Research Article

Exploring Seagrass Diversity and Associated Flora and Fauna in the Coastal Waters of Northwestern Dumanquilas Bay

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Abstract
The coastal waters of northwestern Dumanquilas Bay, specifically in Vincenzo Sagun, Zamboanga del Sur, harbor ecologically important seagrass meadows that serve as critical habitats for a wide variety of marine flora and fauna. However, these ecosystems are increasingly threatened by human activities and climate change. Despite their importance, scientific information on the composition and distribution of seagrass species and associated biota in the area remains limited, creating challenges for effective conservation. This study examined three sampling stations using a descriptive-quantitative approach and the transect-quadrat method. Each station had a 5×100-meter belt transect surveyed during low tide. Species were identified, photographed, and classified, and biodiversity indices—including the Shannon-Wiener Index, Simpson's Diversity Index, Pielou's Evenness Index, and ANOVA—were used to assess abundance and diversity. Four seagrass species were recorded: *Halodule uninervis*, *Thalassia hemprichii*, *Enhalus acoroides*, and *Halodule pinifolia*. Thirteen fauna and six flora species were also documented, such as *Turris babylonia*, *Astropecten polyacanthus*, and *Caulerpa racemosa*. *T. hemprichii* was the most dominant species. Station 2 had the highest seagrass and fauna richness, while Station 3 showed the highest flora diversity. Overall biodiversity was low, and ANOVA results indicated no significant differences in species abundance across stations. The findings highlight the influence of substrate, light, and environmental factors on species distribution. The study recommends wider research coverage, inclusion of water quality data, conservation of rare species, and stronger community-based management. Long-term monitoring and reinforcing marine protected areas are crucial for preserving seagrass ecosystems and their biodiversity.

Keywords: *marine protected areas, species distribution, biological communities, environmental parameters, biodiversity indices*

Introduction

Seagrass ecosystems are globally recognized as highly productive and ecologically significant coastal habitats, serving as essential components of shallow marine environments. These angiosperms are the only flowering plants capable of thriving in fully marine conditions, occurring widely across tropical and temperate coastlines (Phang, 2000). As members of the Monocotyledonae, seagrasses exhibit grass-like forms and develop extensive root and rhizome systems that securely anchor them to sandy or muddy substrates (Zusron et al., 2015). Their role as primary producers enables them to sustain diverse biological communities by providing food sources, nursery grounds, and foraging habitats for numerous marine organisms. A wide variety of species—including fish, sea urchins, dugongs, and sea turtles—depend on seagrass meadows for their survival and ecological functions (Fortes, 2013; Zusron et al., 2015; Unsworth et al., 2019). Ecologically, seagrasses occupy a distinctive transitional zone between mangrove forests and coral reefs. This location facilitates the exchange of nutrients, organic matter, and organisms among interconnected coastal ecosystems (Fortes, 2013). Beyond their habitat provisioning role, seagrass beds contribute significantly to coastal water quality by stabilizing sediments, minimizing turbidity, and filtering pollutants from the water column (Zulkifli et al., 2021). Their high photosynthetic capacity further contributes to oxygen production and substantial carbon sequestration, making seagrass meadows important natural agents for climate change mitigation. Despite these ecological contributions, seagrass ecosystems remain highly vulnerable to a wide range of anthropogenic pressures, which continue to threaten their survival, particularly in shallow waters where light availability is essential. The degradation of seagrass habitats often results in cascading ecological effects, including the loss of species that rely on these ecosystems.

Dumanquilas Bay, located on the southern Zamboanga Peninsula in western Mindanao, is recognized as a biologically rich marine environment characterized by extensive mangroves, coral reefs, and seagrass beds. The bay, shared by the provinces of Zamboanga del Sur and Zamboanga Sibugay, spans several municipalities and was designated a protected seascape in 1999 under the Dumanquilas Bay Protected Landscape and Seascape. The northwestern portion of the bay, particularly in Vincenzo Sagun, contains ecologically important seagrass meadows; however, these habitats remain insufficiently studied despite increasing environmental pressures. Although seagrass habitats in the area are known to support a range of marine flora and fauna, there is limited scientific information on species composition, associated biota, abundance patterns, and diversity levels. This lack of baseline data restricts effective conservation planning and management. Thus, the primary objective of this study is to establish baseline ecological information on seagrass ecosystems in northwestern Dumanquilas Bay by identifying the existing seagrass species, documenting the associated flora and fauna, determining their relative abundance and diversity, and assessing whether significant differences occur among the sampling stations.

