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Geospatial Biodiversity Assessment of Lagadlarin Mangrove Forest in Lobo, Batangas, Philippines for Sustainable Ecotourism

ABSTRACT

Sustainable management of mangrove forests for ecotourism requires knowledge on geospatial biodiversity to ensure that the rehabilitation and conservation interventions are appropriate to its ecological condition. This study aims to assess the floristic diversity of the species in the Lagadlarin Mangrove Forest, Lobo, Batangas, Philippines, and integrate the geospatial analysis using a geographic information system as a basis for the sustainable conservation and management of mangroves for ecotourism. The assessment was conducted through a systematic nested quadrat sampling technique by establishing 20 quadrats measuring 10 x 10 m. The area has a very low species diversity based on Shannon-Weiner's Index (1.82) and Margalef's Richness Index (0.87). In terms of the species distribution and abundance, the area measured high on Pielou's Evenness Index (0.61) and Simpson's Dominance Index (0.78). There are 16 true mangrove species documented in the area, one vulnerable and two near-threatened species. The species that were found dominating the area based on the computed Importance Value are Avicennia marina ssp. rumphiana (89.20%), A. marina ssp. marina (32.85%), Excoecaria agallocha (23.92%), and Acacia farnesiana (21.86%), an invasive species. The enrichment and rehabilitation zones were determined based on the geospatial analysis of the distribution of species diversity for sustainable management of mangrove ecotourism.

Keywords: *geospatial biodiversity assessment, mangrove biodiversity, sustainable mangrove ecotourism*

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INTRODUCTION

Ecological tourism offers an opportunity to achieve sustainability by integrating economic, social, and environmental solutions. It is becoming popular as one of the nature-based solutions in addressing problems of biodiversity while providing economic revenue to the government and livelihood to the community (*Malik et al. 2019; Samal and Dash 2023; Wood 2002*). Other terms associated with ecotourism are "responsible tourism", "green tourism", "soft tourism" and "alternative tourism" (*Hussain 2022*). The International Ecotourism Society (TIES) defines ecotourism as "ethical travel to natural areas that help the well-being of local people and conserves the environment" (*Samal and Dash 2023; Wood 2002*).

World Conservation Union (WCU), on the other hand, defines ecotourism as "environmentally responsible travel and visitation to relatively undisturbed natural areas, to enjoy and appreciate nature (and any accompanying cultural features– both past and present) that promote conservation, has low negative visitor impact, and provides for beneficially active socio-economic involvement of local populations." (*Ceballos-Lascuráin 1996*). *Hussain* (*2022*) and *Sutresna et al.* (*2019*), emphasized the roles and involvements of the communities in the planning and managing of these areas is critical in achieving sustainable ecotourism. Moreover, aside from the social involvement, it is also necessary to integrate economic and ecological aspects to achieve sustainability in the ecotourism industry.

As an archipelagic country, the Philippines has vast potential for mangrove ecotourism. It has a total of 311,400 ha of mangrove forests based on the 2020 Philippines Forestry Statistics of the Department of Environment and Natural Resources- Forest Management Bureau (*DENR-FMB 2022*). Among the regions, MIMAROPA (Mindoro-Marinduque-Romblon-Palawan) Region has the largest mangrove forests with 69,633 ha. On the other hand, CALABARZON (Cavite-Laguna-Batangas-Rizal-Quezon) Region has only 20,732 ha with only 749 ha of mangroves in Batangas Province. In a report by *Primavera et al.* (*2016*), there were 33 true species of mangrove identified in the country. In a more recent report by *Cuenca-Ocay et al.* (*2019*), 35 mangrove species were described in the Philippines and fall under 19 families and 24 genera.

The mangrove ecosystems play a very important role in achieving sustainability for the coastal and beach ecotourism industry. The sustained and long-term benefits from its ecotourism value depend primarily on the nature and state of its biodiversity (*Malik et al. 2019*). The diverse and stable mangrove ecosystems maintain an intricate food web for aquatic ecosystems and serve as the distinct habitat to a variety of life forms by providing the sources of food and nutrients (*Agduma and Cao 2023; Alongi 2020; Hamilton and Friess 2018; Spalding et al. 1997*). Mangroves also play a critical part in maintaining and functioning the nearby ecosystems like the marine, corals, beaches, wetlands, seagrass beds, and salt marshes (*Spalding et al. 1997*). Therefore, the destruction of the mangrove ecosystem may have a consequential impact on the quality and state of the ecological condition of the coastal, mangrove, and beach ecotourism areas.

However, the mangrove forests dwindled significantly over the last 100 years. It has declined from 450,000-500,000 ha in 1920 (*Primavera 2000*) to 311,400 ha in 2020 (*DENR FMB 2022*). *Bryan-Brown et al.* (*2020*) conducted a study on the global trends in the fragmentation of mangrove forests and found that the Philippines ranked 10th in the country with the highest mangrove loss from 2000 to 2012 (2,681 ha). Most reasons for the decline of mangrove forests are conversion to other land uses like fishponds, settlements, croplands, and others (*Primavera 2000*).

Aside from the spatial decline of the mangrove forest in the Philippines, there was a degradation of the quality of the mangrove stands in terms of diversity. Biodiversity assessment studies in some mangrove forests of coastal areas of the country, like Palawan, Samar, Leyte, Siargao Island, and Lobo, Batangas have very low biodiversity (*Abino et al. 2014a; Abino et al. 2014b; Gonzaga et al. 2022; Padilla et al. 2021; Palis et al. 2011*). The degradation of these coastal and mangrove areas threatens the ecotourism industry in the long term due to decreased productivity and reduced ecological functions and support to adjacent ecosystems.

