023).

Marine Protected Areas (MPAs) are established as a management strategy by local governments and other key stakeholders to safeguard biodiversity and conserve both natural and associated cultural resources (De Guzman and Quiñones 2021). These areas are managed through legal frameworks or other effective governance mechanisms (Edgar et al., 2014). MPAs have been shown to support the recovery and sustainability of marine life, including benthic macroinvertebrates, which often occur in significant numbers within well-protected zones where exploitation is restricted or entirely prohibited particularly in the case of threatened species (Conales et al., 2015; Dolorosa et al., 2016). Several studies have demonstrated that protected sites generally support higher abundance and greater species diversity of benthic macroinvertebrates compared to unprotected or heavily exploited areas (Lumayag et al., 2018; Bantayan et al., 2023; Mahilac et al., 2023; Tuang-tuang, 2022).

In the municipality of Jose Abad Santos, Davao Occidental, the coastal barangays of Balangonan and Butulan are home to ecologically significant marine ecosystems, including extensive coral reefs, seagrass beds, and mangrove forests. In response to increasing conservation concerns, a 24.7-hectare Marine Protected Area (MPA) was established in Barangay Butulan on November 4, 2019, through Barangay Ordinance No. 01, series of 2019, to safeguard these interconnected habitats. In contrast, Barangay Balangonan remains an open-access area, where marine resources are vulnerable to unregulated exploitation. While MPAs are widely recognized as effective tools for marine conservation, there has been limited scientific research conducted. In particular, the community structure of benthic macroinvertebrates has not been sufficiently studied in either the protected or unprotected areas (Davies, 2021; Prieto-Amador and Palomar-Abesamis, 2024). The absence of such baseline data hinders the ability of local stakeholders and policymakers to assess the current status of marine resources and to identify specific areas requiring enhanced management and protection. This study aims to address this knowledge gap by assessing and comparing the community structure of benthic macroinvertebrates within the MPA of Butulan and the open-access area of Balangonan. The findings are expected to provide valuable insights into the effectiveness of existing conservation measures and to support evidence-based decision-making for the sustainable management of marine resources in Jose Abad Santos.

MATERIALS AND METHODS

Description of the study area

Jose Abad Santos, formerly known as Trinidad, is a coastal municipality in the province of Davao Occidental. It comprises 26 barangays, with 23 located along the coast. Among the 23 barangays, Balangonan is known for its high abundance of macroinvertebrates, which are an important source of food and income for local communities (Molina et al., 2025). However, the area has remained open-access for many years, allowing unrestricted harvesting. This lack of regulation may lead to the overexploitation of macroinvertebrate populations. In contrast, the barangay of Butulan established a 24.7-hectare no-take zone within its marine protected area (MPA) in 2019. This has contributed to the protection and recovery of marine biodiversity, including macroinvertebrates. The two sampling sites were geographically positioned at 5°36’51” N and 125°25’54” E in Butulan and 5°35’50 N and 125°21’49’’ E in Balangonan (Figure 1).

