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Diversity, distribution and conservation status of mangrove species in the Municipality of Biliran, Biliran Island, Philippines

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Abstract

We determined the diversity of mangrove species and their conservation status in the municipality of Biliran to serve as baseline for conservation and protection of mangal ecosystems in the island. Thirty-two quadrats with a size of 10×10 m were established and each mangrove tree inside the plots was identified. The numbers of individuals per species were counted and diversity indices were computed. Results revealed 13 mangrove species belonging to 7 families including *Avicennia rumphiana*, *A. marina*, *A. alba*, *Rhizophora apiculata*, *R. stylosa*, *R. mucronata*, *Ceriops tagal*, *Bruguiera* sp., *Sonneratia alba*, *Exoecaria agallocha*, *Scyphiphora hydrophyllacea*, *Xylocarpus granatum*, and *Brownlowia tersa*. Majority of the mangrove species belonged to Rhizophoraceae family. *R. apiculata* was the most abundant while *B. tersa* was the least abundant species. Mangroves like *C. tagal, R. apiculata, and A. marina* were generalist species because they were found in all of the study sites, whereas *A. rumphiana, A. alba, S. hydrophyllacea, B. tersa, R. mucronata, and Bruguiera sp.* were specialist because they were only found in 1 study site. *A. rumphiana* was the only mangrove listed as Vulnerable (VU) based on IUCN Red List of Threatened Species. The mean values of the following indices were obtained: H'= 1.1984, D_{Mn}= 0.7124, J= 0.6877 and D= 0.3877. Mangrove diversity in Biliran municipality was very low with a highly even distribution of species and uniform distribution of individuals. Since mangal ecosystems in the municipality of Biliran are facing natural and anthropogenic disturbances, the local government unit should prioritize mangrove forest conservation and rehabilitation.

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Introduction

Mangroves ecosystems are mostly composed of halophytic tree and shrub species that are regularly expose to fluctuations in water level, hydrodynamic energy, salinity, nutrient availability, and anoxia (Friess, 2016). Despite thriving in a dynamic and physiologically stressful location, a plethora of coastal and terrestrial fauna are associated with this vegetation including fish, crustaceans, snakes and mammals. In addition to their unique biodiversity value, mangroves are largely important habitats due to some tangible provisioning ecosystem services they provide to the local coastal populations such as timber, charcoal, non-timber forest products and fish/shellfish. The United Nations Environment Programme (2014) further cited that mangrove ecosystem provides millions of people with food, clean water, raw materials and resilience against future climate change impacts including increasing storm intensity and sea level rise. For instance, when super typhoon Haiyan struck the central Philippines, areas with mangrove forests suffered significantly less damage as the trees acted as shield from the strong winds and waves (Ranada, 2014).

Faustino *et al.* (2020) noted that mangrove forests in the Philippines have been continuously dwindling in terms of forest cover and diversity due to anthropogenic activities which include cutting of trees for the production of firewood, charcoal, and building materials, and residential, urban and industrial development, and conversion to agriculture (Maneja, 2006; Bitantos *et al.*, 2017) as well as natural disturbances. In view of these challenges, it is important to conduct baseline studies to give not only a benchmark of an area's biodiversity but a picture of its overall importance in the landscape (Flora and Fauna International, 2014). A baseline study can highlight areas of importance for biodiversity conservation, identify threats to species and habitats, and help understand how local communities use and value resources.

Fortes and Salmo (2017) cited that mangrove studies in the Philippines are initially categorized under seven topics including taxonomy, physiology, economic uses, biogeography, ecology, biodiversity, and conservation and management. However, information on species composition and diversity studies of mangroves from the different parts of the country remains limited and scarce (Baleta and Casalamitao, 2016). Recent local biodiversity studies and vegetational analysis on mangroves have been carried out in Surigao del Norte (Goloran *et al.*, 2020), Camarines Sur (Faustino *et al.*, 2020), Oriental Mindoro (Raganas *et al.*, 2020), Palawan (Dangan-Galon *et al.*, 2016), Camotes island (Lillo *et al.*, 2022), Timaco Mangrove Swamp in Cotabato City (Cano-Mangaoang *et al.*, 2022), Samar island (Mendoza and Alura, 2001), Zamboanga Sibugay (Bitantos *et al.*, 2017), Pangasinan (Rosario *et al.*, 2021), Aurora (Rotaquio *et al.*, 2017), Cagayan Valley (Calicdan *et al.*, 2017), Isabela (Baleta and Casalamitao, 2016), Aklan (Barrientos and Apolonio, 2017), Quezon province (Abantao *et al.*, 2015), and Leyte island (Bobon-Carnice *et al.*, 2021). To date, mangrove studies on the island of Biliran is not documented, particularly in the municipality of Biliran where a large portion of mangrove forest in the village of Sangalang became a wasteland when many mangrove trees and associated species died during the onslaught of tropical depression (TD) Urduja in 2017. Thus, this study was conducted to gather scientific-based data that can serve as a baseline in determining the diversity and conservation status of mangrove species based on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. Such baseline can be used in prioritizing areas for conservation and protection of mangal ecosystems in the island, especially with the ongoing threats of both anthropogenic and natural disturbances.

