INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 15, No. 4, p. 86-99, 2019
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Mangrove diversity, taxonomic classification, and morphological characteristics of natural and reforested mangrove forests in selected municipalities of Zamboanga Del Sur, Mindanao Island, Philippines

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Article published on October 30, 2019

Key words: Species composition, Evenness, *R. apiculata*, Species diversity, Shannon-Weiner's diversity index

Abstract

This study was conducted in two selected municipalities of Zamboanga del Sur, Mindanao Island, Philippines namely; Tambunan Sanctuary (site 1) Barangay Malim, Tabina and Barangay Balong-balong (site 2), Pitogo; respectively. Mangrove trees within the established 15 quadrats (10m×10m) were recorded. For Tambunan Sanctuary, 7 true mangrove species were identified under 3 families with 211 individuals while in Barangay Balong-balong, 5 true mangrove species were identified up to the species level under 3 families with 271 individuals. *Avicennia rumphiana* was found in both study sites which is known to have the vulnerable conservation status according to the International Union of Conservation of Nature (IUCN) Red List while the others are of least concern. *R. apiculata* has the most number having 111 individuals for site 1 while in site 2 *R. mucronata* has the highest number of individuals among all the species comprising 88 individuals. For species diversity, site 1 has H'=1.40 while site 2 has H'=1.47 which are categorized as very low diversity by the Shannon-Weiner's diversity index. For species evenness, site 2 is evenly distributed in the area with an evenness value of 0.92 while site 1 has 0.72. Considering the low species diversity in both sites, proper protection and management intervention measures like planting and growing of appropriate mangrove species are, therefore, recommended.

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Introduction

Mangroves are salt-tolerant trees that have adapted to living in salt and brackish water conditions. Mangrove ecosystem plays crucial roles in the environment for its ability to support and maintain ecological processes and diverse community of organisms. Mangrove ecosystem serves as habitat for majority of aquatic animals as well as marine and terrestrial organisms. Mangroves are unusually recognized as one of the world's richest ecosystems. Besides, their direct economic contribution in the form of timber firewood, fodder, and other products that can be harvested from them are well known (Roldan *et al.*, 2010).

There are 54 species of true mangroves and 60 mangrove associates worldwide. The Philippines has around 44 "true mangroves". The number of mangroves in the world has been decreasing at an alarming rate due to the anthropogenic activities that pose enormous threat and destruction of the ecosystem and diversity of life in the mangrove areas (Cudiamat & Rodriguez, 2017). In a related development, there are problems that the mangrove ecosystems face such as habitat destruction, invasive species, over population, over exploitation, human encroachment and climate change (Primavera, 2004).

Mangrove ecosystems in the Philippines have suffered from severe degradation attributable to the aquaculture industry during the last century. When the mangroves are converted for aquaculture purposes, various ecosystem services are traded for a single use. These changes can lead to further deterioration and the decrease of various floral and faunal communities leading to drastic changes in species composition and disruption of this vital life-support system (Garcia *et al.*, 2013). The country has about 18,000km of shorelines and vast areas of mangroves about 500,000 hectares were recorded in the early 1900s. But, due to overexploitation, conversion of mangrove areas to various uses, and the simultaneous logging of watersheds in the uplands, the country's remaining mangrove area was documented to have reduced to only about 117,700 hectares in 1995 (Roldan *et al.*, 2010). According to the latest report of the Philippine Forestry Statistics (2017), Philippines has an estimate of 303,387 hectares of mangrove forest. This increase in mangrove forest cover can be attributed to the National Greening Program (NGP) of the government spearheaded by the Department of Environment and Natural Resources (DENR) and also the mangrove planting activities of different Non-governmental Organizations (NGOs), Local Government Units (LGUs), and the private sectors nationwide.

According to the data of the Philippines' National Mapping and Resource Information Authority (NAMRIA) and the United States Geological Survey (USGS) in 2011, the mangrove forest cover in the Municipalities of Pitogo and Tabina, Zamboanga del Sur, Mindanao Island, Philippines from 1947 to 2010 had, however, greatly declined from 640 hectares in 1947 to 462 hectares in 2000 and further down to 403 hectares (2010). This is a notable departure of the national trend of increased mangrove cover. A considerable decline of about 37% had been recorded in the mangrove forest cover in these two municipalities over a period of 63 years.

This corresponds to an average of 3.8% domestic loss per year which is 1.8 times higher than the estimated loss worldwide at a rate of 2.1% per year (UNEP, 2006). If the mangrove forest cover will continue to decline at the current rate and may further be exacerbated by conversion of mangrove areas for other uses like; aquaculture, human settlement and development, the mangrove forest cover in the two municipalities will definitely be lost in less than 26 years. Thus, management interventions are urgently needed to improve, if not, restore to their former glory the mangrove ecosystems in the two municipalities. In this regard, the assessment of mangrove diversity, morphological characteristics and taxonomic classification of mangrove forests in the two municipalities of Zamboanga del Sur and elsewhere, are urgently needed in order to check on the current status of the mangrove ecosystems. Likewise, the results of this assessment will provide benchmark information which will serve as basis for future monitoring and policy recommendations to conserve and protect this vital life-support system in the area.

Materials and methods

The Study Site

The study was conducted in the two municipalities of Zamboanga del Sur, Mindanao Island, Philippines specifically in Barangay Malim, Tabina and Barangay Balong-balong, Pitogo, respectively. These areas are selected due to the presence and abundance of mangroves trees. Sampling site 1 is approximately a 95-hectare marine sanctuary locally known as Tambunan Sanctuary of Barangay Malim, Tabina, Zamboanga del Sur with geographical location of 7°26'43''N and 123°26'28.30''E (Fig. 1). According to the locals, the mangrove forests in Tambunan Sanctuary are naturally grown and primarily dominated by the Rhizophoraceae family. It was declared as a municipal sanctuary in 2002 by virtue of Municipal Resolution No. 306-03A, otherwise known as, "Ordinance Establishing a Marine/Fish Sanctuary". It is being managed by the local government unit (LGU) of Tabina. The Tambunan Sanctuary is protected by 24 hour-bantay dagat deputized officers. Cutting of mangrove trees and entering in the mangrove area without prior permission from the bantay dagat officer is strictly prohibited. Based on the Key Informant Interview conducted in the natural mangrove forest in Tambunan Sanctuary, it was known that it has been in existence for about 40 years.

