Survey of mangrove habitats in Dumanquillas Bay: recent observations and findings

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Abstract. A survey of mangrove species in Dumanquillas Bay, Zamboanga del Sur, identified twelve true mangrove species from five orders and families, representing 30.8% of the total mangrove species in the Philippines. The Rhizophoraceae family, notably including *Bruguiera parviflora*, *Bruguiera sexangula*, *Rhizophora apiculata*, *Rhizophora mucronata*, and *Rhizophora stylosa*, was the most dominant due to its adaptability and specialized traits. The diversity index revealed low species diversity across all stations, namely: Lumbal and Biu-os (Vincenzo Sagun), Bualan and Gusom (Kumalarang), Digon and Tiguian (Margosatubig), and Danganan and Maruing (Lapuyan), reflecting the specialized habitat conditions of mangroves. Bualan (Kumalarang) showed the highest relative abundance (20%), likely due to favorable conditions from a nearby river providing freshwater and nutrients. *Sonneratia alba* was the most widely distributed and dominant species, whereas *Avicennia rumphiana* and *Camptostemon philippinensis* were found only in specific locations, indicating their specialized habitat needs. Conservation concerns were noted for *Aegiceras floridum* (Near Threatened), *A. rumphiana* (Vulnerable), and *C.philippinensis* (Endangered). The study highlights the critical ecological role of mangroves despite their lower plant diversity.

Key Words: conservation, endangered species, *Sonneratia alba*, species diversity.

Introduction. Mangroves are distinctive ecosystems characterized by euryhaline trees, shrubs, and plants that are predominantly found in tropical and some subtropical regions globally (Mitsch & Gosselink 2007). They thrive in challenging environments along wet coastlines, deltas, and estuaries, showcasing diverse adaptations to saline and fluctuating oxygen conditions (Leal & Spalding 2022).

Mangroves play crucial roles in coastal ecosystems, offering diverse ecological, economic, and cultural benefits. They serve as natural buffers against storms and coastal erosion, safeguarding coastal communities and infrastructure (Blankespoor et al 2017). These ecosystems provide essential habitat for numerous species, including commercially important fish and crustaceans, contributing to fisheries and biodiversity conservation (Nagelkerken et al 2008). Mangroves enhance water quality by filtering pollutants and trapping sediments, benefiting adjacent marine ecosystems like coral reefs and seagrass beds (Nagelkerken et al 2008). Moreover, they are significant carbon sinks, sequestering large amounts of carbon dioxide through vegetation and soil processes, thereby mitigating climate change impacts (Donato et al 2011). Economically, mangroves support livelihoods through timber, non-timber forest products, and tourism, while culturally they hold spiritual and recreational value for coastal communities (Primavera 2004; Spalding et al 2010).

According to the Global Mangrove Alliance (2023), global mangrove coverage was 15.26 million hectares in 1996, declining to 14.74 million hectares by 2020 - a net loss of 524,500 hectares (3.4%) primarily due to human activities and unsustainable practices. Annual losses decreased from 32,700 hectares (0.21%) between 1996 and 2010 to 6,600 hectares (0.04%) from 2010 to 2020 (Leal & Spalding 2022). Despite recent reports suggesting an increase in global mangrove cover to 14.8 million hectares, Asia holds the largest share of mangroves (39.2%) but faces challenges in conservation (Jia et al 2023). In the Philippines, ranked 14th globally for mangrove distribution (Jia et al 2023), mangrove coverage spans 311,400 hectares (Philippine Forestry Statistics 2021). However, extensive mangrove loss occurred from approximately 400,000-500,000 hectares in 1920 to about 120,000 hectares by 1994, primarily due to widespread aquaculture development starting in the 1950s (Primavera 1997; Spalding et al 2010). National initiatives focusing on mangrove restoration and community engagement have since facilitated the recovery of damaged mangrove forests (Farley et al 2010; Camacho et al 2011; Garcia et al 2014).