Material and methods

Establishment of Sampling Plots and Identification of Mangrove Species

Five coastal villages with mangrove areas in the municipality of Biliran, namely: Burabod, Busali, Sangalang, Julita, and Villa Enage were selected as study sites based on the preliminary survey (Fig. 1).

The village of Bato was excluded due to the dominance of *Nypa fruticans* Wurmb. in its mangrove area. The methodology followed by Faustino *et al*. (2020) was modified based on the field conditions. Thus, only a total of 32 quadrats or plots with a size of 10×10 m were established.

Inside the plots, each mangrove tree was identified down to the species level using a field guide (Primavera, 2009). The number of individuals per species were counted and recorded on a field notebook. Presence of anthropogenic disturbances whether inside or outside the plots were also noted.

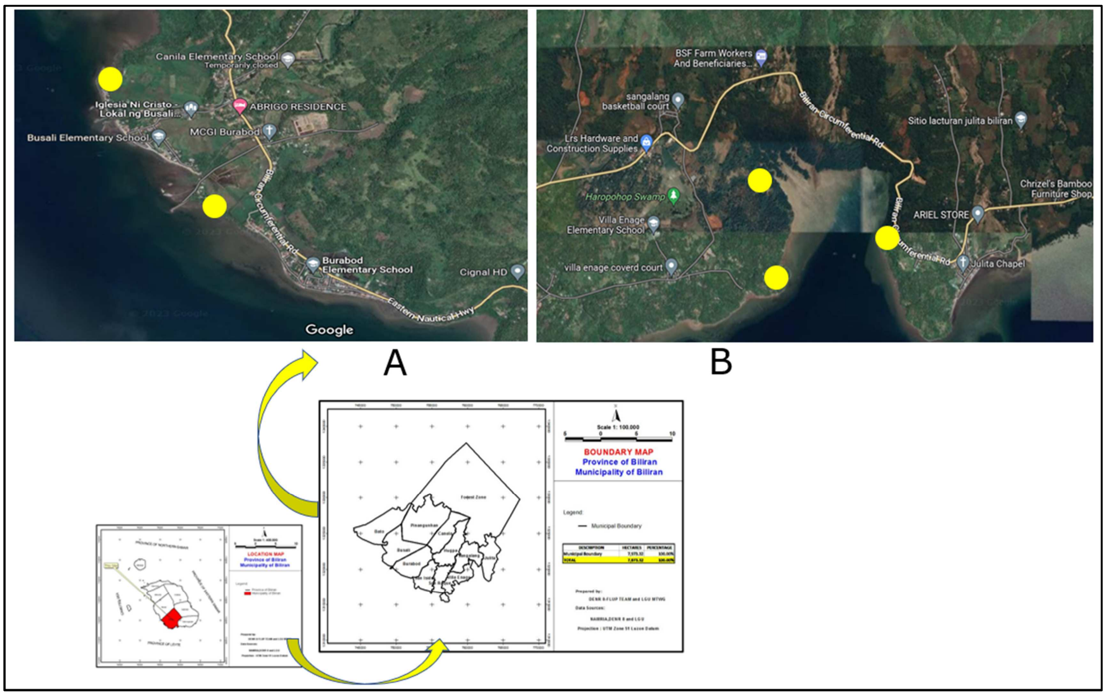

Fig. 1. Map of the location of study sites in the municipality of Biliran showing: A) Busali and Burabod; and B) Villa Enage, Sangalang, and Julita.
Sources: DENR 8-FLUP Team and Biliran LGU MTWG; Google Maps.