Material and Methods

The study employed a descriptive-quantitative research design to examine the seagrass ecosystems and its associated flora and fauna. This design was used to describe the composition of species and determine the number of individuals present in each identified group. Through this approach, all species encountered were accurately recorded, photographed, and systematically organized for further analysis. The design also enabled the assessment of species abundance, richness, evenness, and diversity across the different sampling stations within the study area.

Site Assessment and Sampling Station Selection

A preliminary site assessment was conducted to identify strategic locations for the sampling stations within the seagrass ecosystem of Vincenzo Sagun, Zamboanga del Sur. This evaluation ensured that selected stations represented the habitat variability within the area and yielded ecologically meaningful data. Three sampling stations were established based on habitat characteristics, accessibility, and representativeness.

Seagrass and Associated Biota Sampling

Seagrass and associated flora and fauna were surveyed using the transect–quadrat method following Short et al. (2001). Three transects, each 50 meters in length, were laid perpendicular to the shoreline and spaced 100 meters apart within each sampling station. At each station, a 5×100-meter belt transect (totaling 500 m^2) was used to assess seagrass composition, richness, abundance, and diversity, along with the associated flora and fauna present within the area.

Researchers identified and recorded all species encountered along the belt transects, documenting individual counts, species richness, abundance, evenness, and overall diversity. Data collection was conducted during low tide to maximize visibility and access to intertidal and shallow subtidal areas, where many seagrass species and associated organisms are more exposed. Conducting surveys at low tide reduced water movement and turbidity, improving accuracy in species observation and identification.

Species Identification and Documentation

Identification of seagrass species and associated flora and fauna followed a systematic procedure, noting each organism's common English name, family, and scientific classification. Field guides and marine biology references were used to support accurate identification. All species encountered were photographed to aid verification, serve as reference material, and support ecological documentation and community-awareness initiatives.

Statistical Analysis

Collected data were analyzed using appropriate statistical tools to evaluate biodiversity across stations. Diversity indices—including the Shannon-Wiener Index, Simpson's Diversity Index (1-D), Pielou's Evenness Index, and analyses conducted through Paleontological Statistics (PAST)—were used to assess species richness, abundance, diversity, and evenness. One-way ANOVA ($\alpha = 0.05$) was applied to test for significant differences in species abundance across stations. Results were summarized and presented in tables and figures.

Result and Discussion

Distribution and Ecological Presence of Seagrass Species

Table 1 presents the distribution of seagrass species recorded at the study sites in northwestern Dumanquilas Bay, in Vincenzo Sagun, Zamboanga del Sur.

Table 1. Seagrass Occurrence at Study Sites in Northwestern Dumanquilas Bay, Vincenzo Sagun, Zamboanga del Sur, Philippines

Local Name	Scientific Name	Family Name	Station		
			1	2	3
Needle seagrass	*Halodule uninervis*	Potamogetonaceae	✓	✓	✓
Pacific turtlegrass	*Thalassia hemprichii*	Hydrocharitaceae	✓	✓	✓
Tape seagrass	*Enhalus acoroides*	Hydrocharitaceae	✓	✓	✓
Pineleaf halodule	*Halodule pinifolia*	Potamogetonaceae	✗	✓	✗

Legend: ✓- Present, ✗ - Absent

The study recorded four seagrass species in northwestern Dumanquilas Bay: *Halodule uninervis*, *Thalassia hemprichii, Enhalus acoroides,* and *Halodule pinifolia,* belonging to two distinct families. *H. uninervis, T. hemprichii,* and *E. acoroides* were consistently present across all stations, indicating broad ecological tolerance and the ability to thrive under varying substrate types, tidal exposure, and water movement (Carruthers & Dennison, 2007). Their widespread occurrence suggests that environmental conditions such as light availability, sediment stability, and nutrient levels were generally suitable across the study area. In contrast, *H. pinifolia* occurred only in Station 2, likely due to localized conditions—such as finer sediments, reduced wave action, or clearer water—that better match its ecological requirements (Short et al., 2007). Its absence elsewhere highlights the influence of microhabitat differences on species distribution. The presence of canopy-forming species such as *T. hemprichii* and *E. acoroides* across stations reflects ecological stability and supports key ecosystem functions like sediment binding, nutrient cycling, and habitat provision (Unsworth 2010). Regarding IUCN status, *H. uninervis, E. acoroides,* and *H. pinifolia* are listed as Least Concern (LC), while *T. hemprichii* remains unassessed (IUCN, 2024). Although not currently threatened, their distribution patterns underscore the importance of maintaining habitat quality, as the ecological integrity of these meadows remains vital despite the species' LC classification (Waycott et al., 2009).

