BIODIVERSITAS
Volume 25, Number 5, May 2024
Pages: 2093-2103

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250527

Floristic diversity of Naungan mangrove ecosystem in Ormoc, the largest port city in Leyte, Philippines

ARTURO E. PASA[1], VAL JASON D. SOLANO[1], SHAINA MAE S. FIGUEROA[1], ERNIE O. VALENZONA[1], ANNE FRANCES V. BUHAY[2], INOCENCIO E. BUOT JR[2,♥]

[1]Department of Forest Science, College of Forestry and Environmental Science, Visayas State University. Visca, Baybay City, Leyte 6521, Philippines
[2]Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines Los Baños. College, Batong Malake, Laguna 4031, Philippines. Tel.: +63-49-536-2893, ♥email: iebuot@up.edu.ph

Manuscript received: 20 March 2024. Revision accepted: 17 May 2024.

Abstract. *Pasa AE, Solano VJD, Figueroa SMS, Valenzona EO, Buhay AFV, Buot Jr IE. 2024. Floristic diversity of Naungan mangrove ecosystem in Ormoc, the largest port city in Leyte, Philippines. Biodiversitas 25: 2093-2103.* Assessing the floristic diversity of the Naungan mangrove ecosystem in Ormoc, the largest port city in Leyte and a highly susceptible area to geologic and natural hazards, extreme weather events and human disturbances, is vital to determine available resources and ecosystem services for communities. This study aimed to evaluate the present state of the mangrove ecosystem in Naungan by analyzing its floristic diversity, composition, and structural characteristics. A total of 55 nested quadrats were established as observation points, measuring 10 m x 10 m and 5 m x 5 m to document the upper canopy and understorey vegetation, respectively. Mangroves with a diameter of 10 cm and above were recorded for the upper canopy while plants with diameter below 10 cm were recorded for the understorey. Results showed that the upper canopy vegetation has a total of 331 individuals of which are 10 tree species belonging to 8 families while the understorey canopy has a total of 1,310 individuals of which are 23 species belonging to 15 families. The diversity of upper canopy vegetation, as measured by the Shannon index, is notably low at 1.492. Similarly, the understorey diversity, with a value of 2.198, falls into the low category. When considering the combined diversity of both upper and lower canopies, the overall score remains low at 2.176. *Avicennia marina* is the most dominant upperstorey species with a relative abundance of 0.39275 followed by *Sonneratia alba* with 0.27492 and *Avicennia officinalis* with 0.16012. The understorey is also dominated by *Avicennia marina* with a relative abundance of 0.352672 followed by *Nypa fruticans* with 0.118321 and *Rhizophora apiculata* with 0.10229. *Aegiceras floridum* and *Ceriops decandra* are “nearly threatened” while the other species are under the “least concern” category. The area is managed by a people’s organization but threats such as fishpond establishment, road construction, and subsistence farming remain and are expected to affect mangrove diversity and ecosystem services. A mangrove ecosystem conservation framework is proposed, incorporating the importance of policy intervention and local participation in realizing sustainable mangrove ecosystems and stable provisions of the ecosystem services.

Keywords: Eastern Visayas, ecosystem services, mangrove species, plant diversity

INTRODUCTION

Mangroves cover a total of 18 million hectares around the world, 35% of which are found in Southeast Asian countries (Primavera et al. 2000) including the Philippines. The intricate mangrove ecosystems serve as vital ecological centers, which provide ecosystem services crucial for both environmental sustainability and the livelihoods of the local community. Understanding the extent and availability of mangrove resources is important for conservation and management initiatives. This includes assessing not only the biodiversity within these habitats but also the ecosystem goods and services they offer to surrounding communities (UNEP 2014). These ecosystem services may include coastal protection, support for fishing livelihood, and carbon sequestration. Birch (2023) emphasized the existence of mangroves at the intersection of land and sea which serve as vital ecosystems in supporting estuaries and nature-based economies. They play a substantial role in the global carbon cycle and generate substantial quantities of organic matter, such as fallen leaves, branches, and various debris. Additionally, mangrove environments contribute to complex food webs and the transfer of energy (Nelson et al. 2019; Medina-Contreras et al. 2020; Kathiresan 2021).

Plant resources in mangrove ecosystem are composed by group of about seventy taxonomically diverse, tree, shrub, and fern species (Doydee et al. 2008; Sinfuego and Buot 2008; Tinh et al. 2009; Doydee and Buot 2011; Buot et al. 2013; Sinfuego and Buot 2014; Lillo and Buot 2016; Martinez and Buot 2018; Buot 2020; Buot et al. 2022) uniquely adapted to marine and estuarine conditions (Duke and Schmitt 2015). However, there has been an evident decline in the extent of mangrove areas around the world (Long et al. 2013; Fortes and Salmo III 2017; Thomas et al. 2017). This decrease is primarily attributable to human-induced pressures locally (Abantao et al. 2015; Baclado and Tatil 2017; Ladias 2020; Warui et al. 2020) and globally (Godoy and Lacerda 2015; Makowski and Finkl 2018; Friess et al. 2019; Seary 2019; Bryan-Brown 2020; Turschwell et al. 2020), such as extensive deforestation for fuel and building materials (Chima and Larinde 2016), the expansion of fishponds (Mialhe et al. 2016; Song et al. 2021; Bagarinao 2021; delos Santos et al. 2022), and the establishment of residential and industrial developments

(Menéndez et al. 2018; Gevaña et al. 2019; Primavera et al. 2019; Quevedo et al. 2022).

The Philippines is considered one of the world's eight biodiversity hottest hotspots (Myers et al. 2000). About 5% of the world's flora is found in the Philippines (Pelser et al. 2011; Garcia et al. 2014) comprising at least 13,500 species (Areas and Bureau 1998) including mangroves. In the global context, the nation was positioned as the 23rd country about its quantity of species, and it held the 7th position within the Asian region (Ordonez 2003). The country has at least 50% mangrove species of the world's with approximately 65 species (Garcia et al. 2014). The Philippine Forestry Statistics data in 2020 reported a total of 311,400 hectares of mangrove forest cover (FMB 2022) or equivalent to only about 4.3% of the total area of the Philippines. In the province of Leyte alone, the extent of mangrove forest covers approximately 6,598 hectares. Sadly, the dominance of human activities in socioecological production landscapes and seascapes, such as in Naungan mangrove ecosystem in Ormoc, Leyte results in the overutilization of natural resources and loss of critically important biodiversity (Buot and Osumi 2004; Buot 2008a, Buot 2008b; Buot 2014; Buot and Buhay 2022).

Forest resources, one of the frequently exploited resources that have provided ecosystem services, are affected by deforestation (Dechimo and Buot 2023) and mangroves are not an exemption. Mangrove ecosystems in Ormoc are highly susceptible to geologic and natural hazards and extreme weather events. Historical calamities serve as evidence of the vulnerability of Ormoc to natural threats like floods and landslides. This assertion is further supported by a study conducted by Toda et al. (2015), which highlights the elevated vulnerability and exposure to natural hazards, particularly in Naungan. These valuable ecosystems are also under threat from various anthropogenic activities, including deforestation, port establishment, and pollution exacerbated by dense population. Ormoc serves as a port city and its economy is diversified, encompassing agriculture, industry, tourism, and commercial services. The agricultural sector in Ormoc primarily focuses on the cultivation of staples such as rice and sugar cane as well as pineapple, constituting the main produce (Acob 2018).

