Journal of Ecosystem Science and Eco-Governance (JESEG)

Vol. 7, No. 1 | June 2025
PRINT ISSN 2704 4394 | ONLINE ISSN 2782 8522
DOI: https://doi.org/10.54610/jeseg.v7i1.138

Gastropod and Habitat Associations in Selected Mangrove Wetlands of Butuan Bay, Philippines

Marlon V. Elvira[1], Darlene Jess R. Malinao[1], Marco Polo L. Nicmic[1], Teodoro C. Abrea Jr.[1], Sherryl L. Paz[1], Adam Roy V. Galolo[2], Laurence B. Calagui[2]*

[1]Department of Environmental Science, College of Forestry and Environmental Science, Caraga State University, 8600 Butuan City, Philippines
[2]Department of Biology, College of Mathematics and Natural Sciences, Caraga State University, 8600 Butuan City, Philippines

*Corresponding Author
*Email: mvelvira@carsu.edu.ph

Received: October 7, 2024
Revised: May 9, 2025
Accepted: May 30, 2025
Available Online: June 16, 2025

Cite this article: Elvira, M. V., Malinao, D. J. R., Nicmic, M. P. L., Abrea, T.C., Paz, S.L., Galolo, A. R. V., & Calagui, L. B. (2025). Gastropod and Haabitat Associations in Selected Mangrove Wetlands of Butuan Bay, Philippines, *Journal of Ecosystem Science and Eco-Governance*, 7(1):1-13.DOI: https://doi.org/10.54610/jeseg.v7i1.138

ABSTRACT

The Philippines' extensive coastline and mangrove forests have played a crucial role in biodiversity conservation and coastal protection. The present study aimed to assess the gastropod diversity within the rehabilitated mangrove forests of Barangays Pagatpatan and Lumbocan, Butuan City. It also assessed the correlation of water quality, selected sediment edaphic parameters, and mangrove features to the abundance of gastropods. The analyses showed consistent water pH levels within the DENR DAO 2016-08 standard for Class B marine waters, along with fluctuating dissolved oxygen (DO) and spatial variations in total dissolved solids (TDS) and salinity. Soil pH also varied, along with differences in organic matter, phosphorus (P), and potassium (K) levels. A total of five mangrove species and ten gastropod species, including *Cerithidea quoyii*, were identified across six stations. Among the five gastropod families, the Neritidae family was present in both mangrove ecosystems. Pagatpatan showed higher species richness and diversity than Lumbocan. *Faunus ater* was most abundant and closely linked to the growth of *Avicennia marina* and *Rhizophora mucronata*, with its presence likely influenced by sensitivity to pH and humidity. This relationship significantly contributes to the variation explained by Principal Component Analysis (PCA 1), indicating that *F. ater* plays a major role in differentiating sampling stations. The findings underscore the importance of habitat integrity and biodiversity conservation to guide mangrove management strategies.

Keywords: *Arboreal snail, epifaunal species, abundance, water quality, edaphic factors*

1 Introduction

Mangroves, acting as the protectors of our coastlines, represent a distinctive and essential ecosystem in more than 120 tropical and subtropical countries and regions (Alongi 2008). Mangroves, often referred to as the "rainforests of the sea," occupy a small portion of the world's tropical forests yet span approximately 147,000 square kilometers across 118 tropical and subtropical countries, including the Philippines—where they are recognized for their rich biodiversity and vital ecological and socio-economic functions (Asari et al. 2021, Akram et al., 2023). The Philippines has one of the world's longest coastlines at 36,289 km and supports extensive mangrove growth. In Butuan City, around 7,456.52 hectares of mangroves exist within its total land area of 81,728 hectares (Mangadlao 2024). In addition, gastropods are recognized as effective biological indicators of water quality, underscoring their importance in assessing the ecological health of mangrove ecosystems (Cañada 2020, Pogado & de Chavez 2022, Octavina et al. 2019). Recent research has revealed extremely low mangrove diversity in Butuan Bay due anthropogenic activities posing threats to the long-term viability of rehabilitated mangrove forests in Barangay Lumbocan and Barangay Pagatpatan (Goloran et al. 2020). While some studies have shown the return of gastropod species following restoration efforts, long-term data on ecosystem recovery and factors influencing survival are needed to guide conservation initiatives (Salmo et al. 2016). Further research comparing species assemblages in restored regions to those in wild forests is essential to understanding gastropods' habitat needs and ecosystem services, aiding conservation and management efforts to maintain functional variety and resilience in these crucial coastal ecosystems.

The Pagatpatan Mangrove Project, established in 2013 in Barangay Pagatpatan, Butuan City, underscores the vital role of mangrove conservation by acting as a natural buffer against erosion and storm surges while fostering biodiversity and supporting fisheries, thereby contributing to both ecological stability and community livelihood (Alongi 2008). These ecosystems also help mitigate climate change by sequestering carbon and reducing greenhouse gas emissions (Asari et al. 2021). In addition, they provide local communities with valuable livelihood opportunities, including fishing, shellfish harvesting, tourism, fuel, and construction materials (Garcia et al. 2013). Barangays Pagatpatan and Lumbocan were selected as study sites due to their ecological significance within the Agusan River mangrove wetlands. Pagatpatan features a rehabilitated mangrove forest resulting from sustained local conservation efforts, while Lumbocan contains restored mangroves adjacent to a former industrial site. These sites represent contrasting hydrological and land-use conditions that offer important opportunities for understanding ecosystem recovery andmanagement. In accordance with the Department of Environment and Natural Resources' (DENR) environmental policies, specifically DAO 2016-08 which sets water quality guidelines and DAO 2019-11 which outlines procedures for environmental impact assessments, the project aims to investigate the ecological relationships among gastropod communities, mangrove species, and environmental factors such as water quality and soil characteristics. These mangrove ecosystems harbor a wide range of organisms due to their unique geographic position. Gastropods, in particular, are known for their adaptability and reliance on mangroves for food, shelter, and reproduction. Their population dynamics, shaped by competition, ecological tolerance, and environmental variables, influence nutrient cycling, food web structure, and shellfish availability, thereby affecting both ecosystem health and the livelihoods of local communities.

The main objective of this study was to assess the diversity and ecological associations of gastropods in relation to mangrove ecosystems and environmental conditions in Barangays Lumbocan and Pagatpatan, Butuan City.

2 Methodology

Study Area

The study was conducted in two mangrove sites located within Barangays Lumbocan and Pagatpatan, Butuan City, adjacent to the Agusan River (Figure 1). Sampling was conducted across six stations, with three stations established per site. Each station included three quadrats positioned 15 meters apart, while the distance between stations ranged from approximately 50 to 100 meters. In total, 18 quadrats were established across the two sites. All sampling activities were carried out during the first quarter of 2024 (Figure 2). All sampling activities were carried out during the first quarter of 2024. The Lumbocan sites is part of a restored mangrove area influenced by brackish water and situated near an abandoned industrial zone. In contrast, he Pagatpatan stations are within a rehabilitated mangrove zone along the Mantangue River and are directly connected to the freshwater flow of the Agusan River. These locations were selected due to their contrasting hydrological and land-use conditions, which may influence mangrove and faunal characteristics.