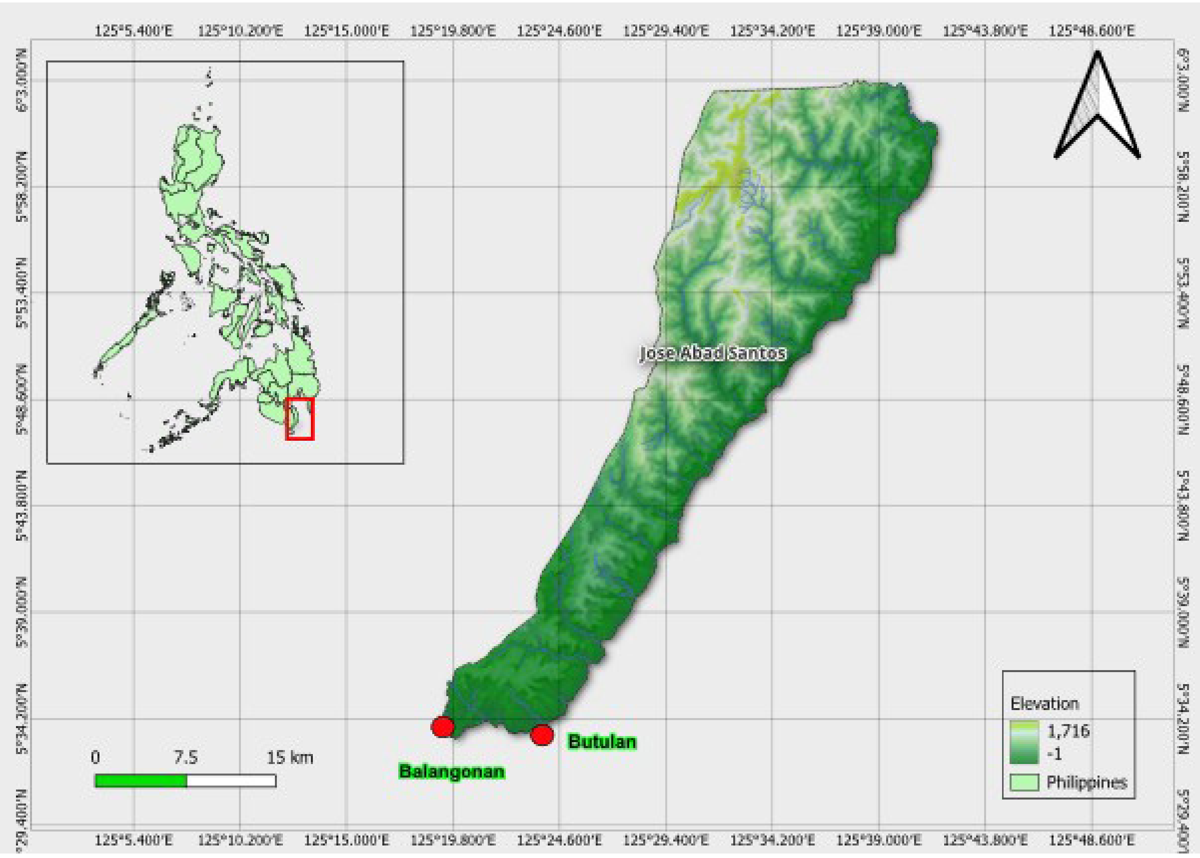

Figure 1. Map showing the two sampling sites in Jose Abad Santos, Davao Occidental.

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Sampling procedure

One-shot sampling was conducted on 01 to 04 December 2023 and 06 to 10 January 2024 at the two established sampling sites in Jose Abad Santos, Davao Occidental. Three 50 m x 4 m belt transects, spaced 50 m apart, were laid parallel to the shoreline in the coral reef area and seagrass beds at each study site. For ease of observation, sampling was done by wading or snorkeling in the seagrass beds, and by skin diving with the help of locals in the coral reef area during the daytime, at the lowest low tide. All epifaunal benthic macroinvertebrates encountered within the belt transects were recorded and identified to the lowest possible taxonomic level using identification keys and relevant literature (Schoppe, 2000; Jontila et al., 2014; Dolorosa et al., 2015). Valid scientific names and taxonomic authorities were confirmed through the World Register of Marine Species (WoRMS) and SeaLifeBase databases. No specimens were collected during the survey.

Determination of physicochemical parameters

During the macroinvertebrate assessment along each transect, water temperature, pH, salinity, and dissolved oxygen were determined in situ at the start, middle and end of the transect. Each sampling points was measured in three readings using a YSI ProDSS Multiparameter Digital Water Quality Meter.

Data analyses

Macroinvertebrate density

The density of macroinvertebrates (*Di*) was computed using the equation 1:

$$D_i = \frac{Ni}{A}$$

Where *Ni* is the total number individuals of each species and *A* is the area of the belt transect. The resulting values were then extrapolated to individuals per 10,000 m^2 or 1 ha.

Calculation of diversity indices

The Shannon-Wiener Index (*H'*) was computed using the equation 2:

