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Macroinvertebrate assessment in seagrass ecosystem in Sinacaban Municipality, Misamis Occidental, Philippines

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Abstract. *Mahilac HMO, Tandingan JP, Torres AG, Amparado JRR, Roa-Quiaoit HA. 2023. Macroinvertebrate assessment in seagrass ecosystem in Sinacaban Municipality, Misamis Occidental, Philippines. Biodiversitas 24: 5586-5597.* Marine ecosystems such as seagrasses are economically and ecologically important in tropical coastal areas like Sinacaban municipality, southern Philippines. This study assessed the macrobenthic species and water quality (e.g., pH, salinity, temperature, Dissolved Oxygen (DO), and total suspended solids (TSS) in three seagrass areas in the municipality. The study showed the seagrass habitats with 40 macrofaunal species from the classes Gastropoda (27), Bivalvia (11), and Crustacea (2), with *Clibanarius longitarsus* as the most abundant species (77 individuals or 24% relative abundance). The Strombidae family holds the highest dominance within the Gastropoda class, whereas the Arcidae family is the most dominant within the Bivalvia class. However, there is no dominant family within the Crustacea class. Water quality showed pH at 7, 30 ppt salinity, and 28°C within their standard limits, while DO (8 mg/L) and TSS (127 mg/L) exceeded their range. This study recorded eight economic important species and five least concern International Union for Conservation of Nature (IUCN) species. Among the three (3) sites, the seagrass area in Libertad has the highest species richness (28), Shannon's Index (2.92), and species evenness (0.66). The Chao estimation result revealed that Libertad (37.17) and Poblacion (18.5) have lower uncertainty in their species estimates than Colupan (39.60), which has a wider range of potential species richness. The Canonical Correspondence Analysis (CCA) proved that there are species that can adapt to a certain level of environmental parameters, like *Angaria delphinus*, while *Decatopecten radula* is one of the species that does not correlate with the water parameters in the study. The findings are critical for biodiversity conservation, ecosystem management, sustainable resource use, and adaptation to changing environments in order to maintain ecological balance and the long-term health of the seagrass ecosystem.

Keywords: Anthropogenic activities, *Clibanarius longitarsus*, diversity, macroinvertebrates, seagrass ecosystem

INTRODUCTION

Seagrasses are flowering plants that can thrive in salty and brackish waters and mainly grow in shallow water (Nordlund et al. 2018; Unsworth et al. 2019a; Quevedo et al. 2020). They belong to the Monocotyledonae group (Zusron et al. 2015) and are vital primary producers in aquatic ecosystems, especially to seagrass-dependent animals like the various fishes, sea urchins, sea turtles and dugongs (Fortes 2013; Zusron et al. 2015; Unsworth et al. 2019a). The seagrass ecosystem is an ecotone between the mangrove forests and coral reefs (Fortes 2013) and influences coastal waters' physical, chemical, and biological environments (Zulkifli et al. 2021).

The seagrass ecosystems provide ecosystem services critical to the aquatic environment and human well-being (Brazas and Lagat 2022; Clores 2023). They function as a home, breeding, protecting, and nursing grounds for the following mollusks, crustaceans, polychaetes, echinoderms, fishes and reptiles (sea turtles), and mammals (dugongs) (Alima et al. 2014; Jumawan et al. 2015; Zusron et al. 2015; Lefcheck et al. 2019; Valdez et al. 2020). The seagrass ecosystems provide food and medicines (Du et al. 2016; Vasarri et al. 2021). They help in carbon sequestration, stabilization of sedimentations, coastal protection, and water quality regulation (Duarte et al. 2013; James et al. 2019; Lefcheck et al. 2019; Valdez et al. 2020).

Seagrass ecosystems support various marine organisms. These include infauna dwelling amongst their roots, epifauna, and epiflora living on their shoots and leaves, and nekton swimming in the water column (Keith et al. 2020). Marine macroinvertebrate species are large animals without vertebral columns/backbones thriving in the marine environment (Superada and Tampus 2015). mollusc is the most commonly found macroinvertebrate group in the seagrass ecosystem, especially gastropods, which are more dominant than the bivalve species (Zusron et al. 2015). These macroinvertebrates play a vital role in the seagrass ecosystem, being responsible for the nutrient cycling within the ecosystem as the primary processors of organic materials (as scavengers or decomposers of dead organisms) (Fajardo et al. 2015; Parcon et al. 2020) serve as an important food for predators and as biological indicators of the ecosystem's health (Labajo-Villantes and Nuñeza

2015). However, overexploitation of Macroinvertebrates for food and used as souvenirs and for crafting jewelry are reported in the study of Balisco et al. (2022). Thus, the assessment of macroinvertebrate species is critical as a measuring tool to determine the biodiversity and health condition of the seagrass ecosystem in the Sinacaban Municipality because the reduction of the flora is directly proportional to the fauna reduction (Dieta and Arboleda 2004).