The biodiversity information, ecological condition, and the application of spatial ecology were sometimes not integrated into the planning and managing of anecotourism area. These resulted in being overused, degraded, and not sustainable. Hence, it is critical for sustainable planning and managing of ecotourism areas to integrate an assessment and spatial analysis of the mangrove biodiversity and ecological status. These could be the basis for determining appropriate species for enhancement, correct zoning for conservation and rehabilitation, and determining ecological limits for infrastructural developments and social activities.

The Lagadlarin Mangrove Forest and Conservation Area is declared by the local government of Lobo, Batangas as a conservation and ecotourism area with a mangrove extent of 0.304 km^2. Barangay Lagadlarin is one of the three barangays in Lobo with existing mangrove forests along with barangays Fabrica and Olo-olo. It has a wide beachfront that serves as one of the tourist sites of the municipality. Despite its ecological status as a conservation site and a famous ecotourism destination, research studies focusing on biodiversity assessment and linking it to the sustainable management of the area is very limited.

This study aims to assess the floristic diversity of the species in the Lagadlarin Mangrove Forest, Lobo, Batangas, Philippines, and integrate the geospatial analysis using a geographic information system as a basis for the sustainable conservation and management of mangroves for ecotourism.

MATERIALS AND METHODS

Study Area

The study site is located in the Barangay Lagadlarin, municipality of Lobo, province of Batangas, Philippines with geographical coordinates 13° 35.00' to 13° 40.00' North and 121° 10.000' to 121° 15.000' East (**Figure 1**). It is situated around 133.2 km southeast of Manila, the capital of the Philippines. It belongs to Climatic Type I, which has two pronounced seasons, dry from November to April and wet from May to October (*PAGASA-DOST 2014*).

Sampling Design

The study used a systematic sampling technique by establishing 20 nested quadrats measuring 10 x 10 m. Eleven quadrats were located in the landward zone, while nine plots are situated at the seaward zone or near the beach area (**Figure 1**).

Diameter at breast height (DBH), total height, and geographical coordinates were determined and recorded. All the species with greater than or equal to 5 cm in

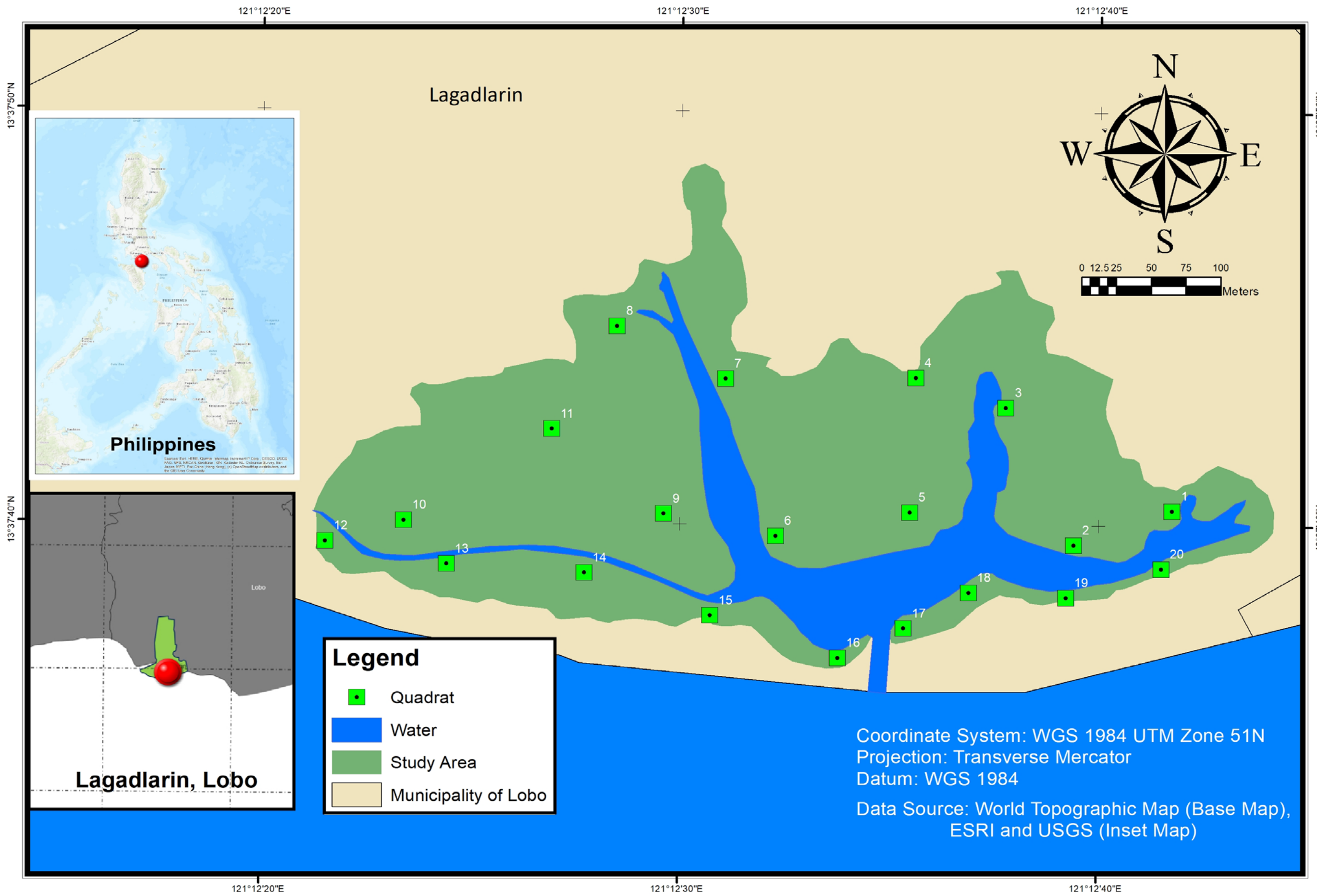

Figure 1. Study site in Barangay Lagdlarin, Lobo, Batangas, Philippines.

diameter at breast height were identified, counted, and measured. Within the quadrat, a 1 x 1m nested plot was established, and all small trees less than five cm in diameter at breast height, propagules, and other vegetation were documented.