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i)$$

Where H' was the Shannon-Wiener Index of diversity, S was the total number of species; $p_i = \frac{n_i}{N}$ was the proportion of individuals of benthic macroinvertebrate species i, n_i was the total number of macroinvertebrate species i, $N = \sum_{i=1}^{s} n_i$ was the total number of all benthic macroinvertebrate species combined; and $\ln(p_i)$ was the natural logarithm of the proportion p_i. The Maximum Shannon-Wiener Index (H_{max}) was calculated using the equation 3:

$$H_{max} = \ln(S)$$

Where H_{max} was the maximum diversity possible given the species richness and S is the total number of benthic macroinvertebrate species; and ln was the natural logarithm function. The Pielou's Index of evenness (J') was calculated using equation 4:

$$J' = \frac{H'}{H_{max}}$$

Where J' was the Pielou's Evenness Index, H' was the Shannon-Wiener Diversity Index, and H_{max} was the Maximum Shannon-Wiener Diversity Index. The Simpson's Dominance Index (D) was calculated using the equation 5:

$$D = \sum_{i=1}^{S} p_i^2$$

Statistical analysis

To determine significant differences in macroinvertebrate density, diversity and physicochemical parameters between the two sampling sites, an independent samples t-test was conducted at a 0.05 level of significance. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 20.

RESULTS

Species composition of benthic macroinvertebrates

A total of 749 individuals from 27 species of benthic macroinvertebrates were recorded across the two sampling sites in Jose Abad Santos, Davao Occidental, Philippines. These species belong to 3 phyla, 6 classes, and 21 families (Table 1 and 2). The highest number of species recorded was from Phylum Mollusca, Class Gastropoda, which included 11 families and 14 species. Species such as *Filifusus filamentosus, Laevistrombus canarium, Harpa articularis, Tectus pyramis, Vasticardium subrugosum, Protoreaster nodosus, Linckia laevigata, Spondylus* sp., *Malleus malleus, Conus eburneus., Lambis millipeda, Parribacus* sp. and *Stichopus horrens* were not present in Balangonan (Figure 2).

Table 1. Species composition of benthic macroinvertebrates found in two sites of Jose Abad Santos, Davao Occidental.

Phylum	Family name	Species name	Butulan	Balangonan
Mollusca	Pisaniidae	*Engina mendicaria* (Linnaeus, 1758)	+	+
Gastropoda	Mitridae	*Strigatella zebra* (Lamarck, 1811)	+	+
	Fasciolariidae	*Filifusus filamentosus* (Röding, 1798)	+	-
	Cymatiidae	*Cymatium* sp.	+	+
	Muricidae	*Tylothais aculeata* (Deshayes, 1844)	+	+
	Strombidae	*Laevistrombus canarium (*Linnaeus, 1758)	+	-
		Lambis millepeda (Linnaeus, 1758)	+	-
		Canarium sp.	+	+
	Neritidae	*Nerita polita* (Linnaeus, 1758)	+	+
	Conidae	*Conus eburneus* Hwass, 1792	+	-
Bivalvia		*Conus* sp.	+	+
	Tegulidae	*Tectus pyramis* (Born, 1778)	+	-
		Tectus fenestratus (Gmelin, 1791)	-	+
	Turbinidae	*Turbo argyrostomus* Linnaeus, 1758	+	+
Echinodermata	Harpidae	*Harpa articularis* (Lamarck, 1822)	+	-
Echinoidea	Cardiidae	*Vasticardium subrugosum*	+	-
Asteroidea		(G.B. Sowerby II, 1839)		
		Tridacna sp.	+	-
Holothuroidea	Spondylidae	*Spondylus* sp.	+	+
	Malleidae	*Malleus malleus* (Linnaeus, 1758)	+	-
Arthropoda	Diadematidae	*Diadema setosum* (Leeke, 1778)	+	+
Malacostraca	Toxopneustidae	*Tripneustes gratilla* (Linnaeus, 1758)	+	+
	Oreasteridae	*Protoreaster nodosus* (Linnaeus, 1758)	+	-
	Ophidiasteridae	*Linckia laevigata* (Linnaeus, 1758)	+	-
	Holothuriidae	*Holothuria leucospilota* (Brandt, 1835)	+	+
	Stichopodidae	*Holothuria atra* (Jaeger, 1833)	+	+
	Arthropoda	*Stichopus horrens (*Selenka, 1867)	+	-
	Scyllaridae	*Parribacus* sp.	+	-

Note: (+) indicates presence, while (-) indicates absence of each benthic macroinvertebrate species at the surveyed sites.

A greater number of benthic macroinvertebrate species were found in the coral reef areas than in the seagrass areas of both sampling sites. Based on the IUCN Red List, three species are classified as "Least Concern" (i.e. *C. eburneus, H. atra,* and *H. leucospilota*), one species has "Data Deficient" status (*S. horrens*), and the remaining species recorded are classified as "Not Evaluated".