Despite the importance of seagrass, there are only a few studies concerning the seagrass ecosystem, unlike the other blue carbon ecosystems in the Philippines (Quevedo et al. 2021; Corcino et al. 2023), and in addition, the seagrass covers show alarming declining rates globally caused by anthropogenic activities, such as coastal development, overexploitation, boating, direct disposal of wastes, urban and industrial run-off, and climate change (Hughes et al. 2013; Dedel et al. 2018; He and Silliman 2019; Unsworth et al. 2019b; McKenzie et al. 2020; Valdez et al. 2020; Zulkifli et al. 2021; Alcantara et al. 2022). The environmental stress and contamination in the seagrass habitat may contribute to the declining seagrass (Libres 2015; Espel et al. 2019). In the Philippines, the status of seagrass extent as of 2009 was 2.73 million hectares, as reported by the Biodiversity Management Bureau-Department of Environment and Natural Resources (BMB-DENR) (2016). The declining rate and loss of seagrass influence the species composition of the coastal ecosystem (Rueda et al. 2009; Quintas et al. 2013). Lunduis et al. (2018) added that the changes in seagrass distribution also affect the ecosystem's function. The negative effects of the loss of seagrass and degradation of the fauna will also cause serious depletion of marine resources and other ecosystem services for human benefit (Short et al. 2011). Thus, it is vital to determine the macroinvertebrate species composition and diversity in the seagrass ecosystem for the long-term management, conservation, and protection success of seagrass and their associates in the study area as the coastal community depends on their marine resources for their welfare. Presently, the municipality faces undue environmental stresses due to the human activities occurring in the area, such as overexploitation of resources and coastal development. The assessment in the area can also provide support, even locally, in achieving the national conservation and ecosystem service targets through the Philippine Biodiversity Strategy and Action Plan (PBSAP). The study generally aimed to assess the seagrass-associated macroinvertebrates and examine the water quality condition of the seagrass ecosystem. Specifically, it aims to i) determine the macrobenthic composition, ii) compute species relative abundance, iii) identify species with economic importance, iv) determine the IUCN conservation status, v) compute species diversity of the ecosystem, vi) determine the estimated species richness and standard errors, and vii) evaluate and determine the relationship between the macrobenthic species distribution with and water parameters.

MATERIALS AND METHODS

Description of the study area

Sinacaban Municipality, Misamis Occidental, Region 10, Philippines, was the study site, which has a municipal land area of 9,909 hectares and a total coastline of 5.5 kilometers, with 24.1 hectares of seagrass covers (Figure 1).

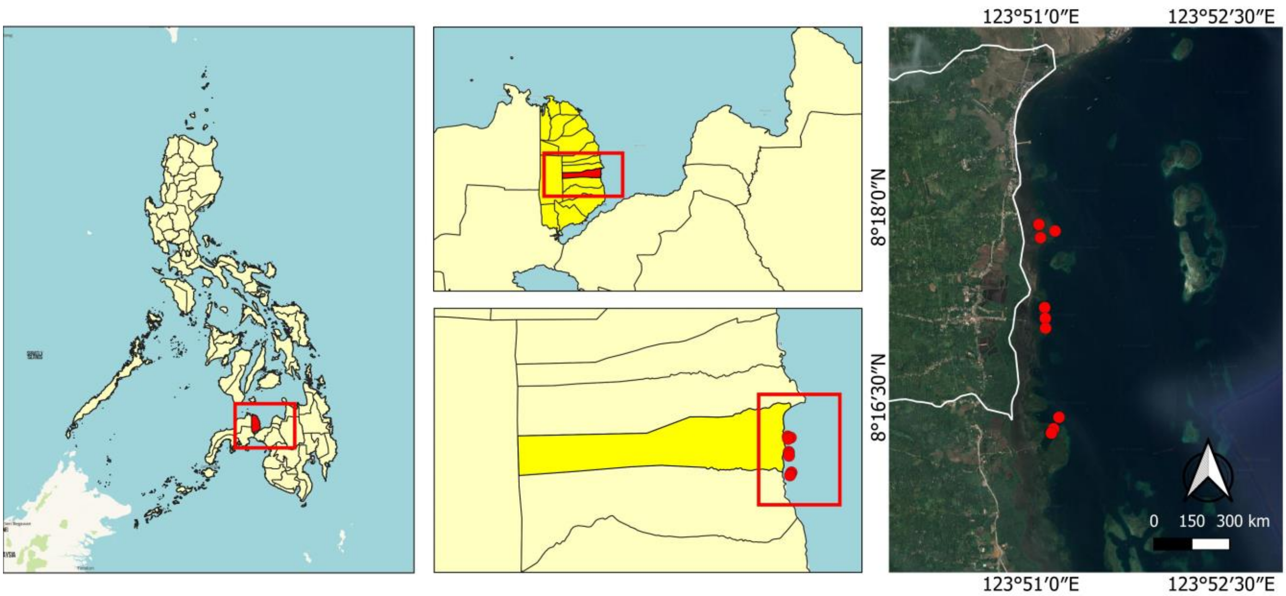

Figure 1. Seagrass sampling sites in the coastal areas of Sinacaban Municipality, Misamis Occidental, Philippines

The study selected three (3) coastal barangays, namely Libertad Bajo, Poblacion, and Colupan Bajo, known for supporting ecologically and economically important marine resources and the local community's habitat. The area actively develops its local economy through agriculture, fisheries, recreational activities such as Sinakbang beach resort, open swimming areas, and tourism (Misamis Occidental Aquamarine Park). However, the municipality faces resource depletion, environmental degradation, declining fishery output, and rapid population growth (PCAMRD Zonal Center 2007). Even though the problems were identified in terms of the municipality's coastal environment in the Participatory Rapid Appraisal report presented in 2007, anthropogenic activities have been observed in the selected study sites. Libertad Bajo was chosen because of its established ecotourism in the coastal area. Poblacion is the second study site because it has a high number of coastal house settlements and an active beach resort. Finally, Colupan Bajo was chosen because it had an abundance of solid waste and few house settlements.