Therefore, interventions must be formulated to avert the further destruction of mangrove ecosystem in the Philippines. An initial step is to undertake a floristic inventory and diversity assessments. Effective management of mangroves needs robust knowledge of their true status (Schmitt and Duke 2015; Webber et al. 2016; Romañach et al. 2018; Friess et al. 2019; Hai et al. 2020; Sheaves et al. 2020). By determining the scope and benefits of mangrove ecosystems, policymakers, researchers, and local communities can collaboratively develop strategies to safeguard these invaluable resources while promoting sustainable development and resilience in coastal areas, including in the Philippines. Hence, this study was conducted to fill the gap of the need to assess the current condition of the mangrove ecosystem like the case of Naungan. Mangrove ecosystem conservation framework is also proposed to realize sustainable mangrove ecosystems and stable provisions of the ecosystem services. This can be done by incorporating the importance of policy intervention and local participation in mangrove conservation and management efforts.

MATERIALS AND METHODS

Study area

The study was located at the mangrove forest in Barangay Naungan, Ormoc City, Philippines located between 10° 59'58.81" to 11° 0'2.81" N and 124° 33'17.09" to 124° 34'12.36" E (Figure 1). It is situated within the vicinity of the Barangay and accessible by foot or by using a motorboat (Figure 2). It is managed by a people's organization but anthropogenic threats like residential, aquaculture, agriculture, and other infrastructure establishments are present. The climate condition prevailing in the area is Type IV characterized by having rainfall that is evenly distributed throughout the year (pagasa.gov.ph, n.d.).

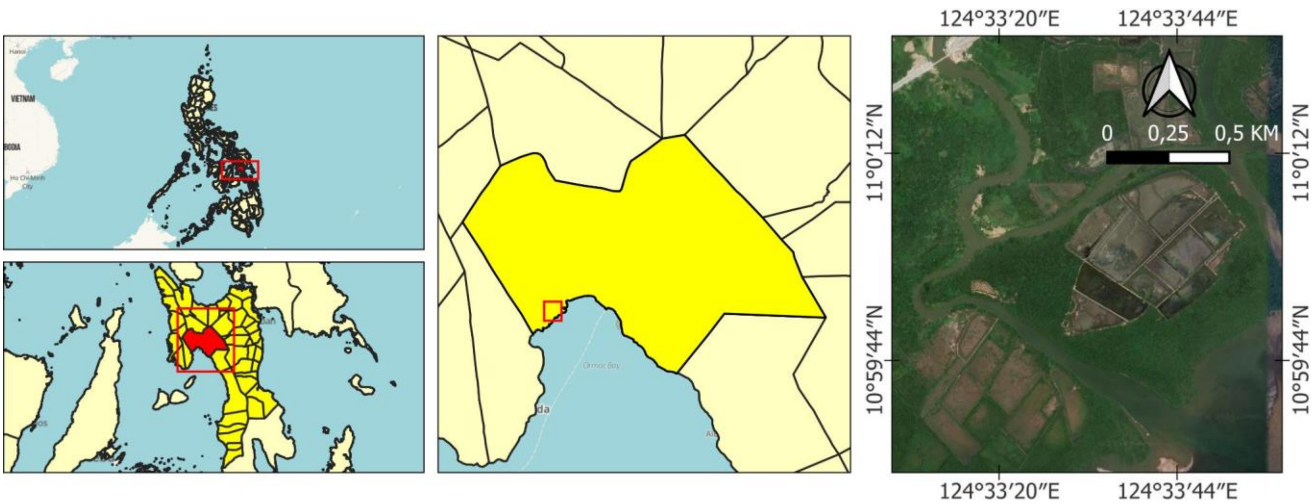

Figure 1. Location map of the study site in Barangay Naungan, Ormoc City, Leyte, Philippines

The mangrove forest is administratively considered as public land. Currently, the vegetation in this area is undergoing a process of rehabilitation initiated by local people's organizations. While there is existing natural vegetation in the area, it is facing gradual degradation and destruction due to various human activities such as the establishment of fishponds, fuelwood gathering, construction of houses, and the development of roads. These activities collectively contribute to the diminishing presence of the natural vegetation, thereby necessitating efforts towards rehabilitation and conservation to preserve the ecological balance and biodiversity of the area.

Procedures

Research design

A descriptive-quantitative research design was used in this study to determine the composition, distribution, abundance, frequency, and diversity of mangrove species in the area. Direct observation and descriptive analysis were also done to identify the present threats. We also conducted interviews with local communities residing near mangrove areas to serve as a crucial component of comprehensive ecological assessments. These interviews provided insights into the human component of the ecosystem, adding a deeper understanding of the interactions between communities and their surrounding environment. By engaging with local residents, researchers were able to gather firsthand information of the activities and occurrences happening within the mangrove site. This supplementary information included details about traditional practices, such as fishing or collecting of natural resources, as well as observations of changes in the ecosystem over time. This approach aimed to integrate awareness from residents who have actual experiences and knowledge, providing a more comprehensive understanding of the dynamics within the mangrove ecosystem. By engaging with the local communities, the study sought to enrich its findings by considering the perspectives and practices of those who have more interaction with the mangroves.

Sampling and data gathering

The study involved identifying species in both the upper canopy and understorey layers of the mangrove ecosystem. A total of 55 observation points were established with distance from the coastline between 0.25 and 1 kilometer (Figure 2). Observation points or plots with size 10m x 10m each were established alternately along a transect line with an interval of 20 meters apart on both sides to assess upper canopy diversity. Within these observation points, additional 5 m x 5 m plots were set up to evaluate the understorey vegetation (Mueller-Dombois et al. 2008). This method explores the dynamics and patterns of mangroves and other plant communities, including their distribution and composition. In the 10 m x 10 m plots, mangrove trees with a Diameter at Breast Height (DBH) of 10 cm and above were recorded for the upper canopy, while trees below 10 cm were documented in the understory plots (5 m x 5 m). The collected data were tabulated and analyzed.

Throughout the data collection phase, the study area is not experiencing inundation. In the case of Naungan, the seaward portion is usually inundated while the middle part is sometimes inundated by high tide. The landward temporarily experiences inundation, especially during high tide and heavy rainfall. Historical records indicate that during periods of heavy rainfall and typhoons, low-lying areas of Naungan become susceptible to rising river water levels, leading to flooding that devastates communities and damages residential properties, livestock, and agricultural land (Resabal 2019).

Figure 2. Observation points established along the mangrove forest in Barangay Naungan, Ormoc City, Philippines (Google Earth 2022)

Data analysis

Abundance of the species was determined by counting the number of individuals of a species that appeared in all observation points while relative abundance evaluates biodiversity by considering all species present in a community and determining the proportion of each species relative to the total. It is computed by dividing the abundance of a particular species by the total abundance of all species present in the community (Magurran 2013). Species diversity was assessed by employing the Shannon diversity index, as outlined by Magurran (1988). The interpretation of species diversity results aligns with the classification scheme formulated by Fernando (1998). In this scheme, a Shannon index equal to or less than 1.9 is categorized as very low, 2.00-2.49 as low, 2.50-2.99 as moderate, 3.0-3.49 as high, and a relative value of 3.5 and above is designated as very high.

