The state of seagrass community in Panguil Bay, Southern Philippines

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Abstract. Seagrass ecosystems play a vital role in coastal marine environments, providing numerous ecological services and supporting diverse faunal communities. Yet, they face increasing threats, including declining cover in many coastal areas. This study investigates the status of seagrasses and associated macroinvertebrates in Panguil Bay, Philippines, where declining trends in seagrass cover have been observed over time, to identify further management strategies to sustain their growth and productivity. Sampling sites were established in the four municipalities in Panguil Bay that were reported to have had the highest seagrass cover in the past years. The seagrass community structure was assessed using the transect-quadrat method, and several parameters were also determined. The macroinvertebrates associated with seagrass were evaluated using the same transect laid for the seagrass survey, employing a belt-transect method for sampling macroinvertebrates. Nineteen years since the area was last studied, six seagrass species were identified with *Cymodocea rotundata* and *Syringodium isoetifolium* as the most frequent species. Seagrass cover ranged from 10% (poor) to 39% (less healthy conditions), highest in Clarin, Misamis Occidental, and lowest in Tubod, Lanao del Norte, where a further 50% decline was observed. Observations of declining seagrass cover in Panguil Bay highlight the urgent need for holistic management to ensure the protection and sustainability of these ecosystems. Forty-six (46) macroinvertebrate species, represented by four phyla, were recorded in the seagrass sites. The highest number of species is under phylum Mollusca, comprising 34 species. These findings suggested that while seagrass cover may be declining over the years, the associated macroinvertebrates appear abundant and species diversity was still rich across different areas of the bay. Understanding the dynamics of seagrass ecosystems and their associated fauna is crucial to informing conservation and management strategies to mitigate the ongoing threats and ensure the long-term health and resilience of coastal ecosystems in Panguil Bay.
Key Words: seagrass, macroinvertebrates, cover, decline, conservation.

Introduction. Seagrasses are marine flowering plants forming extensive meadows in intertidal and shallow-water marine environments (Camara Lima et al 2023). They influence coastal waters' physical, chemical, and biological environments (Zulkifli et al 2021) and are crucial habitats that contribute to biodiversity, food security, and climate mitigation (Unsworth et al 2022). The habitats provided by seagrasses are critically important, providing numerous ecosystem services that include serving as nurseries for the juveniles of many economically important fishery species, enhancing local biodiversity (Lefcheck et al 2019; Unsworth et al 2022), and sequestering and storing carbon, thus mitigating impacts of climate change (Duarte et al 2013). Seagrass ecosystems support human well-being by delivering various ecosystem services (Herrera et al 2022). They play a significant role in supporting economies, food security, and livelihoods through fisheries (Unsworth et al 2018) and also provide non-material benefits to human societies, such as recreation, aesthetics, cultural heritage, and education (Cullen-Unsworth et al 2014; Garcia Rodrigues et al 2017).

Globally, there are approximately 72 seagrass species spread across all continents except Antarctica, belonging to about 12 significant genera (Short et al 2011), distributed among five families (Cymodoceaceae, Hydrocharitaceae, Ruppiaceae, Zosteraceae, and Posidoniaceae), the majority of these species are found in the tropical Indo-Pacific region, while others are present in temperate regions (Short et al 2007). Among the 12 significant genera, six (*Thalassia*, *Enhalus*, *Syringodium*, *Halodule*, *Halophila*, and *Cymodocea*) are found in tropical regions, four (*Posidonia*, *Amphibolis*, *Zostera*, and *Phyllospadix*) are found in temperate regions, and two (*Thalassodendron* and *Ruppia*) are found in both tropical and temperate regions (Short et al 2007). The Philippines has been ranked second worldwide in terms of seagrass diversity, with 18 seagrass species found from 529 sites in the Philippines that have been classified into three families, namely Cymodoceaceae, Hydrocharitaceae, and Ruppiaceae (Fortes 2013) over an area of approximately 22,000 km based on remote sensing (McKenzie 2007). Despite their importance, seagrasses are in crisis as global coverage is decreasing rapidly (Valdez et al 2020) due to anthropogenic impacts (Turschwell et al 2021), a decline in water quality (Schrameyer et al 2018; Espel et al 2019), pollution, aquaculture, invasive species, and capture fisheries (Murphy et al 2019). With a growing emphasis on ecological restoration as a conservation strategy, methods to improve restoration success must be explored (Valdez et al 2020).

In the Philippines, studies on seagrass in Panguil Bay are still insufficient and limited to the works of Roxas et al (2009). Other than this, data in other parts of Panguil Bay are nonexistent. To address this gap, this study aimed to assess the diversity and abundance of seagrasses with their associated marine invertebrates in the selected coastal areas of Panguil Bay, Philippines. Specifically, it aimed to determine the species composition, percent cover, and abundance of the seagrass species among the four sites; identify and make a list of macroinvertebrates associated with seagrasses; compare the diversity, abundance of seagrass beds and associated macroinvertebrates; and determine the physicochemical parameters such as water temperature, pH, salinity, and dissolved oxygen (DO).

The data collected through this study serves as an updated report regarding the diversity, abundance, and distribution of seagrasses and their associated marine macroinvertebrates in the selected coastal areas of Panguil Bay. Additionally, it serves as baseline information for future research, management strategies, and conservation efforts in the area.

Material and Method

Data gathering procedure. Before the actual assessment, a signed letter from the researchers was submitted to the Local Government Unit (LGU) in the Municipalities of Kolambugan, Tubod, Baroy, Lanao del Norte, and Municipality of Clarin, Misamis Occidental, addresed to the Head of the Municipality, and Barangay Councils. This letter formally requested permission to conduct a study and access specific areas in the mentioned municipalities. Additionally, a preliminary evaluation was conducted to assess the location of sampling sites.

Description of the study sites. This study was conducted in the coastal waters of Panguil Bay (7° 56' to 8° 04' N, 123° 36' to 123° 46' E), Southern Philippines (Figure 1). The current survey was conducted on the same sites surveyed in the past. Panguil Bay is an arm of Iligan Bay in Northwestern Mindanao, Philippines. It is one of the richest bodies of water in the Philippine Archipelago, covering a total water area of 18,000 hectares and serving as the natural boundary separating the Zamboanga Peninsula from the rest of the island of Mindanao. It is shaped like a canine tooth and has an irregular coastline that measures about 112 km. The mouth exits into the larger Iligan Bay and is the deepest portion (57.50 m) while the shallowest area (1.50 m) is in the innermost part of the bay. The water current system and circulation pattern in the Bay were mainly influenced by tidal forcing and, to some extent, by strong seasonal monsoon winds (Gorospe & Prado 1992; Canini et al 2013). 29 rivers and 46 minor tributaries transport nutrients and sediments into the bay. The freshwater contribution from tributaries was estimated to reduce the flushing time of bay water in 9 days (Gorospe & Prado 1992).