Water Physicochemical Parameters

The Horiba U-50 multi-parameter water quality checker was used to measure water parameters directly in situ, including pH, dissolved oxygen (DO), and total dissolved solids (TDS). Measurements were taken along the riverbanks adjacent to each quadrat, with readings replicated three times per station to ensure accuracy and account for potential anomalies. This approach allowed for reliable, real-time assessment of water quality conditions at each sampling station.

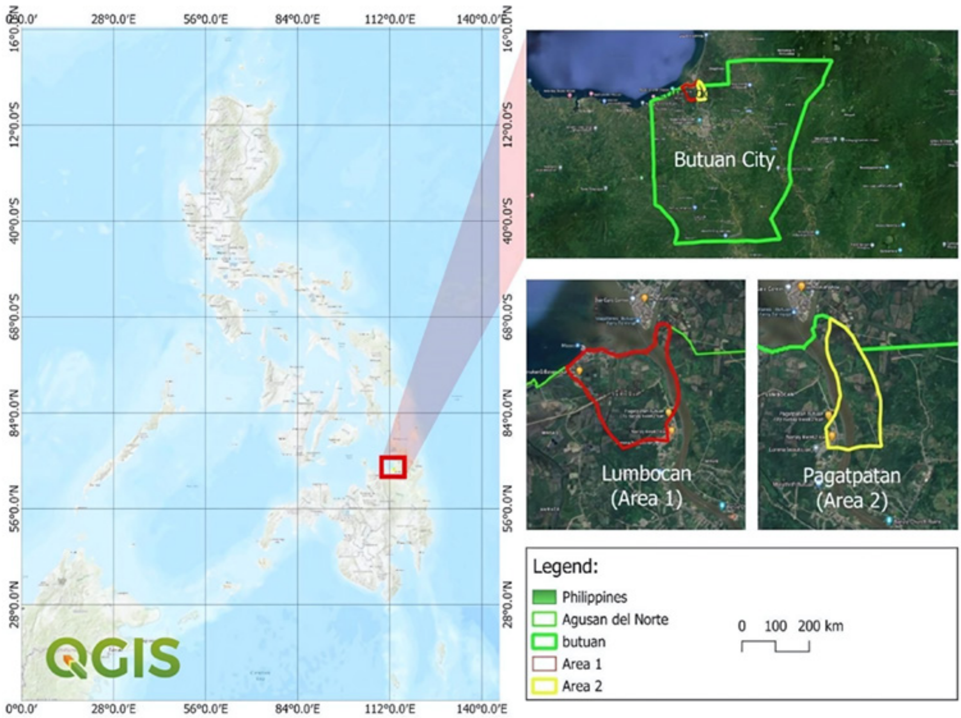

Figure 1. Map of the study area showing the designated sampling sites in Barangays Lumbocan (Area 1) and Pagatpatan (Area 2), Butuan City, Agusan River mangrove wetlands

Collection and Preparation of Soil Samples

Within the established quadrat, relative humdity data was gathered using Extech Instruments' Psychrometer. Approximately 1 kg of soil was collected per quadrat by compositing samples from each corner using a trowel. The composite sample was placed in 15 cm × 15 cm zip-lock bags, and labeled according to their corresponding stations and substations. This procedure was consistently applied across all sampling areas. Finally, the soil samples were sent to the Department of Agriculture for pH, organic matter content, phosphorus, and potassium analysis.

Mangrove Data Collection

In each 3 × 3 m quadrat, all mangrove individuals were also recorded. These quadrats were the same as those used for sediment and gastropod sampling. A transect tape was used to delineate the quadrats, while a straw thread marked the boundaries to ensure systematic evaluation of mangrove characteristics (Figure 2). The diameter at breast height (DBH) of each tree was measured using a tree caliper, and species were identified using the Handbook of Philippine Mangroves by Primavera et al. (2004).

Collection and Identification of Gastropods

Gastropods were collected using the handpicking method. In each quadrat, a 20-minute man-hour effort (three collectors per quadrat) was applied to ensure consistency and reduce sampling bias. While Beasley et al. (2005) suggested that 10 minutes is sufficient to capture an ideal sample size in similar habitats, the sampling duration in this study was extended to 20 minutes to increase the likelihood of detecting less abundant or cryptic species and to enhance species richness accounting. All visible gastropods found on mangrove roots, trunks, and surface sediments were collected during the lowest tide of the day. Specimens were placed in containers filled with 95% ethanol for transport and preservation. Easily identifiable species were counted and immediately released back into their natural habitat to minimize potential mortality. Only representative individuals were retained for photographic documentation and species-level identification. Permission for sample collection was

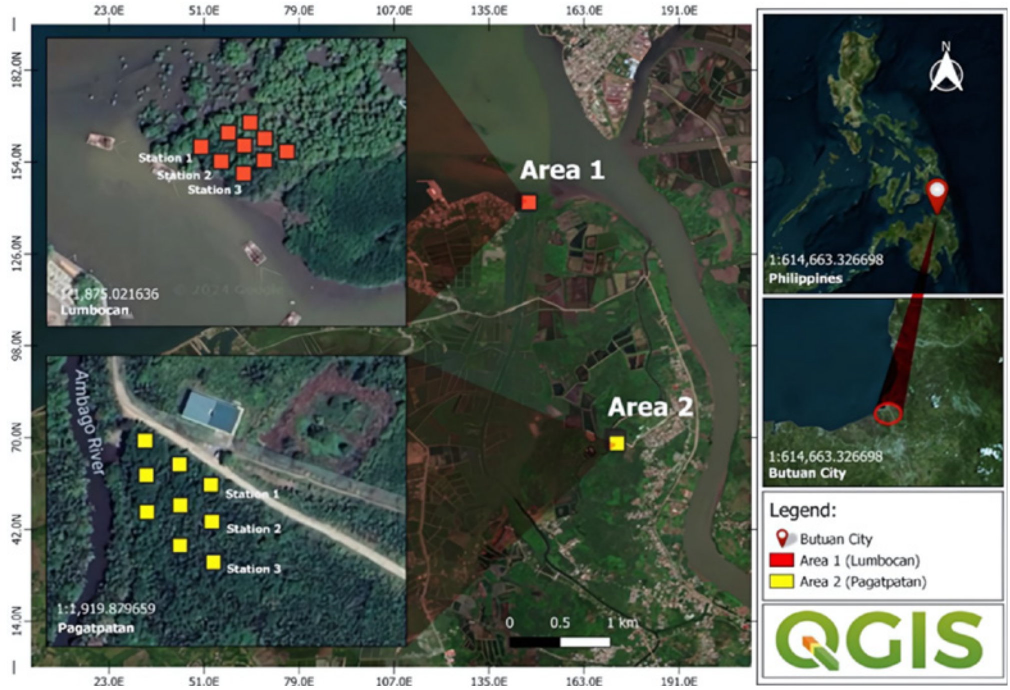

Figure 2. Map showing the layout of 18 sampling quadrats established across the mangrove habitats of Barangays Lumbocan and Pagatpatan, Butuan City

granted at the barangay level, as the local government units have jurisdiction and direct oversight of the wetlands. Specimens were transported to the Caraga State University laboratory, where they were cleaned, photographed, and identified using standard taxonomic references, including Poppe (2008a, 2008b, 2010, 2011), Springsteen and Leobrera (1986), Abbott and Morris (2001), and Laureta and Marasigan (2000).