RESULTS AND DISCUSSION

Species composition

The upper canopy in mangrove ecosystems refers to the highest layer of foliage formed by the crowns and branches of the tallest mangrove trees, which extend above the lower vegetation (Spalding 2010). The upper canopy has a total of 331 individuals of which are 10 mangrove species belonging to 8 families. *Avicennia marina* is the most dominant upper story species followed by *Sonneratia alba* and *Avicennia officinalis*. The understorey in mangroves refers to the layer of vegetation situated beneath the upper canopy and above the ground level. It consists of smaller mangrove trees, shrubs, and herbaceous plants that grow in the shade of the upper canopy (Spalding 2010). The understorey has a total 1,310 individuals of from 23 mangrove species belonging to 15 families. *Avicennia marina* also dominates the understorey followed by *Nypa fruticans* and *Rhizophora apiculata* (Table 1 and Table 2). This implies that there will be more species waiting to replace the upper canopy when the environmental conditions allow. *Aegiceras floridum* and *Ceriops decandra* are "nearly threatened" while the rest of the species are categorized as "least concern" under the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. There is no information on the conservation status of *Cocos nucifera* considering that they are ubiquitous. Included under the same category are *Artocarpus heterophyllus*, *Citrus microcarpa*, *Bambusa* spp., *Leucaena leucocephala*, *Musa* spp. and *Theobroma cacao*. Under the Updated National List of Threatened Species and their Categories or the DENR Administrative Order (DAO) 2017-11, all species present in both upper and lower canopies were categorized as "other wildlife species" or "no information" which means they are not endangered, threatened, or vulnerable. These species were found mostly in cultivated areas as observed during the surveys.

Similar species were observed to be dominant in the study conducted in Malaysia (Islam et al 2022) including *Rhizopora apiculata, Avicennia alba, Sonneratia alba, Nypa fruticans* and other species such as *Rhizopora mucronata* and *Bruguiera gymnorrhiza*. Dominant species found in South Sumatra Indonesia were also *Nypa fruticans, Rhizopora apiculata, Avicennia alba* and other species such as *Excoecaria agallocha, Acrostichum aureum, Cyperus rotundus* and *Nephrolepis* sp (Eddy et al 2019). In Cambodia, commonly found species in mangrove ecosystems are *Rhizophora apiculata* and *Nypa fruticans* (Veettil and Quang 2019).

Species abundance and frequency

The most abundant species in the upper canopy found during the surveys is *Avicennia marina* with a total of 130 individuals followed by *Sonneratia alba* with 91 individuals and *Avicennia officinalis* with 53 individuals (Table 3). Relative abundance is observed to follow the same trend. The relative frequency however shows that *Sonneratia alba* is present in 33 observation points (60.0%) while *Avicennia marina* is only present in 27 observation points (49.091%). This is followed by *Avicennia officinalis* being present in 23 observation points and *Cocos nucifera* in 17 observation points. This means that even if *Avicennia marina* is the most abundant species, they are not as dispersed as the *Sonneratia alba*.

Table 1. Mangroves and other species in the upper canopy in Barangay Naungan, Ormoc City, Philippines

Scientific name	Family	Common name	Conservation status	
			IUCN*	DAO 2017-11
Avicennia marina (Forssk.) Vierh.	Avicenniaceae	Bungalon	LC	OWS
Avicennia officinalis L.	Acanthaceae	Api-api	LC	OWS
Cocos nucifera L.	Arecaceae	Coconut	NI	NI
Ficus nota (Blanco) Merr.	Moraceae	Tibig	LC	OWS
Rhizophora apiculata Blume	Rhizophoraceae	Bakauan Lalaki	LC	OWS
Rhizophora mucronata Lam.	Rhizophoraceae	Bakauan Babae	LC	OWS
Sandoricum koetjape (Burm. f.) Merr.	Meliaceae	Santol	LC	OWS
Sonneratia alba J. Smith	Lythraceae	Pagatpat	LC	OWS
Terminalia catappa L.	Combretaceae	Talisai	LC	OWS
Xylocarpus granatum J. Koenig	Meliaceae	Tabigi	LC	OWS

Note: LC: Least concern; NT: Near threatened; OWS: Other wildlife species; NI: No information

Table 2. Mangrove and other species in the understorey in Barangay Naungan, Ormoc City, Philippines

Species	Family	Common name	Conservation status	
			IUCN*	**DAO 2017-11**
Aegiceras floridum Roem. & Schult.	Primulaceae	Tindok- tindokan	NT	OWS
Alstonia scholaris (Linn.) R. Br.	Apocynaceae	Dita	LC	OWS
Artocarpus heterophyllus Lam	Moraceae	Langka	NI	NI
Avicennia marina (Forssk.) Vierh.	Acanthaceae	Bungalon	LC	OWS
Avicennia officinalis L.	Acanthaceae	Api-api	LC	OWS
Bambusa spp,	Poaceae	Kawayan	NI	NI
Bruguiera cylindrica (L.) Blume	Rhizophoraceae	Pototan-Lalaki	LC	OWS
Ceriops decandra (Griff.) W.Theob.	Rhizophoraceae	Malatangal	NT	OWS
Citrus microcarpa Bunge	Rutaceae	Calamansi	NI	NI
Cocos nucifera L.	Arecaceae	Niyog	NI	NI
Ficus nota (Blanco) Merr.	Moraceae	Tibig	LC	OWS
Ficus septica Burm.f.	Moraceae	Hauili	LC	OWS
Luecaena leucocephala (Lam.) de Wit	Fabaceae	Ipil-ipil	NI	NI
Musa spp.	Musaceae	Banana	NI	NI
Nypa fruticans (Wurmb) Thunb	Arecaceae	Nipa	LC	OWS
Psidium guajava L.	Myrtaceae	Bayabas	LC	OWS
Rhizophora apiculata Blume	Rhizophoraceae	Bakauan lalaki	LC	OWS
Rhizophora mucronata Lam	Rhizophoraceae	Bakauan babae	LC	OWS
Sonneratia alba J. Smith	Lythraceae	Pagatpat	LC	OWS
Terminalia catappa L.	Combretaceae	Talisay	LC	OWS
Theobroma cacao L.	Malvaceae	Cacao	NI	NI
Trema orientalis L. Blume	Cannabaceae	Anabiong	LC	OWS

Note: LC: Least Concern; NT: Near Threatened; OWS: Other Wildlife Species; NI: No Information

Table 3. Species abundance, relative abundance and relative frequency of the upper canopy in Barangay Naungan, Ormoc City, Philippines

Scientific name	Abundance	Relative abundance	Occurrence	Relative frequency
Rhizophora mucronata Lam.	1	0.00302	1	1.818
Sandoricum koetjape (Burm. f.) Merr.	1	0.00302	1	1.818
Terminalia catappa L.	1	0.00302	1	1.818
Xylucarpus granatum J. Koenig	1	0.00302	1	1.818
Ficus nota (Blanco) Merr.	4	0.01208	3	5.455
Rhizophora apiculata Blume	9	0.02719	4	7.273
Cocos nucifera L.	40	0.12085	17	30.909
Avicennia officinalis L.	53	0.16012	23	41.818
Sonneratia alba J. Smith	91	0.27492	33	60.000
Avicennia marina (Forssk.) Vierh.	130	0.39275	27	49.091

The understorey is dominated by *Avicennia marina* with a total count of 462 individuals and a relative abundance of 35.26% which occurred in 34 observation points with a relative frequency of 61.82%. This implies also that they are highly dispersed compared to all other species present in the lower canopy layer. This is followed by *Nypa fruticans* with 155 individuals and a relative abundance of 11.83%. It occurs in 23 observation points with a relative frequency of 41.42%. The remaining top three dominant species were *Rhizophora apiculata* with 134 individuals, *Rhizophora mucronata* with 110 individuals, and *Sonneratia alba* with 100 individuals (Table 4).

