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Assessment of mangrove diversity in Santa Cruz, Davao Del Sur, Philippines

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Abstract

This study assessed the mangrove species in Santa Cruz, Davao del Sur, Philippines. Six sample plots were established and results of the assessment yielded 17 different species of mangroves in the area with one categorized as Vulnerable (*Avicennia rumphiana*). Abundance curve estimated uneven distribution of species. Diversity indices yielded dominance (0.159) and evenness (0.535) values that are relatively lower compared to values from other municipalities in the Davao region. Shannon index value of 2.2 was concluded to be higher than other mangrove assessment studies which suggest higher diversity in the area. Investigation of the mangrove community structure concluded that *Sonneratia alba* (importance percentage of 24%) is a keystone species of the mangrove forest and that it is the most acclimated to the environment of Santa Cruz. Assessment of mangrove diversity is crucial to restoration efforts that address the problems of deforestation brought about by man-made disturbances.

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Introduction

Mangroves are revered as of the most important floras in the world. They are uniquely identified as a group of plants that can easily adapt to their environment (Warne, 2007). They thrive in the coastlines of tropical and sub-tropical countries which exposes them to extreme environmental conditions such as high temperature and salinity (Kathiresan and Bingham, 2001). However, they have a specific ultrafiltration system which enables them to survive that harsh intertidal zone. The Philippines has a rich mangrove diversity with 35 known true mangroves that thrive throughout the country (Long and Giri, 2011).

Moreover, the Philippines is home to approximately 50% of the known mangrove species in the world and this includes various endangered species, vulnerable and some threatened species (Primavera *et al.*, 2004; Spalding *et al.*, 2010; Garcia *et al.*, 2014).

Mangroves are often used for thatching, firewood, charcoal and timber (Brown and Fischer, 1918; Spalding *et al.*, 1997; Long and Giri, 2011). Mangrove forests are known habitats for epibenthic, infaunal and meiofaunal invertebrates while supporting other smaller communities such as phytoplanktons and zooplanktons (Cañizares and Seronay, 2016). They are also proven to be good nursing sites for marine juveniles (Rönnback, 1999; Long and Giri, 2011) which keep the population of marine animals stable considering that fishing is an important livelihood in Philippines. Moreover, mangroves are nesting grounds to hundreds of bird species (Nagelkerken, 2008; Garcia *et al.*, 2014). Mangroves also play a significant role in coastal protection as it helps prevent the erosion of unconsolidated coastlines and eventual flooding (Food and Agriculture Organization, 1994).

The Philippines was identified as a biodiversity hotspot since 1988 (Myers, 1988; Marchese, 2015). This means that while it has a particularly high biodiversity rating, most of its species are very susceptible to extinction due to habitat loss (forestlands, grasslands, mangroves) and other ecological factors. This renders biodiversity hotspots such as Philippines as both irreplaceable and vulnerable (Margules and Pressy, 2000; Brooks *et al.*, 2002). Based on the data collected by the Department of Environment and Natural Resources-Forest Management Bureau (DENR-FMB, 2013), there was a significant decrease in the total forest cover of Philippines from 1934-2010. Recorded data for mangrove habitat area over the past decades also revealed a substantial loss of almost 75% (Primavera, 1995; Primavera, 2000; Samson and Rollon, 2008) which translates very significantly especially because most Philippine villages are along or dependent on coastal resources (Primavera, 2000). If this continues to worsen, habitat loss will result into loss of biodiversity which will soon affect specific ecosystem functions and ultimately the society (Cardinale *et al.*, 2012).

Biological diversity assessment is an important tool in determining the current state of biodiversity in a location. Moreover, this determines how the ecosystem, species and genetic diversity are affected by the execution or the difference in implementation of development and rehabilitation strategies (International Union for Conservation of Nature Monitoring and Evaluation Initiative and International Union for Conservation of Nature Biodiversity Policy and International Agreements Unit, 2000). This study assessed the mangrove diversity of four sites in Sta. Cruz, Davao del Sur, Philippines.