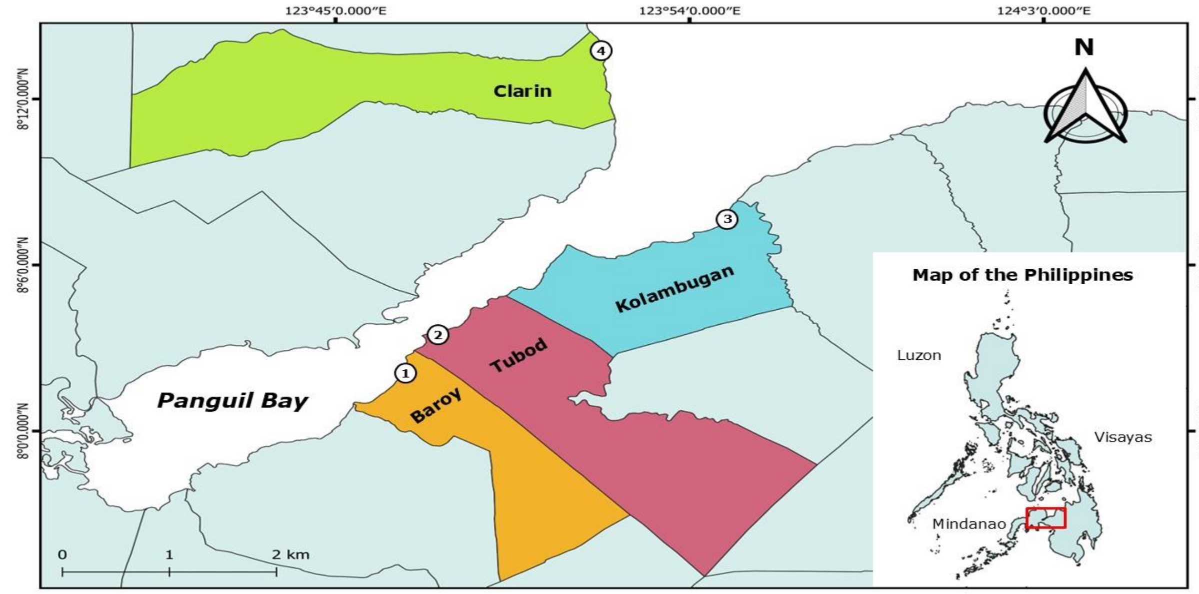

Figure 1. Map of the study area showing the location of Panguil Bay and the four (4) sampling sites: Barangay (Brgy.) Kulasihan, Kolambugan (Site 1), Brgy. Poblacion, Tubod (Site 2), Brgy. San Juan, Baroy (Site 3), and Brgy. Lupagan, Clarin (Site 4).

Four sampling sites were established on the intertidal flats of Panguil Bay (Figure 2). These four sites were reported to have the highest seagrass cover in the past (Roxas et al 2009). Site 1 is located in Barangay Kulasihan, Kolambugan, Lanao del Norte (8° 07' 20" N, 123° 55' 39 E). Fish cages are positioned a few meters away from the seagrass ecosystem. This ecosystem is adjacent to a mangrove area, creating a complex intertidal ecosystem. Gleaners were also observed in the area, collecting edible macroinvertebrates such as mollusks. This activity highlights the direct human use of the seagrass ecosystem for subsistence purposes. Additionally, a few residential houses near the area indicate a small but established human presence. Site 2 is established in Barangay Poblacion, Tubod, Lanao del Norte (8° 03' 02” N, 123° 47' 37” E). This area features numerous residential houses along the coast. It is a well-known gleaning spot for the locals. In fact, during field sampling, several gleaners were noted to harvest edible mollusks for personal consumption. To the west of the site, approximately 100 meters away, is the Sagadan River. Mangroves are also present along the shoreline in this site. Additionally, the under construction Panguil Bay, which will soon connect Tangub City, Misamis Occidental, and Tubod, Lanao del Norte is also found near the area. This bridge project is expected to significantly reduce travel time, stimulate economic growth, and improve transportation links between the provinces of Northern and Central Mindanao and the Zamboanga Peninsula. Site 3, positioned at Barangay San Juan, Baroy, Lanao del Norte (8° 01' 51" N, 123° 46' 44" E). This site is known for its sunset view and has become a popular destination for local tourists, leading to increased human activity. The seagrass ecosystem is situated a few meters from the constructed cafe, boardwalk and several cottages. In addition to the seagrass bed, mangroves are also present along the shoreline in this site. The seagrass meadows are interspersed with patches of bare substrate, indicating possible habitat degradation. Moreover, significant quantities of macroplastics were observed throughout the area, including plastic bottles, bags, and other packaging materials. These pollutants are likely linked to the influx of tourists and the inadequate disposal of waste. Site 4 is situated in Barangay Lupagan, Clarin, Misamis Occidental (8° 13' 24" N, 123° 51' 33" E). This area presents a unique setting where the tourism industry flourishes alongside traditional gleaner communities and vital mangrove ecosystems. Despite being home to several resorts and tourists, there is no visible garbage negatively impacting the ecosystems, indicating that it is well-managed by local residents. Few gleaners were seen around the area, likely because the residential houses are not near the site. Smith & Johnson (2020) emphasized the importance of traditional livelihoods, such as gleaning, in sustaining coastal communities.

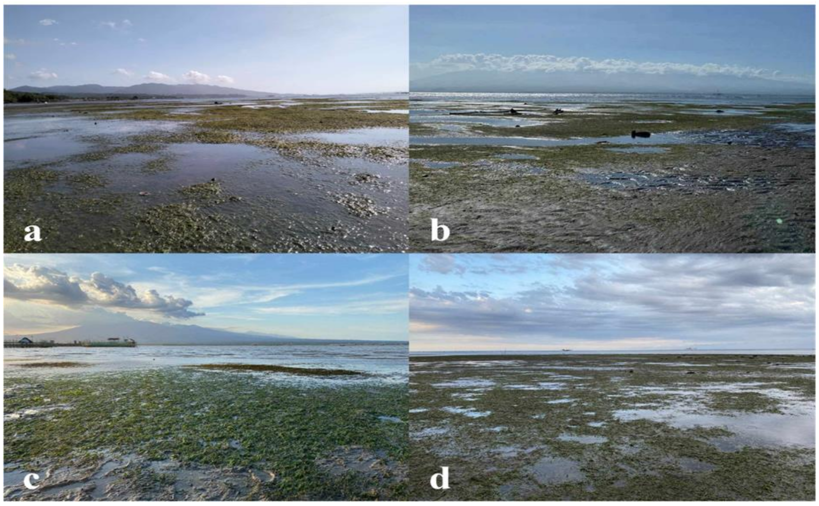

Figure 2. Seagrass beds in the 4 sampling sites of Panguil Bay: (a) site 1, Brgy. Kulasihan, Kolambugan, Lanao del Norte; (b) site 2, Brgy. Poblacion, Tubod, Lanao del Norte; (c) site 3, Brgy. San Juan, Baroy, Lanao del Norte; and (d) site 4, Brgy. Lupagan, Clarin, Misamis Occidental, Philippines.