Species diversity

The diversity of upper canopy vegetation using the Shannon index is 1.492 which is very low based on Fernando's category (Fernando 1998). The understorey diversity is a bit higher with a value of 2.198 but is categorized as low using a similar category. Overall diversity for both upper canopy and understorey combined has only a value of 2.176 which is also low. Cañizares and Seronay (2016) obtained a Shannon index value of 1.856 in their study on the diversity and species composition of mangroves in Dinagat Island, Philippines which is close to the diversity value obtained in this study. Dangan-Galon et al. (2016) also obtained low diversity indexes ranging from 0.439 to 0.912 in their study on the diversity and structural complexity of mangrove forest along Puerto Princesa Bay, Palawan Island, Philippines. These findings imply that there is a declining diversity of mangroves in many parts of the country like the case of Naungan. These findings also signal that strategic interventions to reverse the current situation are essential before those mangrove species will totally vanish.

Table 4. Species abundance, relative abundance and relative frequency of the understorey in Barangay Naungan, Ormoc City, Philippines

Scientific name	Abundance	Relative abundance	Occurrence	Relative frequency
Alstonia scholaris (Linn.) R. Br.	1	0.000763	1	1.818
Artocarpus heterophyllus Lam	1	0.000763	1	1.818
Citrus microcarpa Bunge	1	0.000763	1	1.818
Psidium guajava L.	1	0.000763	1	1.818
Ficus nota (Blanco) Merr.	3	0.014504	2	3.636
Bruguiera cylindrical (L.) Blume	3	0.00229	1	1.818
Musa spp	3	0.00229	2	3.636
Terminalia catappa L.	5	0.00229	3	5.455
Theobroma cacao L.	6	0.003817	3	5.455
Trema orientalis L. Blume	13	0.00458	3	5.455
Aegiceras floridum Roem.& Schult.	19	0.009924	7	12.73
Luecaena leucocephala (Lam.) de Wit	32	0.024427	6	10.91
Avicennia officinalis L.	43	0.032824	7	12.73
Cocos nucifera L.	54	0.041221	15	27.27
Bambusa spp	58	0.044275	7	12.73
Ceriops decandra (Griff.) W.Theob.	76	0.058015	13	23.64
Sonneratia alba J. Smith	100	0.076336	21	38.18
Rhizophora mucronata Lam	110	0.083969	21	38.18
Rhizophora apiculata Blume	134	0.10229	20	36.36
Nypa fruticans (Wurmb) Thunb	155	0.118321	23	41.82
Avicennia marina (Forssk.) Vierh.	462	0.352672	34	61.82

This condition is not only observed in the Philippines. Studies in some ASEAN countries state that they also face similar concerns. Similarly, in a study conducted in Indonesia by Eddy et al. (2019), mangrove diversity was found to be relatively low. It was reported that this was also caused by a variety of human activities, including settlements, farming, agriculture, aquaculture, port operations, and logging leading to the degradation of the mangrove ecosystem. A study conducted in India highlights the low species diversity and underdeveloped structural characteristics of mangroves along the Mumbai coast (Kantharajan et al. 2018). Mangrove forests along the coastlines of Asian countries are declining in recent years due to these various factors such as aquaculture, illegal logging, pollution and climate change (Ward et al. 2016; Thomas et al. 2017; Goldberg et al. 2020).

Threats to Naungan mangrove ecosystem

Within the study site, it is imperative to recognize the presence of numerous anthropogenic threats, which alongside natural hazards, pose significant challenges to the ecological integrity of the area. Among these threats, a variety of human activities contribute to the degradation of the mangrove ecosystem. One prominent concern is the establishment of fishponds, wherein Naungan benefits from the flow of freshwater from the river, making it favorable for aquaculture practices (Olor-Pogado and Evangelio 2020). This involves the conversion of mangrove areas into aquaculture facilities. This was observed by the researchers as well as mentioned by the locals during the interviews with the community. This practice not only leads to the loss of mangrove habitat but also disrupts the natural hydrological patterns essential for the health of the ecosystem (Newton et al. 2020). Additionally, the construction of various infrastructure projects, such as roads, bridges, or buildings, further encroaches upon mangrove areas. This results in fragmenting habitats and impeding the movement of wildlife (Numbere 2021).

Furthermore, the expansion of agricultural farming adjacent to mangrove zones presents another significant threat. Intensive agricultural practices, including the use of agrochemicals and land clearing, result in pollution runoff and habitat destruction, affecting both terrestrial and aquatic components of the ecosystem. These anthropogenic activities not only directly impact the mangrove ecosystem but also exacerbate existing environmental stressors, such as erosion, climate change and sea-level rise (Goldberg et al. 2020). Moreover, they often have socio-economic repercussions, particularly for local communities reliant on mangrove resources for their livelihoods. These can be observed by the land cover map in Figure 3. With the area becoming accessible due to the newly constructed road, more structures are more likely to be established soon. According to random interviews among the residents of Barangay Naungan, it is worth note-taking that there is a plan to establish a megacity proximate to the said mangrove forest. This will impact the species' diversity and structure if not properly managed. The mangrove forest as a socioecological production landscape and seascape is endangered. Indeed, this is the case as well in other mangrove forests in the Philippines as reported by various authors (Doydee et al. 2008; Sinfuego and Buot 2008; Tinh et al. 2009; Doydee and Buot 2011; Buot et al. 2013; Sinfuego and Buot 2014; Lillo and Buot 2016; Martinez and Buot 2018; Buot 2020; Buot et al. 2022).

The presence of nearly threatened mangrove species, such as *Aegiceras floridum* and *Ceriops decandra*, within the study site in Ormoc highlights the fragile state of the local ecosystem. These species play critical roles in maintaining the ecological balance of mangrove habitats, providing essential habitats for various marine organisms and contributing to the overall biodiversity of the area. However, the ongoing threats posed by human activities, such as urban development and resource extraction, put the survival of these species at risk and, consequently, the integrity of the entire ecosystem. The disruption of the harmonious interaction between human communities and the seascape aggravates these threats. Human-centered plans and activities, driven by economic interests and urbanization, often prioritize short-term gains over long-term environmental sustainability. This approach neglects the complex connections between mangrove ecosystems and human well-being, leading to the degradation of ecosystem services and the loss of valuable resources.

As a result of these human-induced pressures, the expected ecosystem services provided by mangroves are at risk of being significantly reduced or even lost altogether. Services such as coastal protection, fishery support, carbon sequestration, and storm surge mitigation may be compromised, leading to negative impacts on both the environment and the livelihoods of local communities. The decline or disappearance of these services can have far-reaching consequences, affecting not only the immediate vicinity of Ormoc but also neighboring areas dependent on healthy mangrove ecosystems. Addressing these threats requires a concerted effort to balance human development with environmental conservation. Implementing sustainable land-use practices, enforcing regulations to protect mangrove habitats, and engaging local communities in conservation efforts are essential steps towards preserving the integrity of mangrove ecosystems in Ormoc and safeguarding the ecosystem services they provide. By recognizing the importance of these threatened species and prioritizing their conservation, it is possible to mitigate the adverse impacts of human activities and ensure the long-term resilience of both mangrove habitats and the communities reliant on them.

Proposed conservation framework

The mangrove ecosystem found in Naungan contains valuable species and provides a range of benefits to the local community. However, due to the threats observed during field data gathering such as land use conversions, waste accumulation and pollution brought about the anthropogenic activities in the adjacent urban communities, mangrove habitats are prone to destruction. Addressing these concerns is a continuous challenge among the local authorities (Delfino et al. 2015). Hence, this research output proposes a framework that contributes to ensuring the protection and conservation of mangrove species. The components included in this framework capture the need for the observed threats, issues and concerns in Naungan mangrove ecosystem as well as the information from the local interviews. In Figure 4, the main dimensions to consider toward mangrove sustainability are the socioeconomic and political dimensions. The socioeconomic dimension revolves around the relationship between the people and the mangrove resources, in terms of economic benefits, livelihood, and daily consumption of its goods and services. Hence, the sub-dimensions are comprised of sustainable development, management practices, and the needed capacity development of the local people towards the mangrove ecosystem management. The political dimension highlights the roles and responsibilities of the local government and non-government institutions in contributing to the management of the mangrove ecosystem. They have an important function in the implementation of local policies that protect the mangroves from illegal harvesting, conversion, and extensive industrial establishment which degrades mangrove habitats. They have the power to regulate the observed threats in Naungan. With the land use plans from the government institutions and devolved authorities on the local government units, the preservation and regulation of extraction of mangrove resources can be achieved.