Figure 2. Some of the benthic macroinvertebrates found in Butulan and Balangonan, Jose Abad Santos, Davao Occidental: *Engina mendicaria* (A), *Strigatella zebra* (B), *Canarium* sp. (C), *Nerita polita* (D), *Tylothais aculeata* (E), *Cymatium* sp. (F), *Filifusus filamentosus* (G), *Conuseburneus* (H), *Laevistrombuscanarium* (I), *Malleus malleus* (J), *Tectuspyramis* (K), *Turboargyrostomus* (L), *Spondylus* sp. (M), *Vasticardium subrugosum* (N), *Harpa articularis* (O), *Lambis millepeda* (P), *Conus* sp. (Q), *Protoreaster nodosus* (R), *Linckia laevigata* (S), *Holothuria atra* (T), *Holothuria leucospilota* (U), *Stichopu horrens* (V), *Parribacus* sp. (W).

Table 2. Diagnostic characteristics of the recorded benthic macroinvertebrates in the two sampling sites of Jose Abad Santos, Davao Occidental.

Species name	Diagnostic characteristics
Engina mendicaria (Linnaeus, 1758)	The shell has a horizontal color pattern of black and yellow stripes.
Strigatella zebra (Lamarck, 1811)	The shell is smooth, with striking zebra-like banding of alternating dark brown and creamy white bands.
Filifusus filamentosus (Röding, 1798)	Fusiform and elongated, with an extended siphonal canal. The shell has a hairy outer layer and appears dark brown in color.
Cymatium sp.	The fusiform shells exhibit prominent axial ribs and spiral cords, with a vibrant orange coloration marked by darker bands and spots.
Tylothais aculeata (Deshayes, 1844)	Fusiform shell with prominent axial ribs and spiral cords. The aperture is ovate, leading into a deep siphonal canal. Shell color ranges from dark gray to brown.

Laevistrombus canarium (Linnaeus, 1758)	High conical spire composed of five furrowed whorls. The outer lip is flared and thickened. The canal is short and straight, with a smooth columella lacking folds.
Lambis millepeda (Linnaeus, 1758)	The outer lip has nine digitiform projections. The spire is striated, and the aperture is narrow.
Canarium sp.	Ovate-fusiform shell with a short spire. The outer lip is moderately flared, and the aperture is elongate. The siphonal canal is short and open. The shell has white and dark brown bands.
Nerita polita (Linnaeus, 1758)	The shell is nearly spherical with a depressed spire. The aperture is crescent-shaped, with a smooth and glossy texture. Shell color varies from gray to creamy white, often marbled.
Conus eburneus (Hwass, 1792)	The shell is broadly conical with a low spire. The shell color is white with three yellowish bands marked with black revolving spots.
Conus sp.	The shell is conical with a low spire. The aperture is narrow and straight. The shell color is light yellow with two golden brown bands.
Tectus pyramis (Born, 1778)	The shell has a pyramid-like shape with prominent spiral ridges and nodules. The whorls are flattened with granulated spiral cords, and the aperture is oval.
Tectus fenestratus (Gmelin, 1791)	The shell has a pyramid-like shape but is less steep than *T. pyramis*. The whorls have window-like depressions.
Turbo argyrostomus (Linnaeus, 17580	The shell is rounded and globose in form, with a rounded spire. It has strong spiral ridges and growth lines. The outer lip of the aperture is silvery.
Harpa articularis (Lamarck, 1822)	The shell is ovate to elongate, with a distinctly rounded body whorl and pronounced axial ribs. The ribs are rounded and smooth. Shell color ranges from cream to light brown with darker brown banding. The aperture is wide and ovate, with a smooth inner lip.
Vasticardium subrugosum (G.B. Sowerby II, 1839)	The shell is heart-shaped, characterized by numerous radial ribs with fine secondary ridges that give it a wrinkled appearance. The shell color is pale brown with dark streaks.
Tridacna sp.	The shell is very large and thick, appearing triangular to ovate in shape. It is prominent with radiating ribs.
Spondylus sp.	The shell structure is ovate, with prominent spines on the upper valve and smaller spines on the lower valve.
Malleus malleus (Linnaeus, 1758)	The shell is T-shaped. The posterior extension of the shell is long and flat.
Diadema setosum (Leeke, 1778)	A visible orange ring surrounds the anus at the center of the aboral surface. The spines are extremely long and slender.
Tripneustes gratilla (Linnaeus, 1758)	The spines are short, orange, and white. Some individuals are covered with seagrass and algae.
Protoreaster nodosus (Linnaeus, 1758)	Body color varies from pale brown to orange, with distinctive dark brown to black conical tubercles on the dorsal side
Linckia laevigata (Linnaeus, 1758)	The central disc is small, and the five-arms are long, cylindrical, and have a vibrant blue coloration.
Holothuria leucospilota (Brandt, 1835)	The body is elongated with numerous papillae. It appears black with white spots on the dorsal surface. The body wall is soft.
Holothuria atra (Jaeger, 1833)	The body has a leathery texture and a glossy black color. It has a distinct orange ring around the anus.
Stichopus horrens (Selenka, 1867)	The body surface has irregular dark blotches, as well as large prominent tubercles and papillae on the dorsal side.
Parribacus sp.	The carapace is flattened and broad, with plate-like antennae covering the head