Data Analysis Tools

Diversity indices including species richness, abundance, dominance, Simpson diversity, Shannon diversity, and evenness were calculated to assess the overall diversity status of the mangrove ecosystem. Abundance data of the identified gastropod species were analyzed using Principal Component Analysis (PCA) to compare and highlight differences among stations. The Unweighted Pair Group Method with Arithmetic Mean (UPGMA) was employed to cluster sampling sites based on similarity, allowing the identification of distinct ecological groupings. Finally, Canonical Correspondence Analysis (CCA) was used to explore the relationships between environmental variables and species composition, providing insights into ecosystem interdependencies. All statistical analyses were conducted using the Paleontological Statistics Software Package (PAST), version 4.10.

3 Results and Discussion

Water and Soil Physicochemical Features

The physicochemical characteristics of water exhibited notable variation between the mangrove wetlands of Barangays Pagatpatan and Lumbocan (Table 1). Both sites showed relatively stable values for key parameters such as pH (6.71-7.04), total dissolved solids (0.43-1.3 g/L), and salinity (0.4-1.03 ppt). However, dissolved oxygen (DO) levels varied significantly, ranging from 6.18 to 9.57 mg/L in Lumbocan and reaching unusually high levels of 21.43 to 23.29 mg/L in Pagatpatan.DO levels in Lumbocan fall within the expected range for brackish waters, sufficient to support most aquatic organisms, including oxygen-sensitive species. In contrast, the elevated DO values in Pagatpatan are atypical and may reflect either specific environmental conditions or potential measurement anomalies (Susi & Ladesma 2020). A likely explanation is oxygen supersaturation caused by photosynthetic activity from phytoplankton blooms in nutrient-rich waters, particularly during daylight hours (Mitra 2013). Given Pagatpatan’s proximity to agricultural and residential areas, nutrient runoff or wastewater discharge could have enhanced primary productivity, contributing to elevated DO concentrations.

According to DAO 2016-08, the observed pH values fall within the slightly acidic to neutral range, suitable for brackish ecosystems. The measured TDS levels are also within the normal range for brackish water and suggest good water quality with low ionic concentration. Salinity at both sites remained at the lower end of the brackish spectrum, and these consistently low values may lead to shifts in species composition and increased mangrove flora diversity (Cuenca-Ocay et al. 2023).

The low salinity readings further reflect strong freshwater input, consistent with both sites' proximity to the Agusan River. Sampling during the first quarter of 2024 coincided with frequent rainfall events, likely contributing to surface runoff and elevated river discharge. Field observations revealed that Pagatpatan, which is directly connected to the Agusan River and bordered by residential and agricultural areas, exhibited consistently lower salinity than Lumbocan. This suggests stronger freshwater influence in Pagatpatan due to combined natural(e.g.,rainfall, river flow) and anthropogenic (e.g.,agricultural and urban runoff) inputs. In contrast, Lumbocan appeared more influenced by estuarine mixing, maintaining relatively higher salinity and moderate DO levels. These site-specific differences highlight the complex interactions shaping water quality in mangrove ecosystems (Khondoker et al. 2023).

Soil properties were stable across the two barangays, with notable organic matter and potassium level variations. In Barangay Lumbocan, soil pH remained stable between 7.43 and 7.62, supporting essential nutrient availability and mangrove species. Conversely, in Barangay Pagatpatan, the pH ranged from 5.24 to 5.56, indicating slight acidity typical in mangrove habitats (Hossain & Nuruddin 2016).

Organic matter (OM) concentration in Lumbocan was relatively low ranged from 1-1.57, suggesting limited nutrient retention, while Pagatpatan exhibited significantly higher levels ranged from 8.9 to 9.07, enhancing soil vitality but posing risks of eutrophication (Bashir et al. 2021). The quantity of organic matter present in soil is commonly utilized as an indicator of its quality, influencing factors such as microbial activity, water retention, and nutrient availability within mangrove ecosystems (Hamada et al., 2024). Higher levels of organic matter typically correspond with greater diversity in gastropod populations (Strong et al. 2007). This organic material serves as both a food source and habitat for these mollusks, emphasizing its importance in supporting their abundance and overall ecosystem health. Phosphorus (P) levels ranged from 12.33 to 16.67, impacting mangrove growth and potentially influenced by community inputs. Stable relative humidity favored mangrove growth and gastropod presence, while potassium variation between the barangays indicated varied nutrient availability, influencing mangrove health and associated species (Akram et al. 2023) (Table 1).

Mangrove Accounts

The mangrove ecosystems of Barangays Lumbocan and Pagatpatan exhibited noticeable differences in species assemblages, structural maturity, and associated gastropod diversity. A total of five mangrove species were recorded across both sites: *Avicennia marina, Rhizophora apiculata, Rhizophora mucronata, Bruguiera cylindrica,* and *Nypa fruticans*.

In terms of species richness, both sites hosted the same number of mangrove species (n=5); however, species abundance and structural maturity varied. Lumbocan demonstrated a higher relative

Table 1. Physicochemical characteristics of water and soil in the two mangrove habitats of Butuan City

Parameters	Lumbocan			Pagatpatan			DAO 2016-08
	S1	S2	S3	S1	S2	S3	
Water pH	6.71±0	7±0.05	7.04±0.16	6.85±0.14	6.82±0.02	6.88±0.04	6.0-9.0
DO	9.57±0	9.57±0.49	6.18±0.29	23.29±1.22	21.62±0.55	21.43±0.47	2
TDS	0.51±0	0.70±0.04	1.3±0.26	0.43±0.06	0.52±0.31	0.67±0.29	110
Salinity	0.4±6.8	0.53±0.29	1.03±0.21	0.37±0.06	0.4±0.26	0.53±0.21	-
Soil pH	7.47±0.15	7.62±0.06	7.43±0.15	5.56±0.11	5.56±0.44	5.24±0.47	-
OM	1.17±0.40	1±0.26	1.57±0.50	8.9±0	9.03±0.06	9.07±0.12	-
P	12.33±2.31	12.67±1.53	14.67±1.53	16.67±1.53	15.67±6.03	14.33±2.52	-

abundance of *Avicennia marina*, which also had the largest average diameter at breast height (DBH) of 21.18 cm. This suggests a more mature and established mangrove community. In contrast, Pagatpatan was dominated by younger *Rhizophora* species (*R. apiculata* and *R. mucronata*), characterized by smaller DBH values and denser sapling populations, indicating ongoing rehabilitation and regrowth processes.