Distribution and Conservation Status of Associated Fauna

Table 2 presents the occurrence of associated fauna species across the three study stations in northwestern Dumanquilas Bay, Vincenzo Sagun, Zamboanga del Sur.

Table 2. Fauna Occurrence at Study Sites in Northwestern Dumanquilas Bay, Vincenzo Sagun, Zamboanga del Sur, Philippines

Local Name	Scientific Name	Family Name	Stations		
			1	2	3
Sand sifting Starfish	*Astropecten polyacanthus*	Astropectinidae	✓	✓	✓
Babylonian Turrid	*Turris babylonia*	Turridae	✓	✓	✓
Long-spined sea urchin	*Diadema setosum*	Diadematidae	✓	✓	✓
Horned sea star	*Protoreaster nodosus*	Oreasteridae	✓	✓	✓
Kops' glassfish	*Ambassis kopsii*	Ambassidae	✓	✓	✓
Leopard sea cucumber	*Bohadschia argus*	Holothuriidae	✗	✓	✓
Porcupinefish	*Diodon hystrix*	Diodontidae	✗	✗	✓
Big blue octopus	*Octopus cyanea*	Octopodidae	✗	✓	✗
Yellow-lipped Sea Krait	*Laticauda colubrina*	Elapidae	✗	✓	✗
Sea nettle jellyfish	*Chrysaora*	Pelagiidae	✗	✓	✗
Long-spined glassfish	*Ambassis interrupta*	Ambassidae	✓	✓	✗
Vaigiensis Damselfish	*Abudefduf vaigiensis*	Pomacentridae	✓	✗	✗
Shorthead anchovy	*Encrosicholina heteroloba*	Engraulidae	✓	✗	✗

Legend: (✓) Present, (✗) Absent

A total of thirteen (13) fauna species from twelve (12) families were recorded across the three stations. Five species—*Astropecten polyacanthus, Turris babylonia, Diadema setosum, Protoreaster nodosus,* and *Ambassis kopsii*—occurred in all stations, indicating high ecological tolerance and adaptability (IUCN, 2024). Their consistent presence aligns with the sandy–muddy substrates and shallow coastal conditions common to all sites, suggesting they can exploit varied food resources and withstand fluctuations in salinity, turbidity, and water movement (Short et al., 2007; Unsworth et al., 2010). In contrast, the remaining species showed restricted or station-specific distributions, likely influenced by localized habitat differences, including substrate type, seagrass density, and availability of shelter or prey. Species with more specialized ecological requirements appeared only where suitable microhabitats were present (Waycott et al., 2009; Short et al., 2006).

Conservation assessment revealed five Data Deficient (DD) species and one Vulnerable (VU) species, *Abudefduf vaigiensis*, underscoring the ecological importance of the seagrass beds as potential refuge habitats (IUCN, 2024). Although the other species were classified as Least Concern (LC), their continued stability depends on preserving seagrass integrity (IUCN, 2024). Ongoing monitoring is recommended to detect shifts in species distribution driven by habitat degradation or anthropogenic pressures (Unsworth et al., 2019).

Marine Flora Composition and Spatial Distribution

Table 3 reveals the occurrence of marine flora species across the study sites in northwestern Dumanquilas Bay, Vincenzo Sagun, Zamboanga del Sur.