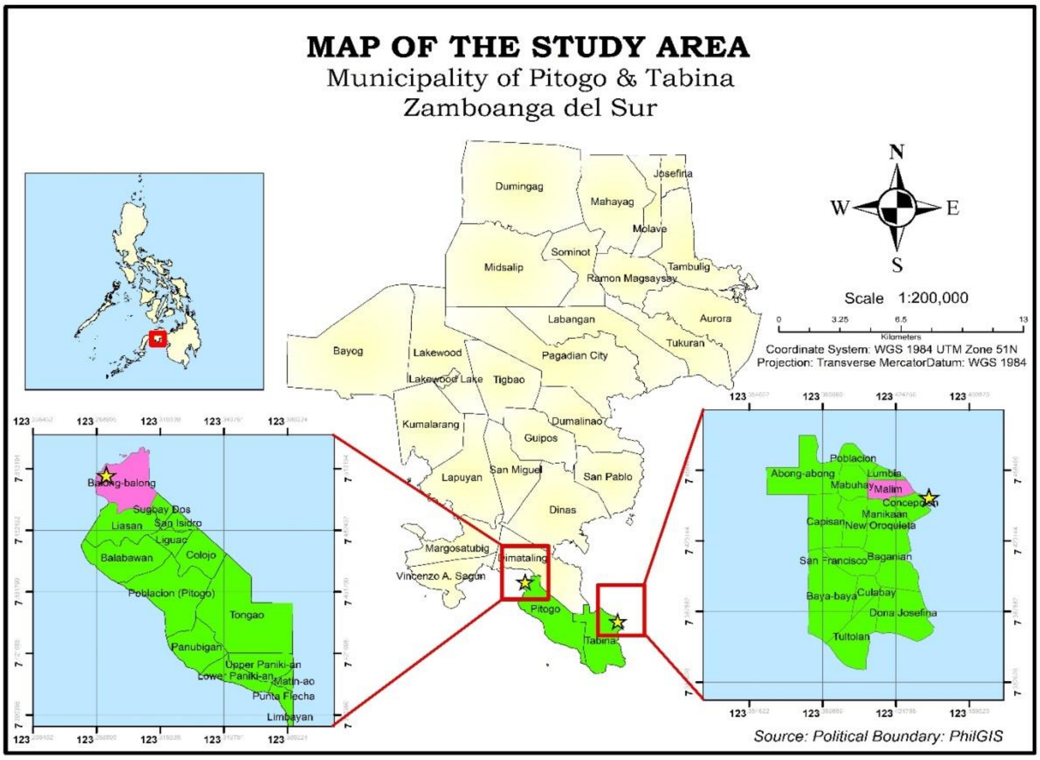

Fig. 1. The Study Area (Source: ArcGIS 10.2).

Sampling site 2 is a 33 year-old reforested mangrove forest situated in Barangay Balong-balong, Pitogo, Zamboanga del Sur with a geographical location of 7°30'38''N and 123°17'37.30''E (Fig. 1). It has a total of approximately 22 hectares of mangrove area. According to the President of the Fisherfolk Association in Barangay Balong-balong that long before, the area was a natural mangrove forest but then it was converted into a fish pond as part of the government's priority program on fish pond development in the countryside between 1950s and 1960s (Primavera, 1995). After the tsunami in Zamboanga del Sur in August 1976, however, the fish pond was destroyed and abandoned by its owner.

In the year 1989, the government headed by Department of Environment and Natural Resources reclaimed the abandoned fishpond area and spearheaded the mangrove reforestation in the same year.

Sampling Design

A non-destructive strip split plot sampling technique was used to determine the biodiversity of the study area. Three 150-meter transects lines, spaced 50 meters apart were established in each study site which are perpendicular to the baseline established along the shoreline. A total of 15 quadrats measuring 10m x 10m were laid in each sampling site. Five quadrats were established in each of the 150m line transect with 20m distance between plots end to end (Fig. 2).

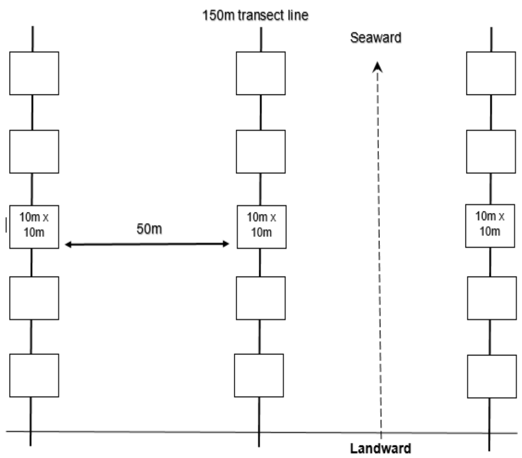

Fig. 2. Strip Split Plot Sampling Method.

Species Composition

Identification of the mangrove trees was done *in situ* with the aid of a Field Guide to Philippine Mangroves by Primavera (2004) and was further classified taxonomically up to the species level.

Species Diversity Determination

The mangrove community's species diversity was calculated using the Shannon-Wiener's Diversity Index (Shannon & Weaver, 1963), which indicated the quantitative description of mangrove habitat in terms of species distribution and evenness. Table 1 shows the categories of species diversity index (H').

Shannon-Weiner Diversity (H'):

$$H' = -\sum_{i=1}^{S} (pix\ln pi) \quad \text{equation 1}$$

Where s, is the total number of species, p_i is the proportion of individuals to the i^{th} species expressed as a portion of the total cover and *ln* is the log base *n*.

Effective Number of Species (ENS) using Shannon-Wiener index:

$$ENS = e^x \quad \text{equation 2}$$

Where e is a constant with a value of 2.6818 and x = *H'*, the Shannon-Weiner species diversity value.

Gini-Simpson and Lande's similarity index are used to determine the similarity among the species (Jost, 2006)

Gini-Simpson index:

$$x = 1 - \sum_{i=1}^{S} pi^2 \quad \text{equation 3}$$

Where s, is the total number of species, p_i is the proportion of individuals to the i^{th} species expressed as a portion of the total cover and *ln* is the log base *n*.