Materials and methods

Study area

Mangrove assessment was performed in November 2017 in Sta. Cruz, Davao del Sur, Philippines. Perpendicular from the shoreline, six plots were established randomly in four different villages (*barangay*) of Sta. Cruz, Davao del Sur (Fig.1). Plots 1 (6°50'36"N 123°25'03"E) and 2 (6°50'39"N 125°25'02"E) were in Zone III, Barangay Miranda. Plot 3 (6°48'49"N 125°23'51"E) was established in Barangay Tuban. Plots 4 (6°47'21"N 125°23'26"E) and 5 (6°47'55"N 125°23'03"E) were in Barangay Bato. Lastly, plot 6 was (6°48'18"N 125°22'44"E) in Barangay Tagabuli. The mangrove forests of Barangay Bato, Tagabuli and Tuban had an estimated total

Marine Protected Area (MPA) of 80 hectares. Unfortunately, there was no size estimate for Barangay Miranda. The plots were fashioned by measuring a 10x10m square (English *et al.*, 1997). Each corner was designated by a 30.48-cm metal pin and the section was cordoned with hemp rope.

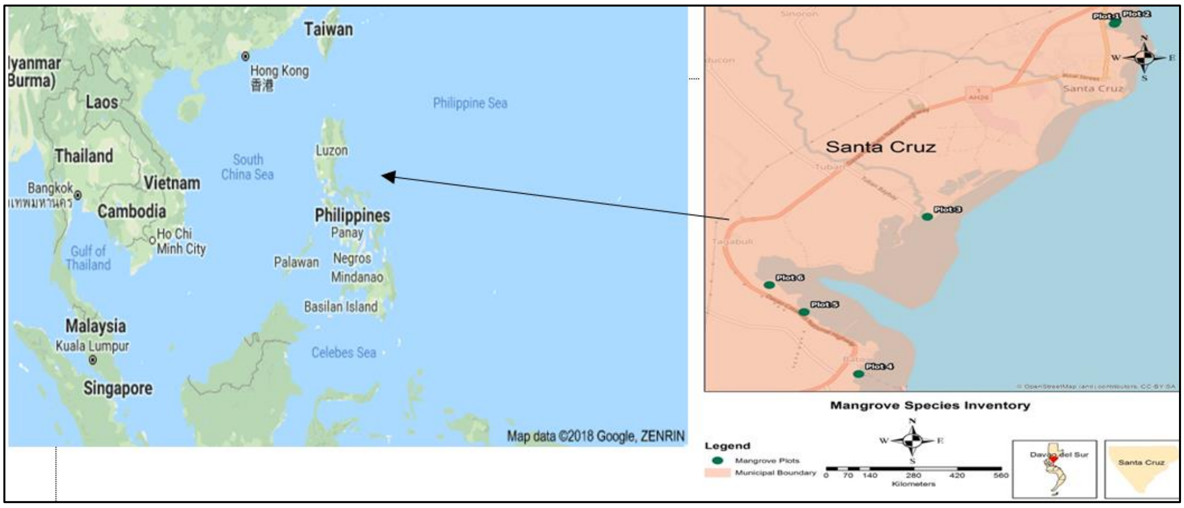

Fig. 1. Mangrove sampling sites in Sta. Cruz, Davao del Sur, Philippines, 6°50' 13" *North*, 125° 24' 47" East.

Species identification and measurement of diversity parameters

In order to identify the mangrove species inside the plots, the mangrove field guide by Primavera and Dianala (2009) was used. Mangroves were identified through their fruits, flowers, leaves and overall structure. Height was measured through a laser rangefinder and diameter at breast height (DBH) was measured through a tree caliper. Moreover, the conservation status of each mangrove species identified was determined through the International Union for Conservation of Nature Red List data.

Data Analysis

Diversity indices and abundance curves: To assess the floral biodiversity of each location, species richness, dominance, evenness and the Shannon Wiener diversity index (equations 1, 2, 3 and 4 respectively) were calculated for each site. The Paleontological Statistical Software Package (PAST) developed by Hammer *et al.* (2001) was used in calculating said indices. Furthermore, a visual representation for species richness and evenness was presented by generating an abundance curve.