Analysis of Data

Using the data on the number of individuals for each species, the following indices were computed:

1. Species Richness (Menhinick Index)

$$(D_{Mn}) = \frac{S}{\sqrt{N}}$$

where:

S = total no. of species observed

N = total number of individuals in the sample

D_{Mn} = Menhinick Index

2. Species Diversity (Shannon-Wiener Index)

$$H' = \sum_{i=l}^{s} P_i \ln P_i$$

where:

H' = Shannon-Wiener Index

S = no. of species

p_i = proportion of individuals of the abundance of the i^{th} species expressed as proportion of total abundance (n_i/N)

ln= natural logarithm

3. Equitability (Pielou's Evenness Index)

$$J = H'/\ln(S)$$

where:

H' = Shannon-Wiener Index of Diversity

S = total number of species

ln = natural logarithm

J = Pielou's Evenness Index

4. Species Dominance (Simpson Index)

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

where:

n= number of individuals of the i^{th} species

N = total number of individuals

∑ = the sum of the calculations

D = Simpson Index

Result and discussion

Species Composition of Mangroves

A total of 13 mangrove species belonging to 7 families could be found thriving in the coastal villages of Biliran municipality (Table 1). The identified species were *Avicennia rumphiana* Hallier f., *Avicennia marina* (Forssk.) Vierh., and *Avicennia alba* Blume from Avicenniaceae family; *Rhizophora apiculata* Blume, *Rhizophora stylosa* Griff., *Rhizophora mucronata* Lam., *Ceriops tagal* (Perr.) C. B. Rob., and *Bruguiera* sp. from Rhizophoraceae family; *Sonneratia alba* Sm. from Sonneratiaceae family; *Exoecaria agallocha* L. from Euphorbiaceae family; *Scyphiphora hydrophyllacea* C. F. Gaertn. from Rubiaceae; *Xylocarpus granatum* J. Koenig from Meliaceae family; and *Brownlowia tersa* (L.) Kosterm. from Tiliaceae family. Majority of the mangrove species found in the study sites belonged to Rhizophoraceae family (57.31%), followed by Avicenniaceae family (29.68%) (Fig. 2). Only 0.23% of the mangroves belonged to Meliaceae family.

Table 1. Mangrove species that can be found in the municipality of Biliran.

Family Name	Species Name	Local Name
Avicenniaceae	*Avicennia rumphiana*	Miapi
Avicenniaceae	*Avicennia marina*	Miapi
Avicenniaceae	*Avicennia alba*	Miapi
Rhizophoraceae	*Rhizophora apiculata*	Bakhaw lalaki
Rhizophoraceae	*Rhizophora stylosa*	Bakhaw bato
Rhizophoraceae	*Rhizophora mucronata*	Bakhaw babae
Rhizophoraceae	*Ceriops tagal*	Tangal
Rhizophoraceae	*Bruguiera* sp.	Pototan
Sonneratiaceae	*Sonneratia alba*	Pagatpat
Euphorbiaceae	*Exoecaria agallocha*	Lipata
Rubiaceae	*Scyphiphora hydrophyllacea*	Nilad
Meliaceae	*Xylocarpus granatum*	Tabigi
Tiliaceae	*Brownlowia tersa*	Magaromon

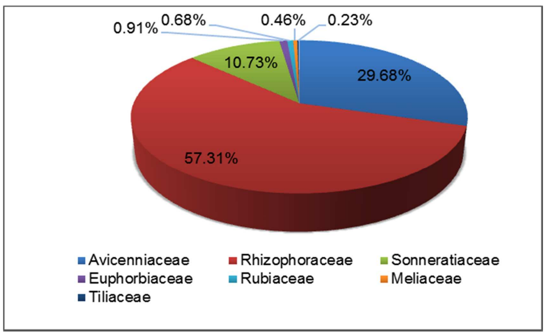

Fig. 2. Composition of mangroves based on families.

Abundance, Occurrence, and Distribution of Mangrove Species

The abundance, occurrence, and distribution of mangrove species in the municipality of Biliran differed based on the study sites (Table 2).

A total of 438 individuals of mangrove species were counted in the study sites, in which, *R. apiculata* Blume was the most abundant (165 individuals) while *B. tersa* (L.) Kosterm. was the least abundant species (1 individual).

The 3 mangrove species, *C. tagal* (Perr.) C.B. Rob., *R. apiculata* Blume, and *A. marina* (Forssk.) Vierh. were found in all of the study sites whereas *S. alba* Sm. Were also found in 4 study sites, except in Busali. *R. stylosa* Griff. and *X. granatum* J. Koenig were seen thriving in Sangalang and Villa Enage while *E. agallocha* L. were found in both Sangalang and Busali.