Biodiversity Indices

The biological diversity was assessed using the ecological indices developed by *Shannon and Wiener* (*1949*), *Simpson* (*1949*), *Margalef* (1968) and *Pielou* (*1966*).

The Shannon-Wiener's diversity index (H') is the most common measure of species diversity of a community and was determined using Equation 1. The H' values were interpreted based on the following classification, very low diversity (1.99 and below), low diversity (2.00 to 2.49), moderate diversity (2.50 to 2.99), high diversity (3.00 to 3.49), and very high diversity (3.50 and above) as adopted from *Fernando* (*1998*).

$$H' = -\sum_{i=1}^{S} pi * \ln(pi) \qquad (1)$$

Where: H' = Shannon-Wiener Diversity Index
pi = proportion of individuals of species *i*
ln = natural logarithm
S = number of species.

Another measure of the diversity was based on Margalef's Index (R), which was estimated using Equation 2. This measure of diversity is based on the number of individuals of every species present in the area. The R values range from 0 to 5 wherein values close to 0 indicate very low species richness and greater than 5 as very high species richness or diversity (*Margalef 1968; Hussain et al. 2012*).

$$R = (S-1) / \ln(n) \qquad (2)$$

Where: R = Margalef's Index
S = number of species.
ln = natural logarithm
n = total number of individuals

The Simpson's Index is a measure of both dominance and diversity of species in an ecosystem. The Simpson's Dominance Index (D) was estimated using Equation 3, while the Simpson's Diversity Index (D') was derived calculated as 1 – D (*Simpson 1949; Brouwer et al. 2024*). The D values range from 0 to 1, wherein values near to 0 represent very low dominance or very high diversity and values close to 1 mean very high dominance or very low diversity.

$$\mathbf{D} = [(\sum_{i=1}^{S} n_i(n_i-1))/(N(N-1))] \quad (3)$$

Where: D = Simpson's Index
n_i = total number of individuals of a particular species
N = total number of individuals of all species
S = number of species

Species evenness by *Pielou* (*1966*) is another measure of the dominance of a species in a community. The Pielou's Evenness Index (J') was determined using Equation 4. The J' values range from 0 to 1, wherein values close to 0 indicate very low evenness or very high diversity while values near 1 mean a very high level of evenness or very low diversity.

$$J' = H' / H'_{max} \quad (4)$$

Where: J' = Pielou's Index
H' = observed Shannon-Wiener Diversity Index
H'_{max} = highest Shannon-Wiener Diversity Index value

Conservation Status

The status of the ecological importance of the species was determined based on *The International Union for Conservation of Nature (IUCN) Red List of Threatened Species Version 2023-1* (*2024*).

Spatial Analysis

The computed diversity indices were subjected to a Kernel Density analysis. The results of the analysis were transformed into a spatial distribution pattern based on the location of the sampling plots. The spatial distribution maps were generated for each index to determine the location and pattern of species diversity in the study site. The spatial patterns generated were used as a basis for the identification of the areas for conservation, protection, enrichment, and rehabilitation.

Species Importance Value

The species dominating the floristic community were determined using the Species Importance Value Index (IV). The IV was estimated using Equation 5. The IV values range from 0 to 300, wherein species with IV close to 0 means very low dominance while species with IV approaches 300 indicate very high dominance (*Curtis and McIntosh 1951*).

$$IV = RDe + RDo + RF \quad (5)$$

Where: IV = Importance Value
RDe = relative density
RDo = relative dominance

RF = relative frequency

Equations 6 to 8 were used to determine the RDe, RDo, and RF values.

$$RDe = \frac{\text{Density value for a species}}{\text{Total density values for all species}} \times 100 \quad (6)$$

Where: Density = number of individuals/total area sampled

$$RDo = \frac{\text{Dominance value for a species}}{\text{Total dominance values for all species}} \quad (7)$$

Where: Dominance = Basal area for a species/total area sampled
Basal area = (0.007854) * $(DBH)^2$

$$RF = \frac{\text{Frequency value for a species}}{\text{Total frequency values for all species}} \times 100 \quad (8)$$

Where: Frequency = Number of plots in which a species occurs/total number of plots

RESULTS AND DISCUSSION

Species composition

A total of 16 true mangrove species belonging to nine families and 11 genera were documented in the area (**Table 1**). Almost similar results were found by *Palis et al.* (*2011*) wherein 14 true mangrove species were found along the coastal zones of Lobo Watershed. This finding is relatively close to the previous biodiversity assessment studies conducted in other coastal areas in the Philippines, which ranged from 8 to 14 species (*Gevaña and Pampolina 2009; Abino et al. 2014a; Abino et al. 2014b; Rosario et al. 2021; Padilla et al. 2021; Gonzaga et al 2022; Bayani et al. 2022; Goloran et al. 2020*). The relatively higher number of species documented in the area can be attributed to the number of enrichment planting efforts conducted by the local governments, national government agencies, people's organization, community, and private sectors.

Table 1. List of true mangrove species documented in Lagardlarin Mangrove Forest, Lobo, Batangas.