Table 3. Flora Occurrence at Study Sites in Northwestern Dumanquilas Bay, Vincenzo Sagun, Zamboanga del Sur, Philippines

Local Name	Scientific Name	Family Name	Stations		
			1	2	3
Cervicornis brown alga	*Dictyota cervicornis*	Dictyotaceae	✗	✓	✓
Macroloba algae	*Halimeda macroloba*	Halimedaceae	✗	✓	✓
Bosse's neomeris	*Neomeris vanbosseae*	Dasycladaceae	✗	✓	✓
Watercress alga	*Halimeda opuntia*	Halimedaceae	✗	✓	✗
Enhalus fruit	*Enhalus fruit*	Hydrocharitaceae	✗	✓	✓
Grape algae	*Caulerpa racemosa*	Caulerpaceae	✗	✗	✓

Legend: (✓) Present, (✗) Absent

Table 3 highlights the distribution of marine flora across three sampling stations in northwestern Dumanquilas Bay, revealing clear spatial differences linked to environmental conditions. A total of six species from five families were recorded. Station 1 lacked any macroscopic flora, likely due to unfavorable conditions such as unstable or coarse substrate, high turbidity limiting light penetration, and strong hydrodynamic forces that impede plant establishment (Short et al., 2007). In contrast, Stations 2 and 3 supported a more diverse flora, with four species—*Dictyota cervicornis, Halimeda macroloba, Enhalus fruit,* and *Neomeris vanbosseae*—consistently present. Their prevalence suggests these sites provide suitable light, substrate, and reduced disturbance, allowing successful colonization and persistence (Waycott et al., 2009; Short et al., 2006). Species like *Halimeda opuntia* and *Caulerpa racemosa* appeared sporadically, indicating dependence on specific microhabitat conditions influenced by nutrient availability, shading, competition, or localized disturbances (Unsworth et al., 2019). All recorded species are classified as “Data Deficient” by the International Union for Conservation of Nature (IUCN, 2024), emphasizing the need for ongoing monitoring. The results highlight that local environmental variability strongly affects flora presence and distribution in the bay, underscoring the importance of targeted conservation and habitat management strategies in maintaining seagrass-associated marine flora.

Relative Abundance of Seagrass Species

The relative abundance of seagrass species recorded across the three stations in northwestern Dumanquilas Bay is presented in Table 4.

Table 4. Relative Abundance of Seagrass species recorded from Three (3) Stations in Northwestern Dumanquilas Bay

Scientific Name	STATION 1		STATION 2		STATION 3	
	Average abundance	Relative abundance (%)	Average abundance	Relative abundance (%)	Average abundance	Relative abundance (%)
Halodule uninervis	987	44.95	768.33	23.10	586	27.31
Thalassia hemprichii	986	44.90	963	28.95	1,204.66	56.34
Enhalus acoroides	222.66	10.14	148.33	4.46	349.33	16.34
Halodule pinifolia	0	0	1,446	43.48	0	0
Total	**2,195.66**	**100**	**3,325.66**	**100**	**2,137.99**	**100**

Seagrass relative abundance varied markedly across the three stations in northwestern Dumanquilas Bay (Table 4). *Thalassia hemprichii* dominated Station 3 (56.34%) but was lowest in Station 2 (28.95%), while *Halodule uninervis* peaked in Station 1 (44.95%) and was least abundant in Station 2 (23.10%). *Enhalus acoroides* was most abundant in Station 3 (16.34%) and least in Station 2 (4.46%). Notably, *Halodule pinifolia* occurred only in Station 2, comprising 43.48% of the local community. These patterns reflect species-specific ecological tolerances and habitat preferences (Short et al., 2007; Waycott et al., 2009). Broadly adaptable species such as *H. uninervis* and *T. hemprichii* occupied multiple stations, whereas *H. pinifolia* showed localized occurrence, indicating narrower ecological niches (Unsworth et al., 2019). Substrate type emerged as a primary determinant of seagrass distribution. Station 1’s muddy substrate favored *H. uninervis*, likely due to vertical rhizome elongation optimizing light capture under turbid conditions (Short et al., 2007). The sandy-muddy mix in Station 3 supported high *T. hemprichii* abundance by balancing substrate stability and nutrient availability (Short et al., 2006). *E. acoroides* tolerated mixed substrates, establishing where nutrient and sediment conditions were adequate, reflecting its flexible habitat requirements (Waycott et al., 2009). The restriction of *H. pinifolia* to Station 2, despite similar substrate elsewhere, suggests that other environmental factors such as water depth, light penetration, and hydrodynamics further influence its occurrence (Duarte et al., 2008). Overall, seagrass distribution in Dumanquilas Bay is shaped primarily by substrate type, with secondary influences from depth, light availability, and hydrodynamic conditions (Unsworth et al., 2010). Species with high morphological plasticity, such as *H. uninervis* and *E. acoroides*, occupy broader environmental ranges, whereas habitat-specific species like *H. pinifolia* demonstrate narrower ecological niches. These findings highlight the need to consider multiple environmental variables when assessing seagrass community structure, as abiotic factors interact to govern species distribution in coastal marine ecosystems.