The ecological structure in Lumbocan characterized by older *A. marina* stands supported a richer gastropod community, with this species hosting up to 14 associated gastropod taxa. In comparison, *R. apiculata* and *R. mucronata* in both sites hosted fewer gastropod species, potentially due to their younger age or less complex root structures (Al-Khayat & Alatalo 2021). *Bruguiera cylindrica* and *Nypafruticans* were sparsely distributed and occurred in lower abundance at both sites. Their limited pneumatophore development and less favorable microhabitats may explain the reduced gastropod association (Abbasi et al. 2022).

Diversity of Mangrove-associated Gastropods

The distribution of gastropod species varied across sampling stations in Barangays Lumbocan and Pagatpatan. *Cerithidea quoyii* (family Potamididae) was consistently recorded at all stations, indicating its probable broad habitat adaptability. Similarly, *Vittina coromandeliana, V. jovis, V. turrita*, and *V. waigiensis* from the Neritidae family were commonly observed across both sites (Table 2; Figure 3). The widespread presence of these species suggests broad ecological tolerance, likely attributed to their euryhaline and eurythermal traits, as well as resistance to sedimentation, as noted in earlier studies (Velasco et al. 2018).

Neritodryas dubia (family Neritidae) exhibited the lowest occurrence among all sampled stations, suggesting that it may have more restrictive ecological requirements compared to other neritid species present in the area. Its limited distribution could be attributed to narrower substrate preferences, specific dietary needs, or sensitivity to fluctuating environmental conditions such as salinity or sedimentation (Craine et al., 2012). In contrast to more generalist species like *Vittina* spp., *N. dubia* may depend on microhabitats with stable physicochemi-cal characteristics, which were less prevalent or fragmented within the sampled mangrove zones.

Furthermore, interspecific competition may have contributed to its reduced abundance. Coexisting *Neritidae* species with overlapping niches may exert competitive pressure through resource exploitation or spatial dominance, further constraining the habitat availability for *N. dubia* (Tan & Clements 2008). These findings underscore the importance of examining biotic interactions and fine-scale habitat characteristics when interpreting gastropod diversity patterns in mangrove ecosystems. The limited presence of *N. dubia* could serve as an indicator of subtle environmental heterogeneity or localized habitat degradation, warranting further investigation into its ecological role and conservation status within Philippine mangroves.

The presence and abundance of gastropod species in Barangays Lumbocan and Pagatpatan reflect the overall ecological condition of the mangrove ecosystems. The widespread occurrence and notably higher abundance of *Cerithidea quoyii*

Table 2. Composition of gastropod species across the two mangrove habitats in Butuan City

		Lumbocan			Pagatpatan		
Species	**Family**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Cerithidea quoyii (Hombron & Jacquinot, 1848)	Potamididae	+	+	+	+	+	+
Stenomelania plicaria (Born, 1778)	Thiaridae	+	-	-	+	+	+
Vittina coromandeliana (G. B. Sowerby I, 1836)	Neritidae	+	+	+	+	+	+
Vittina jovis (Récluz, 1843)	Neritidae	+	+	+	+	+	+
Vittina turrita (Gmelin, 1791)	Neritidae	+	+	+	+	+	+
Vittina waigiensis (Lesson, 1831)	Neritidae	+	+	+	+	+	+
Vittina variegata (Lesson, 1831)	Neritidae	-	-	-	+	+	+
Pythia savaiensis (Mousson, 1869)	Ellobiidae	-	-	-	+	+	+
Neritodryas dubia (Gmelin, 1791)	Neritidae	+	-	-	-	+	-
Faunus ater (Linnaeus, 1758)	Pachychilidae	+	+	+	-	+	+

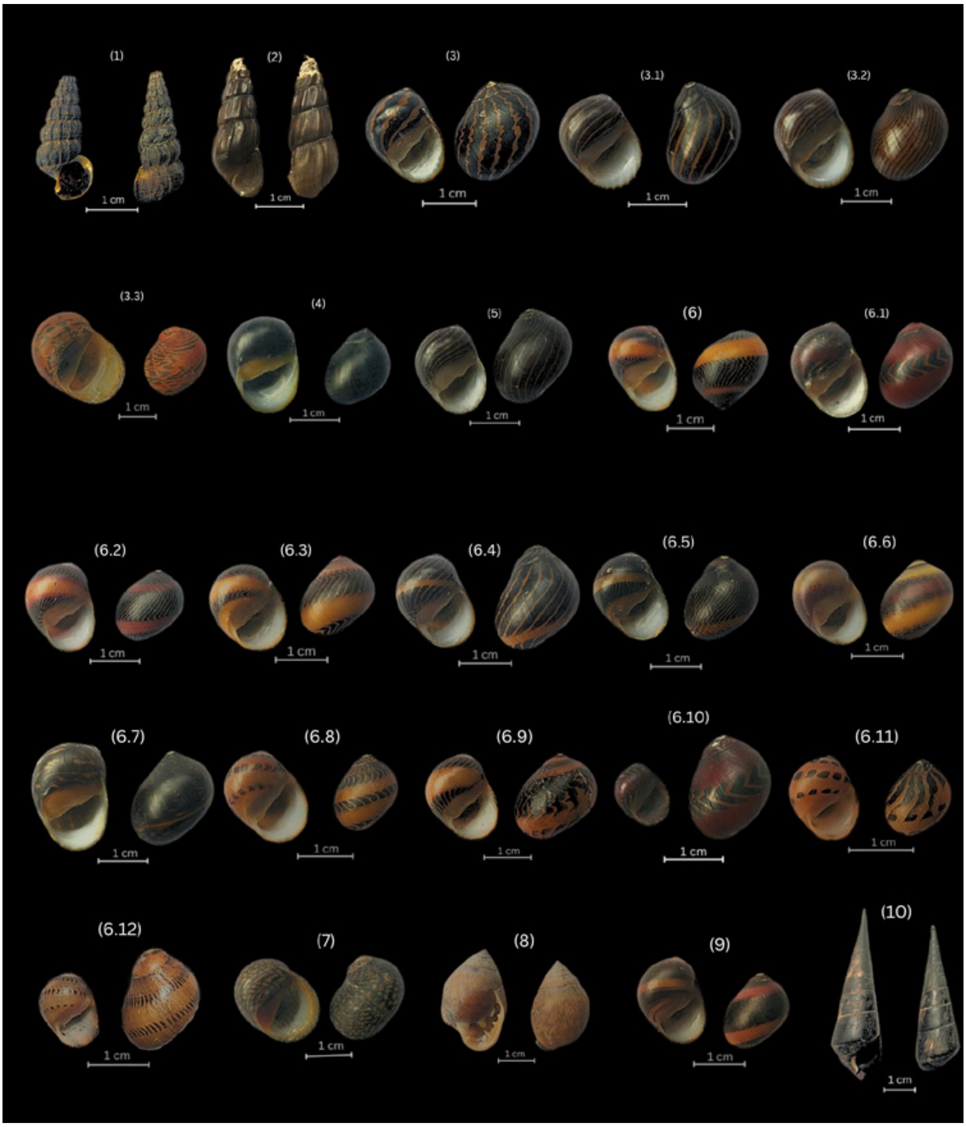

Figure 3. Species of gastropods in Pagatpatan and Lumbocan Mangrove Wetland, Butuan Bay. 1.*Cerithidea quoyii*; 2. *Stenomelania plicaria*; 3-3.3. *Vittina coromandeliana*; 4. *Vittina jovis*; 5. *Vittina turrita*; 6-6.12. *Vittina waigiensis*; 7. *Vittina va-riegata*; 8. *Pythia savaiensis*; 9. *Neriodryas dubia*; 10. *Faunus ater.*

in Pagatpatan suggest favorable environmental conditions that support active nutrient cycling and organic matter decomposition, a key indicators of mang-rove ecosystem functionality (Canencia et al. 2022, Reid et al. 2013). As a detritivore, *C. quoyii* likely benefits from high litterfall and organic enrichment, particularly in areas with strong freshwater input and sediment deposition.

