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Inferring zonation in mangrove ecosystem via leaf size indices in *Rhizophora apiculata* Blume

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Abstract

The present study intends to establish the relationship between the leaf size indices of *Rhizophora apiculata* relative to the zonation of the mangrove ecosystem in Masapelid Island. A transect line with 20 meters width and 160 meters length was established from the sandy soils up to the seaward zone of the forest. The transect was further subdivided into zones based on the typical species zonation patterns with the first zone covering 20 meters from the shore comprising the landward; the second zone considered as the middle covers from >20 to 60 meters while the third zone was the seaward zone includes >60 meters up to where mangrove species still exist. The leaves in every first branch of these species were collected in each zone to determine the variables such as length, width, thickness, and area. Collected samples then undergo tissue analysis to determine the nutrient status. The result shows that except for leaf thickness, a negative correlation between the zones was observed. This implies that the leaf length, area, and width decreases towards the seaward zone. In contrary, the leaf thickness showed a positive correlation which would mean increasing leaf thickness towards the seaward. Moreover, the leaf length and area were negatively correlated to nitrogen and phosphorus which implies that increasing amounts would lead to lower length and area while K has an opposite effect. Despite the seemingly decreasing trend observed,however, LSI, in this case,could not be the reliable indicator to demarcate zonations in the mangrove ecosystem.

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Introduction

The mangrove forest is a unique type of ecosystem characterized by vegetation that is highly adapted to high levels of salinity and stress due to the wind and tidal inundations. In general, the mangrove ecosystem provides many vital resources for utilization in forestry, fisheries, food, agricultural and medicinal industries (Miles *et al.,* 1999). However, overexploitation and conversion to large-scale fish ponds, deforestation, and settlements have tremendously impacted the mangrove forests. In Southeast Asia, more than 100,000 ha of mangrove forest were removed from 2000 to 2012 (Richards *et al.,* 2016) while in the Philippines, mangrove forests havedeclined to only 120,000 ha in 1994 to1995 (Primavera 2000).

The mangrove ecosystems exhibit conspicuous species zonation pattern which has long attracted scientific interest (Walsh 1974; Snedaker 1982; Tomlinson 1986; Hutchings and Saenger 1987) and for many decades has been the subject of scientific inquiry (Watson 1928; Davis 1940; Egler 1950; Macnae 1968; Chapman 1976). Generally, the mangrove ecosystem is divided into three zones with each of this zone comprise different species composition (Primavera *et al.,* 2008; Giesen *et al.,* 2007). There were several factors that have been proposed to account for this pattern including physiological adaptations to flooding and salinity, differential propagules dispersal, interspecific competition, and responses to geomorphological processes (Louda 1989; Smith 1992). Some authors also suggest that elevation and exposure to wave action cause zonation ((Dayton 1971, Stephenson and Stephenson 1972, Sousa 1979a, b, Underwood *et al.*, 1983, Dayton *et al.*, 1984, Menge and Sutherland 1987, Menge and Farrell 1989, Menge and Olson 1990). The general consensus, however, is that the zonation patterns are determined by a combination of these factors, but that tidal inundation is the dominating factor (e.g. Watson 1928; Kint 1934; van Steenis 1958; Chapman 1976a; Aksornkoae 1993). Hossain *et al.* (2016) mentioned that topographic factors such as elevation, determine the frequency and duration of tidal inundation, which subsequently affects the salinity, oxidation state and nutrient availability of the soil, resulting in complex patterns of nutrient demand and supply that contribute to the variable structure of mangrove forests. Tilman (1998) added that the level of nutrients could be an important factor in determining the direction and extent of succession in mangrove communities. In general, salt-marsh vegetation dynamics is thus seen to be quite complex and a deeper understanding of halophyte spatial and temporal patterns requires accurate studies of the physical, chemical and biotic factors affecting plant physiology (Silvestri *et al.*, 2005). This present study was aimed to investigate the relationships of leaf size indices of *Rhizophora apiculata* Blume relative to the zonation pattern in the mangrove ecosystem in Masapiled, Island. Aribal*et al.* (2017) reported that the variation in leaf size indices (LSI) of the plant species in Caimpugan peat swamp conform to the zonation pattern of the peatland which also corresponds to structure and physiognomy of the forests. Buot and Okitsu (1999) observed the same on the forest ecosystems of Mt. Pulag in Luzon. Traiser *et al.,* (2005) emphasize that the physiognomy of leaves can serve as an excellent tool for ecological studies and variation of leaf size provides direct indicators to the physicochemical conditions operating on plants. Thus, this study was conducted to determine whether the LSI could be a tool to describe the zonation of the mangrove ecosystem.