Effective Number of Species (ENS) using Gini-Simpson index:

$$ENS = 1/(1-x) \quad \text{equation 4}$$

Where x is the Gini-Simpson index.

Lande's similarity index:

$$\text{Lande's Index} = [1/(1-x_1)]/[1/(1-x_2)] \quad \text{equation 5}$$

where x_1 is the effective number of species in site 1 and x_2 is the effective number of species in site 2

Table 1. Categories of Species Diversity Index (H').

Relative Values	H' Values
Very High	> 3.50
High	3.00 - 3.49
Moderate	2.50 - 2.99
Low	2.00 - 2.49
Very Low	<1.99

Data Analyses

Descriptive statistics and graphs were computed and plotted using Microsoft Excel® 2016. Regression analysis was also used to determine the relationship between basal area and species diversity in sites 1 and 2.

Results and discussion

Taxonomic Classification and Morphological Characteristics of Mangrove Species

There are 44 true mangrove species in the Philippines. In the study sites, however, seven (7) true mangrove species were identified and recorded under 3 families, namely; Avicenniaceae, Lythraceae, Rhizophoraceae. The family with the highest number of identified species is the Rhizoporaceae having four different species. One of the species recorded, *Avicennia rumphiana*, is known to be in a vulnerable conservation status while the rest are of least concern according to the International Union of Conservation of Nature (IUCN) Red List. The following are the taxonomic classification and morphological features of the recorded species in the sampling sites (Figs. 3-9). This taxonomic account and their descriptions were verified true and correct by a taxonomist.

Bakhaw Lalaki (Rhizophora apiculata Blume*)*

Evergreen tree with a medium to large sized tree that grows up to 30m tall; trunk diameter can reach up to 50cm; it has a stilt roots reaching up to 5m up the stem, and sometimes has aerial roots from the branches; dark green, smooth and leathery leaves that are elliptic with entire leaf margin and reddish leaf stalks. Long, red stipules emerge from the leaf bases; Flowers are composed of cream-coloured, linear petals arranged in a cross-shaped pattern. Prominent, yellow sepals are fleshy and wider than the petals. They occur in pairs and are held on dark grey stalks. Flower buds are broadly elliptic and finely fissured. Brown, pear-shaped fruit hang with the smaller end pointed down. A long, cylindrical seedling emerges from the smaller end, while the fruit is still attached to the parent plant.

This condition is known as viviparity (Fig. 3). It thrives in deep, soft and muddy soils that are flooded by normal high tides, sometimes tidal waterways with strong, permanent freshwater input is preferred.

Kingdom: Plantae

Phylum: Tracheophyta

Class: Magnoliopsida

Order: Rhizophorales

Family: Rhizophoraceae

Genus: *Rhizophora*

Species: *Rhizophora apiculata*

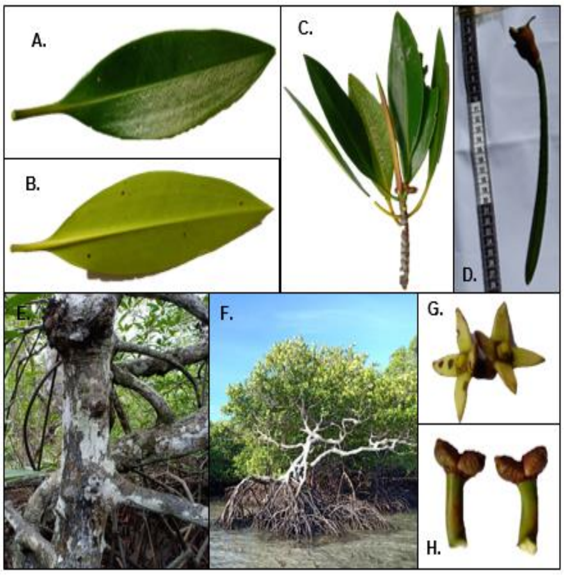

Fig. 3. Morphological characteristics of *Rhizophora apiculata*: A. Leaf margin (adaxial surface); B. Leaf abaxial surface; C. Leaf arrangement (opposite); D. Propagule (25cm); E. Trunk of the tree (almost smooth); F. Growth form; G. Inflorescence (raceme); H. Flower bud.

Bakhaw Babae (Rhizophora mucronata Lam.*)*

Evergreen tree growing erect reaching up to 20-25m tall with dark bark horizontally fissured. Roots have both aerial and stilt roots growing from the lower branches. Leaves are leathery and broadly elliptic to slightly oblong with opposite leaf arrangement. Flower stalks usually have 2-5 flowers, each on a 2.5-5cm long individual stalk. Buds are widest near the base and have two 2-lobed leaflets near the base, 4 white petals having densely hairy margins and about 9 mm long. Calyx is deeply lobed and pale yellow, about 13 - 19mm long (Fig. 4). Found in intermediate to upstream estuarine zone in the lower to mid-intertidal region, and more to the seaward side. Usually found growing in groups near or on the banks of tidal creeks.

Kingdom: Plantae

Phylum: Tracheophyta

Class: Magnoliopsida

Order: Rhizophorales

Family: Rhizophoraceae

Genus: *Rhizophora*

Species: *Rhizopora mucronata*

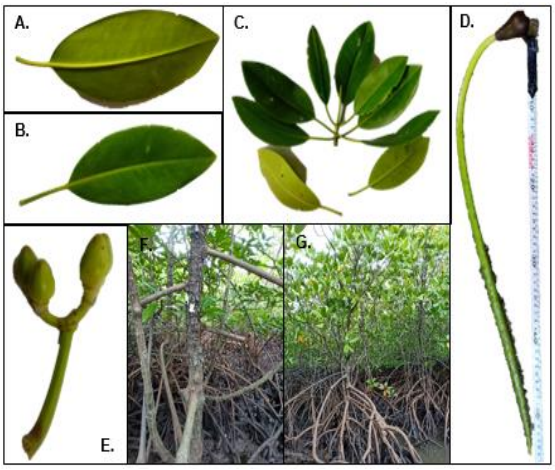

Fig. 4. Morphological characteristics of *Rhizophora mucronata*: A. Leaf margin (abaxial surface); B. Leaf adaxial surface (smooth); C. Leaf arrangement (opposite); D. Propagule (56cm); E. Inflorescence bud; F. Trunk of the tree (rough bark); G. Growth form.