Mangroves are increasingly recognized for their role in climate change mitigation, notably within the United Nations Framework Convention on Climate Change (UNFCCC) and Sustainable Development Goal 14, which targets the conservation of marine life. In the Philippines, national strategies under REDD+ focus on mitigating mangrove destruction and enhancing carbon stocks in mangrove forests. Zamboanga del Sur contributes 6,579 hectares to the country's mangrove cover, with Dumaquillas Bay alone spanning 1,437.5 hectares (Philippine Forestry Statistics 2021; DBPLS–PAMP 2023-2032). The Coastal Resource Management efforts led by the Community Environment and Natural Resource Office (CENRO) have conducted ecological assessments in Dumaquillas Bay. However, literature on mangrove species composition, abundance, species distribution, biodiversity, and vegetation analysis in the Zamboanga Peninsula remains limited. Therefore, comprehensive understanding and ongoing monitoring of this ecosystem are crucial for its effective management, conservation, and sustainable development, benefiting both ecological health and local economies. The objective of this study was to conduct a recent survey of mangroves in Dumanquillas Bay to identify mangrove species, assess their abundance, evaluate species distribution, analyze biodiversity, and examine vegetation structure.

Material and Method

Study area. The study took place in selected coastal municipalities surrounding Dumanquillas Bay, Zamboanga del Sur, Philippines (7.6537° N, 123.0902° E) (Figure 1).

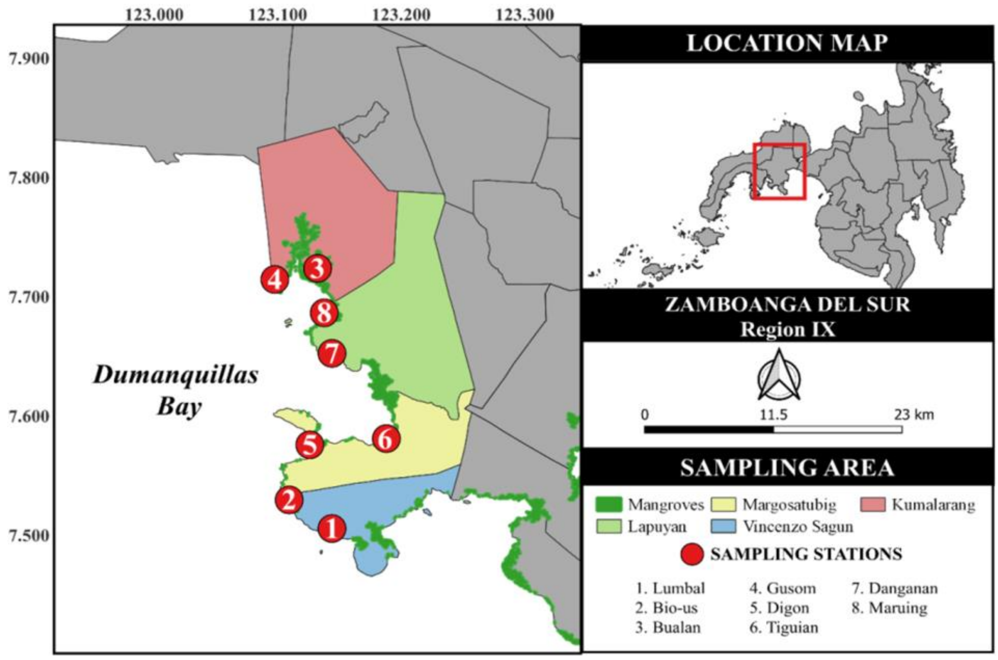

Figure 1. Map of the study area and location of the mangrove sampling stations.