Materials and methods

Study site

The study was conducted at therelatively pristinemangrove forest located at Barangay Fabio, Tagana-an, Surigao del Norte specifically in Masapelid Island with geographic coordinates of 9°42'33.98" N, 125°38'38" E (Fig. 1). The mangrove forest comprises the Municipality of Tagana-an shares common boundaries with Surigao City, Placer and Sison in the mainland, Bucas Grande and Siargao islands off the seawaters of Hinatuan Passage. Based on the Corona system of classification, it has a Type II climate characterized by no pronounced dry season with a very pronounced maximum rain period from November to January and receives an average annual rainfall of 288.13mm.

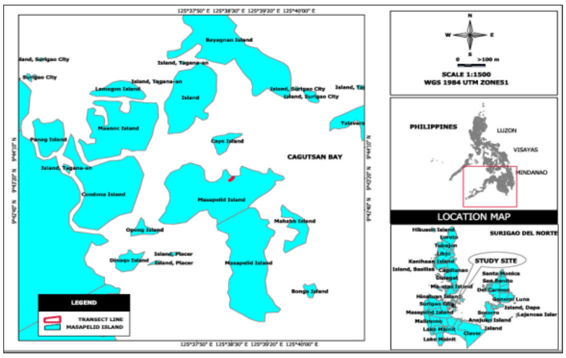

Fig. 1. Map of the study site.

Sampling

A line transect consisting of 20m width and a length of 160m wasestablished from the landward to the seaward direction at the North East of Masapelid island. The transect line was further divided into three zones to represent the landward zone, middle zone and seaward zone of the mangrove ecosystem with respect to the species composition as cited by Agaloos (1994).

Leaf Collection

The leaves of *R. apiculata* found inside the transect line were collected and used in the study. This species was found to be the most abundant and common in all the zones identified. Toeliminate other potential sources of variation, leaf collections were done in every first branch of the tree.

Leaf size measurement

The collected leaves were then measured using a ruler to determine the width and length and a caliper for the thickness. Using the formula of Cain and DeOlivereira- Castro (1959), the leaf area was computed as:

Leaf area = 2/3 (L x W).

Where: L - full length of the leaf.

W - width of the leaf at its widest portion.

Table 1. Leaf Size Measurement.

Categories	Dimensions(cm^2)	Raunkiaer (1934)	Webb (1959)	Merged Categories
1	<0.25	Leptophyll	Leptophyll	Small leaves
2	0.25 - 2.25	Nanophyll	Nanophyll	
3	2.25 - 20.25	Microphyll	Microphyll	
4	20.25 – 45.00		Mesophyll	Large leaves
5	20.25 – 182.25	Mesophyll	Notophyll	
6	182.25 – 1640.25	Macrophyll	Macrophyll	
7	>1640.25	Megaphyll	Megaphyll	

Plant Tissue Analysis

The collected leaf samples were subjected to analyses to determine the variations of leaf tissue elements such as nitrogen, potassium and phosphorus content of the leaves. There were at least 30 samples of leaves per specimen. The leaf samples were air dried for at least 5 days prior to the analyses at the plant analysis laboratory in Central Mindanao University.

Results and discussion

Leaf size Indices

The leaf indices except for the thickness observed in this study shows a decreasing trend relative to species zonation. In terms of length, the highest was obtained in the landward zone with 13.24cm while the lowest was obtained in the seaward zone of 12.09cm.

For the leaf width, the highest was obtained in the middle zone with 5.57cm while the lowest was obtained in the seaward zone with 4.95cm. The leaf area also obtained the highest in the middle zone of 49.04cm^2 while the lowest was obtained in the seaward zone of 39.9cm^2 (Fig. 2). This observed decreasing trend from landward to seaward zone could be due to the wind and tidal inundations, waterlogging, and very high salinity conditions (Giesen *et al.* 2007). Peel *et al.* (2017) stated that salinity increases stomatal density causing reduction of leaf size, however, this does not mean that the landward zone contains less dissolved salts than other zones since during high tides part of the seawater entering this zone evaporates, and leaving salts deposits behind (Giesen *et al.*, 2007).