On the other hand, 4 species including *A. rumphiana* Hallier f., *A. alba* Blume, *S. hydrophyllacea* C. F. Gaertn., and *B. tersa* (L.) Kosterm. seemed to be limited to Sangalang while *R. mucronata* Lam. and *Bruguiera* sp. were seemingly restricted to Julita and Villa Enage, respectively.

Table 2. Abundance, occurrence, and distribution of mangroves per study site in the municipality of Biliran.

Species	Study Site					Total Number of Individuals
	Burabod	Busali	Sangalang	Julita	Villa Enage	
A. alba	X	X	71	X	X	73
A. rumphiana	X	X	10	X	X	10
A. marina	20	9	1	6	11	47
R. stylosa	X	X	1	X	8	9
R. mucronata	X	X	X	2	X	2
R. apiculata	16	6	21	61	61	165
C. tagal	1	9	58	2	2	72
Bruguiera sp.	X	X	X	X	3	3
S. alba	3	X	8	13	23	47
E. agallocha	X	1	3	X	X	4
S. hydrophyllacea	X	X	3	X	X	3
X. granatum	X	X	1	X	1	2
B. tersa	X	X	1	X	X	1
Total	40	25	178	84	111	438

Note: X= Not present

Fig. 3. Both natural and anthropogenic disturbances are threatening the existence of *A. rumphiana* in Sangalang.

Diversity of Mangrove Species

The species richness (D_{Mn}), dominance (D), evenness (J) and diversity (H') of mangrove species per study site in the municipality of Biliran is shown in Fig. 4. The mean species richness obtained was D_{Mn}= 0.7124 and mean species diversity was H'= 1.1984, in which Sangalang recorded both the highest species richness value of D_{Mn} = 0.8245 and species diversity value of H'= 1.5390. However, this mean H' index value could be considered as very low in terms of diversity. On the other hand, the mean equitability index obtained was J'= 0.6877, in which Busali had the highest equitability value of J= 0.8706. This J value indicated a highly even distribution of the mangrove species in the study sites. In terms of dominance, the mean species dominance value obtained was D=0.3877, in which Julita had the highest dominance value of D=0.5575. This D value suggested a uniform distribution of individuals among the mangrove species in the study area.

Table 3. Species richness (D_{Mn}), dominance (D), equitability (J) and diversity (H') index of mangrove species per study site in the municipality of Biliran.

Index	Study Site					Total	Mean
	Burabod	Busali	Sangalang	Julita	Villa Enage		
Species Richness	0.6325	0.8000	0.8245	0.5455	0.7593	3.5618	0.7124
Species Diversity	0.9996	1.2070	1.5390	0.8876	1.3590	5.9922	1.1984
Equitability	0.7210	0.8706	0.6420	0.5515	0.6533	3.4384	0.6877
Dominance	0.4163	0.3184	0.2851	0.5575	0.3614	1.9387	0.3877

Conservation Status of Mangrove Species

Among the 13 identified mangrove species, *A. rumphiana* Hallier f. is the only mangrove species listed as Vulnerable (VU) based on IUCN Red List of Threatened Species of 2022 while the rest of the species were either listed as Least Concern (LC) or Not Evaluated (NE) (Table 4). This mangrove species could only be found in Sangalang where both natural and anthropogenic disturbances are threatening the existence of this species (Fig. 4). Large tracts of mangrove areas in this village were decimated due to mudslide and flooding events caused by tropical depression Urduja in 2017. Insect infestation of the mangroves is highly likely because of the presence of many caterpillars. Indications of anthropogenic disturbances were also evident in the site including presence of cutting marks in 2 mangrove trees and degrading pieces of metallic fishing net.

Table 4. Mangrove species and their ecological status based on IUCN Red List of Threatened Species in the municipality of Biliran.

Family Name	Species Name	Ecological Status
Avicenniaceae	*Avicennia rumphiana*	Vulnerable (VU)
Avicenniaceae	*Avicennia marina*	Least concern (LC)
Avicenniaceae	*Avicennia alba*	Least concern (LC)
Rhizophoraceae	*Rhizophora apiculata*	Least concern (LC)
Rhizophoraceae	*Ceriops tagal*	Least concern (LC)
Rhizophoraceae	*Rhizophora stylosa*	Least concern (LC)
Rhizophoraceae	*Rhizophora mucronata*	Least concern (LC)
Rhizophoraceae	*Bruguiera* sp.	-
Sonneratiaceae	*Sonneratia alba*	Least concern (LC)
Euphorbiaceae	*Exoecaria agallocha*	Not evaluated ()
Rubiaceae	*Scyphiphora hydrophyllacea*	Least concern (LC)
Meliaceae	*Xylocarpus granatum*	Least concern (LC)
Tiliaceae	*Brownlowia tersa*	Not evaluated (NE)

Note: The symbol - means that ecological status could not be determined since it was not identified down to the species level.