Research design

The study was carried out during the month of January and the first week of February, sampling was done three times, then a two-week alternate between sampling periods was applied to all study sites by one researcher, who was assisted by some local people from the municipality. Al-Asif et al. (2020) used a transect-quadrat method but it was modified in this study, by using transect lines and quadrat size, with three 15-meter transect lines and four 1-meter (m) x 1-meter quadrats established perpendicularly from the seaward margin to the seagrass bed in each coastal area of Sinacaban (Coulopan, Libertad, and Poblacion) and a distance of 100 m between transects. After the three sampling periods, 326 individuals of all species were examined, with 109 individuals in Libertad, 141 individuals in Poblacion, and 76 individuals in Colupan.

Water quality assessment

Water temperature, salinity, and pH were determined using a calibrated water quality tester (EZ-9909SP model) and calibrated dissolved oxygen analyzer (D09100 model) for Dissolved Oxygen (DO), all at three replicate samplings. Total Suspended Solid (TSS) was determined by collecting labeled one-liter (1L) water samples at the middle water level for each sampling station, placed inside a cooler, and transporting them to the laboratory for analysis.

Collection, preservation and identification, and classification of macroinvertebrate samples

Collection of macroinvertebrates within the 1m x 1m quadrats, mainly on the substrate or attached to the seagrasses. One representative of each macroinvertebrate species was collected by handpicking and recorded, placed inside a labeled ziplock for later preservation, photo documentation, and identification. Then, samples were cleaned and preserved with 70% ethyl alcohol. The samples were cleaned and dried first, then proceeded to photo documentation using a Digital Single-Lens Reflex (DSLR) camera. The species samples were identified and classified down to the species level based on their morphological features using database and identification guides, such as internet sources (www.idscaro.net/sci/01_coll/, www.crabdatabase.info/en, and www.reeflifesurvey.com/species/search.php) and the Food and Agriculture Organization (FAO) species identification guide for fishery purposes (Carpenter and Niem 1998). The study determines the economic importance and IUCN status of each identified and classified species using the data from the SeaLifeBase website (Palomares and Pauly 2023).

Data analysis

The study uses Microsoft Excel software to determine the total number of individuals per species and relative abundance (number of individuals of one species/total number of all individuals counted x 100). Using Paleontological Statistics (PAST) software determines the species richness, species evenness, and Shannon diversity. Determines the estimated species richness in each sampling using Chao estimation in R studio software. The study used Canonical Correspondence Analysis (CCA) through PAST to evaluate the relationship between the species and the environmental variables in the study (Bandibas and Hilomen 2016).

RESULTS AND DISCUSSION

Physico-chemical analysis

Determining the health condition of the ecosystem and protecting the ecosystem from habitat degradation and destruction is critical through the assessment of the physicochemical characteristics of the water, such as the Water pH, Salinity, Water Temperature, DO, and TSS (Patil et al. 2012; Dirican 2015). The Philippine Department of Environment and Natural Resources Administrative Order No. 2016-08 (DAO 2016-08) provides the guidelines for water quality and general effluent standards. Table 1 shows the physicochemical parameters obtained from water sample analysis in the three barangays, with each parameter's corresponding respective DAO 2016-08 standard limit.

Except for the DO (8 mg/L greater than 5 mg/L) and TSS (127 mg/L above 80 mg/L), the other parameters, such as pH (7 pH within range of 6.5-8.5 pH), salinity (30 ppt equal to 30 ppt) and temperature (28°C within range 25-31°C) of the three seagrass areas did not exceed their respective standard limit which showed the water in the areas are in neutral pH condition, with normal saline water and a warm temperature for species to function well in the ecosystem. The DO content of Libertad (9.04 mg/L) and Poblacion (8.59 mg/L) areas are higher than the Colupan area (6.56 mg/L), all above 5.0 which means healthy for the species, allowing them to function normally and support their growth and development. The presence of abundant plants and algae, as well as low organic matter or low Soil Organic Matter (SOM), are possible factors that may explain the higher levels of Dissolved Oxygen (DO) in this study. Areas with abundant plants and algae engage in photosynthetic activities that increase dissolved oxygen in the water, while areas with low organic matter experience reduced decomposition activity, during which bacteria utilize oxygen to break down organic matter. Consequently, the water environment in this study is conducive for aquatic species to thrive and support their life. The present bacteria in the water will not consume and degrade the average or high DO level. However, the high TSS content in the three areas, the same for Libertad and Colupan (130 mg/L) higher than Poblacion (120 mg/L), showed that these are highly silted and might at extreme can suffocate and prevent the organisms from surviving in the seagrass environment. Solid wastes can contribute to the TSS content of the water, like in Colupan, where the dumping of solid wastes occurs near the sampling areas.

Water pollution is one of the world's major environmental issues, threatening aquatic ecosystems such as the seagrass ecosystem (UNEP 2016; FAO-UN and IWMI 2017; Hakeem et al. 2020). The growing human population may considered as a significant contributing factor threatening the ecosystem (Paudel and Kindlmann 2019). Other factors are urbanization (Bhateria and Jain 2016), industrial waste, and developing and converting agriculture and aquaculture areas (Manju et al. 2012). Moreover, natural processes such as typhoons, soil erosion, storm tides, and other natural hazards exacerbate the situation. Poor and improper tourist activity planning and management (Bhateria and Jain 2016) and oil contamination contribute to water pollution.