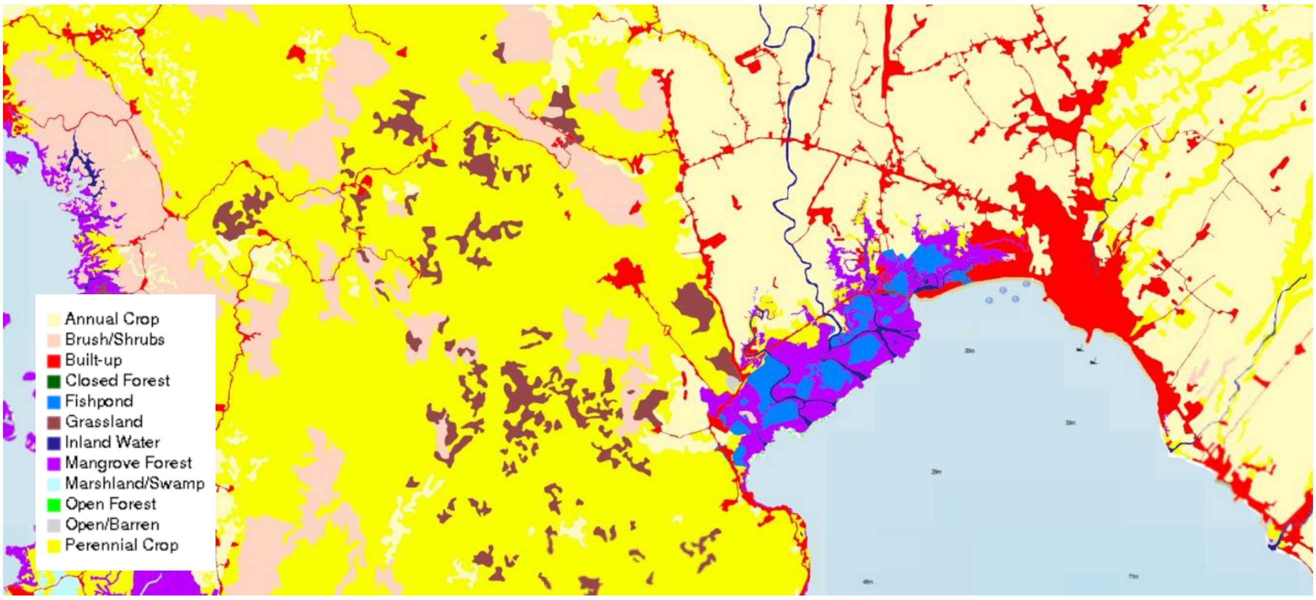

Figure 3. Land cover within the mangrove ecosystem in in Barangay Naungan, Ormoc City, Philippines (geoportal.gov 2023)

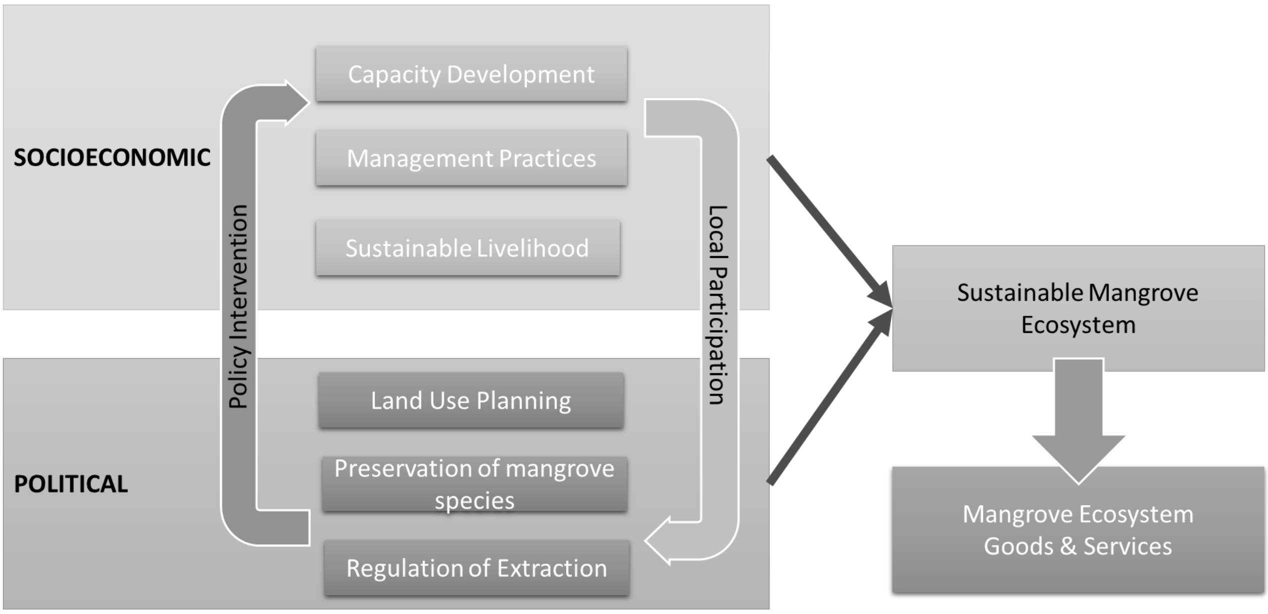

Figure 4. Proposed framework for mangrove ecosystem conservation in in Barangay Naungan, Ormoc City, Philippines

It is best to involve the People's Organizations (POs), Non-Government Organizations (NGOs), and Civil Society Organizations (CSOs) in the crafting of sustainable management of mangroves in Naungan. This will encourage local participation in mangrove conservation efforts. These entities serve as crucial intermediaries, to raise awareness among local communities about the importance of mangroves and the urgent need for their protection. Through various means such as educational programs, workshops, and outreach activities, these organizations shall disseminate information about the ecological significance of mangrove ecosystems and the potential threats they face. Moreover, they facilitate community engagement by empowering residents to take ownership of mangrove conservation through participatory approaches. By promoting a sense of responsibility and stewardship among local inhabitants, these efforts not only enhance the sustainability of mangrove conservation initiatives but also contribute to the overall resilience of coastal communities in the Philippines.

Collaboration between the local government and communities is fundamental for successful mangrove conservation efforts in the Philippines. This collaborative approach ensures that conservation strategies are not only effective but also culturally and socially relevant (Friess et al. 2016; Triyanti et al. 2017; Valenzuela et al. 2020). By working together, the local government and communities can develop sustainable management plans that take into account the unique practices, traditions, and needs of the local population while also preserving the integrity of the mangrove ecosystem. Local traditional knowledge plays a significant role in this collaborative process. Indigenous communities often possess invaluable insights into the dynamics of mangrove ecosystems, acquired over generations of living close to these environments. This traditional knowledge can complement scientific research by providing a nuanced understanding of mangrove ecology, including local species interactions, habitat dynamics, and adaptive strategies. Furthermore, integrating traditional knowledge into decision-making processes enhances the legitimacy and effectiveness of conservation initiatives. By recognizing and valuing the expertise of local communities, authorities can develop more inclusive and sustainable conservation plans that resonate with the cultural identity and aspirations of the people directly affected by mangrove management efforts. In essence, the collaboration between the local government and communities, combined with the integration of traditional knowledge, forms a robust framework for achieving effective mangrove conservation in the Philippines.