Although *Semisulcospira plicaria* contributed to overall gastropod diversity, its low abundance in Barangay Lumbocan may indicate habitat constraints such as limited food resources, unsuitable sediment texture, or increased competition. *Vittina coromandeliana*, which was highly abundant in both sites, played a consistent ecological role in detritus processing, highlighting its resilience and broad habitat tolerance (Tan & Clements 2008). Other *Neritidae* species like *V. jovis, V. turrita, V. waigiensis, V. variegata,* along with *Pirenella savaiensis* and *Neritodryas dubia,* added to the diversity of the gastropod community by occupying different microhabitats and contributing to nutrient turnover (Abbasi et al. 2022, Craine et al. 2012).

The high abundance of *Faunus ater,* particularly in Pagatpatan, emphasizes its ecological significance. As a sediment-dwelling detritivore, its population density may indicate healthy sediment quality and sustained nutrient flow within the ecosystem (Velasco et al., 2018). Continued monitoring of these gastropod communities is essential for detecting early shifts in ecological balance, especially under pressures from urban runoff, pollution, or habitat alteration.

Barangay Pagatpatan exhibited higher species richness compared to Lumbocan, suggesting a more complex ecosystem with diverse microhabitats that support species with narrower ecological niches (Table 3). In contrast, Lumbocan demonstrated greater average species abundance, which may imply a less diverse but more evenly structured community. This contrast highlights differing ecological strategies: Pagatpatan appears to support a wider range of specialized species, while Lumbocan sustains fewer species in greater numbers, possibly due to more stable or less disturbed habitat conditions.

The diversity metrics of gastropods across the mangrove wetlands of Barangays Pagatpatan and Lumbocan reveal distinct ecological profiles between the two sites (Table 3). Pagatpatan exhibited higher species richness (6.78) and greater diversity, as indicated by its Shannon index (1.47) and Simpson index (0.71). These values suggest a more heterogeneous and compositionally diverse community, potentially driven by habitat complexity, varied sub-strate conditions, or stronger freshwater influence due to the site's proximity to the Agusan River (Kovalenko et al. 2012).

In contrast, Lumbocan recorded higher species abundance (681 individuals) but lower species richness (5.67). This indicates that while fewer species were present, they occurred in larger numbers (Magurran 2021). Evenness was slightly higher in Lumbocan (0.72) than in Pagatpatan (0.66), sug-gesting a more balanced distribution of individuals across species, with no single taxon overwhelmingly dominant. Pagatpatan's slightly lower evenness, combined with higher richness, reflects a community with more species but greater variability in their representation, which is common in structurally complex and resource-diverse environments (Magurran 2021, Moreno & Rodriguez 2010).

Dominance values were relatively similar between sites (0.32 in Lumbocan and 0.29 in Pagatpatan), indicating that neither community was heavily skewed toward a single dominant species. However, when interpreted alongside richness and diversity metrics, Pagatpatan's lower dominance and higher diversity point to a more functionally diverse ecosystem.

Distinctive Composition of Gastropods in the Two Mangrove Habitats

The Principal Component Analysis (PCA) provided key insights into the distribution patterns of 10 gastropod species across the mangrove wetlands of Lumbocan and Pagatpatan (Figure 4). PCA 1 alone accounted for 65.47% of the total variation, indicating its strong explanatory power in differentiating species assemblages between the two sites. The most significant contributor to PCA 1 was *Faunus ater* (loading value= 0.89796), suggesting its dominance in Lumbocan and its strong association with local environmental conditions. This implies that *F. ater* is well-adapted to the physicochemical and habitat features (Nair et al. 2024) specific to Lumbocan, possibly benefiting from favorable sediment quality and nutrient availability.

In contrast, *Cerithidea quoyii* exhibited the most negative loading on PCA 1 (-0.43309), indicating an inverse relationship with the conditions favoring *F. ater.* This could reflect *C. quoyii's* broader ecological tolerance or preference for microhabitats less dominated by *F. ater* (Zvonareva & Kantor 2016), such as areas with higher organic matter,

Table 3. Diversity of gastropod species in Pagatpatan and Lumbocan Mangrove wetlands in Butuan City

Parameters	Lumbocan	Pagatpatan
Richness	5.67	6.78
Abundance	681.00	486.00
Dominance	0.32	0.29
Simpson Diversity	0.68	0.71
Shannon Diversity	1.35	1.47
Evenness	0.72	0.66

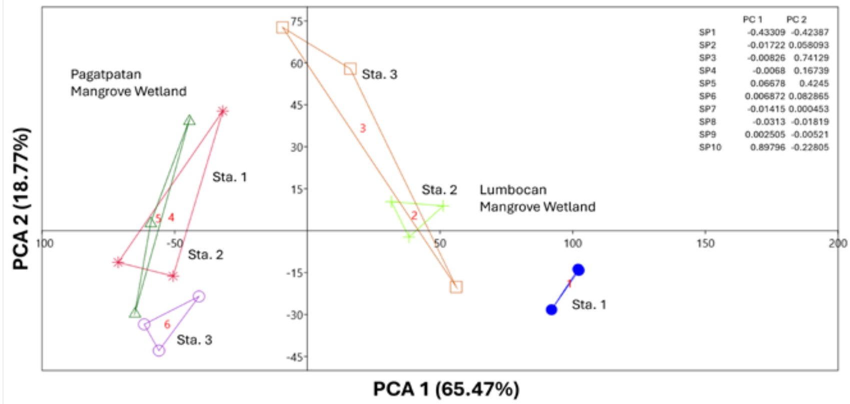

Figure 4. Principal Component Analysis showing the distinct characteristics of stations relative to the abundance of gastropods in the two mangrove habitats of Butuan City

different salinity gradients, or root structures less densely occupied by other species.

The differences observed in species abundance between the two barangays highlight distinct ecological dynamics. While Lumbocan exhibited higher species abundance and notable dominance by *F. ater,* Pagatpatan supported a more evenly distributed assemblage with higher species richness. The dominance of *F. ater* in Lumbocan suggests not only its adaptability but also the ecological resilience of this mangrove habitat, which may be driven by reduced environmental stressors or well-established sediment and hydrological conditions.