Species composition

There are 40 macroinvertebrate species found in the seagrass areas of Sinacaban, belonging to 15 families of Gastropoda, nine (9) families of Bivalvia, and two (2) families of Crustacea, respectively (Table 2). The most dominant marine invertebrates are under Phylum Mollusca, with Class Gastropoda and Bivalvia (Egilsdottir et al. 2019). These two species can maintain their population by producing many larvae (meroplankton) (Irma and Sofyatuddin 2012). Kottè-Mapoko et al. (2017) explained that mollusks are widely distributed along the sea axis and at various elevations on the planet. These two classes are keystone species or ecosystem engineers in the marine ecosystem, and they can be herbivores, predators, scavengers, and filter feeders. As described by Irma and Sofyatuddin (2012), they act as bioindicators of changing environmental conditions. The mollusc species' distribution is more affected by the characteristics of a seagrass meadow, particularly its location in the intertidal zone, than its area size (Cavalcante et al. 2019).

Seagrass beds benefit associated bivalves by serving as a refuge from predation, providing a source of sediment oxygen, and minimizing exposure to bacterial pathogens (Goshima and Peterson 2012; Lamb et al. 2017; Donahers et al. 2021). Figure 2 shows the bivalve species found in Sinacaban seagrass. Class Bivalvia shows fewer species recorded in this study than gastropods (11 bivalves <27 gastropods); most of these bivalves are slow-moving deposit feeders (Roy et al. 2000; Egilsdottir et al. 2019). Yahya et al. (2020) stated that the bivalves' reproductive characteristic is a population survival strategy that allows the species to have a wider distribution and prevents the species from becoming overcrowded in one location.

Figure 3 depicts the 27 gastropod species collected in the study. Most of the studies in the marine ecosystem reported that Gastropoda is the most dominant group in the marine environment. The Class Gastropoda is the dominant species group in Sinacaban's seagrass areas. Probably due to their ability to produce numerous individuals, as explained by Narcio and Flores (2019), Baderan et al. (2019), and Egilsdottir et al. (2019). The high abundance of gastropods in the study area supported the claims of Zusron et al. (2015) and Cob et al. (2008) that the gastropods are the most found groups of mollusks in the seagrass ecosystem. Moreover, several studies have emphasized that the population of gastropods increases in direct proportion to the density of the seagrass flora, indicating that there is a close relationship between the two (Fajeri et al. 2020; Latuconsina and Samal 2020).

Table 1. Results of the water parameters in the mangrove areas of the three coastal barangays with standard limit

Water parameters	Libertad	Poblacion	Colupan	Mean	Standard value (DAO 2016-08)	Description	Remarks
Water pH	7.05	7.09*	7.01	7	6.5-8.5	(>7) Alkaline (=7) Neutral (<7) Acidic	Normal level
Salinity (ppt)	30.7	29.1	30.8*	30	≥ 30	(≥) Saline water (<)Brackish water	Normal level
Water temperature (°C)	28.5*	27.5	28	28	25-31	Within standard limit: Normal for marine life Outside standard limit: lesser marine life	Normal level
Dissolved oxygen (mg/L)	9.04*	8.59	6.56	8	5	(<) stressor for organisms (≥) healthy for species	Above normal level
Total Suspended Solid (mg/L)	130*	120	130*	127	80	(<) clear water (≥) highly silted	Above normal level

Note: *: Highest value

Table 2. Species composition, relative abundance, economic importance, and IUCN status of each species in the seagrass habitat