Scientific Name	Local Name	Family Name
Aegiceras floridum Roemer and Schultes	Tinduk-tindukan	Myrsinaceae
Avicennia marina (Forsk.) Vierh. ssp. marina	Api-api	Acanthaceae
Avicennia marina ssp. *rumphiana* (Hallier f.) Bakh.	Bungalon-puti	Acanthaceae
Bruguiera gymnorrhiza (L.) Lamk.	Pototan	Rhizophoraceae
Bruguiera parviflora (Roxb.) W. & A. ex Griff.	Langarai	Rhizophoraceae
Ceriops decandra (Griff.) Ding Hou	Malatangal	Rhizophoraceae
Excoecaria agallocha L.	Buta-buta	Euphorbiaceae
Lumnitzera littorea (Jack.) Voigt	Libato/Kulas	Combretaceae
Lumnitzera racemosa Willd.	Kulasi	Combretaceae
Osbornia octodonta F. Muell.	Taualis	Myrtaceae
Rhizophora apiculata Bl.	Bakawan lalake	Rhizophoraceae
Rhizophora mucronata Poir.	Bakawan babae	Rhizophoraceae
Rhizophora stylosa Griff.	Bakawan bato	Rhizophoraceae
Scyphiphora hydrophyllacea C.F.Gaertn.	Nilad	Rubiaceae
Sonneratia alba J. Smith	Pagatpat	Lythraceae
Xylocarpus granatum Koen.	Tabigi	Meliaceae

Among the 16 true mangrove species identified, six species belong to Rhizophoraceae family, which include *Bruguiera gymnorrhiza*, *B. parviflora*, *Ceriops decandra*, *Rhizophora apiculata*, *R. mucronata*, and *R. stylosa* (**Figure 3**). *Palis et al.* (*2011*) also documented the same trend with the Rhizophoraceae family as the most common with six species documented in coastal areas of Lobo Watershed. Other mangrove species recorded in the study area were *Aegiceras floridum*, *Avicennia marina* ssp. *marina*, *A. marina* ssp. *rumphiana*, *Excoecaria agallocha*, *Lumnitzera littorea*, *L. racemosa*, *Osbornia octodonta*, *Scyphiphora hydrophyllacea*, *Sonneratia alba*, and *Xylocarpus granatum*. There are also nine other mangrove-associate species encountered in the area belonging to seven families and nine genera (**Table 2**).

Malvaceae family is the next most documented with three, while Acanthaceae, Meliaceae, Combretaceae, and Rubiaceae have two species each. Aizoaceae, Bignoniaceae, Convulvulaceae, Euphorbiaceae, Fabaceae, Lythraceae, Myrtaceae and Myrsinaceae were represented by one species each (**Figure 3**).

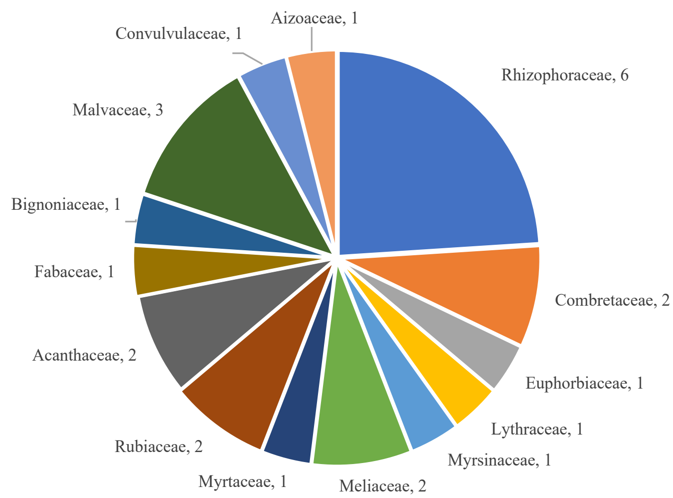

Figure 2. Species count per family name in Lagardlarin Mangrove Forest, Lobo, Batangas.

Conservation status

Based on the *IUCN* (*2024*), one species found in thestudy area is classified vulnerable status and two species under near-threatened classification. *A. marina*

Table 2. List of mangrove-associate species documented in Lagardlarin Mangrove Forest, Lobo, Batangas.

Scientific Name	Local Name	Family Name
Acacia farnesiana (L.) Willd.	Aroma	Fabaceae
Azadirachta indica A. Juss	Neem tree	Meliaceae
Dolichandrone spathacea (L.f.) K.Schum.	Tui	Bignoniaceae
Heritiera littoralis Dryand. ex Aiton	Dungon-late	Malvaceae
Hibiscus tiliaceus L.	Malabago	Malvaceae
Ipomea pes-caprae (L.) R.Br.	Bagasua	Convulvulaceae
Morinda citrifolia L.	Bangkoro	Rubiaceae
Sesuvium potulacastrum (L.) L.	Dampalit	Aizoaceae
Thespesia populnea (L.) Sol. ex Corrêa	Portia tree	Malvaceae

ssp. *rumphiana* is classified as vulnerable status while *C. decandra* and *A. floridum* are under the near-threatened category. The rest are under the least concerned category.

Species importance value

A. marina ssp. *rumphiana* was found to dominate the area with the highest IV of 89.20%. It had the highest number of trees recorded and occurred in a majority of the plots sampled. *A. marina* ssp. *marina* was the second most dominating species with an IV of 32.85% due to high frequency or occurrence in the most number of plots. *E. agallocha* was the third most dominant with an IV of 23.92% (**Table 3**). *Gevaña and Pampolina* (*2009*) also documented *A. marina* as one of the dominant species in Verde Passage Corridor, San Juan, Batangas.

A. farnesiana was recorded as the fourth dominant species with an IV of 21.86%. It was found dominating in some plots, particularly near the landward and beach areas. The presence and widespread distribution of *A. farnesiana* in the area is considered alarming as it threatens the existence of the native mangrove species if not mitigated. It was listed as an invasive species by the *Global Invasive Species Database (GISD)* (*2024*) and was considered as a fast-colonizing species due to prolific seeding and can easily be dispersed (*Arevalo et al. 2010*).