Relative Abundance of Faunal Species

Table 5 presents the relative abundance of faunal species recorded across the three sampling stations in northwestern Dumanquilas Bay.

Table 5. Relative Abundance of Associated Fauna species recorded from Three (3) Stations in Northwestern Dumanquilas Bay

Scientific Name	STATION 1		STATION 2		STATION 3	
	Average abundance	Relative abundance %	Average abundance	Relative abundance %	Average abundance	Relative abundance %
Astropecten polyacanthus	3	4.80	4.33	1.66	1.66	3.41
Turris babylonia	30	48.92	20	48.04	27.66	56.87
Diadema setosum	2.66	4.34	1.66	3.99	2	4.11
Protoreaster nodosus	2.66	4.34	4	9.61	3	6.17
Ambassis kopsii	17	27.72	9.66	23.20	13.66	28.08
Bohadschia argus	0	0	0.33	0.79	0.33	0.68
Diodon hystrix	0	0	0	0	0.33	0.68
Octopus cyanea	0	0	0.33	0.79	0	0
Laticauda colubrina	0	0	0.33	0.79	0	0
Chrysaora	0	0	0.33	0.79	0	0
Ambassis interrupta	1	1.63	0.66	1.59	0	0
Abudefduf vaigiensis	1	1.63	0	0	0	0
Encrosicholina heteroloba	4	6.52	0	0	0	0
Total	**61.32**	**100**	**41.63**	**100**	**48.64**	**100**

Table 5 shows that *Turris babylonia* was the most abundant species across all stations (48.04–56.87%), likely due to its broad ecological tolerance and preference for sandy-muddy substrates that facilitate foraging and shelter (Guzman et al., 2022). *Ambassis kopsii* also exhibited high abundance (23.20–28.08%), reflecting its benthopelagic behavior and adaptability to seagrass-associated habitats (Short et al., 2007). Moderately abundant species included *Astropecten polyacanthus* (3.41–4.80%) and *Diadema setosum* (peak 4.34% at Station 1), whose distributions corresponded to sandy or vegetated substrates suitable for burrowing, foraging, and shelter (Guisan et al., 2005). *Protoreaster nodosus* peaked at Station 2 (9.61%), indicating that sediment composition and seagrass coverage favored its habitat requirements (Guisan et al., 2005; Unsworth et al., 2019). Species with restricted distributions were linked to specific habitat features. *Bohadschia argus* (0.79%) occurred only in Stations 2 and 3, reflecting its reliance on sandy substrates with seagrass or coral fragments (Guisan et al., 2005). *Ambassis interrupta* (peak 1.63% at Station 1) favored heterogeneous seagrass-muddy interfaces, consistent with its ecological flexibility across estuarine and vegetated habitats (Guzman et al., 2022). Station-specific or opportunistic species were recorded only in particular stations. *Diodon hystrix* appeared solely in Station 3, while *Octopus cyanea, Laticauda colubrina,* and *Chrysaora spp.* occurred only in Station 2, likely due to structurally complex substrates that provide shelter and foraging opportunities (Unsworth et al., 2019). In contrast, *Abudefduf vaigiensis* (1.63%) and *Encrasicholina heteroloba* (6.52%) were exclusive to Station

1, suggesting that dense seagrass beds and nutrient-rich detritus created favorable conditions for these species (Guisan et al., 2005; Guzman et al., 202).

Relative Abundance of Aquatic Flora

The relative abundance of associated aquatic flora recorded from three sampling stations in northwestern Dumanquilas Bay is presented in Table 6.