Diversity of benthic macroinvertebrates

The diversity indices of benthic macroinvertebrates at the two sampling sites are shown in Table 3. The mean Shannon-Wiener diversity index (*H'*) was significantly higher in Butulan (*H'* = 3.04) than in Balangonan (*H'* = 2.45), with a significant difference between the sites (*t* = 4.65, *P* = 0.001). Despite the variation in diversity values, both sites exhibited *H'* values close to their respective maximum diversity (H_{max}) values: H_{max} = 3.30 in Butulan and Hmax = 2.64 in Balangonan, indicating that the benthic macroinvertebrate communities at both sites were evenly distributed, with no single species dominating. This is further supported by the high Pielou's evenness index and low Simpson's dominance index observed in Butulan (*J'* = 0.92, *D* = 0.05) and Balangonan (*J'* = 0.93, D = 0.09).

Table 3. Diversity indices of benthic macroinvertebrates in two sites of Jose Abad Santos, Davao Occidental. Note: Shannon-wiener diversity index (*H'*) was statistically significant between sampling sites with *t* = 4.65, *P* = 0.001.

Sites	Diversity indices				
	Species richness (*S*)	Shannon-Wiener diversity index (*H'*)	Maximum diversity (H_{max})	Pielou's Index of Evenness (*J'*)	Simpson's Index of Dominance (*D*)
Butulan	27	3.04	3.30	0.92	0.05
Balangonan	14	2.45	2.64	0.93	0.09

Population density of benthic macroinvertebrates

The overall mean population density of benthic macroinvertebrates across the two sampling sites was 2,550 ± 463.09 ind ha^{-1}. The mean density (± SE) was significantly higher in the MPA of Butulan, at 3,540 ± 701.52 ind ha^{-1}, compared to 1,560 ± 246.36 ind ha^{-1} in the open-access area of Balangonan (*t* = 3.25, *P* = 0.016). In Butulan, the most abundant species recorded was S. zebra with a density of 280.00 ± 55.61 ind ha^{-1}, followed by *Cymatium* sp. (260.00 ± 79.16 ind ha^{-1}) and E. mendicaria (253.33 ± 53.33 ind ha^{-1}) (Figure 3). In Balangonan, *S. zebra* and *T. gratilla* were the most abundant macroinvertebrates, each with a mean density of 173.33 ± 69.79 ind ha^{-1} and 173.33 ± 40.88 ind ha^{-1}, respectively. The least abundant species recorded in Balangonan was *Tridacna* sp., with a mean density of 13.33 ± 9.42 ind ha^{-1} (Figure 4). Several commercially important and commonly gleaned benthic macroinvertebrate species were found in Butulan but were absent in Balangonan. These include *L. millipeda* (33.33 ± 26.16 ind ha^{-1}), *V. subrugosum* (26.67 ± 13.33 ind ha^{-1}), *Spondylus* sp. (60.00 ± 22.51 ind ha^{-1}), *F. filamentosus* (140.00 ± 54.40 ind ha^{-1}), *H. articularis* (200.00 ± 30.98 ind ha^{-1}), *M. malleus* (60.00 ± 20.50 ind ha^{-1}), *L. canarium* (200.00 ± 38.64 ind ha^{-1}), *T. pyramis* (53.33 ± 19.78 ind ha^{-1}), *C. eburneus* (33.33 ± 16.05 ind ha^{-1}), *S. horrens* (20.00 ± 13.67 ind ha^{-1}), and *Parribacus* sp. (53.33 ± 26.67 ind ha^{-1}).