Other species included in the top 10 highest IV include *C. decandra* (14.07), *X. granatum* (12.31%), *B. parviflora* (11.90%), *R. apiculata* (10.38%), *Heritiera littoralis* (9.85%), and *Azadirachta indica* (9.11%).

Species diversity

Based on the average Shannon-Weiner's Index, the diversity of the species in the area was very low (H' = 1.82) according to the classification scheme by *Fernando* (*1988*). The H' values varied across the sampled plots which ranged from 0.87 (very low) to 2.99 (moderate) (**Figure 3**).

Table 3. The 10 most dominant species documented in Lagardlarin Mangrove Forest, Lobo, Batangas.

Scientific Name	RDe	RF	RDo	IV
Avicennia marina ssp. *rumphiana*	23.68	6.58	58.94	89.20
Avicennia marina ssp. *marina*	11.74	11.84	9.27	32.85
Excoecaria agallocha	10.12	6.58	7.22	23.92
Acacia farnesiana	7.29	7.89	6.68	21.86
Ceriops decandra	7.29	5.26	1.52	14.07
Xylocarpus granatum	4.66	3.95	3.71	12.31
Bruguiera parviflora	5.06	5.26	1.58	11.90
Rhizophora apiculata	4.25	5.26	0.86	10.38
Heritiera littoralis	2.63	5.26	1.95	9.85
Azadirachta indica	3.24	3.95	1.92	9.11

The computed H' value is similar to the findings of *Palis et al.* (*2011*) from their biodiversity assessment study conducted in the whole Lobo Watershed, specifically in the coastal/mangrove-beach forests, which obtained a very low diversity value of 1.023. Comparing to the species diversity assessment conducted in some of the mangrove forests in the Philippines, the computed H' value is relatively close to the findings 0.82 - 1.42 for Verde Passage Corridor, San Juan, Batangas (*Gevaña and Pampolina 2009*); 1.64 in Botoc, Pinabacdao, Samar (*Abino et al. 2014a*); 0.99 in Bahile, Puerto Princesa City, Palawan (*Abino et al. 2014b*); 1.25 in Matalom, Leyte, Philippines (*Gonzaga et al. 2022*); 0.79 to 1.90 in Gonzaga, Cagayan (*Bayani et al. 2022*); 1.79 in Butuan Bay, Agusan del Norte (*Goloran et al. 2020*); 0.72 in Binmaley, Pangasinan (*Rosario et al. 2021*); and 1.63 in Pilar, Siargao Island, Surigao Del Norte (*Padilla et al. 2021*). All have were very low species diversity. On the other hand, the species diversity of the mangrove forest in Lobo, Batangas is far below compared to the mangrove forest in Camotes Island, Cebu, Philippines, with an H' value of 3.01 or high diversity (*Lillo et al. 2022*).

The very low diversity of mangrove forests in the Philippines is because of the unique stand formation in contrast to other tropical forest ecosystems (*Gevaña and Pampolina 2009; Kovacs et al. 2011; Abino et al. 2014a; Abino et al. 2014b; Bayani et al. 2022*). Other reports cited that anthropogenic factors as major contributors to the deforestation of mangrove forests in the Philippines, which include urbanization, conversion to aquaculture and agriculture, harvesting of timber for charcoal making, and disasters due to impacts of climate change (*Primavera 2000; Alongi 2002; Garcia et al. 2014*).

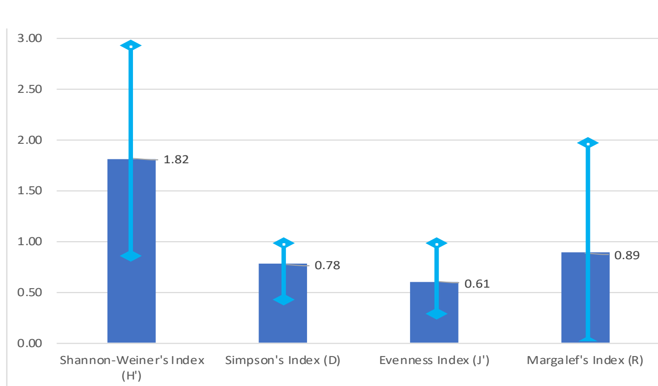

Figure 3. Computed diversity indices in Lagardlarin Mangrove Forest, Lobo, Batangas.

In terms of Margalef's Richness Index (R), the average computed value was 0.89 which means a very low species richness level. The computed R values across the sampled plots ranged from 0 (very low) to 2.01 (moderate). An almost similar result was found by *Rosario et al.* (*2021*) for Binmaley, Pangasinan with only 0.63 richness index. The very low richness values can be attributed to the pattern of species distribution in the area, which is dominated by few species.

Based on Simpson's Dominance Index (D), the computed values ranged from 0.43 to 1.00. The average D value was 0.78, which means high dominance (**Figure 3**). When converted into D' through 1 – D, the diversity value was low with only 0.28. Similar results were found using the evenness index (J') with values ranging from 0.29 to 1.00. The average J' value 0.61 which is high evenness where most of the plots sampled have an even distribution of species.

Spatial floristic diversity

Low to moderate diversity values were observed near the inland water (**Figures 4** and **5**). This finding might be attributed to the role of the tidal wave and lake or river ecosystem in nutrient cycling. Lateral influxes and deposition of nutrients like nitrogen and phosphorus were found higher in mangrove areas near the estuaries and rivers due to tidal waves (*Wang et al. 2021*). This helps in the growth and survival of propagules in the mangrove stand.

Very low diversity was found in areas farther from the inland water and in some beach areas dominated by non-mangrove species like *A. farnesiana*, an invasive alien species. The condition in these areas were observed to be relatively drier and degraded which facilitates the spread of *A. farnesiana* and inhibits the growth of mangrove and beach-type species.