Table 6. Relative Abundance of Associated Flora species recorded from Three (3) Stations in Northwestern Dumanquilas Bay

Scientific Name	STATION 1		STATION 2		STATION 3	
	Average abundance	Relative abundance %	Average abundance	Relative abundance %	Average abundance	Relative abundance %
Dictyota cervicornis	0	0	2.66	10.79	3.33	21.29
Halimeda macroloba	0	0	5.66	22.97	1.33	8.50
Neomeris vanbosseae	0	0	13.66	55.44	7.66	48.98
Halimeda opuntia	0	0	2	8.12	0	0
Enhalus fruit	0	0	0.66	2.68	2.66	17.01
Caulerpa racemosa	0	0	0	0	0.66	4.22
Total	**0**	**0**	**24.64**	**100**	**15.64**	**100**

The relative abundance of aquatic flora in northwestern Dumanquilas Bay (Table 6) showed distinct spatial patterns across the three sampling stations. Station 1 lacked any flora, indicating that its homogeneous muddy substrate created unsuitable conditions for plant colonization. Reduced light penetration due to turbidity, anaerobic sediment conditions, and poor structural stability likely inhibited photosynthesis, root development, and plant anchorage (Hamisain et al., 2020; Bostrom et al., 2006; Koch, 2001). In contrast, Stations 2 and 3, characterized by sandy-muddy substrates, supported more diverse flora assemblages. Station 2 exhibited the highest richness and relative abundance, dominated by *Neomeris vanbosseae* (55.44%) and *Halimeda macroloba* (22.97%), while Station 3 had peak abundances of *Dictyota cervicornis* (21.29%) and *Enhalus fruit* (17.01%). Some species were station-specific: *Halimeda opuntia* occurred only in Station 2 (8.12%) and *Caulerpa racemosa* only in Station 3 (4.22%). The richer assemblage at Station 2 can be attributed to improved sediment aeration, root penetration, nutrient availability, and light exposure, as well as slightly elevated microtopography that enhances drainage (Short et al., 2001; Almadin et al., 2020; Guzman et al., 2022). These results indicate that substrate composition is a primary determinant of aquatic flora presence, but local environmental factors such as nutrient availability, sunlight exposure, and sediment stability modulate species abundance and distribution within seagrass ecosystems. The absence of flora in Station 1 underscores the limiting effects of muddy sediments, including low light penetration, anoxic conditions, and poor structural integrity. Overall, these findings highlight the complex interplay of physicochemical and structural habitat factors in shaping aquatic plant communities in coastal ecosystems.

Seagrass Diversity Level

Table 7 summarizes the seagrass diversity levels across Stations 1, 2, and 3, evaluated using various biodiversity indices, including species richness (taxa count), Simpson's Diversity Index (1-D), Shannon-Wiener Diversity Index (SWDI), and Pielou's Evenness Index (PEI).

Table 7. Seagrass Diversity Level across Stations 1, 2, and 3

	Station 1	Station 2	Station 3
Taxa_S	3	4	3
Simpson_1-D	0.586	0.6717	0.5815
Shannon_H	0.951	1.198	0.974
Evenness_e^H/S	0.8628	0.8286	0.8829

Note: SWDI values ≤ 1.5 indicate low diversity; 1.5–2.05, moderate; 2.05–3.5, high; > 3.5, very high. SDI (1–D) ranges from 0 to 1, with higher values indicating greater diversity. PEI ranges from 0 to 1: 0.90–1.00 = very high evenness; 0.70–0.89 = high; 0.50–0.69 = moderate; 0.25–0.49 = low; 0.00–0.24 = very low.

Species richness varied among stations, with Station 2 supporting the highest number of taxa (four), while Stations 1 and 3 each recorded three. The greater richness at Station 2 is likely due to favorable conditions such as substrate heterogeneity, moderate water movement, and adequate light, which provide diverse microhabitats for multiple species (Short et al., 2007; Duarte, 2002). Stations 1 and 3 may have experienced environmental limitations, restricting species establishment (Fonseca et al., 2000). Diversity indices mirrored these patterns. Simpson's Index (1-D) was highest at Station 2 (0.672), reflecting a more balanced species distribution, whereas Stations 1 and 3 showed slightly lower values (0.586 and 0.582), likely due to dominance by one or two species (Magurran, 2004). Similarly, Shannon-Wiener Diversity Index values were higher at Station 2 (1.198), indicating moderate diversity, compared to lower values at Stations 1 (0.951) and 3 (0.974), consistent with fewer or unevenly distributed species (Magurran, 2004). Despite variations in richness and diversity, Pielou's Evenness Index was high across all stations (0.829–0.883), indicating relatively uniform distribution of individuals and preventing dominance by any single species. Overall, these patterns suggest that local environmental factors—particularly habitat heterogeneity, light availability, and water movement—strongly influence seagrass richness and diversity (Short et al., 2001), while the consistently high evenness reflects balanced community structure across all stations. Moderate hydrodynamic conditions at Station 2 may facilitate nutrient exchange and reduce sediment accumulation, supporting both pioneer and climax species (Fonseca et al., 2000). Conversely, lower diversity in Stations 1 and 3 may result from environmental stressors such as limited light, sediment instability, or increased turbidity (Short et al., 2001).