Established on August 10, 1999, Dumanquillas Bay is a protected area under the National Integrated Protected Areas System (NIPAS) Act (RA 11038), spanning across Zamboanga del Sur and Zamboanga Sibugay provinces. It encompasses 41 coastal barangays spread across six municipalities: Vincenzo Sagun, Margosatubig, Lapuyan, Kumalarang, Buug, and Malangas. The study focused on eight coastal barangays within Dumanquillas Bay: Lumbal and Biu-os (Vincenzo Sagun), Bualan and Gusom (Kumalarang), Digon and Tiguian (Margosatubig), and Danganan and Maruing (Lapuyan). These municipalities, classified from 3rd to 5th class, predominantly rely on agriculture and fishing for livelihoods (DILG IX - ZAMPEN, n.d.). The marine resources of these areas are managed and protected by the Dumanquillas Bay Protected Landscape and Seascape (DBPLS) under the Provincial Environment and Natural Resources Office (PENRO).

Establishment of plots. Nine plots, each measuring 20 meters by 10 meters, were established at 300-meter intervals at each site. Plot placement and set-up were adjusted based on site accessibility. Typically, 20 meters is the maximum distance that can be accurately surveyed in dense forest environments (Dallmeier 1992). In total, 72 plots were set up across eight designated mangrove sites in Dumanquillas Bay.

Identification of mangrove species. Mangroves were identified based on their leaf morphology, phyllotaxy, and characteristics of their flowers and fruits. The taxonomic classification was determined using Primavera (2004, 2009).

Measurement of relative abundance, diversity, species distribution and vegetation structures of magroves. The relative abundance of mangroves at each sampling station was determined by calculating the proportion of mangroves at each station compared to the total number of mangroves across all stations. In this study, only mature trees were included, defined as those exceeding 4 meters in height, as per the criteria established by Ashton & Macintosh (2002). The diversity indices included in this study were dominance, Shannon-Weiner diversity, Simpson richness and evenness. The Shannon-Weiner diversity index values were categorized according to the diversity scale established by Fernando (1998). The distribution of mangrove species was assessed through direct observation, recording their presence or absence at each sampling site. Moreover, the vegetation structure was analyzed by calculating the importance value index (IVI) for each species. The IVI is derived from the sum of three components: relative density (RD), relative frequency (RF), and relative dominance (RDOM) of each species within each sampling site. The IVI was calculated using the standard formula as described by Krebs (1989): IVI = relative density + relative frequency + relative dominance, where: Relative density (RD, %) = density of species A / total density x 100; Relative frequency (RF, %) = frequency of species A / total frequency x 100; Relative dominance (%, RDOM) = basal area of species A / total basal area x 100. The basal area (BA) was computed using the formula: $3.1416 (DBH)^2 / 4$ as described by English et al (1997). The diameter at breast height (DBH) was measured with a tape measure and determined by dividing the circumference by 3.1416. This comprehensive index provides a measure of each species' overall contribution to the vegetation structure of mangroves.

Statistical analysis. The differences in relative abundance and vegetation structure among mangrove species and sampling stations were assessed using Kruskal-Wallis test ($p < 0.05$, SPSS Software version 8). Diversity indices were calculated with the Paleontological Statistics Software (PAST).

Results and Discussion

Identification and classification of mangrove species. A total of twelve true mangrove species, representing five orders and five families, were recorded and identified across eight sampling stations in Dumanquillas Bay, Zamboanga del Sur (Table 1). This number constitutes 30.8% of the 39 mangrove species documented throughout the Philippines (Primavera 2004). The family Rhizophoraceae, within the order Malpighiales, was notably predominant, including species such as *Bruguiera parviflora*, *Bruguiera sexangula*, *Rhizophora apiculata*, *Rhizophora mucronata*, and *Rhizophora stylosa*. The prevalence of Rhizophoraceae in the area can be attributed to the family's adaptability, resilience, and rapid reproductive strategies, which allow these species to flourish in challenging environmental conditions (Guo et al 2017; de Silva & Amarasinghe 2021). Key adaptive features of Rhizophoraceae include viviparous embryogenesis, which safeguards delicate propagules and facilitates effective seedling dispersal (Tomlinson & Cox 2000; Guo et al 2017); high salt tolerance due to the osmotic potential of their wood structure (Sheue et al 2012; Guo et al 2017); and aerial roots that improve oxygen absorption in oxygen-poor soils (Xu et al 2017). In contrast, the families Primulaceae and Malvaceae, which belong to the orders Ericales and Malvales respectively, were represented by the fewest species. Among the twelve mangrove species identified, three are highlighted for conservation concern according to the International Union for Conservation of Nature (IUCN) Red List: *Aegiceras floridum* is classified as Near Threatened, *Avicennia rumphiana* is categorized as Vulnerable, and *Camptostemon philippinensis* is considered Endangered (IUCN 2024).