Assessment of seagrasses. This study followed a standardized field sampling design adapted from English et al (1997) and McKenzie et al (2008) using transect-quadrat method. At each sampling site, three transect lines were established perpendicular to the shore, with 30 m intervals between transects. Eleven (11) 0.5 m x 0.5 m quadrats were placed 5 m apart along each transect line. Within each quadrat, all seagrass species present were identified on the spot up to species level using field guide manuals by McKenzie et al (2003) and the classification system used by Fortes (2013). The estimation of the percent cover for each seagrass species found in each quadrat was recorded through visual estimates, using a photo guide representing various seagrass cover conditions by McKenzie et al 2003, (Figure 3). The McKenzie's Guide for Seagrass Percentage Coverage Standards (2003) provides a solid foundation for methodological consistency and accuracy. Purposive sampling was done in all quadrats in each transect, early morning, and during low tides.

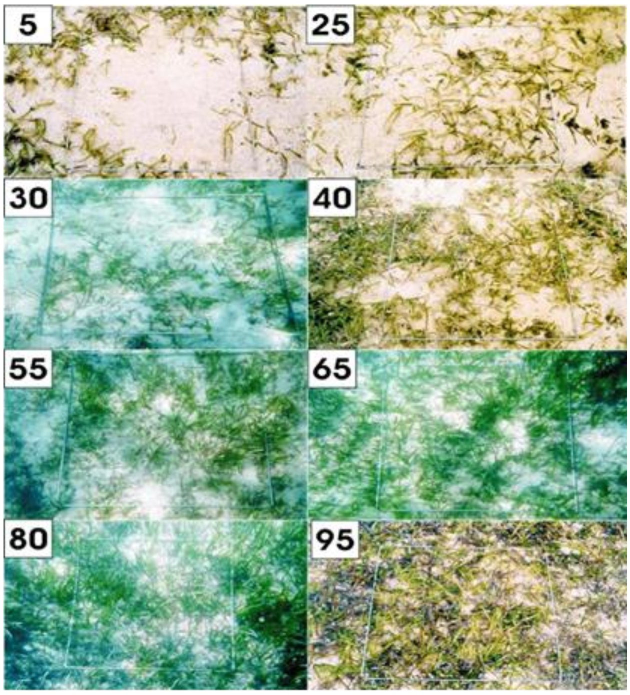

Figure 3. Guide for seagrass percent cover standards by McKenzie (2003).

Seagrass conditions. After the assessment of the seagrass cover through visual observation, the result refers to the Standard Criteria for Damage and Guidelines for Determining the status of Seagrass, as referred to by Reyes et al (2023), presented in Table 1. Standardized data collection and analysis methods were used, which improved the results' reliability and comparability.

Table 1

The standard for damage and guidelines for determining the status of seagrass (Reyes et al 2023)

Description	*Condition*	*Coverage*
Good	Healthy	> 60%
Moderate	Less healthy	30-59.9%
Bad	Poor	< 29.9%

These criteria categorize seagrass conditions as good (>60%), moderate (30-59.9%), and poor (<29.9%), providing a clear framework for interpreting seagrass health and guiding conservation efforts (Orth et al 2006). These standards not only help in the accurate monitoring of seagrass meadows but also help in identifying areas that require immediate restoration and protection efforts. Healthy seagrass beds, defined by coverage of 60% or more, promote high biodiversity, improve water quality, and stabilize sediments (Waycott et al 2009). Low seagrass coverage (<29.9%) can cause erosion and loss of habitat for marine life. Thus, consistent and reliable assessment methods are required to effectively manage and conserve these critical ecosystems.

Assessment of macroinvertebrates. The macroinvertebrate was assessed using the same transect laid for the seagrass survey. The approach for collecting macroinvertebrates employed a belt-transect method, based on the study conducted by Fortaleza et al (2020), with slight modifications. The observation corridor along the transect was 1 meter to the left and right of the transect, covering a census area of 100 m^2 per transect. Within the 100 m^2 area, the visible macroinvertebrates found were collected. This was done on foot as the sampling occurred during low tide. All collected individuals were placed in a labeled big container containing seawater and brought to the shore for photographing, counting, and identification. After this, all individuals of macroinvertebrates were released alive back into the wild. Macroinvertebrates were identified up to species level by external morphological examination using available published references (Fortaleza et al 2020; Arabaca et al 2022; Arriesgado et al 2022) and "A Field Guide to the Marine Invertebrates Occurring on Tropical Pacific Coral Reefs, Seagrass Beds and Mangroves" by Colin & Arneson (1995), and "Field Guide to Cryptic Marine Invertebrates of the Philippines: A Sample of Biodiversity from Autonomous Reef Monitoring Structures" by Moews-Asher et al (2018). In addition, each organism was classified taxonomically based on the World Register of Marine Species (WoRMS 2024).

Water quality and sediment composition. Determination of the physicochemical parameters were done *in situ*. Temperature, pH, and salinity were measured using the 7-in-1 water quality tester C-600 (RC Yago, Shenzen, China), while the dissolved oxygen was measured using a DO analyzer D09100 (made in China). The measurements of these physicochemical parameters included three replicates taken in each of the following: Quadrat 1 (first quadrat: 0 m), Quadrat 6 (middle quadrat: 25 m), and Quadrat 11 (last quadrat: 50 m), resulting in a total of 27 replicates for each site. The composition of marine sediment, it was assessed by digging the fingers at a depth of 1 cm at 0 m, 25 m, and 50 m of each transect line to feel the texture. Marine sediment was described by noting the grain size in the order of dominance (e.g., sand, fine sand, coarse sand, mud, and gravel). The manual for describing marine sediment composition by McKenzie (2007) for seagrass watch was used to distinguish among: mud if it has a smooth and sticky texture; fine sand if it has a fairly smooth texture and with some detectable roughness;

sand, if it has a rough grainy texture and particles that are distinguishable; gravel if it has a very coarse texture with some small stones (McKenzie 2007).

Data analysis. The data recorded was transcribed in Microsoft Excel spreadsheet 2021. The following formulae were used to calculate population parameters, following English et al (1997).