Fauna Diversity Level

Table 8 summarizes the fauna diversity levels across Stations 1, 2, and 3, evaluated using various biodiversity indices, including species richness (taxa count), Simpson's Diversity Index (1-D), Shannon-Wiener Diversity Index (SWDI), and Pielou's Evenness Index (PEI).

Table 8. Fauna Diversity Level across Stations 1, 2, and 3

	Station 1	Station 2	Station 3
Taxa_S	8	10	7
Simpson_1-D	0.6728	0.6932	0.591
Shannon_H	1.438	1.499	1.164
Evenness_e^H/S	0.5263	0.4478	0.4574

Note: SWDI values ≤ 1.5 indicate low diversity; 1.5–2.05, moderate; 2.05–3.5, high; > 3.5, very high. SDI (1–D) ranges from 0 to 1, with higher values indicating greater diversity. PEI ranges from 0 to 1: 0.90–1.00 = very high evenness; 0.70–0.89 = high; 0.50–0.69 = moderate; 0.25–0.49 = low; 0.00–0.24 = very low.

Station 2 exhibited the highest species richness (10 taxa) compared to Stations 1 (8 taxa) and 3 (7 taxa), indicating a habitat that supports a wider range of species. This richness is likely due to greater substrate heterogeneity and seagrass cover, which create diverse microhabitats (Gullstrom et al., 2002). Lower richness at Stations 1 and 3 may result from simpler habitat structures that favor fewer species. Diversity indices mirrored these patterns. Simpson's Index (1–D) was highest at Station 2 (0.6932) versus 0.6728 at Station 1 and 0.591 at Station 3, while Shannon-Wiener Diversity Index values were 1.499, 1.438, and 1.164, respectively (Magurran, 2004). Despite Station 2's higher diversity, values below 0.70 indicate dominance by a few species, likely due to environmental constraints such as sediment type, nutrient availability, or disturbances that favor generalist taxa (Gullstrom et al., 2002). Species evenness was highest at Station 1 (0.5262), whereas Stations 2 (0.4478) and 3 (0.4574) showed uneven species distribution. The low evenness at Station 2 suggests that, although more species are present, certain tolerant species dominate, reflecting competitive advantages in complex habitats (Clores, 2023). Overall, Station 2 supports the most taxonomically rich and diverse fauna, highlighting the role of habitat heterogeneity and seagrass cover in maintaining coastal biodiversity. However, generally low diversity and uneven distributions across all stations point to environmental limitations shaping community structure and indicate that benthic communities may be influenced by localized stressors or early successional stages (Gullstrom et al., 2002; Clores, 2023).

Flora Diversity Level

Table 9 summarizes the flora diversity levels across Stations 1, 2, and 3, evaluated using various biodiversity indices, including species richness (taxa count), Simpson's Diversity Index (1-D), Shannon-Wiener Diversity Index (SWDI), and Pielou's Evenness Index (PEI).

Table 9. Flora Diversity Level across Stations 1, 2, and 3

	Station 1	Station 2	Station 3
Taxa_S	0	5	5
Simpson_1-D	0	0.6209	0.6769
Shannon_H	0	1.206	1.323
Evenness_e^H/S	0	0.668	0.7512

Note: SWDI values ≤ 1.5 indicate low diversity; 1.5–2.05, moderate; 2.05–3.5, high; > 3.5, very high. SDI (1–D) ranges from 0 to 1, with higher values indicating greater diversity. PEI ranges from 0 to 1: 0.90–1.00 = very high evenness; 0.70–0.89 = high; 0.50–0.69 = moderate; 0.25–0.49 = low; 0.00–0.24 = very low.