Langarai (Bruguiera parviflora Wight & Arn. ex Griffith*)*

Slender tree that can grow up to 10 to 15m tall with grey trunk and fissured bark. Laterals roots which grow just below the surface and part of it sticking out of the mud in a "bent knee" position. Leaves pointed, 5.5-13 by 2-4.5cm, elliptic, black dotted beneath and turning yellowish-green with age. Grows in downstream to intermediate estuarine zones in the mid-intertidal region.

Typically forms single species in areas that are not frequently inundated (Fig. 5). Can also occur along tidal waterways and coastal fish ponds. Its habitat is threatened by construction of commercial and industrial purposes, such as shrimp farms and tourist resorts.

Kingdom: Plantae

Phylum: Tracheophyta

Class: Magnoliopsida

Order: Rhizophorales

Family: Rhizophoraceae

Genus: *Bruguiera*

Species: *Bruguiera parviflora*

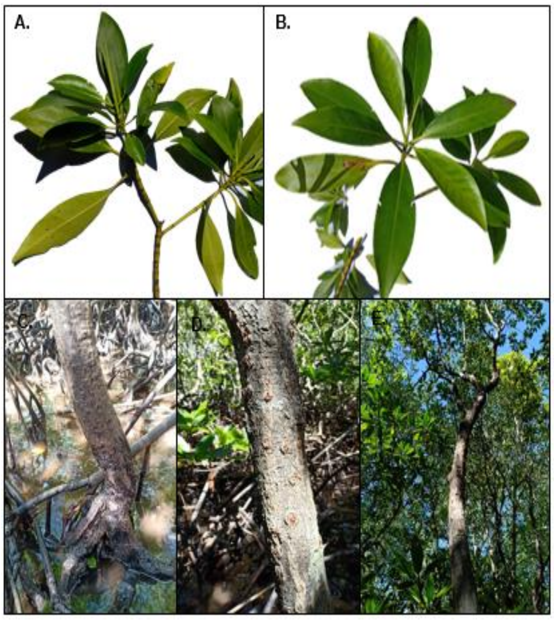

Fig. 5. Morphological characteristics of *Bruguiera parviflora*: A & B. Leaf Margin (Abaxial and Adaxial surface) and the leaf arrangement (Whorly opposite); C. Roots (knee roots); D. Bark (fissured bark); E. Tree crown.

Tungog (Ceriops tagal (Perr) CB.Rob.)

A small to medium sized tree, growing up to 20m approximately with smooth bark sometimes fissured. It has short buttress roots forming from short stilt roots originating from the base of a mature trunk. Rounded, glossy-green leaves, obovate-elliptic and often having an inwardly-curled margin. 5-10 flowered, pendulous flower head measuring 2 by 10-20. It has a long, slender stalk, is resinous and occurs at the ends of new shoots or in the axils on older ones. Calyx lobes are erect in flower, recurved in fruit, 4-5mm in length, with a 2mm long tube. Stamens have long, slender filaments that extend far beyond the blunt anthers. Fresh flowers are white in color and they turn brown quickly. Flowers emit a faint fragrance which attracts moths and bees. Fruits are inverted hypocotyl with angular ridges, slender and measuring 4-25cm in length. Characteristic white collar below the calyx (Fig. 6). Can thrive in downstream to intermediate estuarine areas. Forms dense shrub lands on the landward edge of tidal forests, in areas inundated by spring tides. Likes to grow in areas with well-drained soils.

Kingdom: Plantae

Phylum: Tracheophyta

Class: Magnoliopsida
Order: Rhizophorales
Family: Rhizophoraceae
Genus: *Ceriops*
Species: *Ceriopstagal*

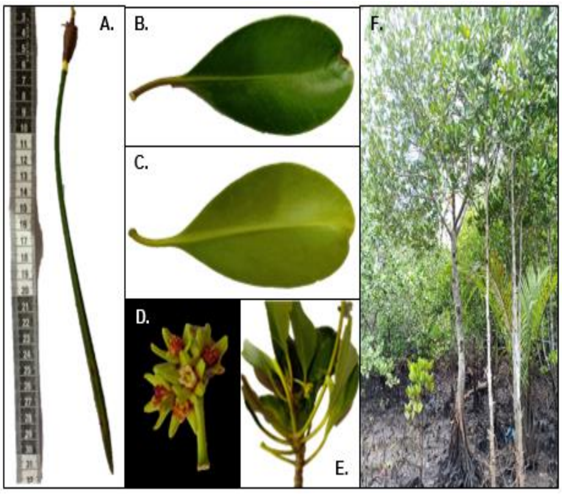

Fig. 6. Morphological characteristics of *Ceriops tagal*: A. Propagule (29cm); B. Leaf margin (adaxial surface); C. Leaf abaxial surface; D. Inflorescence (compound umbel); E. Leaf arrangement (opposite); F. Growth form (short stilt roots).

Bungarol (*Avicennia rumphiana* Hallier f.)

A medium to large tree that grows up to 30m tall with dark grey and smooth bark. It grows straight in a close stand. Roots are pencil-like pneumatophores which emerge above ground from long shallow underground roots with ovate or elliptic leaves, simple, opposite, measuring up to 10 by 6cm, thick, margin entire with non-curved edges, dark green above, beneath covered with dense, powdery hairs. Midrib of leaf is prominent beneath, covered with hairs, leaf stalk about 18-20mm long. Listed as vulnerable species in the IUCN Red List (Fig. 7). Usually occurring in the downstream estuarine zone in the high intertidal region.

Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Lamiales
Family: Avicenniaceae
Genus: *Avicennia*
Species: *Avicennia rumphiana*

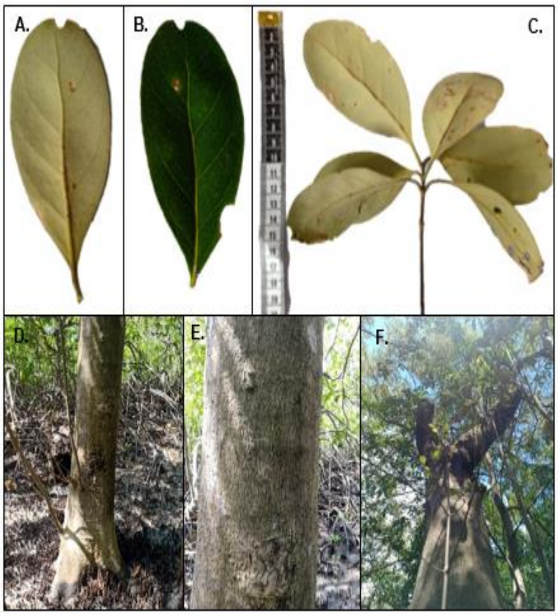

Fig. 7. Morphological characteristics of *Avicennia rumphiana*: A. Leaf abaxial surface (hairy); B. Leaf margin (adaxial surface); C. Leaf arrangement (opposite); D. Roots (pencil-like pneumatophores); E. Tree trunk (smooth bark); F. Tree crown.

Miapi (Avicennia marina (Forssk.) Vierh.)

A medium to large tree growing up to 30m tall approximately with smooth or slightly flaky grey trunk. It has Extensive lateral root system stretching just below the soil surface with pencil-like breathing roots, also known as pneumatophores, sticking vertically out of the muddy ground to take in oxygen. Pneumatophores may grow up to a height of 15-20cm. Elliptic or oblong-obovate leaves with a round tip, pale green lower surface and measuring up to 9 by 4.5cm. Upper surface is covered with glandular dots. Cross section of small branches or stems will show a characteristic square shape, unlike other Avicennia species which are rounded. Fruits are light green in colour, ovoid in shape with a broad base and sharp apical beak, measuring about 2cm across (Fig. 8). Mostly found in riverbanks, mouth of rivers, lagoons, rocky beaches and lower tidal areas. Avicennia spp. are usually pioneer species in newly formed mangrove forests.

Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Lamiales

Family: Avicenniaceae

Genus: *Avicennia*

Species: *Avicennia marina*

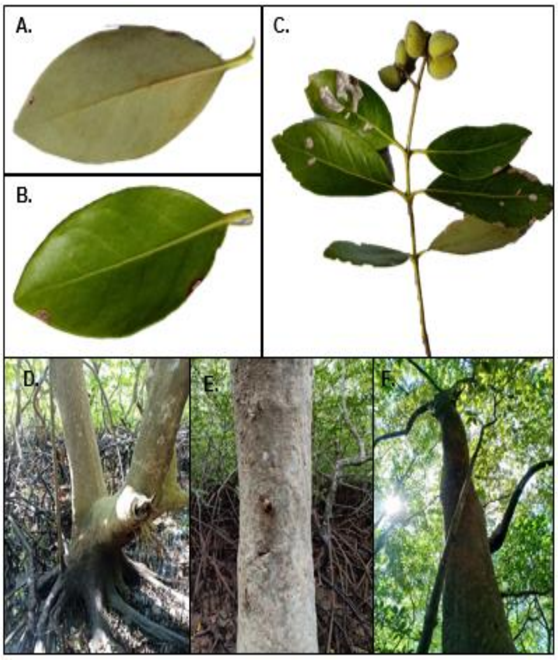

Fig. 8. Morphological characteristics of *Avicennia marina*: A. Leaf abaxial surface (yellowish); B. Leaf margin (adaxial surface); C. Leaf arrangement (opposite); D. Roots (pencil-like pneumatophores); E. Tree trunk (smooth bark w/lenticels); F. Tree crown.

Pagatpat (*Sonneratia alba* Sm.)

It is a tree, with a broad, spreading canopy, usually 15-20m tall, and sometimes up to 30m tall. Cream-colored to brown bark, with smooth, fine, longitudinal fissures. Roots bear thick and blunt pneumatophores (conical roots that emerge vertically from the ground) that are up to 1m tall. Stalked, opposite leaves are elliptic to ovate or obovate in shape, with a rounded or broad leaf tip, 5-11cm long and 4-8cm wide. Leaf stalks are 6-15mm long and has vestigial glands at the base. Fruits are hard, fleshy berries that are round and flattened, with a persistent calyx at the base, 2-4.5cm across, ripening green (Fig. 9). It grows in tropical coasts, in mangrove forests, sandy beaches and mudflats.

Kingdom: Plantae

Phylum: Tracheophyta

Class: Magnoliopsida

Order: Myrtales

Family: Lythraceae

Genus: *Sonneratia*

Species: *Sonneratia alba*

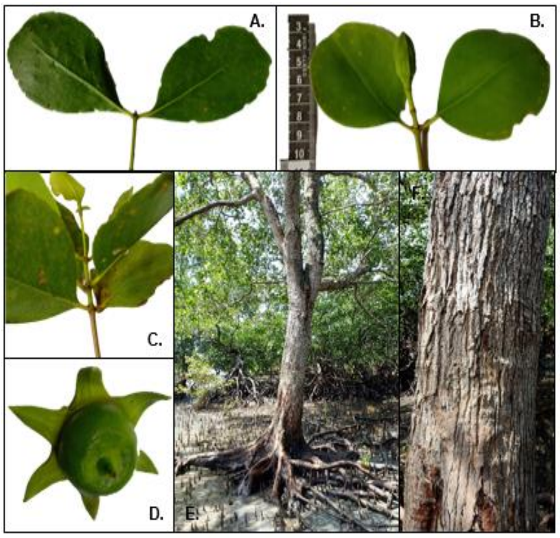

Fig. 9. Morphological characteristics of *Sonneratia alba*: A. Leaf abaxial surface; B. Leaf margin (adaxial surface) and flower bud; C. Leaf arrangement (opposite); D. Tree fruit; E. Tree roots (thick pneumatophores) and growth form; F. Tree trunk (fine fissures).