An almost similar trend was observed in terms of the species richness using the Margalef's Index (R) (**Figure 5**). Areas near the lake and river were found to have low to moderate species richness index values. Three to six species documented in these areas. On the other hand, the areas farther from the water were found with very low species richness index values. Around one to two species were recorded in these areas and mostly dominated by *A. farnesiana* and other associated species.

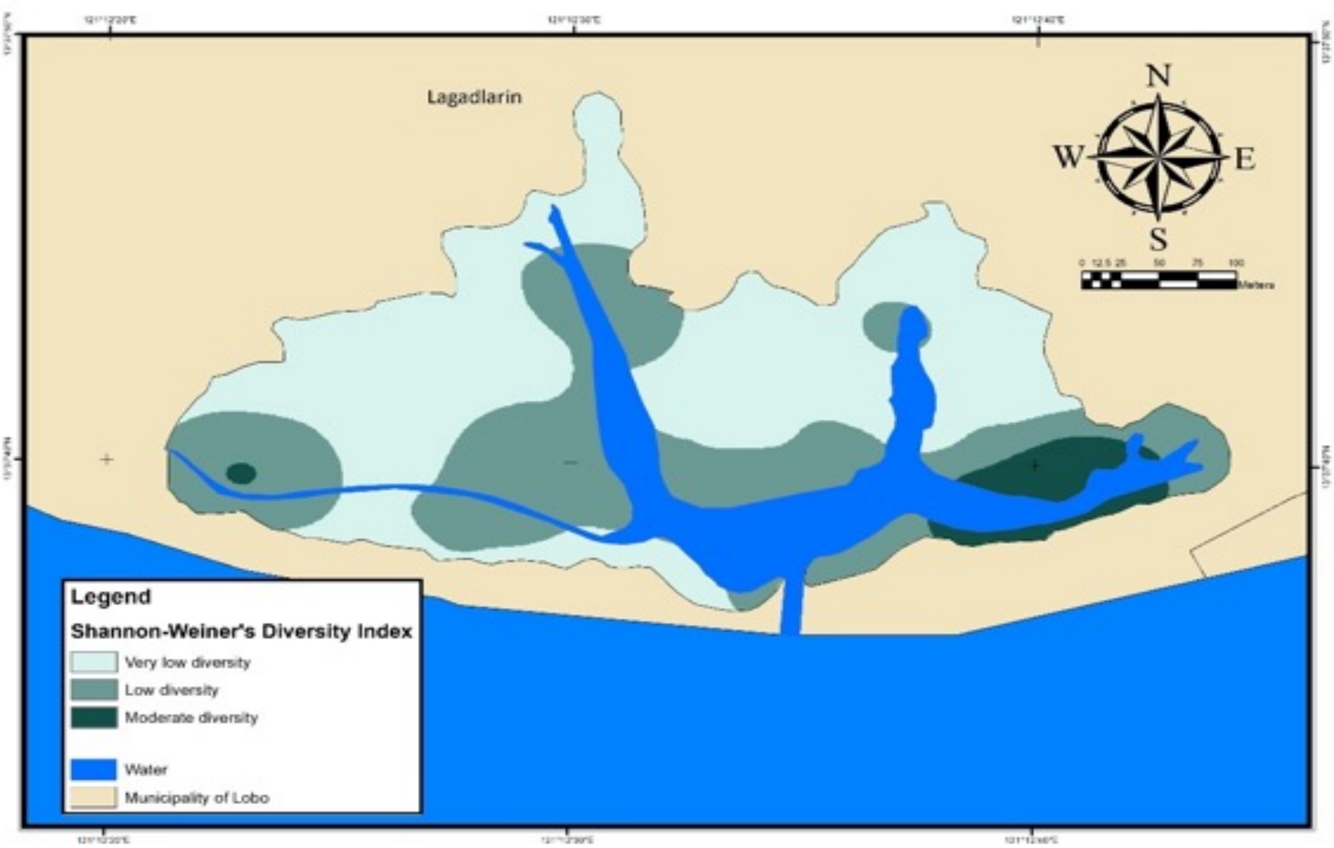

Figure 4. Result of the Kernel Density spatial analysis for the Shannon-Weiner's diversity index in Lagardlarin Mangrove Forest, Lobo, Batangas.