Table 9 presents the diversity indices of flora across the three sampling stations. No flora were observed at Station 1, likely due to unfavorable substrate, low light penetration, high turbidity, or other site-specific disturbances, and it was therefore excluded from further analysis (Short et al., 2001). Stations 2 and 3 both recorded five species (S = 5), indicating similar species richness, although richness alone does not reflect species distribution or dominance. Analysis using Simpson's Diversity Index (SDI) and the Shannon-Wiener Diversity Index (SWDI) indicated low diversity at both stations, with Station 3 (SDI = 0.6769, PEI = 0.7512) showing higher evenness than Station 2 (SDI = 0.6209, PEI = 0.668), suggesting a more balanced distribution of individuals at Station 3 while both stations remained dominated by a few species (Magurran, 2004). Differences in diversity and evenness are likely influenced by local habitat conditions, including substrate composition and environmental stability. Station 3's sandy-muddy substrate provides better anchorage, nutrient retention, and light penetration compared to Station 2, while water quality factors such as turbidity and salinity may further shape floral community structure (Fonseca et al., 2000). Overall, these results indicate that Station 3 supports the most balanced and diverse flora, Station 2 has moderate diversity and evenness, and Station 1 lacks flora entirely, highlighting the key role of local habitat conditions in determining benthic flora diversity and distribution.

ANOVA Results on Seagrass Species Abundance

Table 10 presents the results of the Analysis of Variance (ANOVA) conducted to compare the abundance of seagrass species across Stations 1, 2, and 3.

Table 10. Analysis of Variance (ANOVA) Results for Seagrass Species

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	223817.7	2	111908.9	0.414807	**0.672477**	4.256495
Within Groups	2428070	9	269785.5			
Total	2651888	1				

The resulting *p*-value from the ANOVA is 0.672477, substantially higher than the standard alpha level (α = 0.05). This indicates that the abundance level in seagrass species among the three stations is not statistically significant.

ANOVA Results on Fauna Species Abundance

Table 11 presents the results of the Analysis of Variance (ANOVA) conducted to compare the abundance of fauna species across Stations 1, 2, and 3.

Table 11. Analysis of Variance (ANOVA) Results for Associated Fauna Species

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	15.32355	2	7.661777	0.129803	**0.878678**	3.259446
Within Groups	2124.945	36	59.02625			
Total	2140.268	38				

As indicated in the table, the computed p-value is 0.878678, well above the standard significance level of α = 0.05. Based on this result, it is concluded that there is no statistically significant difference in the abundance of fauna species among the three stations.

ANOVA Results on Flora Species Abundance

Table 12 presents the results of the Analysis of Variance (ANOVA) conducted to compare the abundance of flora species across Stations 1, 2, and 3.

Table 12. Analysis of Variance (ANOVA) Results for Associated Flora Species

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	51.81884	2	25.90942	2.323986	0.132069	3.68232
Within Groups	167.2305	15	11.1487			
Total	219.0493	17				

As indicated in the table, the p-value is 0.132069, higher than the standard significance level of α = 0.05. The results indicate no statistically significant difference in the abundance of flora species among the three stations.

Conclusion

This study revealed that the northwestern portion of Dumanquilas Bay hosts four seagrass species—*Halodule uninervis, Thalassia hemprichii, Enhalus acoroides, and Halodule pinifolia*—with *T. hemprichii* being the most abundant. The distribution of seagrasses, associated fauna, and aquatic flora varied across stations, reflecting habitat-specific preferences influenced by substrate type, water depth, light availability, and seagrass bed structure. Thirteen faunal species and six flora species were recorded, though overall biodiversity was low, with Station 2 showing the highest richness and diversity for both seagrass and fauna. Statistical analysis indicated no significant differences in species abundance among stations, suggesting either ecological uniformity or limitations in sampling scope. These findings underscore the ecological complexity of seagrass ecosystems and the need for continued conservation efforts due to their critical role in supporting coastal biodiversity. To enhance understanding and protection of these habitats, future studies should expand spatial and seasonal coverage, integrate water quality and sediment analyses, and focus on rare or data-deficient species. Conservation efforts should include long-term biodiversity monitoring, establishment or reinforcement of marine protected areas, stricter regulation against destructive practices, and community engagement through education and participatory management. Collaborative policies and sustainable livelihood programs are recommended to ensure the ecological and economic benefits of seagrass ecosystems are maintained for the region.

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