For seagrass average percent cover (C%):

C (%) = total percent cover of species per transect/no. of quadrats

For seagrass and macroinvertebrates relative abundance (RA):

RA (%) = (individual species count/total species count) × 100

For macroinvertebrates density (D):

D = number of individuals/sampled area (m^2)

Additionally, to determine species richness, species evenness, and Shannon diversity indices of macroinvertebrates, Paleontological Statistics (PAST) software was employed (Hammer & Harper 2001). A non-parametric Kruskal-Wallis Test was also used to determine whether there is a significant difference in the abundance of macroinvertebrate species among the sampling sites, with a significance level, P of 0.05 (Brazas & Lagat 2022).

Results and Discussion

Seagrass composition of seagrass. A total of 6 seagrass species from 2 families: Cymodoceaceae and Hydrocharitaceae, were identified at 4 sampling sites in Panguil Bay (Table 2). These *include Cymodocea rotundata*, *Cymodocea serrulata*, *Syringodium isoetifolium*, *Enhalus acoroides*, *Halophila ovalis*, and *Thalassia hemprichii*. The most common species are *Cymodocea rotundata* and *Syringodium isoetifolium*, both belonging to the family Cymodoceaceae. The rest of the species are distinct to each site; *C. serrulata*, *E. acoroides*, *H. ovalis*, and *T. hemprichii.* Site 1 had two (2) species; site 2 and site 3 had three (3) species; and at the site 4, all seagrass species are present. The same number of species were reported in the past studies in the area (Roxas et al 2009; Capin et al 2020; Brazas & Lagat 2022). Numerous complex environmental factors affect the existence of seagrass in a given area. These include the characteristics of sediment (substrates), the hydrodynamics of the area, human perturbation, nutrient influx (nitrogen and phosphorus) (Borum et al 2004), and other environmental and anthropogenic factors that influence its abundance and existence.

Table 2

Species composition and distribution of seagrass species among four sampling sites in Panguil Bay, Philippines

Family	*Species name*	*Site*			
		1	*2*	*3*	*4*
Cymodoceaceae	*Cymodocea rotundata* (Ascherson & Schweinfurth, 1870)	✓	✓	✓	✓
	Cymodocea serrulata (R. Brown) Ascherson & Magnus, 1870	×	×	×	✓
	Syringodium isoetifolium (Ascherson) Dandy, 1939	✓	✓	✓	✓
Hydrocharitaceae	*Enhalus acoroides* (Linnaeus F.) Royle, 1839	×	✓	×	✓
	Halophila ovalis (R. Brown) J.D. Hooker, 1858	×	×	✓	✓
	Thalassia hemprichii (Ehrenberg) Ascherson, 1871	×	×	×	✓
	Total number of species	2	3	3	6

(✓) present; (×) absent

The seagrass composition was comparable to those in Lopez Jaena, Misamis Occidental with 8 species of seagrass (de Guzman et al 2009); Dasol, Pangasinan with 6 species (Reyes et al 2023) and Maribojoc Bay, Bohol, with 7 species (Mascarinas & Otadoy 2022). Images of these seagrass species are presented in Figure 4.

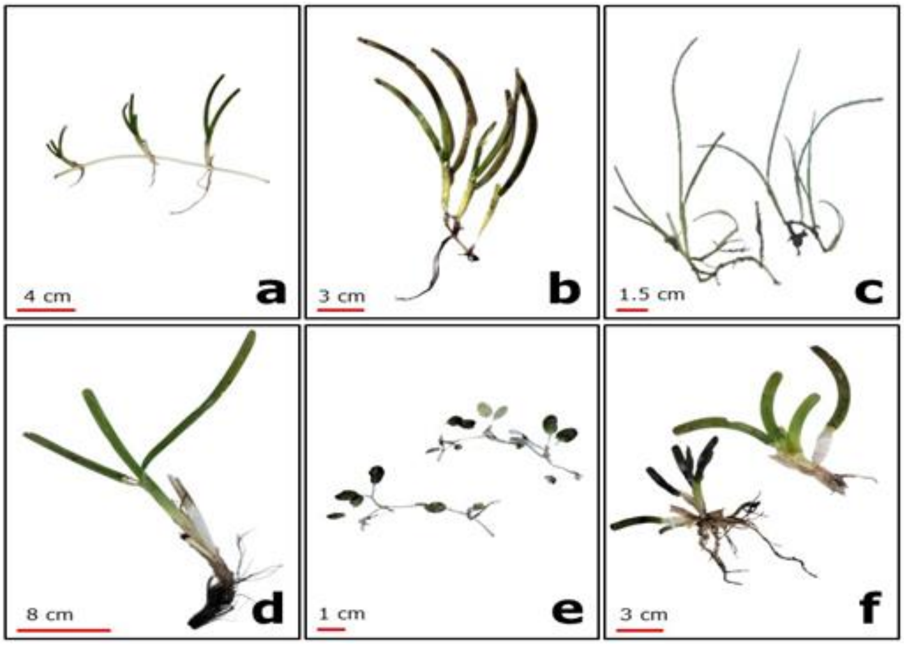

Figure 4. Images of seagrass species found within the four sampling sites of Panguil Bay. (a) *Cymodocea rotundata*, (b) *Cymodocea serrulata*, (c) *Syringodium isoetifolium*, (d) *Enhalus acoroides*, (e) *Halophila ovalis*, (f) *Thalassia hemprichii.*

Seagrass percent cover and relative abundance. The study investigated the percent cover and relative abundance of seagrass species across four different sites. The results revealed variations in both parameters among the sites, indicating spatial heterogeneity in seagrass communities presented in Table 3. The average percent cover of seagrass at Kolambugan and Clarin is 34 and 39%, respectively, indicating moderate and less healthy conditions. At the same time, Tubod and Baroy are in poor condition, with averages of 10% and 15%, respectively.

Table 3

Average percent cover, identified species, percent cover and relative abundance of seagrasses in the four selected coastal areas of Panguil Bay, Philippines

Site	*Average cover (%)*	*Identified species*	*Cover per species (%)*	*Relative abundance (%)*
(1) Kolambugan	34	*S. isoetifolium*	63	93
		C. rotundata	5	7
(2) Tubod	10	*S. isoetifolium*	5	19
		C. rotundata	15	51
		E. acoroides	9	30
(3) Baroy	15	*S. isoetifolium*	10	23
		C. rotundata	33	71
		H. ovalis	3	6
(4) Clarin	39	*S. isoetifolium*	55	28
		C. rotundata	39	20
		H. ovalis	35	18
		C. serrulata	42	21
		T. hemprichii	23	12
		E. acoroides	3	2