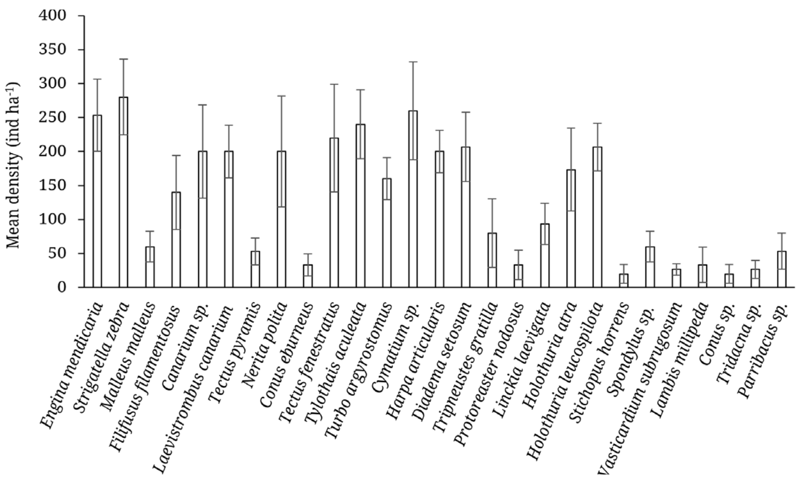

Figure 3. Mean density of benthic macroinvertebrates found Butulan in Jose Abad Santos, Davao Occidental. Vertical bars are the standard error (± SE) of means.

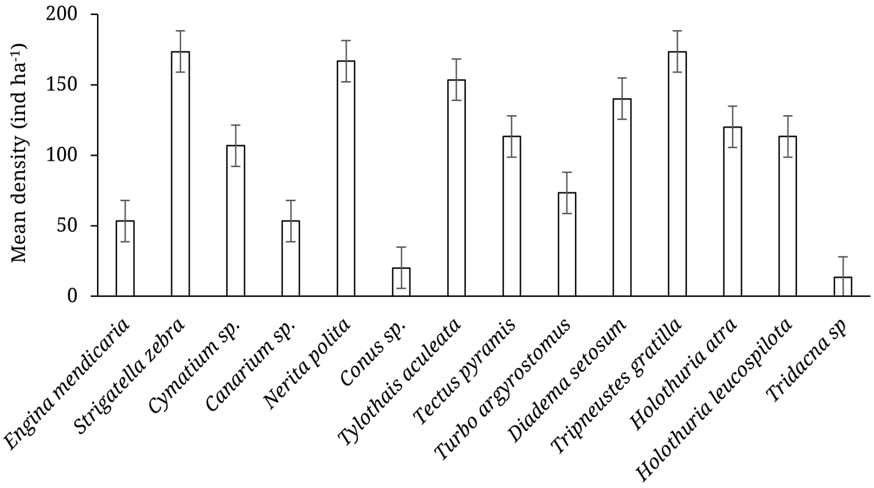

Figure 4. Mean density of benthic macroinvertebrates found in Balangonan in Jose Abad Santos, Davao Occidental. Vertical bars are the standard error (± SE) of means.

Physicochemical conditions of the water

The recorded mean values of physicochemical parameters in Butulan were as follows: temperature at 30.8°C ± 0.17, pH at 8.1 ± 0.04, salinity at 30.8 ppt ± 0.11, and dissolved oxygen at 9.2 mg L-1 ± 0.09. Similarly, in Balangonan, the mean values were 31°C ± 0.13 for temperature, 8.1 ± 0.11 for pH, 31 ppt ± 0.10 for salinity, and 9.2 mg L-1 ± 0.05 for dissolved oxygen. These values fall within the acceptable limits set by the Department of Environment and Natural Resources (DENR) under DAO 2016-08 on the guidelines for water quality and general effluent standards in coastal waters. Statistical test showed no significant difference in temperature (t = 0.19, P = 0.85), salinity (t = 0.54, P = 0.60), pH (t = 0.62, P = 0.70) and dissolved oxygen (t = 0.32, P = 0.76) between two sites.