Discussion

Species Composition of Mangroves

Noor *et al.* (2012) cited that species within Rhizophoraceae family are among the most significant and most widely distributed mangal species. Species dominance of Rhizophoraceae family could even reach 90% of the total vegetation, in which optimal growth usually occurs in deeply inundated land and humus-rich soil. Families of Avicenniaceae and Rhizophoraceae often dominate the mangal population in terms of number of species and abundance (Hogarth, 2013). In Indonesia, the Rhizophoraceae family primarily consisting of *Bruguiera gymnorrhiza* (L.) Lam., *R. mucronata* Lam., *R. apiculata* Blume, *R. stylosa* Griff., and *C. tagal* (Perr.) C.B. Rob. was found more often than the other families of mangroves (Utina *et al.*, 2019). They have highly developed morphological and physiological adaptations to extreme intertidal environments, and are predisposed with genes which are crucial for increased capability of stress tolerance including defense against salt and oxidative stress, and development of adaptive traits like vivipary (Guo *et al.*, 2017). All *Rhizophora* taxa are also characterized by large water-buoyant propagules with a remarkable ability for long-distance dispersal (Rabinowitz, 1978). The strong enclosure of its young shoots by conspicuous rounded or flattened stipules and colleter exudates offer structural and mechanical protection, shielding the young shoots of these mangrove plants from their harsh environments (Sheue *et al.*, 2012).

Along with Rhizophoraceae family, species from Avicenniaceae family also form the dominant plant communities of mangrove forests (Duke, 1991). As an important member of the mangal formation, all species of this family exhibit adaptations convergent with those of other mangroves such as tolerance of high salt concentrations, excretion of hypersaline solutions on both leaf surfaces via subsessile glandular hairs, xerophytic specializations of leaves, sea-water dispersed viviparous fruits, and soft mud catching hypocotyl of the embryo that allows immediate growth of the seedling (Sanders, 1997).

Abundance, Occurrence, and Distribution of Mangrove Species

Mangrove species including *C. tagal* (Perr.) C. B. Rob., *R. apiculata* Blume, and *A. marina* (Forssk.) Vierh. were generalist species because they were found in all of the study sites, whereas *A. rumphiana* Hallier f., *A. alba* Blume, *S. hydrophyllacea* C. F. Gaertn., *B. tersa* (L.) Kosterm., *R. mucronata* Lam., and *Bruguiera* sp. were specialist species because they were only found in one study site. Kirsch (2021) cited that generalist species have a wider range of environmental tolerance and utilize a variety of resources by possessing widely applicable features that are not constricted to a narrow function. On the contrary, ecological specialist species have narrowly evolved characteristics that optimize their fitness in their local environment at the cost of vulnerability to disturbance and a high level of dependence on their available niche. It has been shown that habitat heterogeneity tends to favor generalist species temporally and spatially, while specialists benefit from homogeneous habitat conditions (Büchi and Vuilleumier, 2014; Marvier *et al.*, 2004; Devictor *et al.*, 2008; Verberk *et al.*, 2010). Büchi and Vuilleumier (2014) further explained that life-history traits such as niche breadth and dispersal ability, and environmental factors like disturbance, spatial heterogeneity, and autocorrelation could influence the coexistence of specialist and generalist species.

Diversity of Mangrove Species

Rosario *et al.* (2021) interpreted H' index of diversity as very low (<1.999), low (2.000-2.499), moderate (2.500-2.999), high (3.000-3.499), or very high (>3.500). The very low diversity of mangroves in the municipality of Biliran was comparable to the mangrove forests in Tacloban City, Leyte (Patindol and Casas, 2019), Binmaley, Pangasinan (Rosario *et al.*, 2021), Dumanquillas Bay, Zamboanga Sibugay ((Bitantos *et al.*, 2017), Cancabato Bay, Leyte (Bobon-Carnice *et al.*, 2021), and Mabini, Davao de Oro (Manual *et al.*, 2022). Morris *et al.* (2014) after Shannon (1948) explained that in a highly diverse system, an unknown individual could belong to any species which often leads to a high uncertainty in predicting its identity. In a less diverse system dominated by one or a few species, it is easier to predict the identity of unknown individuals and there is less uncertainty in the system.