In Kolambugan, Lanao del Norte, the average percent cover was 34%. *S. isoetifolium* dominated the area with a percent cover of 63% and a relative abundance of 93%, indicating its high abundance and dominance within the community. *C. rotundata* constituted a smaller proportion of the community with a percent cover of 5% and a relative abundance of 7%. Tubod, Lanao del Norte exhibited a lower average percent cover of 10%. *C. rotundata* displayed the highest percent cover at 15% with a relative abundance of 51%, followed by *E. acoroides* at 9% with a relative abundance of 30%. *S. isoetifolium* had the lowest percent cover at 5% with a relative abundance of 19%, suggesting a less dominant presence compared to Kolambugan. Additionally, Baroy, Lanao del Norte showed an average percent cover of 15%, with *C. rotundata* being the most dominant species, accounting for 33% of the cover and a relative abundance of 71%. *S. isoetifolium* had a lower percent cover at 10% with a relative abundance of 23%, while *H. ovalis* contributed 3% accounting to 6% of relative abundance to the community. The highest average percent cover of 39% was recorded in Clarin, Misamis Occidental, where *S. isoetifolium* remained dominant with a percent cover of 55% and a relative abundance of 28%, followed in decreasing order by *C. serrulata* at 42% (21% relative abundance), *C. rotundata* at 39% (20% relative abundance), *H. ovalis* at 35% (18% relative abundance), *T. hemprichii* at 23% (12% relative abundance), and *E. acoroides* at 3% (2% relative abundance). The findings in Clarin, Misamis Occidental, aligns the findings of Reyes et al (2023), indicating the continued prevalence of *S. isoetifolium* in this coastal area. Moreover, the presence of multiple seagrass species, including *C. serrulata*, *H. ovalis*, *and T. hemprichii*, highlights the biodiversity of Clarin's seagrass communities, in line with the comprehensive assessment conducted by Reyes et al. (2023). Thus, this reinforces the importance of considering localized ecological factors in understanding seagrass community dynamics. By building upon the findings of Reyes et al (2023) and integrating additional field data, this study further examines the complex interactions shaping the coastal ecosystems in Panguil Bay, Northern Philippines.

The average percent cover of seagrasses in Panguil Bay was compared across four sampling sites, over multiple years, as presented in Table 4. In 2005, the percent cover of seagrasses varied among the sampling sites, with Kulasihan recording 28.85%, Baroy 16.93%, Tubod 22.60%, and Clarin 42.04%. However, the recently conducted study showed notable changes in seagrass percent cover. Kulasihan exhibited an increase to 39% (an increase of 5%), while Baroy and Clarin showed a slight decrease to 15.35% and 39%, respectively. Among all sampling sites in Panguil bay, Tubod experienced a substantial decline to 10% from 22.60% in 2005, which is equivalent to a 55.75% reduction. The survey method conducted in 2005 was merely a rapid assessment using the transect-quadrat method as described by English et al (1997), with some modifications, to estimate the cover, frequency, and density of every species present in the area (Roxas et al 2009), which is almost the same as the approach used in this study. Thus, the differences in results of percent cover in the year 2005 are comparable to the results in the present study. This suggests that the differences could be attributed to anthropogenic activities, growing populations leading to numerous residential houses near the coast, and other coastal development projects over the years.

Table 4

Average percent cover of seagrasses in Panguil Bay, Philippines in the past years, in 1991 (MSUN 1992), 1995-96 (MSUN 1996) and 2005 (MSUNFSTDI 2006), and in the present study

Site	*Year*			
	1991	*1996*	*2005*	*2024 (present study)*
Kolambugan	18.75%	-	28.80%	34%
Tubod	47.92%	-	22.60%	10%
Baroy	81.11%	10.73%	16.93%	15%
Clarin	-	8.98%	42.04%	39%

Legend: (-) no data

The alarming decline of about 90% in the percent cover at Tubod raised concerns about potential environmental stressors or disturbances impacting seagrass habitats in the area. Seagrasses are sensitive to changes in water quality, sedimentation rates, and physical disturbances, which can influence their distribution and abundance (Orth et al 2006). High sedimentation rates, for instance, can smother seagrass beds and inhibit light penetration, decreasing seagrass cover over time. This significant reduction underscores the need for targeted monitoring and management efforts to address the area's underlying drivers of seagrass loss. Overall, the declining seagrass ecosystems in most sites in Panguil Bay highlight the urgent need for comprehensive conservation strategies. Effective management practices and environmental protection measures are crucial to mitigating further degradation and promoting the recovery of these vital marine ecosystems.

Species composition of macroinvertebrates. A list of macroinvertebrates collected and identified on the seagrass beds of the intertidal zone among the four sampling sites in Panguil Bay, Philippines is presented in Table 5. A total of 46 macroinvertebrates species from 4 different phyla were recorded, 8 classes and 28 families were recorded (Figure 5).

Table 5

Species composition of macroinvertebrates found in the seagrass beds of selected coastal areas along Panguil Bay, Philippines

Phylum	*Class*	*Family*	*Species name*	*Site*			
				1	*2*	*3*	*4*
Arthropoda	Malacostraca	Diogenidae	*Clibanarius longitarsus* (De haan, 1849)	✓	✓	✓	✓
		Portunidae	*Scylla olivacea* (Herbst, 1796)	✓	×	✓	✓
	Thecostraca	Balanidae	*Amphibalanus amphitrite* (Darwin, 1854)	×	✓	×	✓
Cnidaria	Hexacorallia	Actiinidae	*Anthopleura artemisia* (Pickering in Dana, 1846)	×	×	×	✓
Echinodermata	Asteroidea	Oreasteridae	*Protoreaster nodosus* (Linnaeus, 1758)	×	×	×	✓
			Protoreaster nodulosus (Perrier, 1875)	×	×	×	✓
		Ophidiastiridae	*Linckia laevigata* (Linnaeus, 1758)	×	×	×	✓
		Astropectinidae	*Astropecten spinulosus* (Philippi, 1837)	×	×	×	✓
	Echinoidea	Diadematidae	*Diadema antillarum* (Philippe, 1845)	×	×	×	✓
		Toxopneustidae	*Tripneustes gratilla* (Linnaeus, 1758)	×	×	×	✓
		Echinometridae	*Echinometra mathaei* (Blainville, 1825)	×	×	×	✓
	Ophiuroidea	Ophiuroidea	*Ophiocoma erinaceus* (Muller &Troschel, 1842)	×	×	×	✓
Molluska	Bivalvia	Arcidae	*Anadara antiquata* (Linnaeus, 1758)	✓	✓	✓	✓
		Veniridae	*Anomalocardia squamosa* (Linnaeus, 1758)	×	✓	✓	×
			Dosinia elegans (Conrad, 1843)	×	✓	✓	×
			Gafrarium pectinatum (Linnaeus, 1758)	✓	✓	✓	×
			Marcia hiantina (Lamarck, 1818)	×	✓	✓	×
			Marcia japonica (Gmelin, 1791)	×	✓	✓	×
			Meretrix lyrata (G. B. Sowerby II, 1851)	×	✓	✓	×
		Lucinidae	*Codakia tigerina* (Linnaus, 1758)	×	✓	×	×
		Cyrenoididae	*Geloina expansa* (Mousson, 1849)	×	✓	×	×
		Mytilidae	*Mytella strigata* (Hanley, 1843)	×	✓	✓	×
		Tellindae	*Nitidotellina nitens* (Deshayes, 1855)	×	✓	×	×
			Serratina capsoides (Lamarck, 1818)	×	✓	✓	×
	Gastropoda	Architectonicidae	*Architectonica modesta* (R.A. Philippe, 1849)	×	×	×	✓
		Neritidae	*Clithon oualaniense* (Lesson, 1831)	×	×	✓	✓