Understanding the roles of key species like *F. ater* is crucial, as they contribute significantly to nutrient cycling, detritus processing, and overall ecosystem functioning. Their abundance and spatial distribution can also serve as reliable indicators of environmental change (Fullerton et al. 2021). Thus, PCA not only highlights species-level associations but also underscores the importance of maintaining diverse and balanced gastropod communities to support mangrove ecosystem health.

Association of Mangrove-associated Gastropods Towards Soil and Water

Physicochemical Parameters

The Canonical Correspondence Analysis (CCA) revealed significant associations between gastropod species and measured environmental variables across the mangrove wetlands of Barangays Lumbocan and Pagatpatan (Figure 5). The first canonical axis (CCA 1), explained 68.68% of the total variance, indicating that most of the variation in gastropod distribution is strongly influenced by environmental factors.

Among the species examined, *Vittina waigiensis* showed a strong positive association with several environmental variables, including water availability, soil pH, relative humidity, total dissolved solids (TDS), and salinity. This suggests that *V. waigiensis* thrives in areas with well-defined physicochemical gradients. Conversely, *Faunus ater* demonstrated minimal correspondence with the measured environmental variables. Its broad ecological tolerance and high adaptability likely explain its stable occurrence across diverse conditions, supporting previous findings on its euryhaline and sediment-tolerant nature (Raganas & Magcale-Macandog 2020).

The second canonical axis (CCA 2), which captured 16.31% of the total variance, highlighted more specific relationships. Species such as *Semisulcospira plicaria*, *Vittina coromandeliana*, and *V. jovis* were positively associated with elevated soil phosphorus levels, implying nutrient-specific habitat preferences (Almadin et al. 2020). In contrast, *Cerithidea quoyii, V. waigiensis, V. variegata,* and *Pirenella savaiensis* displayed negative correlations with dissolved oxygen, potassium, and organic matter. This inverse relationship suggests these species may be more prevalent in areas with relatively lower concentrations of these soil parameters.

Association of Gastropods Towards Mangrove Species

Figure 6 illustrates the relationships between gastropod species and mangrove tree abundance across Barangays Lumbocan and Pagatpatan using Canonical Correspondence Analysis (CCA). CCA 1 explained 71.27% of the total variation, indicating a strong correspondence between gastropod distribution and mangrove structure in the area.

A notable pattern observed is the inverse relationship between *Rhizophora mucronata* and gastropod species such as *Vittina turrita, Neritodryas dubia*, and *Faunus ater*. This suggests that in areas where *R. mucronata* is less abundant or experiencing growth limitations, these gastropods tend to be more prevalent. Such an association may reflect a compensatory ecological role of gastropods in nutrient cycling, detritus decomposition, and maintaining trophic balance in microhabitats with sparse canopy cover or reduced structural complexity. Gastropods also utilize available mangrove structures for refuge and substrate, while their feeding and burrowing behaviors enhance nutrient availability and support ecosystem function (Ebadzadeh et al. 2021).

In contrast, CCA 2 accounted for a smaller

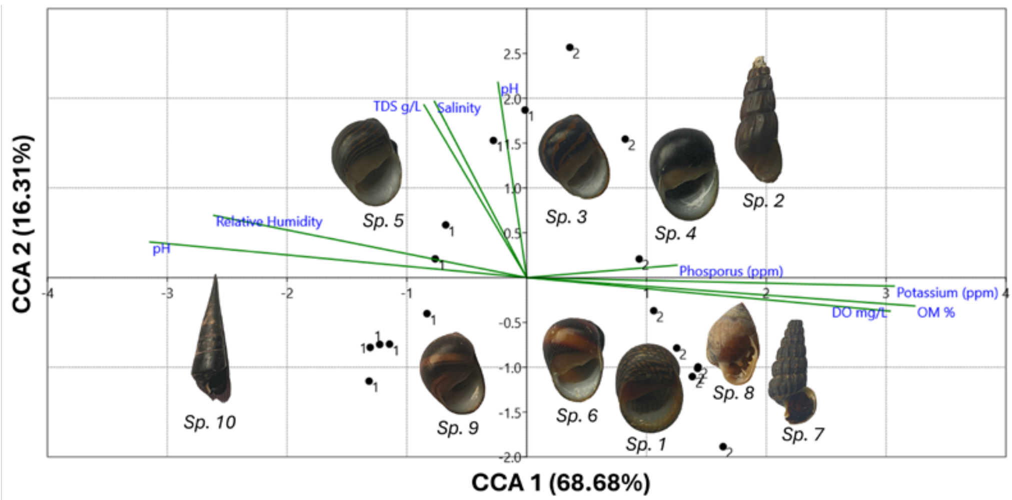

Figure 5. Canonical Correspondence Analysis showing the association of gastropods, and the water and soil parameters in the two mangrove habitats of Butuan City. Sp. 1. *Cerithidea quoyii;* Sp. 2. *Stenomelania plicaria;* Sp. 3. *Vittina coromandeliana;* Sp. 4. *Vittina jovis;* Sp 5. *Vittina turrita;* Sp. 6. *Vittina waigiensis;* Sp. 7. *Vittina variegata;* Sp. 8. *Pythia savaiensis;* Sp. 9. *Neriodryas dubia;* Sp. 10. *Faunus ater.*

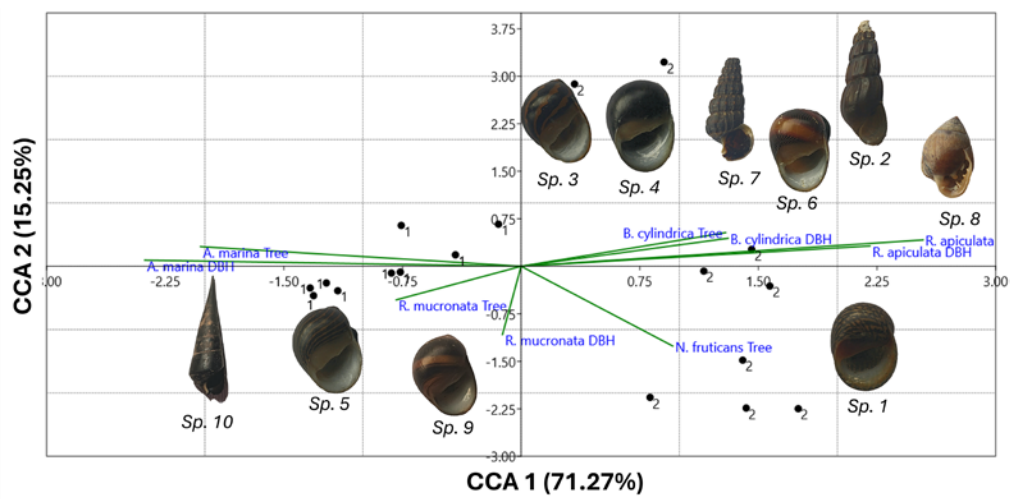

Figure 6. Canonical Correspondence Analysis showing the association of gastropods and mangrove features in the two mangrove habitats of Butuan City. Sp. 1. *Cerithidea quoyii*; Sp. 2. *Stenomelania plicaria*; Sp. 3. *Vittina coromandeliana*; Sp. 4. *Vittina jovis*; Sp 5. *Vittina turrita*; Sp. 6. *Vittina waigiensis*; Sp. 7. *Vittina variegata*; Sp. 8. *Pythia savaiensis*; Sp. 9. *Neriodryas dubia*; Sp. 10. *Faunus ater*.