A well-managed mangrove ecosystem provides a wide array of goods and services that are essential for the long-term sustainability of both the environment and the communities reliant on them (Sofian et al. 2019). These benefits are multifaceted and play crucial roles in supporting biodiversity, mitigating climate change impacts, and enhancing the resilience of coastal ecosystems and communities (Aladano et al. 2016). One of the primary benefits of a well-managed mangrove ecosystem is the provision of sustained habitats for diverse flora and fauna. Mangroves serve as nurseries, feeding grounds, and shelter for numerous species of fish, crustaceans, birds, and other wildlife. Their intricate root systems provide refuge for young marine organisms and offer protection from predators, contributing to the overall richness and abundance of coastal biodiversity. Additionally, mangroves act as important carbon sinks, sequestering large amounts of carbon dioxide from the atmosphere and storing it within their biomass and sediments. This helps mitigate climate change by reducing the concentration of greenhouse gases in the atmosphere, thereby slowing the rate of global warming. Furthermore, mangroves serve as natural buffers against the impacts of climate change-induced phenomena such as storm surges, coastal erosion, and flooding. Their dense root systems dissipate wave energy and stabilize shorelines, reducing the vulnerability of coastal communities to extreme weather events. By conserving mangrove ecosystems and safeguarding the services they provide, communities can increase their resilience to environmental disturbances and enhance their capacity to adapt to changing conditions. This resilience extends not only to the mangrove forests themselves but also to the broader marine ecosystem and the human communities that depend on them for sustenance and livelihoods. Thus, investing in the conservation and sustainable management of mangrove ecosystems yields significant long-term benefits for both the environment and society, ensuring a resiliency in the future for all.

In conclusion, the upper canopy vegetation of mangrove ecosystem in Naungan has a total of 10 tree species belonging to 8 families and 331 individuals while the understorey vegetation has 23 species belonging to 15 families and 1310 individuals. *Avicennia marina* is the most dominant upper canopy species followed by *Sonneratia alba* and *Avicennia officinalis*. *Avicennia marina* also dominates the understorey followed by *Nypa fruticans* and *Rhizophora apiculata*. The Shannon diversity index of upper canopy is 1.492 (very low), while the understorey diversity is a bit higher with a value of 2.198 but is still categorized as low. Overall diversity for both upper and lower canopies combined has only a value of 2.176 which is also low. *Aegiceras floridum and Ceriops decandra* are nearly threatened while the rest of the species are categorized as "least concern". The present threats in the site include fishpond establishment, road construction, and subsistence agricultural farming which are expected to affect further mangrove diversity in the area. In summary, the preservation of mangroves necessitates a comprehensive strategy that takes into account both the ecological and human aspects of these ecosystems. By comprehending the socioeconomic and political factors involved and engaging local communities as well as governments in conservation initiatives, we can secure the stable safeguarding of mangroves and their contributions to community welfare and environmental health. Hence, this study is an important basis for improving the management and conservation plans of mangrove ecosystems in Naungan. Careful planning of future land uses is vital to protect the remaining mangrove species on the site.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Emerging Interdisciplinary Research (EIDR) of the Office of the Vice President for Academic Affairs (OVPAA) of the University of the Philippines System for funding this research. There are no conflicts of interest during this study.

REFERENCES

Abantao SC, Apacible TC, Cortez SP, Pereda LT, Yllano OB. 2015. Mangrove species diversity and on-site impact assessment of mangal coastal areas. Expert Opin Environ Biol 4: 3. DOI: 10.4172/2325-9655.1000122.

Acob JRU. 2018. Lived experiences of the abused elderly. Public Health Indonesia 4 (1): 1-8. DOI: 10.36685/phi.v4i1.172.

Aladano A, Cimene FT, Asuncion JJ. 2016. Community sustainability through mangrove rehabilitation: The Taytay, El Salvador City, Philippines experience. Intl J Ecol Conserv 19: 70-86.

Areas P, Bureau W. 1998. The First Philippine National Report to The Convention on Biological Diversity. Department of Environment and Natural Resources, Republic of the Philippines.

Baclado AM, Tatil WT. 2017. Mangrove conservation in the coastal areas of Lala, Lanao del Norte, Philippines: Management strategies and impacts on the status of the mangrove forest. Proceedings of International Forestry and Environment Symposium 22. DOI: 10.31357/fesympo.v22i0.3264. [Philippines]

Bagarinao TU. 2021. Biodiversity in mangrove-derived aquaculture ponds in Dumangas, Iloilo, Philippines. Philipp J Sci 150 (1): 153-169. DOI: 10.56899/150.01.13.

Birch A. 2023. Importance of mangroves. The Nature Conservancy. www. nature.org.

Bryan-Brown DN, Connolly RM, Richards DR, Adame F, Friess DA, Brown CJ. 2020. Global trends in mangrove forest fragmentation. Sci Rep 10 (1): 7117. DOI: 10.1038/s41598-020-63880-1.

Buot Jr IE. 2008a. New way of looking at environmental health: Focused on man and his environment. Asian Intl J Life Sci 2: 1-5.

Buot Jr IE. 2008b. Sustaining environmental health in the Philippines Satoyama Landscape. Asian Intl J Life Sci 2: 129-138.

Buot Jr IE. 2014. Conservation and sustainability of socio-ecological production landscapes and seascapes. IAMURE Intl J Ecol Conserv 10 (1): 1-1. DOI: 10.7718/ijec.v10i1.771.

Buot Jr IE. 2020. Status, issues and concerns of mangrove ecosystems: Rethinking the role of the university in crafting a sustainable management and conservation strategy. J Wetlands Biodiver 10: 73-93.

Buot Jr IE, Buhay AF. 2022. Types of socioecological production landscapes of the Philippines based on dominant biodiversity: Status, problems and future directions. Biodiversitas 23 (7): 3755-3770. DOI: 10.13057/biodiv/d230752.

Buot Jr IE, Osumi K. 2004. Satoyama Landscape in the Philippines. J Nat Stud 3: 1-11.

Buot Jr IE, Origenes MG, Obeña RDR. 2022. Conservation status of native mangrove species in the Philippines. J Wetlands Biodiver 12: 51-65.

Buot Jr IE, Pampolina NM, Almazol AE, Cervancia CR. 2013. Floral composition and physiognomy of Pagbilao Mangrove, Quezon Province, Philippines. IAMURE Intl J Ecol Conserv 7 (1): 1-1. DOI: 10.7718/ijec.v7i1.725.

Cañizares LP, Seronay RA. 2016. Diversity and species composition of mangroves in Barangay Imelda, Dinagat Island, Philippines. Aquac Aquar Conserv Legis 9 (3): 518-526.

Chima UD, Larinde SL. 2016. Deforestation and degradation of mangroves in the Niger Delta Region of Nigeria: Implications in a changing climate. In 38th Annual Conference of the Forestry Association of Nigeria.

Dangan-Galon F, Dolorosa RG, Sespene JS, Mendoza NI. 2016. Diversity and structural complexity of mangrove forest along Puerto Princesa Bay, Palawan Island, Philippines. J Mar Isl Cult 5 (2): 118-125. DOI: 10.1016/j.imic.2016.09.001.

Dechimo Jr AA, Buot Jr IE. 2023. Biophysical assessment of the plant biodiversity of Northern Negros Natural Park, Negros Island, Philippines. Biodiversitas 24: 583-602. DOI: 10.13057/biodiv/d240167.