Fatonah *et al.* (2021) emphasized that species evenness values equal to or close to 1 means the species are evenly distributed. It is also categorized as uneven (0.00-0.40), moderately even (0.41-0.60), and highly even (0.61-1.00). Equitability represents the degree to which individuals are split among species with low values indicating that one or a few species dominate, and high values indicating that relatively equal numbers of individuals belong to each species (Morris *et al.*, 2014). Meanwhile, dominance values close to one (1) imply a clumping of individuals in a few species whereas values close to zero (0) mean a more uniform distribution of individuals among the species (Doherty *et al.*, 2011). The dominance has a range value of 0 where all taxa are equally distributed to 1 where one taxon dominates the community completely (Manual *et al.*, 2002).

A variety of both biotic and abiotic factors play a role in influencing the diversity of mangrove species and their distributional patterns. Mangroves are forest types consisting of all plants along the coast or river estuary which are affected by tides and interacting with their environment (Irsadi *et al.*, 2019). Duke *et al.* (1998) stated that numerous factors affect the distribution of mangrove plants including direction of sea currents, presence of land barriers, and species-specific characteristics such as their water-buoyant propagules, establishment success and growth development rate, and tolerance limits and growth responses. Ellison (2021) further explained that mangrove ecosystem diversity and dynamics are influenced by physical factors of temperature, coastal typology, ocean currents and land barriers, wave action and sediment supply, river catchment discharge and sediment yield, and tidal range and inundation frequencies. Factors of gradients and tidal ranges control the lateral extent of mangroves through inundation frequency, and factors influencing accretion rates in the context of relative sea level change can shift or eliminate mangrove extents over time.

Conservation Status of Mangrove Species

Triest *et al.* (2021) reported that the IUCN Red List of Threatened Species considered *A. rumphiana* Hallier f. is a species with vulnerable status because of its patchy distribution, being uncommon in some areas, and declining population. It also thrives in the upper part of the intertidal zone where it is most vulnerable to human activities and habitat destruction. Chan *et al.* (2022) explained that population trend of this species is decreasing and the mangrove habitat within this species range has declined at least 30% from 1980 to 2005. However, there are no available data to estimate the decline of population as well as no measures have been in placed for the conservation and protection of this species.

Conclusion

Results revealed 13 mangroves belonging to 7 families including *A. rumphiana*, *A. marina*, *A. alba*, *R. apiculata*, *R. stylosa*, *R. mucronata*, *C. tagal*, *Bruguiera* sp., *S. alba*, *E. agallocha*, *S. hydrophyllacea*, *X. granatum,* and *B. tersa*. Majority of the mangroves belonged to Rhizophoraceae family.

R. apiculata was the most abundant while *B. tersa* was the least abundant species. *C. tagal*, *R. apiculata*, and *A. marina* were found in all of the study sites whereas *S. alba*. was found in 4 study sites. *R. stylosa* and *X. granatum* thrived in Sangalang and Villa Enage while *E. agallocha* inhabited Sangalang and Busali. *A. rumphiana*, *A. alba, S. hydrophyllacea*, and *B. tersa* were limited to Sangalang while *R. mucronata* and *Bruguiera* sp. were restricted to Julita and Villa Enage, respectively.

The mean values of the following indices were obtained: H'= 1.1984, D_{Mn}= 0.7124, J= 0.6877 and D= 0.3877. Mangrove diversity in Biliran municipality was very low with a highly even distribution of species and uniform distribution of individuals. *A. rumphiana* was the only mangrove species listed as Vulnerable (VU) based on IUCN Red List of Threatened Species while rests of the species were either listed as Least Concern (LC) or Not Evaluated (NE).

Recommendation(S)

The mangal forests of Biliran municipality are facing both natural and anthropogenic disturbances. To protect these fragile ecosystems, a multi-sectoral and science-based conservation and rehabilitation programs must be formulated and undertaken. The local government unit of Biliran, Biliran Province State University-Biliran Campus, and People's Organizations in the municipality of Biliran must work hand-in hand to ensure the sustainability of the programs. Since the diversity of mangrove species in the municipality of Biliran was very low, tree planting activities that take into account zonation patterns of mangrove species and site-species matching principles are also recommended.

To capture on-ground status and conditions of mangroves in the entire Biliran island, similar baseline studies must be conducted in the other municipalities, particularly in the island municipality of Maripipi due to the known effects of island biogeography on distributional patterns and diversity of species.

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