Species richness (S) = total number of taxa [1]

Dominance (D) = $\sum_{i=1}^{S} {p_i}^2$ [2]

Where,

p_i = abundance of ith species over total number of individuals across all species

S = species richness

Evenness = $\frac{e^H}{S}$ [3] Where:

H = Shannon Wiener Index

S = species richness

Shannon Wiener Index (H) = $\sum_{i=1}^{S} p_i \ln p_i$ [4]

Where,

p_i = abundance of ith species over total number of individuals across all species

S = species richness

Species community structure analysis

Relative density, relative frequency, relative dominance and importance value (equations 5, 6, 7 and 8 respectively) were calculated for each site to analyze the community structure of the species identified (Netto *et al.*, 2015).

Relative density determines which species have the highest count per unit area. Relative frequency establishes which species occur most in the location. Relative dominance identifies the species that constitutes the largest part of the biomass of the mangrove area. Importance value designates which component species are relatively acclimated to Sta.

Cruz.Relative Density=

$$\left(\frac{\frac{\text{Total number of individuals of a species throughout the five plots}}{\text{Total plot area}}}{\text{Total density}}\right)*100 \text{ [5]}$$

Relative Frequency=

$$\left(\frac{\text{Total number of times species is present in the five plots}}{\text{Total plot frequency}}\right)*100 \text{ [6]}$$

Relative Dominance=

$$\left(\frac{\frac{\text{Total area of a species throughout the five plots}}{\text{Total plot area}}}{\text{Total basal area}}\right)*100 \text{ [7]}$$

Importance Value Percentage=

$$\frac{\text{Relative density + Relative frequency + Relative dominance}}{3} \text{ [8]}$$

Results and discussion

Species diversity

Identification of mangroves in the six sampling plots yielded species 17 species from 11 Families (Table 1). There are around 35 to 40 species of mangrove in the Philippines (Long and Giri, 2011). Our study recorded 43% of the total known species in the country. This is comparatively higher than results of other studies in the Davao Region. Pototan *et al.* (2017) inventoried 12 species (30%) from Carmen, 11 (27%) from Tagum and 16 (40%) from Panabo, all in Davao del Norte. A study in Hagonoy, Davao del Sur also yielded a low number of 7 species (17%; Jumawan *et al.*, 2015). Hence, it can be inferred that Sta. Cruz has high species richness compared to neighboring places in the Davao region.

Table 1. True mangroves and mangrove associates from the mangrove sampling site of Santa Cruz with their respective conservation status from IUCN (2010).

Family	Species	Common Name	Conservation Status
True Mangroves			
Acanthaceae			
	Acanthus ebracteatus Vahl.	Lagiwliw	Least concern
Arecaceae			
	Nypa fruticans Wurmb	Nypa	Least concern
Avicenniaceae			
	Avicennia marina (Forsk.) Vierh.	Miapi	Least concern
	Avicennia rumphiana Hallier f.	Piapi	Vulnerable
Combretaceae			
	Lumnitzera racemosa Willd.	Culasi	Least concern
Meliaceae			
	Xylocarpus granatum J.König	Tabigi	Least concern
	Xylocarpus moluccensis (Lam.) M.Roem.	Piagao	Least concern
Myrisinaceae			
	Aegiceras corniculatum (L.) Blanco	Saging-Saging	Least concern
Rhizophoraceae			
	Ceriops tagal (Perr) CB.Rob.	Tangal	Least concern
	Rhizophora apiculata Blume	Bakauan Lalake	Least concern
	Rhizophora mucronata Lam.	Bakauan Babae	Least concern
	Rhizophora stylosa Griff.	Bakauan Bato	Least concern
Sonneratiaceae			
	Sonneratia alba Sm.	Pagatpat	Least concern
	Sonneratia caseolaris (L.) Engl.	Padada	Least concern
Mangrove Associates			
Bignoniaceae			
	Dolichandrone spathacea (L.f.) Baill. ex K.Schum.	Tui	Least concern
Lecythidaceae			
	Barringtonia asiatica (L.) Kurz	Botong	Least concern
Malvaceae			
	Hibiscus tiliaceus (L.) Fryxell	Malubago	Not assessed