Naidoo (2010) also mentioned that salinity and waterlogging conditions causes an overall reduction in the growth and this include reduced leaf size.

For the leaf thickness, an increasing trend of leaf thickness in relation to species zonation *i.e.* the highest was obtained in the seaward zone (0.48 cm) while lowest was obtained in the middle zone (0.44cm) (Fig. 2). This increased leaf thickness exhibited may be due to wind inundations. For instance, Grace (1988) stated that leaves grown at high wind speeds are thicker than those grown at low wind speeds. Typically, plants exposed to mechanical stress developed adaptation mechanisms such as shorter and more branched canopies, reduced leaf area, shed leaves, and altered root biomass in order to reduce the drag that leads to wind damage. De Lima *et al.* (2015) also mentioned that sclerophylly (*i.e.* increased leaf thickness) is a morphological trait as a non-specific response to stressful environments specifically in mangroves with flooded and unconsolidated soil, low availability of nutrients and high salinity.

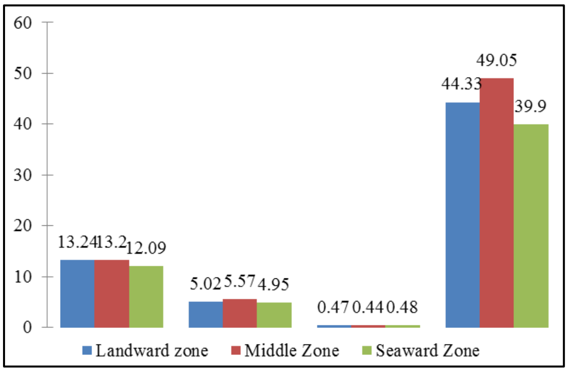

Fig. 2. Leaf Size Indices of *R. apiculata.*

Spearman's correlation analysis revealed that leaf length, width and area of *R. apiculata* exhibit a negative correlation to the forest zones (at $p<0.05$; $r^2= 0.813$, $r^2=0.80$, $r^2=0.80$; n=3). This further support to the scenario mentioned above that the leaf length, area, and width decreases towards the seaward zone. In contrary, the leaf thickness showed a positive correlation (at $p<0.05$; $r^2=0.108$; n=3) which implies increasing leaf thickness towards the seaward. Moreover, analysis of variance and Tukey's post hoc test (table 2) also showed that the length, thickness, and width is significant to species zonation at $p<0.01$ while the leaf area shows significance at $p<0.05$. Fig. 3 shows the regression analysis.