Seriation Analysis of the Species in Sites 1 and 2

Seriation analysis (Fig. 10) was done to determine the similarities and differences of mangrove species present in the natural mangrove forest and the reforested mangrove forest, respectively. It shows that 5 common species are present in the two study sites namely; *Sonneratia alba, Avicennia rumphiana, Avicennia marina, Rhizophora apiculata,* and *Rhizophora mucronata*. It also shows that the natural mangrove forest has greater number of species compared to the reforested mangrove forest. This is because the latter had been planted with selected species depending on the available propagules at that time. According to Mr. Noel Torres, the President of the Fisher Folk Association of Barangay Balong-balong, the species recorded during sampling were also the species available during the reforestation conducted in 1989 headed by the DENR. He further added that, the trees having small circumferences during the time of sampling are the trees that were planted in that year (*Personal communication*).

Species	Natural	Reforested
Sonneratia alba		-
Avicennia rumphiana	-	-
Avicennia marina	-	-
Bruguiera parviflora	-	-
Ceriops tagal	-	-
Rhizophora apiculata	-	-
Rhizophora mucronata	-	-

Fig. 10. Seriation analysis of mangrove species present in natural and reforested mangrove forests in two selected municipalities of Zamboanga del Sur.

Species Composition in Site 1 and Site 2

Site 1 (natural mangrove forest) which is the Tambunan Sanctuary, Barangay Malim, Tabina, Zamboanga del Sur, has seven (7) true mangrove species recorded under 3 families (Table 2). The family with the highest number of identified species is the Rhizophoraceae having four different species. *Avicennia rumphiana* which is also present in this study site has been classified having a vulnerable conservation status while the rests are of least concern. A total of 211 mangrove trees were recorded in a 1.5-hectare sampling area. Based on the functional classification of mangroves (Karthiresan and Qasim, 2005), mangrove forests in Tambunan Sanctuary are categorized as fringing mangrove forest. Accordingly, the fringing mangrove forests occur along the borders of protected shorelines and islands and are influenced by daily tidal range.

R. apiculata has the highest number having 111 individuals or about 53% of the total individuals recorded followed by *R. mucronata* with 19% or 41 individuals in site 1 (Fig. 11A). *R. apiculata* and *R. mucronata*are very common mangrove species in the Philippines since the fruits of these species have very high viability lasting for months. These species have one-seeded fruits which start to germinate while still hanging on the tree. Eventually, the seedling falls from the fruit, floats with the high tide and establishes if it reaches a suitable site (Tamai & Lampa, 1988).

Table 2. Mangrove species identified in site 1 with their conservation status.

Local Name	Scientific Name	Family	Conservation Status (IUCN)
Pagatpat	*Sonneratia alba (L.) Smith*	Lythracea	LC
Bungarol	*Avicennia rumphiana*(Hallier) Bak	Avicennia ceae	VU
Miapi	*Avicennia marina* (Forsk.)Vierh.	Avicennia ceae	LC
Langarai	*Bruguiera parviflora* (Roxb.) Wight &Arn. exGriff.	Rhizophor aceae	LC
Tangal	*Ceriops tagal*(Perr.) C.B. Rob.	Rhizophor aceae	LC
Bakhawl alaki	*Rhizophora apiculata*Blume	Rhizophor aceae	LC
Bakhawb abae	*Rhizophora mucronata*Lamk.	Rhizophor aceae	LC

These species belong to Rhizophoraceae family which are indicators of the intermediate estuarine zone. However, in this study *R. apiculata* is present from seaward to landward zones, indicating that some species of the Rhizoporaceae family are prolific and can survive in all tidal zones. *R. apiculata* and *R. mucronata* can withstand high currents and tides, can tolerate very high salinity (Cañizares and Seronay, 2016). Moreover, these species are the ones being propagated in the nurseries because they are highly available and have high survival rates. The results in site 1 conform to the study of Cañizares and Seronay (2016) which indicated the abundance of Rhizoporaceae family in their study sites specifically the *R. apiculata* having the highest count per unit area. Both have low diversities but ten (10) mangrove species in Barangay Imelda, Dinagat Island, Philippines were recorded as compared to only seven in this site. Moreover, the study of Pototan *et al.*, (2017) indicated that in the Municipality of Carmen, *R. apiculata* was present in all sampling quadrats indicating its widespread distribution which is comparable to the findings of this study. Furthermore, the study of Calumpong & Menez (1996) likewise observed the presence of common mangrove genera belonging to family Rhizophoraceae, Avicenniaceae, and Lythraceae in the country.

In site 2 (reforested mangrove forest) which is located in Barangay Balong-balong, has a total of 5 true mangrove species under 3 families. Avicenniaceae and Rhizophoraceae are the families with the highest number of identified species having two different species.

Avicennia rumphiana has been recorded in this site which has vulnerable conservation status while the others are of least concern as indicated previously (Table 3). Similar to sampling site 1, the mangrove forests in barangay Balong-balong are also categorized as fringing mangrove forest. A total of 271 mangrove trees are recorded in this site.

Table 3. Mangrove species identified in site 2 with their conservation status.

Local Name	Scientific Name	Family	Conservation Status (IUCN)
Pagatpat	*Sonneratia alba (L.) Smith*	Lythraceae	LC
Bungarol	*Avicennia marina* (Forsk.) Vierh. var.*rumphiana*(Hallier) Bak	Avicenniaceae	VU
Miapi	*Avicenniaofficinalis*L.	Avicenniaceae	LC
Bakhawlalaki	*Rhizophora apiculata*Blume	Rhizophoraceae	LC
Bakhawbabae	*Rhizophora mucronata*Lamk	Rhizophoraceae	LC

Fig. 4 shows that *R. mucronata* has the highest number of individuals among all the species comprising 88 or 32% of the total number of individuals recorded followed by *A. marina* having 84 or 31% individuals in site 2 (Fig. 11B). The species recorded in site 2 are slightly similar to those found in site 1, however *B. parviflora* and *C. tagal* are not found in site 2. Given that the latter site is a reforested mangrove forest, it shows that *R. mucronata* is the common species planted during the reforestation of mangrove trees in the area. This result conforms to the statement of Mr. Flores, the President of the Fisherfolk Association, stating that during the reforestation efforts *R. mucronata* was the most planted species (*personal communication*). The number of species present in site 2 is lower compared to the species recorded in the study of Lunar and Laguardia, (2013). In this study, it has identified five (5) true mangrove species while in the former 7 true mangrove species were recorded given that both areas are reforested mangrove forests. This indicates that during the reforestation in site 2 there were only a few number of species planted even if the area is favorable for mangrove species to thrive based on its history that it was once was a natural mangrove forests and converted to fish pond for aquaculture. Furthermore, the results of this study are comparable with the study of Picardal *et al.* (2011) in terms of the number of species identified. In their study, they have identified 5 true mangrove species which is the same with the number of species identified in this study. The only difference is that *R. stylosa* was not present in site 2 of this study while *R. rumphiana* was not present in the study of Picardal *et al.* (2011).