Table 1

Classification of mangroves identified in Dumanquillas Bay, Zamboanga del Sur

Order	*Family*	*Genus*	*Species*	*Local name*
Ericales	Primulaceae	*Aegiceras*	*floridum*	Tinduk-tindukan
Lamiales	Acanthaceae	*Avicennia*	*alba*	Bungalon-puti
		Avicennia	*marina*	Bungalon
		Avicennia	*rumphiana*	Api-apian
Malphighiales	Rhizophoroceae	*Bruguiera*	*parviflora*	Langarai
		Bruguiera	*sexangula*	Karakandang
		Rhizophora	*apiculata*	Bakhawan lalaki
		Rhizophora	*mucronata*	Bakhawan babae
		Rhizophora	*stylosa*	Bakhawan bato
Malvales	Malvaceae	*Camptostemon*	*philippinensis*	Gapas-gapas
Myrtales	Lythraceae	*Sonneratia*	*alba*	Pagatpat
		Sonneratia	*caseolaris*	Pedada

Relative abundance, diversity, species distribution and vegetation structure of mangroves. A survey of 803 trees across eight sampling stations in Dumanquillas Bay revealed significant variations in mangrove abundance, as evidenced by the Kruskal-Wallis test results ($H = 29.451$; $df = 7$; $p = 0.000$). Among these stations, Bualan (Kumalarang) stood out with the highest relative abundance, totaling 20% (Figure 2). This notable abundance is likely attributed to Bualan's location near a large river that feeds into the main Kumalarang River, one of the largest rivers in the Zamboanga Peninsula. The river's substantial flow enhances mangrove growth by providing a robust supply of freshwater and sediment. Crucially, the mangrove forest at Bualan is situated centrally within the river's delta, where nutrient and sediment delivery is particularly effective. This strategic position creates a stable and favorable environment for mangroves, contributing to their high density and vitality. Mangroves benefit greatly from river runoff, which dilutes seawater and lowers salinity levels - conditions essential for their growth. High salinity can have detrimental effects such as seedling mortality (Ball & Pidsley 1995), canopy loss (Lovelock et al 2017), reduced water uptake (Nguyen et al 2017), and osmoregulation failure (Hasegawa et al 2000; Li et al 2008), potentially leading to death and degradation of biodiversity (Munns & Termaat 1986; Lee et al 2017). River runoff also provides essential nutrients that boost mangrove productivity and carries sediments that help build and maintain mangrove soils. In regions with limited rainfall, this runoff is a vital source of freshwater. The interplay of freshwater and nutrient-rich conditions fosters diverse habitats that support a wide range of species within the mangrove ecosystem (Kathiresan & Bingham 2001). Additionally, Bualan benefits from minimal disturbances, with residential areas situated farther from the mangrove zones, thereby mitigating anthropogenic pressures and further protecting its mangrove ecosystems.