Class	Family	Species	L	P	C	T	RA %	EI	IUCN
Phylum Mollusca									
Bivalvia	Arcidae	*Anadara antiquata* (Linnaeus, 1758)	9	3	4	16	5	COM	NE
	Arcidae	*Anadara trapezia* (Deshayes, 1839)	2	2	0	4	1	ND	NE
	Mytilidae	*Arcuatula senhousia* (W.H. Benson, 1842)	3	0	0	3	1	ND	NE
	Pinnidae	*Atrina rigida* ([Lightfoot], 1786)	1	0	2	3	1	COM	NE
	Pectinidae	*Decatopecten radula* (Linnaeus, 1758)	0	1	1	2	1	COM	NE
	Veneridae	*Gafrarium tumidum* (Röding, 1798)	10	2	0	12	4	ND	NE
	Margaritidae	*Pinctada fucata* (A. Gould, 1850)	1	0	0	1	0	ND	NE
	Spondylidae	*Spondylus sinensis* (Schreibers, 1793)	8	0	8	16	5	COM	NE
	Veneridae	*Tapes literatus* (Linnaeus, 1758)	0	0	2	2	1	ND	NE
	Glycymerididae	*Tucetona pectunculus* (Linnaeus, 1758)	1	0	0	1	0	ND	NE
	Cardiidae	*Vasticardium flavum* (Linnaeus, 1758)	1	0	1	2	1	ND	NE
Gastropoda	Angariidae	*Angaria delphinus* (Linnaeus, 1758)	5	0	3	8	2	ND	NE
	Turbinidae	*Astraea heliotropium* (Martyn, 1784)	0	0	1	1	0	ND	LC
	Bursidae	*Bursa rosa* (Perry, 1811)	0	2	0	2	1	ND	NE
	Strombidae	*Canarium labiatum* (Röding, 1798)	1	3	1	5	2	ND	NE
	Strombidae	*Canarium microurceus* (Kira, 1959)	8	4	5	17	5	ND	NE
	Strombidae	*Canarium urceus* (Linnaeus, 1758)	2	3	4	9	3	ND	NE
	Cerithiidae	*Cerithium atratum* (Born, 1778)	1	0	1	2	1	ND	NE
	Muricidae	*Chicoreus capucinus* (Lamarck, 1822)	3	0	0	3	1	ND	NE
	Strombidae	*Conomurex luhuanus* (Linnaeus, 1758)	3	2	0	5	2	ND	NE
	Conidae	*Conus catus* (Hwass, 1792)	0	0	1	1	0	ND	LC
	Conidae	*Conus ebraeus* (Linnaeus, 1758)	0	0	1	1	0	COM	LC
	Conidae	*Conus eburneus* (Hwass, 1792)	0	3	1	4	1	ND	LC
	Conidae	*Conus muriculatus* (G. B. Sowerby I, 1833)	1	3	0	4	1	ND	LC
	Strombidae	*Euprotomus chrysostomus* (Kuroda, 1942)	2	1	0	3	1	ND	NE
	Nassariidae	*Ilyanassa obsoleta* (Say, 1822)	2	0	0	2	1	ND	NE
	Cypraeidae	*Monetaria annulus* (Linnaeus, 1758)	5	0	1	6	2	ND	NE
	Olividae	*Oliva reticulata* (Röding, 1798)	0	2	0	2	1	ND	NE
	Naticidae	*Polinices uber* (Valenciennes, 1832)	0	0	1	1	0	ND	NE
	Tegulidae	*Rochia nilotica* (Linnaeus, 1767)	1	0	0	1	0	COM	NE
	Muricidae	*Semiricinula muricoides* (Blainville, 1832)	0	1	0	1	0	ND	NE
	Muricidae	*Semiricinula turbinoides* (Blainville, 1832)	1	10	1	12	4	ND	NE
	Mitridae	*Strigatella ambigua* (Swainson, 1829)	0	0	1	1	0	ND	NE
	Strombidae	*Strombus gibberulus* (Linnaeus, 1758)	10	21	0	31	10	ND	NE
	Tegulidae	*Tectus pyramis* (Born, 1778)	8	0	1	9	3	COM	NE
	Trochidae	*Umbonium vestiarium* (Linnaeus, 1758)	1	0	2	3	1	COM	NE
	Mitridae	*Strigatella retusa*	1	0	0	1	0	ND	NE
	Costellariidae	*Vexillum plicarium* (Linnaeus, 1758)	0	0	2	2	1	ND	NE
Phylum Arthropoda									
Crustacea	Balanidae	*Amphibalanus amphitrite* (Darwin, 1854)	2	28	20*	50	15	ND	NE
	Diogenidae	*Clibanarius longitarsus* (De Haan, 1849)	16*	50*	11	77*	24*	ND	NE

Note: *: Highest number of individuals. Legend: L: Libertad, P: Poblacion, C: Colupan, T: Total number of individuals, RA: Relative Abundance, EI: Economic Importance, COM: Commercial, ND: No Data, NE: Not Evaluated, LC: Least Concern

Figure 4 depicts two (2) crustacean species found in the Sinacaban municipality's seagrass ecosystem, representing two families: Balanidae and Diogenidae. Acorn barnacles are members of the Balanidae family. Around 50% of the members of Balanidae are alien barnacles, including *Amphibalanus amphitrite* (Torres et al. 2012). The barnacles are known to be invasive (Pfaff et al. 2022). On the other hand, the Diogenidae family includes hermit crab species known as left-handed hermit crabs due to the enormous size of the chela on their left, such as *C. longitarsus*.

Species relative abundance

Species of *C. longitarsus* contributed significantly to the highest number of macroinvertebrate individuals in the seagrass beds of Sinacaban, with the highest relative abundance (77 at 24%), as shown in Table 2. This species is usually widely distributed in marine habitats ranging from brackish to marine water. This species commonly thrives in marine habitats ranging from brackish to seawater, and locals do not collect it for human consumption. The high abundance of *C. longitarsus* might explain their high abundance in Sinacaban's seagrass areas (Hossain et al. 2015). Gorman et al. (2018) revealed that the species' characteristic could influence their fitness and the dynamics of populations in their environment. Furthermore, this species is known as a bioindicator of pollution, especially in monitoring changes in heavy metals (iron and manganese) (Lyla and Ajmal 1996; Dunbar and Coates 2003).

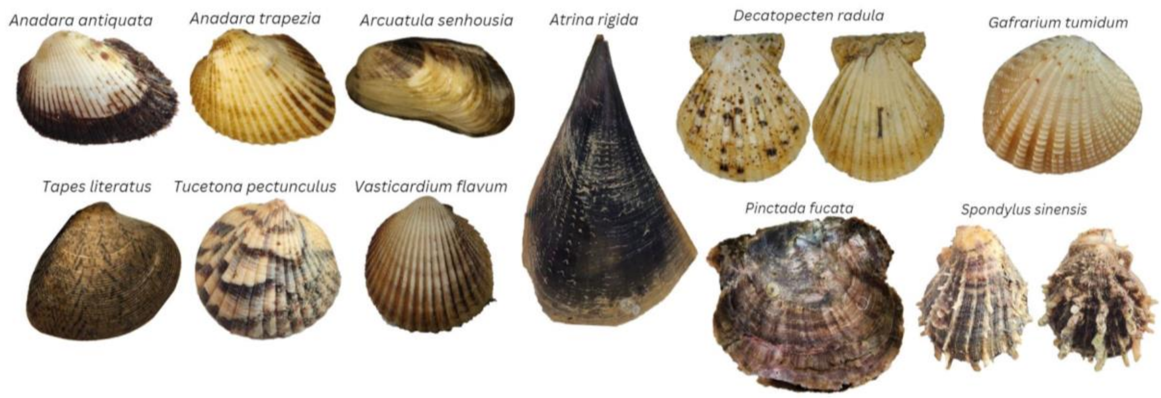

Figure 2. Bivalves found in Sinacaban Municipality, Misamis Occidental, Philippines