Phylum	Class	Family	Species name	Site			
				1	2	3	4
			Neritina parallela (Lamarck, 1816)	×	✓	×	✓
		Elobiidae	*Ellobium aurisjudae* (Linnaeus, 1758)	×	×	×	✓
		Nassariidae	*Hebra corticata* (A. Adams, 1852)	✓	×	✓	✓
			Nassarius graphiterus (Hombron & Jacquinot, 1848)	✓	✓	✓	✓
			Nassarius mutabilis (Linnaeus, 1758)	✓	✓	✓	✓
			Nassarius olivaceus (Bruguiere, 1789)	✓	×	×	✓
			Nassarius pullus (Linnaues, 1758)	✓	×	✓	✓
		Littorinidae	*Littoraria ardouiniana* (Heude, 1885)	✓	✓	×	×
			Littoraria intermedia (R.A Philippe, 1846)	✓	✓	×	✓
			Littoraria pallescens (R.A Philippe, 1846)	✓	✓	×	✓
		Naticidae	*Natica limbata* (A. d'Orbigny, 1837)	✓	✓	✓	×
			Polinices uber (Valenciennes, 1832)	✓	✓	✓	✓
		Olividae	*Oliva sericea* (Roding, 1798)	×	×	×	✓
		Pyramidellidae	*Otopleura auriscati* (Holten, 1802)	×	×	✓	×
		Potamididae	*Pirenella alata* (R.A Phillipi, 1849)	×	×	✓	×
		Tegulidae	*Tectus fenestratus* (Gmelin, 1791)	✓	✓	×	✓
		Trochidae	*Trochus niloticus* (Linnaeus, 1767)	×	×	×	✓
			Umbonium elegans (Kienner, 1838)	×	✓	×	×
			Umbonium giganteum (Lesson, 1832)	×	✓	×	×
			Umbonium vestiarium (Linnaeus, 1758)	×	✓	×	×
Total number of species				15	26	20	28

(✓) present; (×) absent

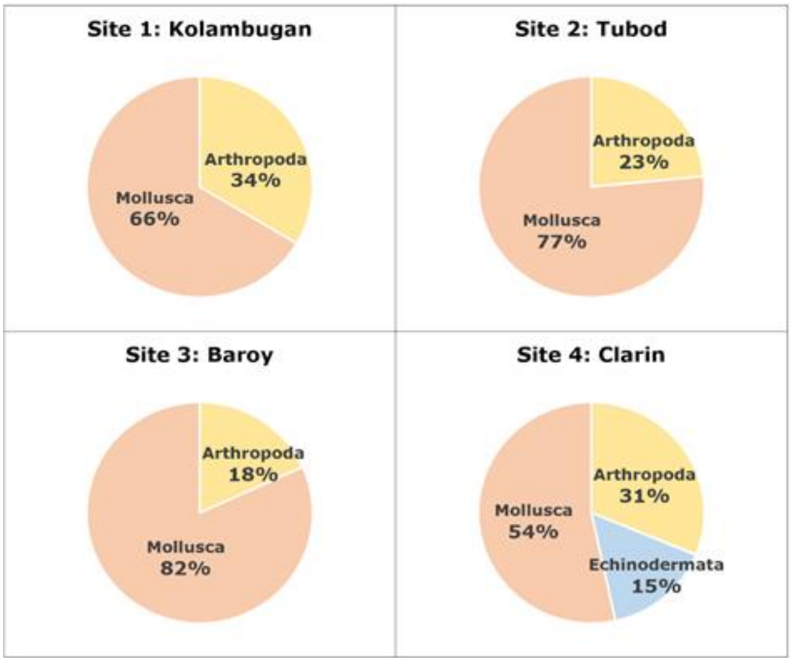

Figure 5. Percentage distribution of phyla identified in the sampling sites in Panguil Bay, Philippines.

In site 1, the phylum Mollusca dominates the majority of macroinvertebrates (66%) comprising 12 species, and followed by Arthropoda (34%) with 2 species. In site two, the most abundant species belongs to the phylum Mollusca (77%) with 24 species, followed by phylum Arthropoda (23%) with 2 species. Phylum Mollusca was revealed to be the most abundant in site 3 (82%) consisting of eighteen (18) species, and followed by phylum Arthropoda (18%) with 2 species. Lastly, in site 4, phylum Mollusca was found to be the most frequently encountered macroinvertebrate (54%) with 16 species, followed in decreasing order by Arthropoda (31%) comprising of 3 species, and Echinodermata (15%) with 8 species. Across all sampling sites, the most dominant macroinvertebrate species are under Phylum Mollusca, with Class Gastropoda and Class Bivalvia. The dominance of these two classes is due to their ability to maintain their population by producing many larvae (meroplankton) (Irma & Sofyatuddin, 2012). Additionally, they are keystone species or ecosystem engineers in the marine ecosystem, and they can be herbivores, predators, scavengers, and filter feeders (Mahilac et al 2023). Moreover, within the benthic community, the phylum Mollusca is one of the most diverse and widespread in the marine environment (Rueda et al 2009), they are commonly found in seagrass meadows and tend to be richer in species than soft-bottoms (Riera et al 2012; Urra et al 2013).

Species richness and diversity. The diversity indices for the macroinvertebrate communities at four sites reveal differences in species richness, abundance and evenness which are critical for understanding the ecological status of these sites presented in Table 6.

Table 6

Diversity profile of macroinvertebrates in the four sites of Panguil Bay, Philippines

Diversity index	*Sites*			
	1 (Kolambugan)	*2 (Tubod)*	*3 (Baroy)*	*4 (Clarin)*
Taxa (S)	15	26	20	28
Individuals	623	579	697	771
Dominance (D)	0.1618	0.07601	0.2445	0.08481
Shannon (H’)	2.201	2.853	2.031	2.859
Equitability (J)	0.8128	0.8755	0.6779	0.8581

Site 1 shows moderate species diversity with a Shannon index (*H’*) of 2.201 and 15 taxa. The equitability (*J*) is low (0.08128), indicating an uneven distribution of individuals among species, where a few species dominate. The dominance index of 0.1618 supports this, reflecting a moderate dominance by some species. The number of individuals is moderate compared to other sites.