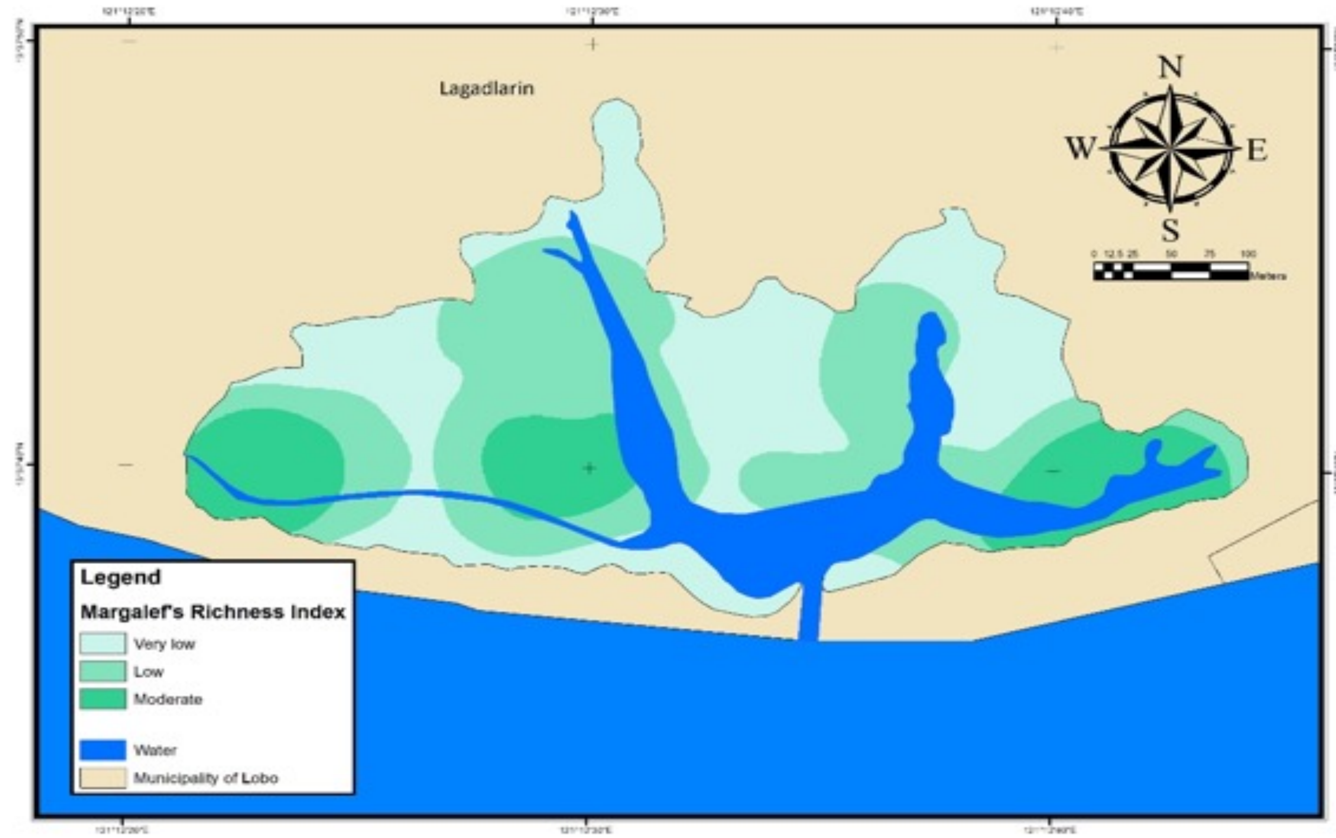

Figure 5. Result of the Kernel Density spatial analysis for the Margalef's richness index in Lagardlarin Mangrove Forest, Lobo, Batangas.

Understorey vegetation

The presence of the understorey vegetation is important for the regeneration potential of the mangrove species. Based on the assessment, there was an average of 5.2 regenerants counted per square meter. These are mostly the propagules or wildlings from the nurse mangrove trees like the *A. marina* ssp. *rumphiana*, *A. marina* spp. *marina*, *E. agallocha*, and *C. decandra* in mangrove-dominated plots. The average height of the propagules or wildlings was found at 0.47 m. The relativelylow density of propagules in the stand was due to the collection of wildlings by the people's organization as a source of their planting materials.

CONCLUSION AND RECOMMENDATIONS

Despite the potential of the Lagadlarin Mangrove Forest for ecotourism due to its remaining mangrove forest, it was found that a very low species diversity was documented. The computed Shannon-Weiner's Index and Margalef's Richness Index are only 1.82 and 0.87, respectively. The very low diversity is attributed to the higher dominance and evenness values based on Simpson's Dominance Index and Pielou's Evenness Index of 0.78 and 0.61, respectively. This means that few species dominated the mangrove community, almost even throughout the sampled plots. Among the dominant mangrove species documented were *A. marina* ssp. *rumphiana*, *A. marina* ssp. *marina*, and E. *agallocha* with the highest IV values of 89.20%, 32.85%, and 23.92%, respectively. Another species that was found dominating in some portions of the area is *A. farnesiana* with an IV of 21.86%, listed as an invasive weed species.

Based on the geospatial analysis, the higher species diversity was recorded in areas near the lake or water. These areas are potential areas for enrichment with appropriate true mangrove and beach-type species. On the other hand, areas far from the water or landward portion and some portions of beach areas were dominated by *A. farnesiana*. The proliferation of *A. farnesiana* is an indicator of environmental degradation and threatens the mangrove diversity when not mitigated.

There were 16 true mangrove species documented with one species under vulnerable status and two species under the near-threatened category based on *IUCN* (*2024*) classification. *A. marina* ssp. *rumphiana* is classified as vulnerable status while *C. decandra* and *A. floridum* are under the near-threatened category. The rest are listed under the least concerned category. Rhizophoraceae family is the most dominant with six species. Malvaceae family is the next most documented with three, while Acanthaceae, Meliaceae, Combretaceae, and Rubiaceae have two species each. Aizoaceae, Bignoniaceae, Convulvulaceae, Euphorbiaceae, Fabaceae, Lythraceae, Myrtaceae, and Myrsinaceae were represented by one species each.

To sustain and boost the potential of the Lagadlarin Mangrove Forest as one of the promising ecotourism destinations in Lobo, Batangas, the appropriate management interventions have to be implemented by the people's organization and the local government. It is recommended that the area should be classified into two management zones, namely, the enrichment zone and the rehabilitation zone (**Figure 6**). These management zones were derived by overlaying the spatial distribution of the species diversity and density levels in the area. The enrichment zone is the area with existing mangrove stands and is suited for enrichment planting with appropriate species based on mangrove zonation. These areas are mostly near the water (**Figure 6**). Among the recommended species for enrichment planting for blocks 1, 2, and 3 are *A. marina* spp. *marina* for the seaward/ muddy area, *A. marina* ssp. *rumphiana*, *R. apiculata*, *R. mucronata*, *R. stylosa*, *C. decandra*, *L. littorea*, *L. racemosa* and *B. gymnorrhiza* for the mid part, and *E. agallocha*, *O. octodonta*, and *X. granatum* for the landward portion. For the beach areas in blocks 4 and 5, species that can be planted for enrichment are *Terminalia catappa*, *Calophyllum inophyllum*, *P. pinnata*, and *I. pes-caprae*.