Eleven of 15 mangrove families were identified. These include all the Rhizophoraceae species, both Sonneratiaceae species and one of each from Meliaceae and Avicceniaceae. This strongly suggests that common mangroves in the Philippines thrive well in the coastal environment of Sta. Cruz. Additionally, it is also note-worthy that the study identified three uncommon species namely *Acanthus ebracteatus*, *Avicennia rumphiana*, *Xylocarpus moluccensis* and three mangrove associates which were *Dolichandrone spathacea, Barringtonia asiatica* and *Hibiscus tiliaceus*.

Among the 11 Families, four had more than one species in each Family. These were the Rhizophoraceae, Sonerratiaceae, Meliaceae and Avicenniaceae. Leading the four prominent Families was Rhizophoraceae (23%) with four species identified under the Family.

Sonneratiaceae, Meliaceae and Avicenniaceae follows with two species per Family, each accounting for 12% of the total percentage composition of the mangrove Families (Fig. 2). Canizares and Seronay (2016) also reported Rhizophoraceae as the leading Family of mangroves in Dinagat Islands, with five species identified. The same goes for Carmen and Panabo in Davao del Norte (Pototan *et al.*, 2017), Samar (Abino *et al.*, 2014) and in Puerto Princesa, Palawan (Dangan-Galon *et al.*, 2016).

This suggests that species under the Rhizophoraceae Family are more abundantly spread throughout the archipelago and that it is the species most adapted to the Philippine coastal environment.

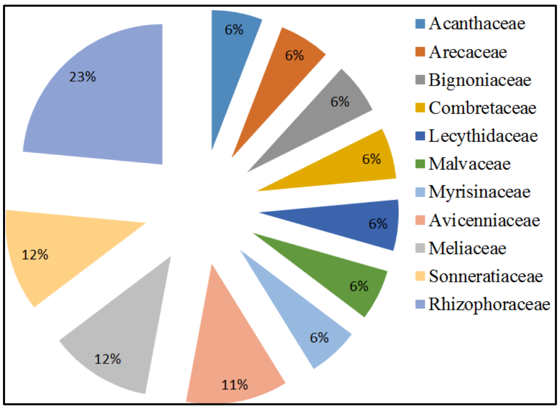

Fig. 2. Percentage composition of the Families of mangrove and mangrove associates found in the sampling areas of Sta. Cruz.

Moreover, among all the species identified, one is a threatened species, *Avicennia rumphiana* (Fig. 5). It was the only one categorized as Vulnerable by the International Union for the Conservation of Nature Red List of Threatened Species (IUCN, 2017).

According to the Philippine's Research Initiative on Mangrove Management and Enhancement Strategies Against Natural Disasters (PRIM²E StAND) (2014), there are only two vulnerable species among the list of true mangroves: *Avicennia rumphiana* and *Avicennia lanata*. Both are threatened due to destruction for the purpose of human settlement (IUCN, 2017).The presence of *A. rumphiana* in the sampling areas of Sta. Cruz is a positive sign. This also calls for immediate assessment and action to preserve the population of *A. rumphiana* in Sta. Cruz.

Abundance Curve

Results of the generated abundance curve yielded a species richness of 17 and a steep slope (Fig. 3; Table 2). Species evenness can be roughly estimated visually by looking at the slope of the abundance curve. This is affected by how abundant the high-ranking species are compared to the low-ranking ones. In this case, the high-ranking species are greatly abundant and this results in a strong and prominent slope that cascades sharply. As highlighted by the red line, the slope is steep and this itself suggests low evenness. The impact of even distribution varies between ecosystems and is not fully understood. However there has been known direct linkages such as fine partitioning of available habitat space and species survival (Verberk, 2011). For trees that interact with their environment religiously, changes in species composition due to uneven distribution (and eventual extinctions) affect several ecosystem functions and properties (Gauthier *et al.*, 2014). This implies that a higher evenness of distribution is a more desirable result when assessing species abundance.