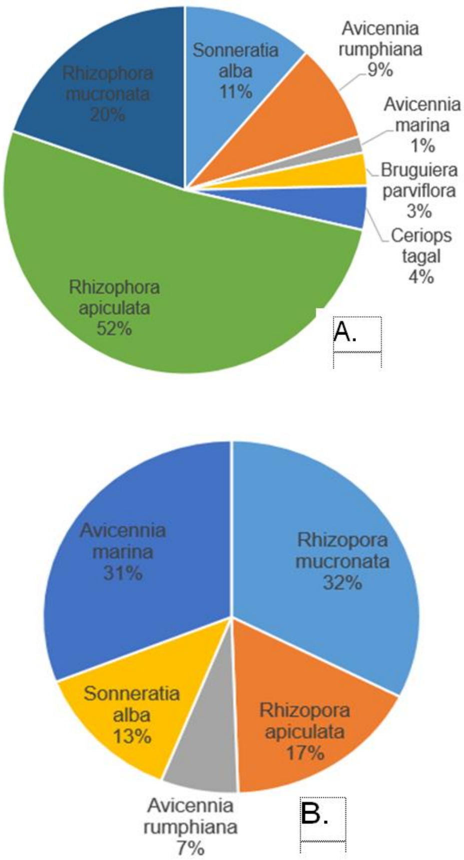

Fig. 11. A) Percent composition of mangrove species in site 1 (natural) B) Percent composition of mangrove species in site 2 (reforested).

Site 2 (reforested mangrove forest) has more mangrove trees count per unit area having a total of 271 mangrove trees recorded while in site 1 (natural mangrove forest) has a total of 211 mangrove trees tallied. But for the number of species identified, site 1 has more number of identified true mangrove species having 7 different species compared to 5 true mangrove species in site 2. A similar trend is found in the study of Lunar and Laguardia (2013) which indicated that the marine protected area namely; Calatagan Mangrove Forest Conservation Park has more identified true mangroves species having 9 species while 7 true mangrove species were identified in the rehabilitation area.

The results reveal that there is a need for human intervention in rehabilitating a mangrove forests but a proper intervention is required as what results reveal in site 1 which has higher number of species identified but has lower mangrove trees count per unit area. The opposite is true in site 2 which has higher number of mangrove trees count per unit area but lower identified true mangrove species. Site 1 was declared as municipal marine sanctuary by the Local Government Unit (LGU) of Tabina in 2002. Since then, there was a regular bantay dagat officer assigned in the sanctuary protecting it from the threat of illegal poaching of mangrove trees for construction materials, fuel wood, harvesting of crabs and shell fishes. Since the establishment of the marine sanctuary, the mangrove forest in Tambunan Sanctuary remain in its good condition. Tambunan Sanctuary provides protection to the local community from typhoons and also improving the fish catch of the fisherfolks in the barangay. In site 2, the mangrove forests is currently managed and protected by the fisherfolk organization in the barangay ensuring no illegal activities in the mangrove forests. Locals in site 2 hardly visit the mangrove forests due to a very muddy substrate making it very hard to enter or move around inside the mangrove forests which deter illegal humans activities.

Species Diversity

For species diversity (Table 4), results show that both areas have <1.99 values which can be categorized as having very low diversity by Shannon-Weiner's diversity index (Table 1). The low diversity in the mangrove areas is primarily due to the lack of species variation in the mangrove stands (Abino *et al.*, 2014). A number of studies coincidentally concluded that the mangrove stands have very low diversity indices dueto their unique stand formation compared to other tropical forest ecosystems (Gevaña *et al.,* 2008; Picardal *et al.,* 2011; Cudiamat & Rodriguez, 2017). As previously shown that the reforested mangrove forest has slightly higher diversity compared to natural mangrove forest with H'=1.47 (reforested) while the natural mangrove forests has H'=1.40. The higher species diversity index of the reforested mangrove stand may be attributed to the number of individual mangrove trees recorded with a total of 271 species compared to 211 mangrove trees recorded in the natural mangrove forest. It can be recalled that the reforested mangrove stand has five (5) number of mangrove species while the natural mangrove forest has seven (7). The formula of Shannon-Weiner's diversity index is also a function of the total number of mangrove trees recorded. These results conform to the study of Lunar and Laguardia (2013) indicating that the rehabilitated mangrove forest has higher diversity index with H'=1.21 compared to H'=1.05 of the marine protected area even if the marine protected area has more number of mangrove species than the former.

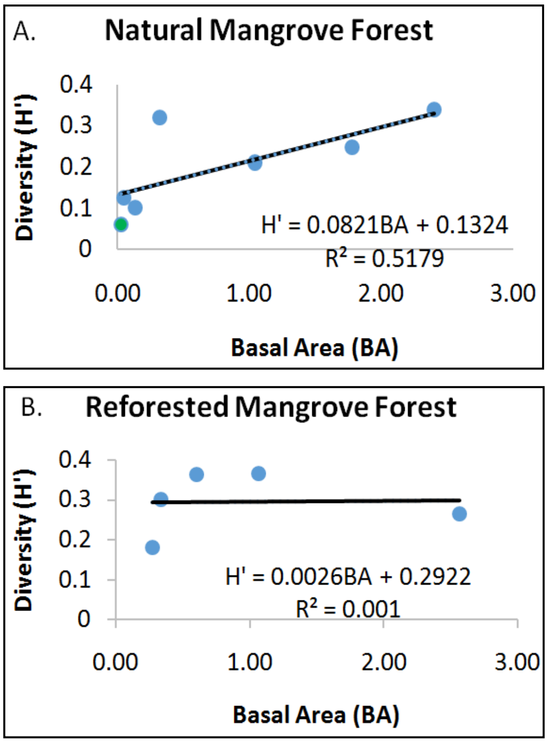

Fig. 12. Regression plots of mangrove species in A.) Natural Mangrove Forest and B.) Reforested Mangrove Forest.