Figure 3. Gastropod species found in the seagrass ecosystem of Sinacaban Municipality, Misamis Occidental, Philippines

Figure 4. Crustacean species found in seagrass of Sinacaban Municipality, Misamis Occidental, Philippines

According to Rizvi et al. (2020), the major sources of heavy metal release are biological, agricultural, industrial, domestic, and miscellaneous activities. Furthermore, the presence of heavy metals from domestic wastes may be the source and explanation of the highest number of individuals in Poblacion because some damaged electronic devices and batteries were observed dumped in the coastal areas, which may explain the presence of *C. longitarsus* in these areas with heavy metals in the domestic wastes.

Economic importance

There are eight (8) economic importance species found in the area, consisting four (4) Bivalvia: *Anadara antiquata, Atrina rigida, Spondylus sinensis* and *D. radula*, and four (4) Gastropoda: *Conus ebraeus, Rochia nilotica, Tectus pyramis* and *Umbonium vestiarium* (Palomares and Pauly 2023) (see Table 2). These species are harvested or cultured for their meat, consumed as food, and their shells are used to produce decorative items, jewelry, and ornaments (Nijman et al. 2015). Additionally, some mollusc species, such as *Conus* species, have shown potential for pharmaceutical research (Puillandre et al. 2014, 2015; Rajabi et al. 2020). However, these important species are not commonly found in the Public Market of Sinacaban, possibly due to the municipality's restrictions on harvesting or controlled collection policies.

Conservation status

The five (5) Least Concern (LC) species recorded in Table 2 are *Astraea heliotropium*, *Conus catus*, *Conus ebraeus*, *Conus eburneus*, and *Conus muriculatus*, while the other species (35) recorded were not evaluated by the IUCN Red List authority (Palomares and Pauly 2023). The classification is based on thoroughly examining factors such as population size, trends, distribution, and threats to the species (IUCN 2012).

Diversity indices

Table 3 summarizes the species richness of each class in Sinacaban. Overall, Sinacaban has 11 bivalves, 27 gastropods, and two crustaceans. In contrast, the Crustacea species in the three sampled seagrass areas only recorded two species. The table revealed that Libertad has the highest bivalve and gastropod species (9 and 17), followed by Colupan (6 and 16) and Poblacion (4 and 12), respectively. Low gleaning activity in the Libertad area was observed, unlike the other seagrass beds of Poblacion and Colupan, where gleaning is high and active. The Poblacion seagrass area has the lowest composition of macroinvertebrates among the others since it is highly disturbed by humans. It is more accessible or convenient to glean due to its proximity to the shore and more sandy substrate than other areas. Gleaning influences the macroinvertebrate diversity in the area because the high collection of organisms threatens the species' abundance, which might lead to low production. The gleaning of Macroinvertebrates is vital for the coastal people, which can provide them with food and income (Aldea et al. 2015; Furkon et al. 2019; Aldea 2022; Bantayan 2022; Aldea 2023) it is possible that there was an over gleaning occurred in Poblacion since there are more local occupants near the seagrass areas.

Table 4 summarizes the species evenness and Shannon index results and reveals that Libertad has the most species number (28), the most evenly distributed (0.66), and the most diverse (2.92), followed by Colupan (24, 0.57, and 2.61) and Poblacion (18, 0.44, and 2.08), respectively, as defined by Ulfah et al. (2019). According to Docile et al. (2016) and Sun et al. (2018), anthropogenic disturbances in the coastal areas are responsible for the species richness and diversity results of the macroinvertebrate communities thriving in the ecosystem. Aside from gleaning, The following anthropogenic activities are establishing coastal houses and boat docking areas, swimming areas, beach resorts, and ecotourism parks and disposal of domestic wastes that may affect the species communities.

The three seagrass areas in Sinacaban municipality are observed to be polluted by plastic litter, as in the study by Gaboy et al. (2021). According to Gallitelli et al. (2022), plastics can harm marine life and may influence macro-invertebrate communities. Poblacion and Colupan are more disturbed by the community than Libertad. The Poblacion area has many local occupants on the coast, an active beach resort, a boat docking area, a good swimming area, and more convenient for gleaning activity than in other barangays. In the Colupan coastal area, coastal houses are present but in smaller numbers than in Poblacion, and fewer people are active users on the coast. No coastal houses, beach resorts, or swimming areas in and around Libertad; only an ecotourism park is present. When anthropogenic disturbances increase or are still high, the declining or low abundance and diversity of macroinvertebrates will be observed in the area (M'Erimba et al. 2014).