DISCUSSION

A total of 749 individuals representing 27 species of benthic macroinvertebrates were recorded across the two sampling sites in Jose Abad Santos, Davao Occidental, Philippines. The most abundant macroinvertebrates in both Butulan and Balangonan belonged to Phylum Mollusca, Class Gastropoda. The dominance of gastropods may be attributed to their high reproductive capacity, allowing them to produce large numbers of offspring (Irma and Sofyatuddin, 2012; Baderan et al., 2019; Tuang-tuang, 2022; Mahilac et al. 2023). Additionally, gastropods are known for their resilience and adaptability to a wide range of environmental conditions, including fluctuations in salinity and temperature (Baharuddin et al., 2019). Among these, S. zebra was the most abundant gastropod species recorded at both sites. This gastropod is commonly found in various marine environments, from brackish waters to fully saline conditions. Its high abundance may also be linked to the fact that it is not typically harvested by local communities for consumption or trade, reducing the anthropogenic pressure on its population and allowing it to proliferate in the area. However, the observed abundance may also be influenced by sampling limitations. The study focused solely on epifaunal macroinvertebrates, potentially underrepresenting infaunal species. Furthermore, since sampling was conducted during daytime, most of the recorded species were diurnal (i.e., active during the day), and nocturnal macroinvertebrates may have been overlooked (Balisco et al., 2022). Therefore, future studies should incorporate infaunal sampling and night time surveys to provide a more comprehensive assessment of macroinvertebrate diversity and abundance in the area.

The mean density of macroinvertebrates was significantly higher in Butulan at 3540 ± 701.52 ind ha^{-1} than in Balangonan at 1560 ± 246.36 ind ha^{-1} (t = 3.25, P = 0.001). It is comparably higher than in reef of West Sulu Sea, Palawan at 25.1 ind ha^{-1} (Balisco et al. 2022), in Danjugan Island Marine Reserve and Sanctuaries of Negros

Occidental at 300 ind ha^{-1} (Prieto-Amador and Palomar-Abesamis 2024), in the Tubbataha Reef National Marine Park at 730 ind ha^{-1} (Dolorosa and Schoppe 2005). The results of the diversity index showed a significantly higher value in Butulan (H' = 3.04, H_{max} = 3.30) compared to Balangonan (H' = 2.45, H_{max} = 2.64) (t = 4.65, P = 0.001), indicating that macroinvertebrates in these sites were evenly distributed, with no dominant species. This is further supported by the high evenness index values, which are close to 1, indicating that most macroinvertebrate species had similar abundances, resulting in a higher H' value. However, the significant difference in diversity between the sites, along with the lower diversity value in Balangonan, may reflect a decline in species richness and diversity. Moreover, the diversity value in the MPA of Butulan is also higher than that of the protected area of Ban-ao, Baganga, Davao Oriental (H' = 0.81) (Bantayan et al. 2023), the Danjugan Island Marine Reserve and Sanctuaries of Negros Occidental (H' = 1.79) (Prieto-Amador and Palomar-Abesamis 2024), in Libertad, Sinacaban, Misamis Occidental (H' =2.92) (Mahilac et al. 2023) and in Tinabilan Marine Protected Area, Northwest Leyte (H' = 2.75) (Tuang-tuang 2022). The higher density and greater diversity of macroinvertebrates in Butulan can be attributed to the strict protection of the MPA by the "Bantay Dagat", a coastal law enforcement team designated by the local government. As noted in several studies, protected sites tend to have more individuals and greater diversity compared to exposed or unprotected sites (Lumayag et al., 2018; Bantayan et al., 2023; Mahilac et al., 2023; Tuang-tuang 2022). These findings underscore the critical role of MPAs in supporting the recovery, conservation, and sustainability of marine ecosystems, including benthic macroinvertebrate communities.