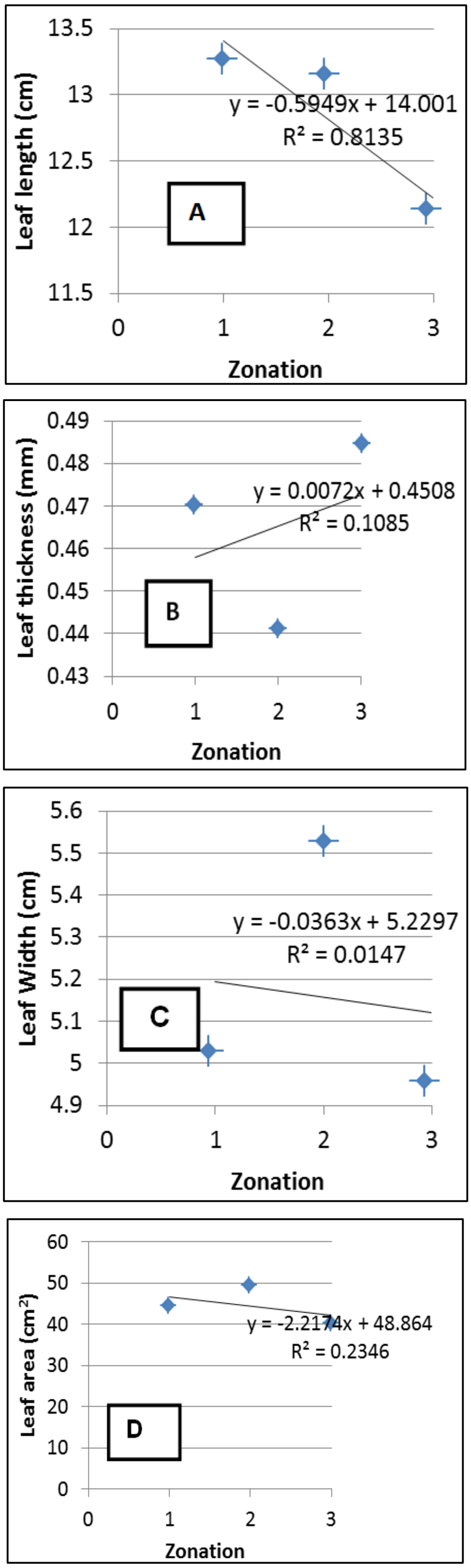

Fig. 3. Leaf morphometrics of *R. apiculata* Blume.

Table 2. Result for the Analysis of variance (One way ANOVA) and Tukey post hoc test for. *Apiculata*found in Zone 1 up to Zone 3.

Leaf morphometrics	Sig.	Zone	N	Subset for alpha=0.05
Length	0.000**	3	479	120.3069 [b]
Width	0.000**	2	390	124.8410 [a]
Thickness	0.000**	1	241	128.1992 [a]
Area	0.030*			

Means of the different letter are significantly different from each other.

** Significant at 0.01 level; *significant at 0.05 level; ns- not significant

Variations in Leaf Nutrients

Nitrogen is the primary nutrient that limits the growth of mangrove species (Elser and Hamilton, 2007). Nevertheless, N and P have been suggested as limiting nutrients in estuarine ecosystems (Yates *et al.,* 2002). The total nitrogen content was highest in zone 1 with 1.230%, however, zone 2 obtained the highest phosphorus and potassium content with 0.231% and 1.850%. Based on Spearman's correlation analysis phosphorus content is highly significant to its leaf length were ($p<0.01$, $r^2=1$, $n=3$). The result shows that phosphorus causes the *R. apiculata* leaf length increases. The leaf length of *R. apiculata* found in zone 3is lower compared to zone 1 and 2. However, nitrogen can cause *R. apiculata* leaf area decline.

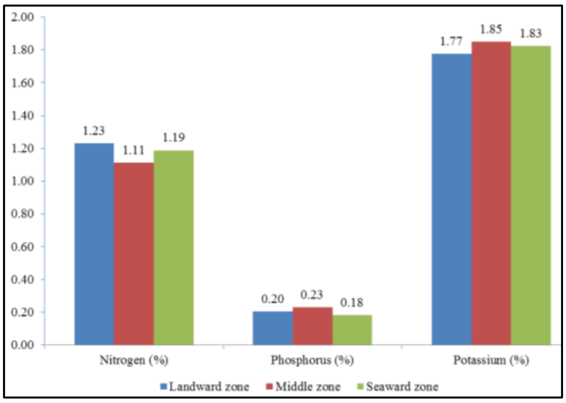

Fig. 4. Nutrient contents *of R. apiculata* leaves.

Conclusion

The leaf size indices(LSI) between its zonation of *R. apiculata* in Masapelid Island shows a decreasing trend from the landward up to the seaward zone of the mangrove ecosystem. However, different zones possess different exposures to tidal inundation, waterlogging, and salinity that may have contributed to the variations of LSI. The nutrient takes dynamics was found to affect the LSI especially phosphorus and nitrogen content. Despite the seeminglydecreasing general trend of LSI however, the variables being studied could not be considered as a reliable indicator to demarcate the mangrove zonation contrary to the earlier reports ofAribal*et al.* (2017) and Buot and Okitsu (1999) in the peat swamp forest and forest mountain ecosystem, respectively. This was further emphasized on the overall leaf classification which belongs to mesophyll category for all the three zones. Finally, this present study suggests considering all other species to further determine whether LSI could be a tool in demarcating the recognized zones when taken collectively.

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Conflict of interest

The author declares that there is no conflict of interests regarding the publication of this manuscript.

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