proportion of variation and revealed weaker species–mangrove associations, as indicated by the disper-sed distribution of species in the ordination space. Despite this, species such as *Semisulcospira plicaria, Vittina coromandeliana, V. jovis, V. waigiensis, V. variegata,* and *Pirenella savaiensis* showed po-sitive correlations with the growth and abundance of *Rhizophora apiculata* and *Bruguiera cylindrica* (Imamsyah et al. 2020). These mangrove species likely provide preferred microhabitats, offering shade, detritus-rich sediments, and root complexity that support gastropod settlement, foraging, and reproduction. This underscores a mutually reinforcing ecological relationship, where gastropods benefit from structural shelter and substrate, while their presence contributes to sediment aeration and nutrient turnover (Lee et al. 2019).

Additionally, *Cerithidea quoyii* demonstrated a strong association with *Nypa fruticans* (Hilmi et. Al 2022), a mangrove palm typically found in the muddy, low-lying fringes of mangrove zones. This rela-tionship may be mutually beneficial, with *C. quoyii* utilizing the soft sediments around *N. fruticans* for burrowing and detritus feeding, while in return aid-ing nutrient cycling and organic matter breakdown in areas where *N. fruticans* thrives (Alongi 2008). The observed patterns emphasize the importance of conserving both gastropods and their associated mangrove hosts, given their functional interdependence and contributions to the resilience and health of coastal ecosystems.

4 Conclusion

The study demonstrates a strong influence of environmental variables on gastropod diversity and distribution in Barangays Lumbocan and Pagatpatan. Pagatpatan exhibited higher gastropod species richness, diversity, and evenness, which were linked to elevated organic matter and more heterogeneous mangrove habitats. In contrast, Lumbocan, though richer in abundance, was dominated by a few species, particularly *Faunus ater*.

These findings imply that mangrove ecosystem health and biodiversity can be effectively assessed through gastropod community structure. Therefore, conservation and management strategies should prioritize maintaining mangrove habitat heterogeneity and minimizing anthropogenic stressors such as nutrient runoff. The use of gastropods as ecological indicators offers a cost-effective and locally adaptable tool for monitoring environmental quality and guiding rehabilitation efforts in coastal wetlands.

5 Acknowledgement

The authors sincerely express their deepest appreciation to the Barangay Councils of Pagatpatan and Lumbocan for their permission and support in conducting this assessment. Their cooperation was instrumental to the successful completion of the study. Special acknowledgment is extended to Mr. Harold Lipae, a malacologist from the University of the Philippines Manila, for his expertise in the identification and confirmation of gastropod specimens. Appreciation is also extended to Mr. Archie Along of Caraga State University for his assistance in identifying mangrove species.

6 Statement of Conflict of Interest

MV Elvira, who serves on the JESEG Editorial Board, had no involvement in the review of this manuscript to preserve objectivity in the evaluation process. Furthermore, the authors affirm that there are no financial or personal relationships that could be perceived as potential conflicts of interest in relation to this work.

7 Author Contribution

DJR Malinao, MPL Nicmic, and TC Abrea Jr contributed to the conception and design of the study, analysis and interpretation of data, as well as the drafting and revision of the manuscript for significant intellectual content. ARV Galolo was involved in the drafting and revision of the manuscript for significant intellectual content and approved the final version to be published. L Calagui participated in the study's conception and design and approved the final manuscript. SL Paz contributed to the conception and design of the study, drafting and revision of the manuscript for significant intellectual content, and approved the version for publication. MV Elvira was involved in the conception and design of the study, data analysis and interpretation, drafting and revision of the manuscript for significant intellectual content, and gave final approval for the version to be published.

8 Literature Cited

Abbasi UA, Mattsson E, Nissanka SP, Ali, A. 2022 Species α-diversity promotes but β-diversity restricts above ground biomass in tropical forests, depending on stand structure and environmental factors. *Journal of ForestryResearch/Journal of Forestry Research*, **34** (4),889–901.https://doi.org/10.1007/s11676-022-01560-8

Abbot RT, Morris PA. 2001. A Field Guide to Shells: Atlantic and Gulf Coasts and the West Indies. *USA: Houghton Mifflin Harcourt.* 512 p.

Akram H, Hussain S, Mazumdar P, Chua K, Butt TE, Harikrishna JA. 2023. Mangrove Health: A Review of Functions, Threats, and Challenges Associated with Mangrove Management Practices. Forests.

Al-Khayat JA, Alatalo JM. 2021. Relationship between tree size, sediment mud content, oxygen levels, and pneumatophore abundance in the mangrove tree species Avicennia Marina (Forssk.) Vierh. J*ournal of Marine Science and Engineering* **9**(1): 100.

Alongi DM. 2008. Mangrove forests: menaces and management for the future. *Conservation Biology* **22**: 234-248.

Almadin FJF, Abing BRL, Arbas BJR, Culob EG, Dichos MLB, Padios RB Jr, Solania CL. 2020. Relationship of Floral Community and Soil Properties in Selected Riparian Banks of Lower Agusan River Basin, Philippines. *Journal of Ecosystem Science and Eco-Governance* **2**(1): 32-41.

Asari N, Suratman MN, Mohd A, Hamid A. 2021. Mangrove as a Natural Barrier to Environmental Risks and Coastal Protection. *Springer EBooks*: 305-322.

Bashir O, Ali T, Baba ZA, Rather GH, Bangroo SA, Mukhtar SD, Naik N, Mohi-Ud-Din R, Bharati V, Bhat RA. 2021. Soil organic matter and its impact on soil properties and nutrient status. *In Springer eBooks*: 129-159.

Beasley, C. R., Fernandes, C. M., Gomes, C. P., Brito, B. A., Santos, S. D., & Tagliaro, C. H. (2005). Molluscan diversity and abundance among coastal habitats of northern Brazil. *Ecotropica* **11**(1), 9-20.

Canencia MO., Arances JB., Lagunzad DA. 2022. Gastropods as bioindicators of mangrove habitat condition in northern Mindanao, Philippines. *Philippine Journal of Science*, **151**(3), 897–908.

Cañada MCB. 2020. Species richness and abundance of bivalves and gastropods in mangrove forests of Casiguran, Aurora, Philippines. *Open Journal of Ecology* **10** (12): 778-787.

Craine JM, Bettina, Lusk CH, Mcdowell NG, Poorter H. 2012. Resource limitation, tolerance, and the future of ecological plant classification. *Frontiers in Plant Science* **3**.