The habitat complexity of coral reefs and seagrass beds at the sampled sites may also contribute to the observed high abundance and species diversity of benthic macroinvertebrates. As highlighted by Attrill et al. (2000), the structural complexity of a habitat is often considered a key factor influencing the diversity and abundance of associated communities. Variations in both biotic and abiotic characteristics promote the formation of diverse niches and habitats for macrofauna within the intertidal zone (Gondal et al., 2012). These biotic and abiotic factors such as salinity, pH, dissolved oxygen, temperature, and substrate type strongly influenced the community structure and diversity of benthic macroinvertebrate (Libres, 2015; Nurhasballah et al., 2019; Onwona Kwakye et al. 2021; Li et al., 2022). Although the physicochemical conditions in both study sites fall within the acceptable ranges set by DENR-DAO 2016-08 and showed no significant differences, further investigation of other biotic and abiotic parameters is recommended. These include nutrient concentrations (e.g., nitrate, nitrite, and phosphate), total suspended solids, substrate type as well as seagrass and coral cover, to provide a more comprehensive understanding of habitat characteristics in the area.

In contrast to the MPA of Butulan, the open-access nature of Balangonan has facilitated unregulated gleaning activities by coastal residents, who view gleaning as both a source of alternative income and a recreational activity (Bantayan et al., 2023). As mentioned by Mahilac et al. (2023) that gleaning impacts macroinvertebrate diversity in Sinacaban, Misamis Occidental, as the intensive collection of organisms poses a threat to species abundance and may lead to reduced reproductive output and population decline. Similarly, this has contributed to the lower macroinvertebrate density and reduced species richness observed at the study site. In addition to gleaning, other anthropogenic pressures including the construction of coastal homes, boat docking areas, swimming zones, beach resorts, ecotourism facilities, and the discharge of domestic waste may also adversely affect benthic macroinvertebrate communities (Mahilac et al., 2023). These disturbances have been widely linked to declining species richness and diversity in coastal ecosystems (Sun et al., 2018). It is also noteworthy, the consequences of these human activities are reflected in the absence of several ecologically and economically important macroinvertebrate species in Balangonan such as *C. eburneus*, *L. millipeda*, and *S. horrens* locally known as "kibul," "Saang" and "bat mani-mani" respectively, which local communities recall as previously abundant in the area's coral reefs. Moreover, the increasing market value of many gleaned species, particularly top shells and giant clams, has raised concerns over potential overexploitation, as elevated prices drive small-scale fishers to intensify harvesting efforts (Balisco et al. 2022; Aldea, 2023). For instance, *Tripneustes gratilla*, the second most abundant macroinvertebrate species in Balangonan, has begun to decline in number and size due to excessive fishing driven by local demand, where the species is commonly sold in bottles to the local market (Molina et al., 2025).

Notably, the presence of *Tridacna* spp. and other high-value benthic macroinvertebrates such as *T. argyrostomus*, *T. pyramis*, and the abundance of *T. gratilla* during the survey in Balangonan underscores the urgency of implementing appropriate management interventions. If left unmanaged, continued unregulated exploitation of marine macroinvertebrate resources may lead to overharvesting, threatening species sustainability and accelerating habitat degradation (de Guzman et al., 2016).

CONCLUSION

A total of 749 individuals representing 27 species of benthic macroinvertebrates were recorded across two sampling sites in Jose Abad Santos, Davao Occidental, Philippines. The most abundant macroinvertebrates in both Butulan and Balangonan belonged to the phylum Mollusca, class Gastropoda. The mean density and diversity of benthic macroinvertebrates were higher in the MPA of Butulan compared to the open-access area of Balangonan, underscoring the critical role of MPAs in protecting and conserving macroinvertebrate resources. Conversely, the open-access status of Balangonan highlights the potential for overharvesting, which can lead to declining wild stock populations and reduced species diversity. Thus, it is recommended that local stakeholders implement regulatory measures to ensure the sustainable use of this important resource in Balangonan. These measures may include catch limits (e.g., no more than 20 pounds per day, including shells), size quotas (which may vary by species; for example, T. gratilla with a test diameter greater than 60 mm, and shellfish such as Trochus species with a base diameter of at least four inches), restrictions on the harvesting of juveniles and gravid individuals, and stock enhancement. Community-based resource management, combined with continuous ecological monitoring, is essential to maintain the long-term ecological integrity and socioeconomic sustainability of these marine ecosystems.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors

AUTHOR CONTRIBUTIONS

Molina, J. R.: Conceptualization, methodology, supervision, data validation, writing-original draft and revising manuscript; Muda, R. and Dela Cruz, R.: Data collection and data analyses. All authors read and approved the final manuscript.

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