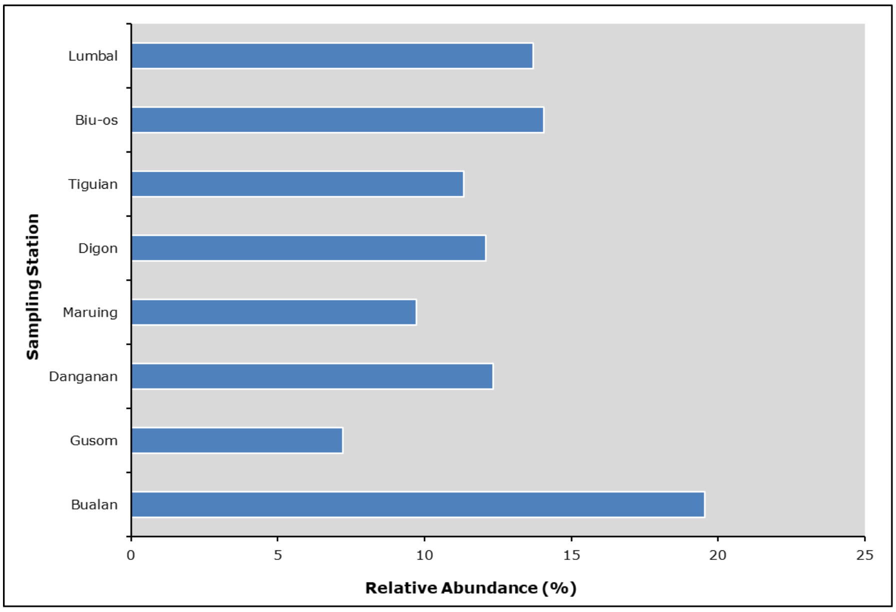

Figure 2. Relative abundance of mangroves in Dumanquillas Bay, Zamboanga del Sur.

The Shannon-Wiener index (H') reveals that all mangrove stations in Dumanquillas Bay have a low diversity index (Table 2). This lower plant diversity in mangroves compared to other ecosystems is attributed to their specialized habitat requirements, including high salinity, tidal inundation, and anoxic soils, which limit the number of plant species that can thrive (Kathiresan & Bingham 2001). Furthermore, before being designated as a protected area by the Department of Environment and Natural Resources (DENR-Region 9), the mangrove ecosystem in Dumanquillas Bay was subjected to anthropogenic pressures such as logging and fishpond conversion. Specifically, many mangroves in Kumalarang are remnants of logging operations by Philippine Capital Incorporated during the 1950s and 1960s. Despite these challenges, mangroves play crucial ecological roles, including coastal protection and carbon sequestration, and support a diverse range of animal species, especially in Dumanquillas Bay. This underscores their significant ecological function, even with lower plant species diversity, particularly evident within the mangrove communities of Dumanquillas Bay (DBPLS-PAMP 2023-2032).

Table 2

Diversity profile of mangroves in Dumanquillas Bay, Zamboanga del Sur

Diversity indices	*Sampling station*							
	BUA	*GUS*	*DAN*	*MAR*	*DIG*	*TIG*	*BIU*	*LUM*
Taxa (S)	4	3	5	3	7	3	7	6
Individuals	157	58	99	78	97	91	113	110
Dominance index (DI)	0.30	0.56	0.55	0.81	0.58	0.46	0.26	0.29
Diversity index (H’)	1.30	0.76	0.84	0.41	0.94	0.88	1.59	1.36
Richness index (R)	0.70	0.44	0.45	0.19	0.42	0.55	0.74	0.72
Evenness index (J’)	0.92	0.71	0.46	0.50	0.36	0.80	0.70	0.65

Legend: BUA is Bualan; GUS is Gusom; DAN is Danganan; MAR is Maruing; DIG is Digon; TIG is Tiguian; BIU is Biu-os; LUM is Lumbal.