On the other hand, the rehabilitation zone is the area mostly inhabited by *A. farnesiana*. These are areas mostly located in the landward portion and part of the beach areas. These areas are recommended for rehabilitation and application of control measures to mitigate the growth and expansion of *A. farnesiana*. The *A. farnesiana* stand is recommended to be subjected to mechanical control or manual removal of trees and roots before planting of appropriate species. Among the recommended species for the landward areas of blocks 1, 2, and 3 are *Nypa fruticans*, *D. spathacea*, *H. littoralis*, and *Pometia pinnata*. For the beach areas in blocks 4 and 5 are *H. littoralis*, *T. catappa*, *C. inophyllum*, *P. pinnata*, *Capparis micrantha*, *Tabernaemontana pandacaqui*, Mallotus sp., *Sesuvium portulacastrum* and *Premna Serratefolia*.

The collection of wildlings or propagules from the existing mangrove stand should be limited to 60% of the

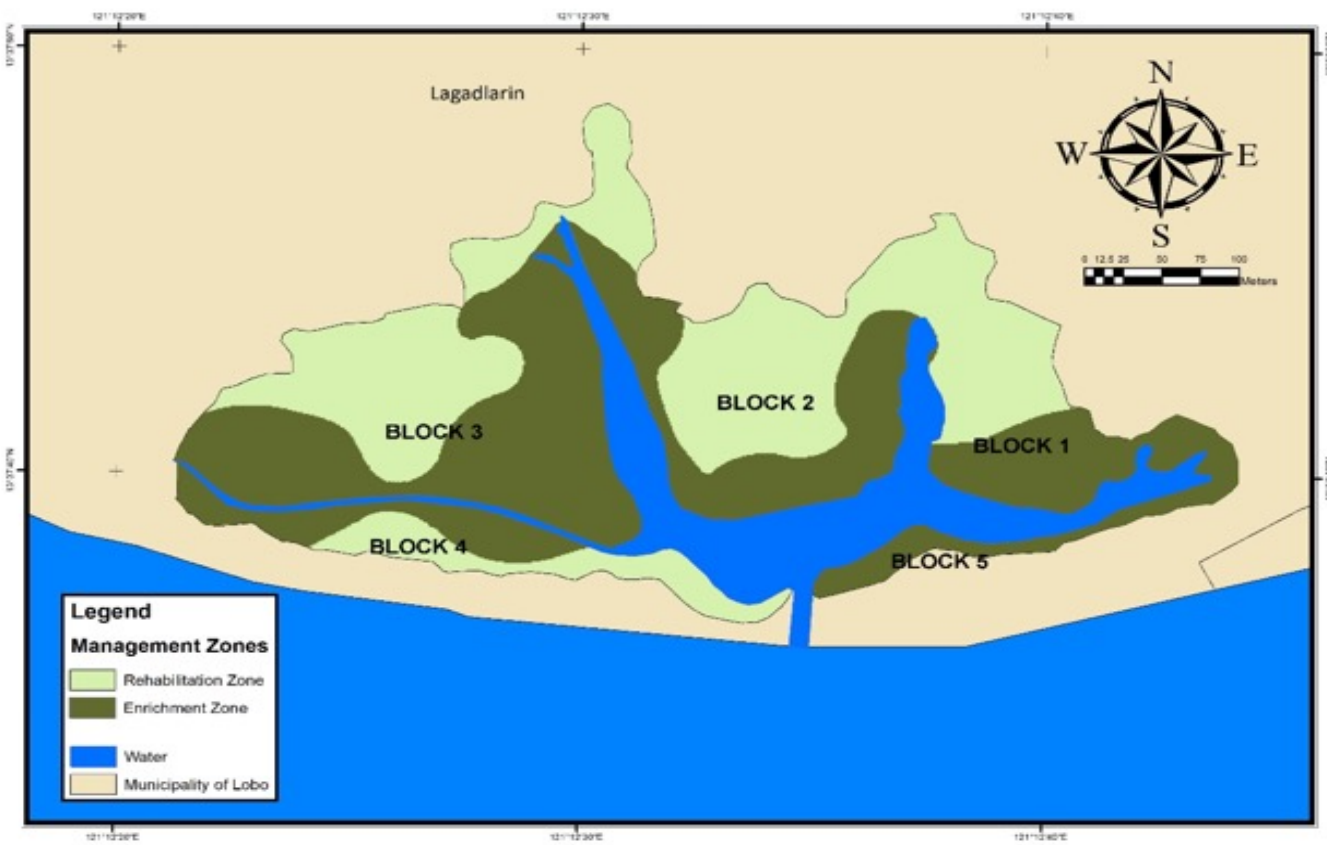

Figure 6. Proposed management zones for the Lagadlarin Mangrove Forest, Lobo, Batangas.

existing number of propagules or wildlings. This is to allow a sufficient number of propagules for regeneration of the mangrove stand and prohibit the possible entry and growth of *A. farnesiana*. It is also recommended to source out the planting materials from other provenance like from Quezon and San Juan mangrove areas to enhance genetic diversity.

The results of this biodiversity assessment should also be included in the computation of the tourism carrying capacity of the area to set the threshold for the number of tourists that have a minimal impact on the habitat of wildlife flora and fauna. Infrastructure development should also be confined to areas with less density of the mangrove stand and avoid the locations of the ecologically important species.

Aside from the tourism carrying capacity assessment, assessing the physical carrying capacity of Lobo, Batangas is also recommended. It is important to note that the ecological status of mangroves partly depends on anthropogenic factors due to urbanization. The result of the physical carrying capacity assessment will provide the threshold for infrastructural developments for residential, commercial, and other socio-economic purposes. This will eventually improve the ecological health of the mangroves in Lobo, Batangas.

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