Diversity Indices

For species evenness, it was established from the abundance curve that evenness of the sample mangrove population from Sta. Cruz is low and that distribution is uneven (Table 2). Evenness refers to how evenly distributed the individuals are among the different species (Heip *et al.*, 1998). A lower value from the range of 0 to 1 means lower evenness and the results presented a considerably middle value of 0.5355.

In comparison with the assessment by Canizares and Seronay (2016) which yielded a value of 0.6399 for Dinagat Island, it can be inferred that the distribution of the individuals in Sta. Cruz is more uneven. Uneven distribution suggests that some of the species are dominating the area in terms of individuals and this could cause problem in the diversity and species composition of the area (Fonseca, 2001).

Table 2. Summary of the number of individuals inventoried from each species of mangrove identified in the six plots in Sta. Cruz and their respective abundance ranks.

Species	Number of Individuals Identified						Total	Rank
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6		
Acanthus ebracteatus Vahl.						3	3	14
Aegiceras corniculatum (L.) Blanco			4				4	11
Avicennia marina (Forsk.) Vierh.	12	6	2	1		2	23	4
Avicennia rumphiana Hallier f.					1	3	4	12
Barringtonia asiatica (L.) Kurz	3	1					4	13
Ceriops tagal (Perr) CB.Rob.			6	5			11	6
Dolichandrone spathacea (L.f.) Baill. ex K.Schum.		2					2	15
Hibiscus tiliaceus (L.) Fryxell			1				1	17
Lumnitzera racemosa Willd.			3			2	5	9
Nypa fruticans Wurmb	5						5	10
Rhizophora apiculata Blume	3	1	12	2	4		22	5
Rhizophora mucronata Lam.	3	20	13	24	12	3	75	1
Rhizophora stylosa Griff.						6	6	8
Sonneratia alba Sm.	8	6		11	15	4	44	2
Sonneratia caseolaris (L.) Engl.			3	16	3	2	24	3
Xylocarpus granatum J.König			5	2		2	9	7
Xylocarpus moluccensis (Lam.) M.Roem.						2	2	16

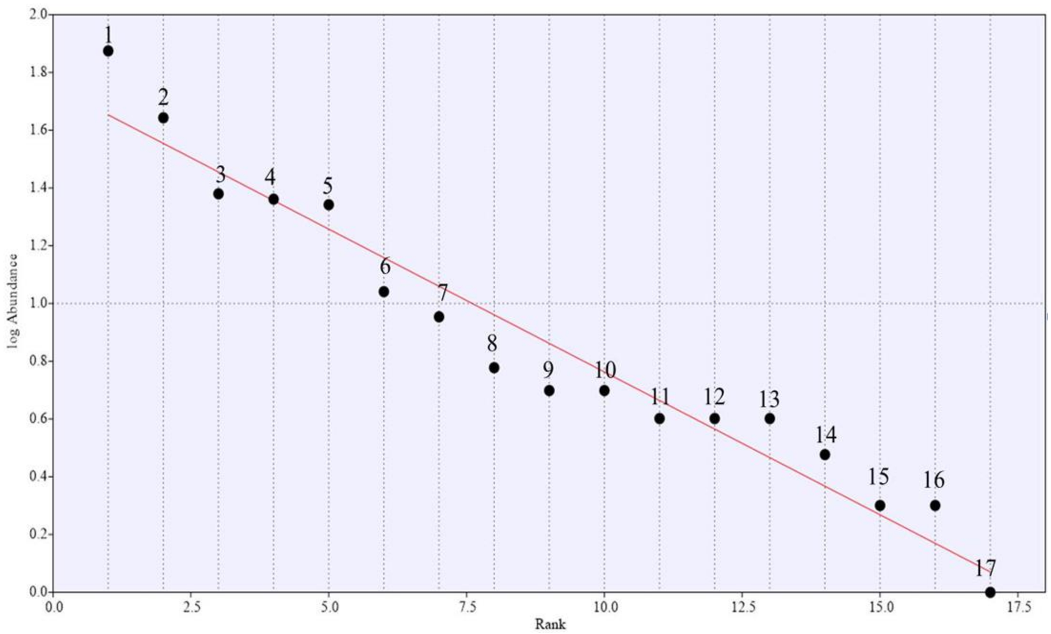

Fig. 3. Rank abundance curve of the identified mangroves in Sta. Cruz, Davao del Sur.