Delfino RJ, Carlos CM, David LT, Lasco RD, Juanico DEO. 2015. Perceptions of Typhoon Haiyan affected communities about the resilience and storm protection function of mangrove ecosystems in Leyte and Eastern Samar, Philippines. Climate Disaster Develop J 1 (1): 15-24. DOI: 10.18783/cddj.v001.i01.a03.

delos Santos KA, Avtar R, Salmo III S, Fujii M. 2022. Assessment of mangrove colonization of aquaculture ponds through satellite image analysis: Implications for mangrove management. In Assessing, Mapping and Modelling of Mangrove Ecosystem Services in the Asia-Pacific Region. Springer Nature Singapore, Singapore. DOI: 10.1007/978-981-19-2738-6_3.

DENR Administrative Order (DAO) 2017-11. Updated national list of threatened Philippine plants and their categories. www.philippineplants.org.

Doydee P, Buot Jr IE. 2011. Mangrove vegetation zones in Ranong coastal wetland ecosystem, Thailand. J Fisheries Environ 35 (1): 14-28.

Doydee P, Kamwachirapitak P, Buot Jr IE. 2008. Species composition of a mangrove ecosystem in Ranong, Thailand. Thailand Nat History Museum J 3 (1): 51-58.
Duke NC, Schmitt K. 2015. Mangroves: Unusual Forests at The Seas Edge. Tropical Forestry Handbook. DOI: 10.1007/978-3-642-41554-8_129-1.
Eddy S, Ridho MR, Iskandar I, Mulyana A. 2019. Species composition and structure of degraded mangrove vegetation in the Air Telang Protected Forest, South Sumatra, Indonesia. Biodiversitas 20 (8): 2119-2127. DOI: 10.13057/biodiv/d200804.
Fernando ES. 1998. Forest formations and flora of the Philippines: Handout in FBS 21. College of Forestry and Natural Resources, University of the Philippines at Los Baños. [Unpublished]
FMB [Forest Management Bureau]. 2022. Philippine Forestry Statistics. Department of Environment and Natural Resources. www.forestry.denr.gov.ph.
Fortes MD, Salmo III S. 2017. Status of mangrove research and management in the Philippines: Challenges and opportunities. State of the Mangrove Summit.
Friess DA, Thompson BS, Brown B, Amir AA, Cameron C, Koldewey HJ, Sidik F. 2016. Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia. Conserv Biol 30 (5): 933-949. DOI: 10.1111/cobi.12784.
Friess DA, Rogers K, Lovelock CE, Krauss KW, Hamilton SE, Lee SY, Shi S. 2019. The state of the world's mangrove forests: Past, present, and future. Annu Rev Environ Resour 44: 89-115. DOI: 10.1146/annurev-environ-101718-033302.
Garcia KB, Malabrigo PL, Gevaña DT. 2014. Philippines' mangrove ecosystem: Status, threats and conservation. Mangrove ecosystems of Asia: Status, challenges and management strategies. DOI: 10.1007/978-1-4614-8582-7_5.
Gevaña DT, Pulhin JM, Tapia MA. 2019. Fostering climate change mitigation through a community-based approach: Carbon stock potential of community-managed mangroves in the Philippines. Coastal management. Academic Press, Cambridge. DOI: 10.1016/B978-0-12-810473-6.00014-5.
Godoy MD, Lacerda LDD. 2015. Mangroves response to climate change: A review of recent findings on mangrove extension and distribution. Anais da Academia Brasileira de Ciências 87: 651-667. DOI: 10.1590/0001-3765201520150055.
Goldberg L, Lagomasino D, Thomas N, Fatoyinbo T. 2020. Global declines in human-driven mangrove loss. Glob Change Biol 26 (10): 5844-5855. DOI: 10.1111/gcb.15275.
Google 2022. Map of Naungan, Ormoc City.
Hai NT, Dell B, Phuong VT, Harper RJ. 2020. Towards a more robust approach for the restoration of mangroves in Vietnam. Ann For Sci 77 (1): 18. DOI: 10.1007/s13595-020-0921-0.
IUCN [International Union for Conservation of Nature]. 2023. IUCN Red list of threatened species. https://www.iucnredlist.org.
Islam MA, Idris MH, Bhuiyan MKA, Ali MS, Abdullah MT, Kamal AHM. 2022. Floristic diversity, structure, and carbon stock of mangroves in a tropical lagoon ecosystem at Setiu, Malaysia. Biodiversitas 23 (7): 3685-3696. DOI: 10.13057/biodiv/d230746.
Kantharajan G, Pandey PK, Krishnan P, Ragavan P, Jeevamani JJJ, Purvaja R, Ramesh R. 2018. Vegetative structure and species composition of mangroves along the Mumbai coast, Maharashtra, India. Reg Stud Mar Sci 19: 1-8. DOI: 10.1016/j.rsma.2018.02.011.
Kathiresan K. 2021. Mangroves: Types and Importance. Mangroves: Ecology, Biodiversity and Management. DOI: 10.1007/978-981-16-2494-0_1.
Ladias JA. 2020. Diversity and abundance of gastropods in the intertidal zone of Muduing Bay, Zamboanga Peninsula, Philippines. Proc Intl Acad Ecol Environ Sci 10 (2): 45.
Lillo EP, Buot Jr IE. 2016. Species composition of Argao mangrove forest, Cebu, Philippines. J Wetlands Biodiver 6: 37-45.
Long J, Napton D, Giri C, Graesser J. 2014. A mapping and monitoring assessment of the Philippines' mangrove forests from 1990 to 2010. J Coast Res 30: 260-271. DOI: 10.2112/JCOASTRES-D-13-00057.1.
Magurran AE. 2013. Ecological Diversity and Its Measurement. Springer Science and Business Media, Berlin.
Magurran AE. 1988. Ecological diversity and its measurement. Princeton University. Zaragoza. Princeton University Press, Princeton, NJ. DOI: 10.1007/978-94-015-7358-0.
Makowski C, Finkl CW. 2018. Threats to Mangrove Forests: Hazards, Vulnerability, and Management. Springer International Publishing, Cham. DOI: 10.1007/978-3-319-73016-5.
Martinez MR, Buot Jr IE. 2018. Mangrove assessment in Manamoc Island for coastal retreat mitigation. J Mar Island Cultures 7 (1): 65-83. DOI: 10.21463/jmic.2018.07.1.05.
Medina-Contreras D, Arenas-González F, Cantera-Kintz J, Sánchez-González A, Giraldo A. 2020. Food web structure and isotopic niche in a fringe macro-tidal mangrove system, Tropical Eastern Pacific. Hydrobiologia 847: 3185-3199. DOI: 10.1007/s10750-020-04295-x.
Menéndez P, Losada IJ, Beck MW, Torres-Ortega S, Espejo A, Narayan S, Díaz-Simal P, Lange GM. 2018. Valuing the protection services of mangroves at national scale: The Philippines. Ecosyst Serv 34: 24-36. DOI: 10.1016/j.ecoser.2018.09.005.
Mialhe F, Gunnell Y, Mering C, Gaillard JC, Coloma JG, Dabbadie L. 2016. The development of aquaculture on the northern coast of Manila Bay (Philippines): An analysis of long-term land-use changes and their causes. J Land Use Sci 11 (2): 236-256. DOI: 10.1080/1747423X.2015.1057245.
Mueller-Dombois D, Bridges KW, Daehler CC. 2008. Biodiversity assessment of tropical island ecosystems: PABITRA manual for interactive ecology and management. Bishop Museum Press, Honolulu, Hawai'i.
Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature 403 (6772): 853-858. DOI: 10.1038/35002501.
Nelson JA, Lesser J, James WR, Behringer DP, Furka V, Doerr JC. 2019. Food web response to foundation species change in a coastal ecosystem. Food Webs 21: e00125. DOI: 10.1016/j.fooweb.2019.e00125.
Newton A, Icely J, Cristina S, Perillo GME, Turner RE, Ashan D, Cragg S, Luo Y, Tu C, Li Y, Zhang H, Ramesh R, Forbes DL, Solidoro C, Béjaoui B, Gao S, Pastres R, Kelsey H, Taillie D, Nhan N, Brito AC, de Lima R, Kuenzer C. 2020. Anthropogenic, direct pressures on coastal wetlands. Front Ecol Evol 8: 144. DOI: 10.3389/fevo.2020.00144.
Numbere AO. 2021. Impact of Urbanization and Crude Oil Exploration in Niger Delta Mangrove Ecosystem and Its Livelihood Opportunities: A Footprint Perspective. In: Banerjee A, Meena RS, Jhariya MK, Yadav DK (eds). Agroecological Footprints Management for Sustainable Food System. Springer, Singapore. DOI: 10.1007/978-981-15-9496-0_10
Olor-Pogado FO, Evangelio JC. 2020. Survey of macrobenthic organisms associated in selected mangrove areas of Ormoc city, Leyte, Philippines. J Wetlands Biodiver (10): 7-19.
Ordoñez JA. 2003. Environmental Biology: Philippine Setting. National Book Store, Mandaluyong City, Philippines.
Pelser PB, Barcelona JF Nickrent DL. 2011. Co's digital flora of the Philippines. www.philippineplants.org.
Primavera JH, Friess DA, Van Lavieren H, Lee SY. 2019. The Mangrove Ecosystem. World Seas: An Environmental Evaluation. Academic Press, Cambridge. DOI: 10.1016/B978-0-12-805052-1.00001-2.
Primavera JH, Garcia LMB, Castaños MT, Surtida MB. 2000. Mangrove-Friendly Aquaculture: Proceedings of the Workshop on Mangrove-Friendly Aquaculture organized by the SEAFDEC Aquaculture Department, January 11-15, 1999, Iloilo City, Philippines. Aquaculture Department, Southeast Asian Fisheries Development Center. www.repository.seafdec.org.ph.
Quevedo JMD, Uchiyama Y, Kohsaka R. 2022. Community perceptions of long-term mangrove cover changes and its drivers from a typhoon-prone province in the Philippines. Ambio 51 (4): 972-989. DOI: 10.1007/s13280-021-01608-9.
Resabal C. 2019. Rising but remembering - Ormoc 28 years after the deadly flood. Vera Files, truth is our Business.
Romañach SS, DeAngelis DL, Koh HL, Li Y, Teh SY, Barizan RSR, Zhai L. 2018. Conservation and restoration of mangroves: Global status, perspectives, and prognosis. Ocean Coast Manag 154: 72-82. DOI: 10.1016/j.ocecoaman.2018.01.009.
Schmitt K, Duke NC. 2015. Mangrove management, assessment and monitoring. Tropical Forestry Handbook. DOI: 10.1007/978-3-642-41554-8_126-1.
Seary R. 2019. The future of mangrove fishing communities. Predicting Future Oceans. Elsevier. DOI: 10.1016/B978-0-12-817945-1.00036-8.
Sheaves M, Abrantes K, Barnett A, Benham C, Dale P, Mattone C, Bradley M. 2020. The consequences of paradigm change and poorly validated science: The example of the value of mangroves to fisheries. Fish Fisheries 21 (5): 1067-1075. DOI: 10.1111/faf.12479.
Sinfuego KS, Buot Jr IE. 2014. Mangrove zonation and utilization by the local people in Ajuy and Pedada Bays, Panay Island, Philippines. J Mar Island Cultures 3 (1): 1-8. DOI: 10.1016/j.imic.2013.11.002.