Table 3. Species richness in Sinacaban Municipality, Misamis Occidental, Philippines

Class	Libertad	Poblacion	Colupan
Bivalves	9*	4	6
Gastropods	17*	12	16
Crustaceans	2	2	2
Total	28*	18	24

Note: *: Highest value

Table 4. The species evenness and Shannon's index of the seagrass ecosystem in Sinacaban, Misamis Occidental, Philippines

	Libertad	Poblacion	Colupan	Mean	Category	Remarks
Species evenness	0.66*	0.44	0.57	0.6	$0 < E \leq 0.5$: Depressed community/low evenness $0.5 < E \leq 0.75$: Unstable community/moderate evenness $0.75 < E < 1$: Stable community/high evenness (Ulfah et al. 2019)	Unstable community/ moderate evenness
Shannon's Index	2.92*	2.08	2.61	2.5	H'>3: High diversity 1.0<H'<3: Moderate diversity H'<1.0: Low diversity (Ulfah et al. 2019)	Moderate diversity

Note: *: Highest value

The seagrass biomass and structure are biotic factors influencing the benthic macrofauna, as Leopardas et al. (2014) stated. Aside from the abiotic factors, the community structure and distribution of the species are profoundly affected by physicochemical factors such as salinity, pH, dissolved oxygen, temperature, and substrate type (Nurhasballah et al. 2019; Potts et al. 2020; Li et al. 2022). In the sampling areas, two major seagrass substrate types are observed, the muddy and sandy substrate and most of the collected species are observed to be occurring in the sandy substrate than in the muddy substrate, which means that the species have substrate preference.

Chao estimation

Chao estimation is a statistical method used to determine the estimated species richness or number of distinct species in a sampling site, including those that may be rare or unobserved species (Gotelli and Colwell 2011). Figure 5 depicts the chao estimate with standard errors for each site. It demonstrates that Libertad has a moderate chao estimate with 37.17 that is higher than the observed species (28) with a modest standard error, implying that there may be more species but with a reasonable level of confidence. Poblacion has a chao estimate with 18.5 that is close to the number of species observed (18), indicating a low number of unseen or rare species. The standard error is minimal, indicating that the level of confidence is high. Colupan has the highest Chao estimate with 39.60 that is higher than the observed species (24), indicating the presence of a large number of unobserved or rare species. The estimate, however, has a comparatively large standard error, indicating increased uncertainty. Each site's Chao estimation results may be influenced by several factors, such as the species' rarity, spatial distribution, microhabitat and species association. The presence of rare or unobserved sampled species is described by species rarity. For example, in Colupan, the greatest Chao estimate indicates the highest potential occurrence of undetected or rare species. In terms of spatial distribution, certain species may be localized to a specified region, while others may have a broader distribution. It describes how some species are closely linked with specific seagrass species or substrates in terms of microhabitat and species relationship.

Relationship of macroinvertebrate species to the physico-chemical parameters

Figure 6 shows the CCA plot result of the different species of macroinvertebrates and physic-chemical parameters of the seagrass ecosystem in the study area. The links between biological assemblages of species and their surroundings can be better understood using the multivariate technique known as Canonical Correspondence Analysis (CCA) (ter Braak and Verdonschot 1995). The technique takes synthetic environmental gradients out of ecological data sets. Results revealed that species, namely *S. sinensis*, *V. flavum*, *C. atratum*, *A. rigida*, *U. vestiarium*, *A. delphinus*, *C. microurceus*, and *A. antiquata*, have a weak positive correlation with the salinity and TSS and these species have no correlation with the temperature. Species, namely *M.annulus*, *T. pyramis*, *S. retusa*, *C. capucinus*, *I. obsoleta*, *R. nilotica*, *P. fucata*, *T. pectunculus*, *A. senhousia*, *G. tumidum*, *E. chrysostomus*, *A. trapezia*, and *C. luhuanus* are observed to have a weak positive correlation to pH and also have weak negative correlation with the DO content. Despite the weak relationship between specific parameters and the species composition, several macrobenthic invertebrates in this study continue to thrive in some specific conditions due to their tolerance capacity. Like, some species are linked to elevated levels of salinity and TSS, while some species are associated to diminished levels of certain environmental parameters (e.g., with dissolved oxygen). The CCA results in this study imply that there are correlations (although some are weak) between macroinvertebrates and physico-chemical parameters (salinity, TSS, pH, and DO), except for *A. amphitrite, D. radula, C. urceus, T. literatus, A. heliotropium, P. uber, S. ambigua, V. plicarium, C. catus, and C. ebraeus*, which shows no correlation with the parameters. The results of this study supported the claim of Nurhasballah et al. (2019) and Potts et al. (2020) that the community structure and distribution of the species are profoundly affected by physicochemical factors such as salinity, pH, dissolved oxygen, temperature, and substrate type, as well as biotic factors.

Overall, the water quality of the seagrass ecosystem in Sinacaban, as characterized, falls within their respective standard limits, such as pH (7 pH), salinity (30 ppt) and temperature (28°C), except for the DO (8 mg/L) and TSS (127 mg/L) that are higher than their respective standard value. The pollutants and unsettled sediments might cause the high TSS in the municipality's seagrass areas in the area.

Figure 5. The result of chao estimate with standard errors in each site

There are a total of 40 macrobenthic species thriving in the sampling areas of the municipality, with Bivalvia (11), Gastropoda (27), and Crustacea (2). There are eight economic importance species recorded in the study (*A. antiquata*, *A. striata*, *A. rigida*, *P. fucata*, *C. ebraeus*, *R. nilotica*, *T. pyramis*, and *U. vestiarium*) and five least concern species found (*A. heliotropium*, *C. catus*, *C. ebraeus*, *C. eburneus* and *C. muriculatus*). There are also other groups of invertebrate species observed that occurs near the sampling areas, such as echinoderms, sponges, and corals, and fishes for vertebrates.