Sonneratia alba is present at all sampling stations and is extensively distributed across most mangrove areas (Table 3). In contrast, *Avicennia rumphiana* and *Camptostemon philippinensis* were exclusively found in Digon, while *Bruguiera parviflora* and *Bruguiera* *sexangula* were observed only in Biu-os. This distribution pattern suggests that these species have specific habitat preferences influenced by localized environmental conditions or unique ecological factors at each sampling station. The dominance of *S. alba* in the mangrove forest of Dumanquillas Bay is highlighted by its high IVI (Table 3). Despite its low seed viability, *S. alba* thrives due to its role as a pioneering, fast-growing species that typically inhabits the seaward edge of mangrove forests (Thampanya 2006). Its adaptability to varying environmental conditions, especially its tolerance for high salinity and significant fluctuations in saltwater inundation, is well-documented (Ball & Pidsley 1995; Raganas et al 2020; Jeffry et al 2024). This resilience contributes to its widespread dominance and abundance in mangrove ecosystems, aligning with observations by Mendoza & Alura (2001), Becira (2006), and Kasawani et al (2007). Additionally, *S. alba's* pneumatophores aid in salt excretion, enhancing its ability to thrive in challenging conditions (Polidoro et al 2010). Locally, *S. alba* is found in regions such as Bacolod (Benecario et al 2016), Sarangani Bay (Natividad et al 2015; Barcelete et al 2016), Bohol (Middeljans 2014), Leyte (Picardal et al 2011), Camotes Island in Cebu (Lillo et al 2022), and Zamboanga Sibugay (Bitantos et al 2017). On a global scale, it is prevalent in Indonesia (Setyawan 2009; Imamsyah et al 2020; Matatula et al 2021; Zulhalifah et al 2021) and Malaysia (Kasawani et al 2007; Ismail & Muhammad 2014).

Table 3
Distribution of species and vegetation structure of mangroves in Dumanquillas Bay, Zamboanga del Sur

Species	*IVI*	*Sampling station*							
		BUA	*GUS*	*DAN*	*MAR*	*DIG*	*TIG*	*BIU*	*LUM*
Sonneratia alba	174.06	+	+	+	+	+	+	+	+
Rhizophora apiculata	44.16	+	-	+	+	+	+	+	+
Avicennia alba	26.20	+	+	+	-	+	-	-	+
Sonneratia caseolaris	19.22	-	+	+	-	+	-	+	+
Avicennia marina	9.99	-	-	+	-	-	-	-	+
Rhizopora mucronata	9.80	+	-	-	+	-	-	+	-
Bruguiera parviflora	3.99	-	-	-	-	-	-	+	-
Rhizophora stylosa	3.80	-	-	-	-	-	+	+	-
Avicennia rumphiana	3.63	-	-	-	-	+	-	-	-
Aegiceras floridum	2.41	-	-	-	-	+	-	+	-
Bruguiera sexangula	1.94	-	-	-	-	-	-	+	-
Camptostemon philippinensis	0.81	-	-	-	-	+	-	-	-

Legend: (+) present; (-) absent; BUA is Bualan; GUS is Gusom; DAN is Danganan; MAR is Maruing; DIG is Digon; TIG is Tiguian; BIU is Biu-os; LUM is Lumbal.

Conclusions. The dominance of *Sonneratia alba* throughout the mangrove forest of Dumanquillas Bay underscores its critical role in shaping the ecosystem's structure and composition. Recognizing its dominance and understanding its ecological functions are essential for the effective conservation and management of mangrove ecosystems in Dumanquillas Bay and similar regions. The IUCN classifications indicate that *Aegiceras floridum* is Near Threatened, *Avicennia rumphiana* is Vulnerable, and *Camptostemon philippinensis* is Endangered, highlighting the urgent need for protective measures to prevent further decline and ensure the survival of these species. Additionally, the high relative abundance of mangroves in Bualan, located at the river delta, demonstrates the significant impact of increased river runoff. The influx of nutrients and sediment from the river supports vigorous mangrove growth and contributes to the overall health and sustainability of the ecosystem in this delta region.

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Conflict of interest. The authors declare that there is no conflict of interest.

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