Evenness is the measure of how evenly the individuals in the community are distributed over the different species, which ranges from 0 to 1 (Heip *et al.*, 1998). Table 4 shows that the mangrove species recorded in the reforested mangrove forest are evenly distributed with an evenness value of 0.92 which is much higher compared to the 0.72 evenness value of natural mangrove forest The result reveals that the species in reforested mangrove forest are evenly distributed in the area which means that the mangrove species composition in site 2 is greatly affected by humans during the reforestation conducted. The species evenness of the natural mangrove species is low because of the zonation of the mangrove species. According to Sivasothi *et al.* (2002) in the book entitled "A Guide to Mangrove of Singapore", who observed that the seaward edge is primarily occupied by *Avicennia* and *Sonneratia* species. *Rhizophora* sp. is found further inland, and finally *Bruguiera* sp., *Ceriops* sp., *Xylocarpus* sp. and *Heritiera* sp. forming the back mangrove. In site 2 of this study *S. alba*, *A. marina*, *R. apiculata* and *R. mucronata* are found in all sampling quadrats from seaward to landward zones. Thus, the result implies that established sites do not necessarily follow the community structure as illustrated by Duke (1992). It follows that community structure is a very important consideration in establishing a mangrove community. For instance, in the seaward zone, *Sonneratia* species provide protection against strong waves and reduces further wave action landward. Furthermore, this genus are known to have well established root system generally tall and straight-boled. The mid-intertidal and landward zones consist of the genera *Rhizophora* sp., *Avicennia* sp. and *Bruguiera* sp. which are known to trap inland sediments and land-based pollution, serve as spawning grounds for many marine species and reduce current velocity and water depth. In contrast, reforested sites are less effective in curtailing the above occurrences.

Table 4. Species diversity indices used in Natural and Reforested Mangrove Forests.

Site	Shannon-Weiner's Index	Effective Number of Species	Gini-Simpson Index	Effective Number of Species	Lande's Index	Evenness
Natural Mangrove Forest (Site 1)	1.40	4.0552	0.662833	2.965892	0.74570	0.72
Reforested Mangrove Forests (Site 2)	1.47	4.3492	0.748574	3.977308		0.92

The Shannon-Weiner and Gini-Simpson diversity indices according to Lou Jost (2006) are highly non-linear with increasing diversity and therefore are very hard to interpret. Converting indices to true diversities (effective numbers of species) gives them a set of common behaviors and properties. In this study, we converted the Shannon-Weiner diversity indices for sites 1 and 2 to effective number of species which are 4.06 and 4.35, respectively (Table 4). Results showed that both sites when rounded-off have 4 effective number of species which indicate that both sites have almost the same diversity. The Gini-Simpson diversity index was likewise used to determine the difference in the diversity of species between the natural and reforested mangrove forests. The Gini-Simpson indices for Sites 1 and 2 were further converted to effective number of species which are 2.97 and 3.98, respectively with a difference of 1.01 (Table 4). This implies that Site 2 has higher effective number of species than Site 1. To analyze similarity among communities along different ecological dimensions, Lande's similarity index of species with values ranging from 0 to 1 was further used for sites 1 and 2 using the effective number of species of Gini-Simpson diversity index. Gini-Simpson diversity index is recommended by Lande's because it is always close to unity for diverse ecosystems. Results show that sites 1 and site 2 have a Lande's similarity index of 0.75 which means that the species found in site 1 and site 2 are slightly similar.

To further discuss the species diversity, regression analysis was used to determine the functional relationship between species diversity using Shannon-Wiener's diversity index and basal area (Chatterjee & Hadi, 2006). Simple regression analysis was done on the above relational data in sites 1 and 2. Fig. 12 shows that site 1 has a moderate positive relationship between the basal area and species diversity with best fit line having a R^2=0.52 or R=0.72 compared to site 2 indicating no relationship between the basal area and species diversity which is indicated by a flat line and R^2=0.001 or R = 0.03. This is because most species recorded in site 1 have larger average diameter at breast height (DBH) compared to site 2. Besides, site 1 has greater number of species (n=7) than in site 2 (n=5). This difference and trend in basal area can be further explained by the age of both mangrove stands which are 40 and 33 years old, respectively.

Conclusion

Based on the findings of the study, it can be shown that both natural mangrove forests in Tambunan Sanctuary, Barangay Malim, Tabina and the reforested mangrove forest in Barangay Balong-balong have similarities in terms of the presence of some species. For instance, the reforested mangrove forest holds the same species as the natural forest except for the following species, namely; *Bruguiera parviflora* and *Ceriops tagal*. A total of 7 true mangrove species under 3 families were identified in site 1 with a total of 211 individuals while 5 true mangrove species under 3 families were recorded in site 2 with a total of 271 individuals. It shows that site 2 (reforested mangrove forest) has higher diversity compared to site 1 (natural mangrove forest). The species present in site 2 are evenly distributed compared to siten 1. Moreover, the species in site 1 and site 2 are highly similar using the species similarity indices. In the light of the findings of this study, it can be recommended that the use of bio-molecular analysis to verify and confirm the species present and to further clarify their taxonomic position. The use of Geographic Information System as well as the use of spectral analysis to discriminate unique spectral signatures of the mangrove forest stand to determine the species composition of any given mangrove stand visually and computationally are highly recommended. Lastly, further studies need to be conducted to validate the findings of this present study.

Acknowledgements

The authors would like to acknowledge the Local Government Units of Tabina and Pitogo, Zamboanga del Sur for the assistance during sampling and data gathering. The CENR Officer of DENR-CENRO Guipos For.Vitaliano Q. Valdez, Jr. for allowing the researcher to conduct the study in the area. The Mindanao State University, Iligan Institute of Technology (MSU-IIT) for being the researcher's institution during the making of the study. The Mindanao State University, Main Campus, Marawi City for the financial assistance for the study. The Department of Science and Technology, Science Education Institute (DOST-SEI) is gratefully acknowledged for the funding support of this research.

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