Cuenca-Ocay G, Bualan YN, Macusi E. 2023. Philippine mangroves: species composition, characteristics, diversity, and present status. *Davao Research Journal* **12** (2): 6-29.

Ebadzadeh H, Shojaei MG, Seyfabadi J. 2021. The effect of habitat structural complexity on gastropods in narid Mangrove Wetland. Research Square.

Fullerton DJ, Zhang LM, Kleitman S. 2021. An integrative process model of resilience in an academic context: Resilience resources, coping strategies, and positive adaptation. *PloS One* **16**(2): e0246000.

Garcia K, Malabrigo PL, Gevaña DT. 2013. Philippines' Mangrove ecosystem: status, threats and conservation. In Springer eBooks: 81-94.

Goloran AB, Laurence C, Glenn B, Tricia MA. 2020. Species Composition, Diversity and Habitat Assessment of Mangroves in the Selected Area along Butuan Bay, Agusan Del Norte, Philippines. *OAlib* **07**(04): 1-11.

Hamada K, Ohtsuka T, Fujitake N, Miyajima T, Yokoyama Y, Miyairi Y, Kida M. 2024. Functional organic matter components in mangrove soils revealed by density fractionation. *Soil Science and Plant Nutrition*: 1-12.

Hilmi, E., Sari, L. K., Cahyo, T. N., Dewi, R., & Winanto, T. (2022). The structure communities of gastropods in the permanently inundated mangrove forest on the north coast of Jakarta, Indonesia. *Biodiversitas Journal of Biological Diversity*, **23**(5).

Hossain M, Nuruddin AA. 2016. Soil and Mangrove: a review. J*ournal of Environmental Science and Technology* **9**(2): 198-207.

Imamsyah, A., Arthana, I. W., Astarini, I. A. 2020. The influence of physicochemical environment on the distribution and abundance of mangrove gastropods in Ngurah Rai Forest Park, Bali, Indonesia. *Journal: Biodiversitas,* **21**(7), 3178–3188.

Khondoker M, Mandal S, Gurav R, Hwang S. 2023. Freshwater shortage, salinity increase, and Global Food Production: A Need for Sustainable Irrigation Water Desalination—A Scoping Review. *Earth* **4**(2): 223-240.

Kovalenko, K.E., Thomaz, S.M., Warfe, D.M. 2012. Habitat complexity: approaches and future directions. *Hydrobiologia*. 685:1–17

Laureta LB, Marasigan ET. 2000. Habitat and reproductive biology of angelwings, Pholas orientalis. *Journal of Shellfish Resource.* **19**: 19-22.

Lee NLY, Huang D, Quek ZBR, Lee JN, Wainwright BJ. 2019. Mangrove-associated fungal communities are differentiated by geographic location and host structure. *Frontiers in Microbiology* **10**: 2456.

Magurran, A.E. 2021. Measuring biological diversity. *Current Biology*. **31**(19), R1174-R1177

Mangadlao IM. 2024. Butuan ramps up reforestation efforts vs flooding, water supply depletion. Rappler.

Mitra A. 2013. Brackish-Water Aquaculture: A new horizon in climate change matrix. *In Springer eBooks*: 245-323.

Moreno, C. E., Rodríguez, P. 2010. A consistent sampling protocol for biodiversity inventories: Optimizing specimen number and survey effort. *Revista Mexicana de Biodiversidad*, **81**, 105–113.

Nair, R.A., Jisha, S., Hari, B. 2024. Allometry and condition factor of Faunus ater(Cerithioidea: Pachychilidae) from An Estuarine Habitat of Kerala, Southern India. *Journal of Tropical Life Science.* **14** (2), 377–388.

Octavina C, Defira C, Ulfah M, Purnawan S, Dwiriansyah R. 2019. Community structure of Gastropods in mangrove ecosystem of Pulo Sarok Village, Aceh Singkil Regency, Indonesia. IOP Conference Series: *Earth and Environmental Science* **348**: 012005.

Pogado F, de Chavez ERC. 2022. Diversity and community assembly patterns of gastropods in island and fringing mangrove forests in Calatagan, Batangas, Philippines. *Journal of Wetlands Biodiversity* **12**: 7-23.

Poppe GT. 2008a. Philippine Marine Mollusks Volume I (Gastropoda Part I). – Hackenheim, Germany (ConchBooks):759 pp, 312 pls.

Poppe GT. 2008b.Philippine Marine Mollusks Volume II (Gastropoda Part II). – Hackenheim, Germany(ConchBooks): 848 pp, 313-707 pls.

Poppe GT. 2010. Philippine Marine Mollusks Volume III (Gastropoda Part III & Bivalvia Part I). – Hackenheim, Germany (ConchBooks): 665 pp, 708-1014 pls.

Poppe GT. 2011. Philippine Marine Mollusks Volume IV (Bivalva Part II). – Hackenheim, Germany (ConchBooks): 676 pp., 1015-1315 pls.

Primavera, J.H., R.S. Sadaba, M.J.H.L. Lebata and J.P. Altamirano. 2004. Handbook of Mangroves in the Philippines-Panay. SEAFDEC Aquaculture Depart ment, Iloilo, Philippines. 106pp.

Raganas AF, Magcale-Macandog DB. 2020. Physicochemical factors influencing zonation patterns, niche width and tolerances of dominant mangroves in southern Oriental Mindoro, Philippines. *Indo Pacific Journal of Ocean Life* **4**(2).

Reid DG, Claremont M, Smith L, Shamoto M, Glaubrecht M, Ozawa T. 2013. Mosaics in the mangroves: allopatric diversification of tree-climbing mudwhelks (Gastropoda: Potamididae:Cerithidea) in the Indo-West Pacific. *Biological Journal of the Linnean Society* **110**(3): 564-580.

Salmo SG, Tibbetts IR, Duke NC. 2016. Colonization and shift of mollusc assemblages as a restoration indicator in planted mangroves in the Philippines. *Biodiversity and Conservation* **26**(4): 865-881.

Springsteen FJ, Leobrera FM. 1986. Shells of the Philippines. Manila: Carfel Seashell Museum. 377 p.

Strong EE, Gargominy O, Ponder WF, Bouchet P. 2007. Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. *Hydrobiologia* **595**(1): 149-166.

Susi Cgo, Ladesma J. 2020. Floral Assessment in Kayam Forest in Brgy. Pagatpatan, Butuan City, Agusan del Norte, Philippines. *Journal of Biodiversity and Envi ronmental Sciences* **17**(2): 1-4

Tan SK, Clements R. 2008. Taxonomy and Distribution of the Neritidae (Mollusca: Gastropoda) in Singapore. *Zoological Studies* **47**: 481-494.

Velasco RU, Lopez ML, Devanadera MK. 2018. Gastropod diversity in the Riparian Zone of Balingasay River, Bolinao, Pangasinan, Philippines. *Acta Manilana* **66**: 45-53.

Zvonareva, S., Kantor, Y. 2016. Checklist of gastropod molluscs in mangroves of Khanh Hoa province, Vietnam. *Zootaxa*, **4162** (3), 401–437.