Sinfuego KS, Buot Jr IE. 2008. Floral composition and analysis of the true mangrove vegetation in the Philippine Islands. J Nat Stud 7: 83-90.

Sofian A, Kusmana C, Fauzi A, Rusdian O. 2019. Ecosystem services-based mangrove management strategies in Indonesia: A review. Aquaculture, Aquarium, Conservation and Legislation 12: 151-166.

Song AM, Dressler WH, Satizábal P, Fabinyi M. 2021. From conversion to conservation to carbon: The changing policy discourse on mangrove governance and use in the Philippines. J Rural Stud 82: 184-195. DOI: 10.1016/j.jrurstud.2021.01.008.

Spalding M. 2010. World Atlas of Mangroves. Routledge, London. DOI: 10.4324/9781849776608.

Thomas N, Lucas R, Bunting P, Hardy A, Rosenqvist A, Simard M. 2017. Distribution and drivers of global mangrove forest change, 1996-2010. PLoS One 12 (6): e0179302. DOI: 10.1371/journal.pone.0179302.

Tinh HQ, Pacardo EP, Buot Jr IE, Alcantara AJ. 2009. Composition and structure of the mangrove forest at the protected zone of Ca Mau Cape National Park, Vietnam. J Environ Sci Manag 12 (1): 14-24.

Toda L, Orduña J, Lasco, R, Santos CT. 2015. Geography of social vulnerability of Haiyan affected areas to climate-related hazards: Case study of Tacloban City and Ormoc City. The Oscar Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc., The Philippines.

Triyanti A, Bavinck M, Gupta J, Marfai MA. 2017. Social capital, interactive governance and coastal protection: The effectiveness of mangrove ecosystem-based strategies in promoting inclusive development in Demak, Indonesia. Ocean Coastal Manag 150: 3-11. DOI: 10.1016/j.ocecoaman.2017.10.017.

Turschwell MP, Tulloch VJD, Sievers M, Pearson RM, Andradi-Brown DA, Ahmadia GN, Connolly RM, Bryan-Brown D, Lopez-Marcano S, Adame MF, Brown CJ. 2020. Multi-scale estimation of the effects of pressures and drivers on mangrove forest loss globally. Biol Conserv 247: 108637. DOI: 10.1016/j.biocon.2020.108637.

UNEP [United Nations Environment Programme]. 2014. The Importance of Mangroves to People: A Call to Action. van Bochove J, Sullivan E, Nakamura T. (eds). United Nations Environment Programme World Conservation Monitoring Centre, Cambridge. www.researchrepository.napier.ac.uk.

Valenzuela RB, Yeo-Chang Y, Park MS, Chun J-M. 2020. Local people's participation in mangrove restoration projects and impacts on social capital and livelihood: A case study in the Philippines. Forests 11 (5): 580. DOI: 10.3390/f11050580.

Veettil BK, Quang NX. 2019. Mangrove forests of Cambodia: Recent changes and future threats. Ocean Coastal Manag 181: 104895. DOI: 10.1016/j.ocecoaman.2019.104895.

Ward RD, Friess DA, Day RH, Mackenzie RA. 2016. Impacts of climate change on mangrove ecosystems: A region by region overview. Ecosyst Health Sustain 2 (4): e01211. DOI: 10.1002/ehs2.1211.

Warui MW, Manohar S, Obade P. 2020. Current status, utilization, succession and zonation of mangrove ecosystem along Mida Creek, Coast Province, Kenya. Bonorowo Wetlands 10: 32-43. DOI: 10.13057/bonorowo/w100103.

Webber M, Calumpong H, Ferreira B, Granek E, Green S, Ruwa R, Soares M. 2016. Mangroves. The First Global Integrated Marine Assessment: World Ocean Assessment I. Cambridge University Press, Cambridge. DOI: 10.1017/9781108186148.058.