Site 2 is high in diversity with a Shannon index (*H’*) of 2.853 and 26 taxa. It has also a high equitability (*J*) of 0.8755, indicating a very even distribution of individuals across different species. The low dominance index (*D*) of 0.07601 confirms a minimal dominance by any single species. Despite having the fewest individuals (579) compared to other sites, the high species richness and evenness suggest a stable ecosystem. The high macroinvertebrate diversity and evenness in the area, despite having low seagrass diversity and ongoing construction disturbances could indicate that some species can thrive in disturbed conditions, while others, particularly those sensitive to environmental changes, may decline.

Site 3 displays lower diversity with a Shannon Index (*H’*) of 2.031 and a moderate number of taxa (20). The equitability (0.6779) is higher than Site 1 but lower than Sites 2 and 4, indicating a more balanced distribution of individuals among species. However, the dominance index (*D*) of 0.2445 is relatively high, suggesting that a few species are particularly dominant. The number of individuals is higher than Site 2 but lower than Site 4.

Site 4 is comparable to Site 2 in terms of high diversity, with a Shannon index (*H’*) of 2.859 and the highest number of taxa (*S*) which is 28. The equitability (*J*) of 0.8581 is also high, indicating a well-distributed population among species. The dominance index 0.08481 is low, suggesting a minimal dominance by any species. This site has the highest number of individuals (771), further supporting its status as a highly diverse and stable ecosystem.

These findings have significant implications for the management and conservation of aquatic ecosystems. High diversity and evenness generally indicate healthy environments that can sustain a wide range of species. In contrast, lower diversity and higher dominance may signal ecological disturbances or habitat degradation (Magurran

2004). Efforts to protect and enhance biodiversity at these sites should focus on mitigating the stressors and maintaining or improving the habitat quality.

Abundance and density of macroinvertebrates. The top marine macroinvertebrate species with an abundance of ≥9% at all sites are shown in Figure 6. In Kolambugan (site 1), *Clibanarius longitarsus* (32.7% or 2.04 ind m^{-2}) was the most abundant, followed in decreasing order by *Nassarius pullus* (15.4% or 0.96 ind m^{-2}), *Nassarius graphiterus* (10.1% or 0.63 ind m^{-2}), and *Anadara antiquata* (9.1% or 0.57 ind m^{-2}). In Tubod (site 2), *C. longitarsus* (17.6% or 1.02 ind m^{-2}) was found to be the most frequently encountered marine macroinvertebrate species, followed by *Umbonium elegans* (9.5% or 0.55 ind m^{-2}) and *A. antiquara* (9% or 0.52 ind m^{-2}). A mollusk, *Clithon oualaniense* (45.8% or 3.19 ind m^{-2}), was revealed to be the most abundant species in Baroy (site 3), followed by *C. longitarsus* (14.2% or 0.99 ind m^{-2}). *C. longitarsus* (21.3% or 1.64 ind m^{-2}) was the most abundant species found in Clarin (site 4), followed by *C. oualaniense* (9.3% or 0.74 ind m^{-2}). The remaining marine macroinvertebrate species were ≤9% of the overall population. Across all sites, *C. oualaniense* was the most abundant marine macroinverterbrate species found. This species, commonly known as the ladder horn snail, is known for its herbivorous feeding habits and its role in controlling algal populations in intertidal habitats (Lee et al 2020), typically inhabits muddy sandflats and seagrass areas (Chou & Tan 2008). *Clibanarius longitarsus*, consistently present across all sites, is commonly known as the hermit crab, and is known for its adaptability to various habitats and its role in sediment bioturbation processes (Lim et al 2018). *Nassarius pullus* and *Nassarius graphiterus*, commonly known as the black nassa and graphite nassa, respectively, are marine gastropod mollusks in the family Nassariidae. They actively forage and also feed on dying invertebrates and fish carcasses (Aloy et al 2011). They are typically found on sandy shores, particularly near depressions formed during low tides to avoid desiccation (Proud 1977) and in seagrass beds (Puturuhu 2004). *Umbonium elegans*, a marine gastropod mollusk in the family Trochidae, the top snails, occurred in very high numbers in the lower intertidal areas (Dolorosa & Dangan-Galon 2014) in seagrass beds and mangrove areas (Al-Asif et al 2020). *Anadara antiquata* is a marine bivalve mollusk, also known as antique ark, from the Arcidae family. Members of this family are filter feeders inhabiting intertidal waters with sandy mud substrates at a water depth of between 2 and 20 m (Putri et al 2020) or rubble semi-buried in seagrass beds (Graham Oliver et al 2004).

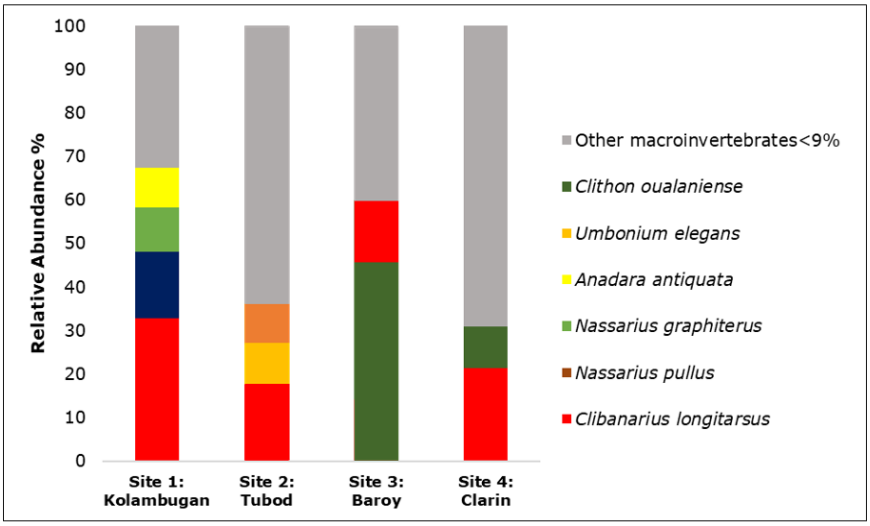

Figure 6. Relative abundance and density of the marine macroinvertebrate species representing ≥9% of the entire population in all sites in Panguil Bay, Philippines.

Comparing the relative abundance and density of marine macroinvertebrate species among sites revealed no significant difference, as indicated by the Kruskal Wallis Test ($p>0.05$). This implies that the overall abundance of marine macroinvertebrate species among different sites was predominantly similar or comparable. This similarity might be due to the shared habitat of seagrass meadows, where this species is commonly found. Moreover, mangroves are also present along the shoreline in all sites. Additionally, all sites are similarly affected by human activities such as fishing, pollution, or coastal development, and these factors could homogenize the macroinvertebrate communities. Lastly, the macroinvertebrate species present might be adaptive generalists capable of thriving in various conditions, leading to their ubiquitous presence across all sites.