C. longitarsus is the most abundant species, with 77 individuals and a relative abundance of 24% recorded in Sinacaban seagrass areas; it is a crustacean, but it is not for food consumption, which explains its high abundance, unlike the other highly exploited species with a high economic value. Seagrass areas of Libertad, compared to two other barangays, revealed high species richness (28), highly diverse (2.92), and the species are more evenly distributed (0.66). Libertad is poorly disturbed by anthropogenic activities than Poblacion and Colupan. The anthropogenic activities influencing the composition and diversity of the seagrass ecosystem in Sinacaban are gleaning activity, domestic wastes, coastal development, and disturbed recreational activities. Another factor is the antibiotics, such as pH, temperature, salinity, TSS and DO, substrate type, and other possible abiotic factors. The CCA plot of the seagrass ecosystem in Sinacaban proved that each of the seagrass-associated species has different preferences in certain water parameter levels to support their life, *like A. delphinus*, which have higher abundance at higher TSS levels than species of *C. microurceus*. The occurrence of the species in specific parameters is due to the species' ability to adapt to their environment. There are species found in seagrass areas of Sinacaban with no relationship with any water parameters, such as *A. amphitrite*, *D. radula*, *C. urceus*, *T. literatus*, *A. heliotropium*, *P. uber*, *S. ambigua*, *V. plicarium*, *C. catus*, and *C. ebraeus*, which might mean that any parameters in the study did not affect their abundance but maybe by other factors like human activities, natural hazards and other abiotic factors present in the areas.

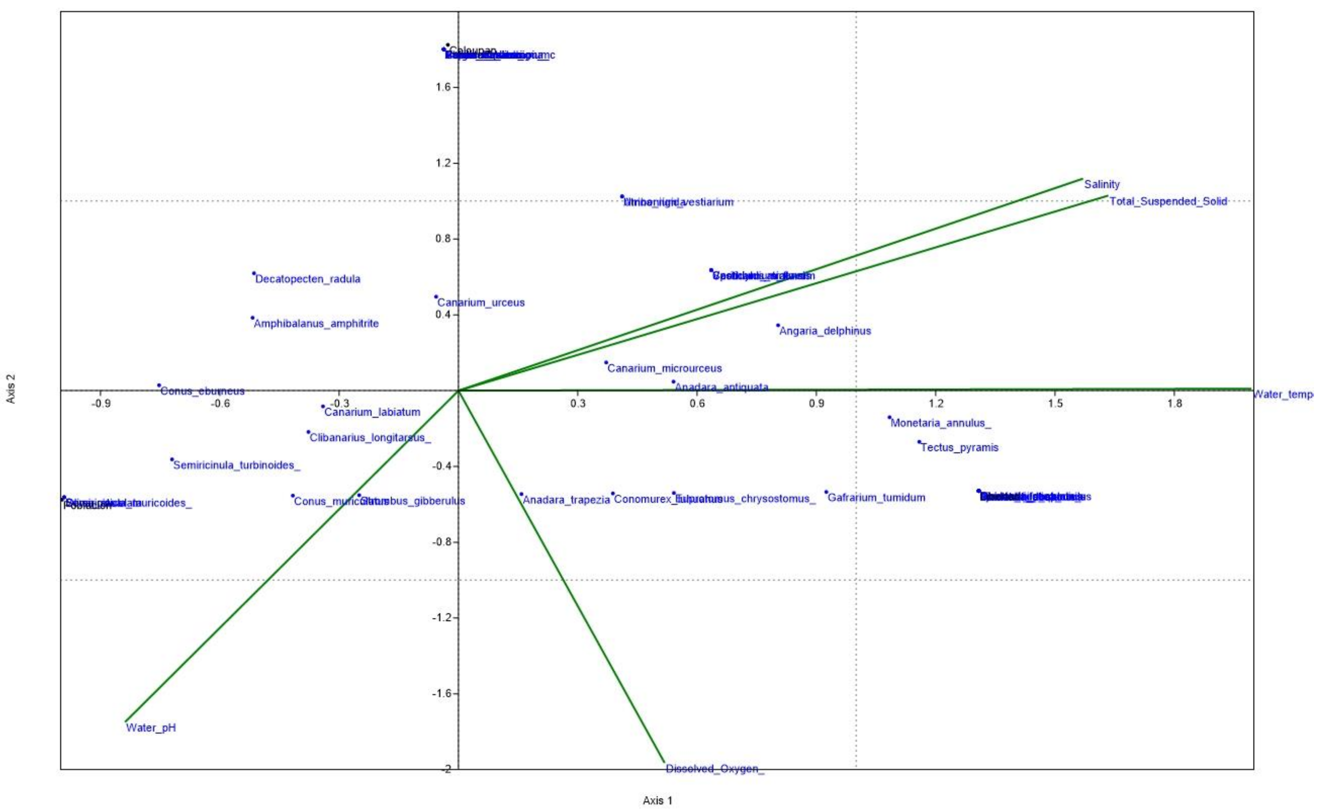

Figure 6. CCA plot result of the seagrass ecosystem

The study's findings are essential in various areas, including environmental management, biodiversity conservation, economics, and research, all of which contribute to the municipality's natural resource use and preservation. The species identified are considered bio-indicators of the ecosystem's health. Monitoring the changes in species composition and abundance can contribute to determining and addressing the environmental issues in the area, such as habitat degradation, pollution and climate change effects. The results obtained are essential for the environmentalists and policymakers to understand the seagrass ecosystem's health and diversity for conservation measures to protect the examined species and their habitat from anthropogenic activities like non-environmental friendly development projects. In addition, the sustainable use of economically important species is critical to maintaining a stable income source for local communities in Sinacaban. Data from this study can serve as a basis for further research and conducting educational programs regarding the biology, ecology, and behavior of the investigated macroinvertebrate species in the study.

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