Dominance has a range of 0 where all taxa are equally distributed to 1 where a specific taxon dominates the community completely. Computation for the samples yielded a dominance value of 0.1596 which suggests a low chance of dominance in the area. While this is contradictory with the result for evenness, note that 0.1596 is considerably far from 1. This means that a very few species could be contributing to the uneven distribution but is/are not completely dominant. Moreover, a quick comparison with the value from Canizares and Seronay (2016) which was 0.214 and Pototan (2017) which were 0.1596 (Carmen), 0.1836

(Tagum) and 0.2333 (Panabo) reveals Sta. Cruz to have a lower dominance value. This further proves that relatively no mangrove species in Sta. Cruz are overly abundant than the others. For an ecosystem that provide to the society, having dominant species exert a deterrent force on the functioning of the ecosystem.

This is because diversity of organisms alongside identity of organisms jointly controls the functioning of ecosystems (Wohlgemuth *et al.*, 2016). Therefore, the result leans positively towards the continued functioning of the mangrove forest in Sta. Cruz.

Lastly, the resulting Shannon index of the samples was 2.209. To make use of the Shannon index as a biodiversity tool more effectively, it can be converted into its equivalent number of species (ENS) by raising Euler's number (e) with the Shannon index value (Jost, 2006). In this case, the ENS is 9 which imply that a Shannon index of 2.2 is equal in diversity with a community bearing 9 equally common species. Moreover, the Shannon index of this study is comparatively higher than that of Canizares and Seronay (2016) which yielded a value of 1.856 for Dinagat Islands. The study utilized the same protocol this study used albeit having only five plots.

The Shannon index was also relatively comparatively higher than that of Abino *et al.*, (2014) which had a value of 1.6 for Samar mangroves. This is in spite of having 12 10x10m plots using the same non-destructive quadrat sampling technique. This suggests a higher status of diversity in Sta. Cruz than the mentioned places.

Though there is a broad consensus on the effects of high biodiversity, it also has specific implications. One is that it ensures a stable supply of ecosystem goods and services (Meyer *et al.*, 2016). Therefore, with Sta. Cruz mangrove forest having a higher biodiversity status, it has more stable ecosystem supplies. This is important in adjusting to the ever increasing spatial and temporal variability especially with the onset of climate change and global warming.

Mangrove Community Structure Analysis

The relative density, frequency, dominance and importance value for each species were calculated and presented in Fig. 4. *R. mucronata* had the highest values for relative density (31%) and relative frequency (14%) while *S. alba* (Fig. 6) had the highest values for relative dominance (43%) and importance value (24%).

A study on survivability of mangrove species in Davao del Sur (Pacyao and Llameg, 2018) concluded that *Rhizophora* species prefers places with clay loam soil type on which was part of the soil type for each sampling plot except for plot 3.

One of our sampling sites was also their site (Tagabuli) wherein survival rate of *Rhizophora* species (87.49%) was reported. Moreover, our team concluded *R. mucronata* to be the most acclimated mangrove species for Tagum, Davao del Norte Pototan *et al.* (2017).

Therefore, it is understandable for *R. mucronata* to have a higher relative density and frequency.

Table 3. Diversity indices of the mangrove samples from Sta. Cruz with additional results for each plot.

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	TOTAL
Species Richness	6	6	9	7	5	10	17
Dominance_D	0.224	0.368	0.172	0.265	0.322	0.117	0.159
Evenness_e^H/S	0.852	0.601	0.775	0.655	0.726	0.925	0.535
Shannon_H	1.633	1.283	1.943	1.523	1.290	2.225	2.209