Environmental conditions. Physicochemical parameters and sediment structure were measured and recored in all sampling sites of Panguil Bay, Philippines, as shown in Table 7. At site 1 (Kolambugan), the water temperature ranged from 26.5 to 27.1°C, while the bottom water pH ranged from 7.71 to 7.97, falling within the acceptable range set by the Philippine Department of Environmental and Natural Resources (DENR) Administrative Order No. 2016-08, which specifies a range from 6.5 to 8.5. Additionally, the salinity values obtained at site 1 ranged from 30.1 to 31.8 ppt, which is within the standard values set by the DENR, specifying not less than 30 ppt, the lower salinity being attributed to the mixing of seawater with freshwater from the Kulasihan River. The dissolved oxygen levels ranged from 6.2 to 7.4 g mL^{-1}, meeting the standard values set by the DENR, with a minimum of 5 g mL^{-1}. Furthermore, the substrate at Site 1 was classified as sandy. At Site 2 (Tubod), water temperature values ranged from 25.9 to 27°C, with field sampling conducted during the early morning to capture cooler temperatures before the sun reached its peak intensity. The bottom water pH ranged from 7.28 to 7.37, falling within the acceptable range set by the DENR. The salinity, ranging from 26.6 to 27.2 ppt, is likely influenced by freshwater input from the nearby Sagadan River. Dissolved oxygen values obtained at Site 2 ranged from 6.8 to 6.9 g mL^{-1}, meeting the standard values set by the DENR. Additionally, the sediment structure of the site is characterized as sandy. At Site 3, situated in Baroy, water temperature ranged from 24.7 to 28.5°C, with cooler temperatures observed due to sampling conducted in the early hours of the day around 5:00 AM, when the sun was still rising. The bottom water pH ranged between 7.36 and 7.45, falling within the acceptable range set by the DENR. Salinity values recorded ranged from 29.8 to 31.3 ppt, meeting the DENR's acceptable range. Salinity tends to be lower in coastal areas due to freshwater inputs from streams and uplands. Dissolved oxygen values obtained at Site 3 ranged from 6.5 to 8.1 g mL^{-1}, within the standard values set by the DENR. Additionally, the sediment structure of this site is characterized as sandy. At Site 4, situated in Clarin, water temperature ranged from 27.8 to 29.6°C, with sampling conducted early in the morning resulting in cooler temperatures. The bottom water pH ranged from 7.77 to 8.61, indicating a slightly alkaline condition that falls within the Philippine Standard for Marine and Waste Waters (DENR Administrative Order No. 2016-08). Salinity values obtained at Site 4 ranged from 30.3 to 32.9 ppt, possibly influenced by freshwater input from uplands and streams, which may have diluted the marine waters' salinity content. Dissolved oxygen measured at Site 4 ranged from 6.2 to 8.9 g mL^{-1}, meeting the standard values set by the DENR. Additionally, the substrate at Site 4 was categorized as sandy.

Table 7

Range of values for the environmental parameters and sediment structure in the four sites of Panguil Bay, Philippines

Environmental parameters	*Site*			
	1	*2*	*3*	*4*
Temperature (°C)	26.5-27.1	25.9-27	24.7-28.5	27.8-29.6
pH	7.71-7.97	7.28-7.37	7.36-7.45	7.77-8.61
Salinity (ppt)	30.1-31.8	26.6-27.2	29.8-31.3	30.3-32.9
Dissolved oxygen (g mL^{-1})	6.2-7.4	6.8-6.9	6.5-8.1	6.2-8.9
Sedimentary structure	Sandy	Sandy	Sandy	Sandy

The environmental parameters measured at the four sites in Panguil Bay (Kolambugan, Tubod, Baroy, and Clarin) all fall within the acceptable ranges set by the Philippine Standard for Marine and Waste Waters (DENR Administrative Order No. 2016-08) according to DENR-EMB (2016). Water temperature values are low because the field samplings were conducted early in the morning, which means incoming solar radiation was lower, resulting in a low water temperature. Water temperature influences the rate of growth and health of seagrass in the marine environment (McKenzie & Yoshida 2009). The range values of water temperature measured at each sampling site were within the optimal range for seagrass growth. Seawater temperatures above 40°C will stress seagrass, and temperatures above 43°C can lead to seagrass death (McKenzie & Yoshida 2009).The pH levels at all sites are slightly alkaline and falls within the Philippine Standard for Marine and Waste Waters (DENR Administrative Order No. 2016-08), which specifies a range from 6.5 to 8.5. The salinity values measured at all sites are within the standards set by the DENR. Freshwater inputs from nearby rivers and uplands influence the salinity levels, leading to lower salinity values. This freshwater input likely dilutes the marine waters, resulting in reduced salinity. However, the salinity values obtained from all sites in Panguil Bay are tolerable to seagrass growth because this group of marine angiosperms can adapt to a wide range of salinity, from full-strength seawater to either brackish or hypersaline waters (Hemminga & Duarte 2000). Dissolved oxygen levels at all sites are well within the standard values set by the DENR, with a minimum of 5 g mL^{-1}, indicating a good water quality. Furthermore, the sediment structure at all sites is characterized as sandy, which is consistent across the study area.

Conclusions. The water quality parameters in the four sampling sites of the bay may have shown variations in its values, but these are within the tolerable limits for marine waters, favorable for seagrass growth. This study showed that 6 seagrass species from 2 families, namely *Cymodoceaceae* and *Hydrocharitaceae,* were identified at the 4 sampling sites in Panguil Bay. These species included *C. rotundata*, *C. serrulata*, *S. isoetifolium*, *E. acoroides*, *H. ovalis*, and *T. hemprichii.* Clarin, Misamis Occidental has the most diverse and highest seagrass percent cover with an average of 39% and identified six (6) species, compared to other sampling sites in this study. Tubod, Lanao del Norte has the lowest average seagrass percent cover at 10%, with only three identified species, indicating an alarming decline, compared to the previous years. This decline is more likely influenced by the nearby infrastructure projects and growing populations leading to numerous residential houses. Kolambugan, Lanao del Norte, has reported the lowest seagrass diversity, with only 3 identified species and a percent cover of 34%. Overall, results showed a decline of seagrass percent cover in most of the coastal areas of Panguil Bay compared to the previous years. In addition, 46 macroinvertebrate species associated with seagrass from 4 different phyla, 8 classes and 28 families were recorded in the 4 sites of Panguil Bay, Philippines. Clarin was reported as the most ecologically balanced and healthy environment, exhibiting high species richness of macroinvertebrates. Baroy demonstrated a lower diversity and higher dominance of associated macroinvertebrates, indicating a potential environmental stress or factors favoring a few species' dominance.

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