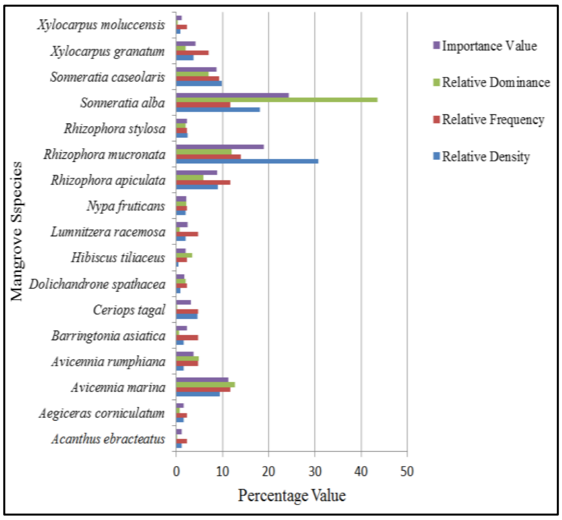

Fig. 4. Relative measures for the mangrove species from Sta. Cruz and their importance value percentage.

Fig 5. Shoot sample of *Avicennia rumphiana* obtained from Sta. Cruz, Davao del Sur.

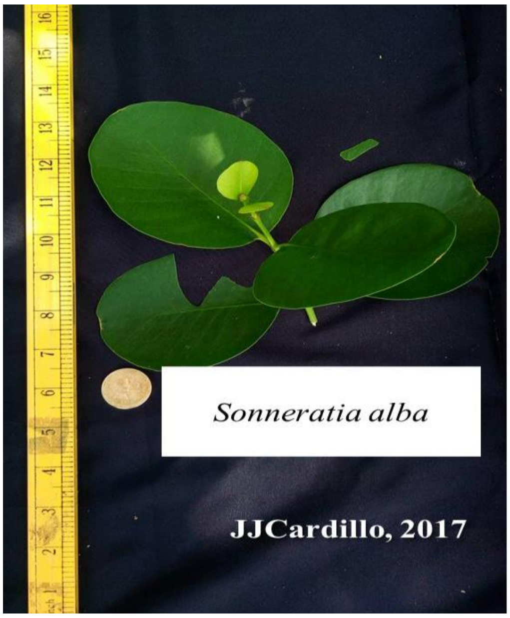

Fig 6. Shoot sample of *Sonneratia alba* obtained from Sta. Cruz, Davao del Sur.

Moreover, results showed that *S. alba* is the taxon with the highest relative dominance. This concurs with Carlos *et al.* (2016), confirming that *S. alba* has high coppicing potential along with *A. marina*. Coppicing is the ability of trees to regenerate into a full tree after being cut down. Moreover, since it is a natural colonizer (Kathiresan *et al.*, 2010a), its growth pattern is much faster than that of other mangrove species. This makes it excellent in bulking up and contributing a larger biomass for the area. *S. alba* also had the highest importance value of 240 or 24% importance percentage.

This implies that it is the least likely candidate for conservation efforts in Sta. Cruz since it is highly adapted to the area and has the most effective set of environmental tolerances. Moreover, while the *R. mucronata* may have higher relative dominance and density, its relative frequency is comparatively far from that of *S. alba*. Moreover, its value is comparatively higher than that of *R. apiculata and A marina* of Carmen (19%), and *R. mucronata* of Tagum (21%) while falling a few points short Panabo's *A. marina* (30%) from Panabo (Pototan, 2017). This suggests that faster growth pattern and higher coppicing ability contributes a lot to the importance of a species in its community.

Conclusion

From this study we identified seventeen mangrove species under 11 Families among six random sampling plots throughout the shores of Sta. Cruz, Davao del Sur, Philippines. One species, *Avicennia rumphiana* Hallier f.*A.* is categorized by the IUCN as Vulnerable state. Results of the diversity indices implied that the mangrove forests of Sta. Cruz have low evenness but with fair distribution of dominant species. However, it was concluded that Sta. Cruz had relatively higher species richness in comparison to other neighboring areas in the Davao region. However, the Shannon Wiener diversity index of 2.2 was relatively higher than other published values from other Philippine mangrove studies. *Sonneratia alba* Sm., a species of Least Concern, yielded higher relative dominance value and an overall higher importance value. It was concluded to be the keystone species of the mangrove forests of Sta. Cruz that would make a good candidate for use in mangrove restoration efforts.

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