Library Progress International *Print version ISSN 0970 1052*
Vol.44, No.4, Jul-Dec 2024: P. 220-226 *Online version ISSN 2320 317X*

Original Article *Available online at www.bpasjournals.com*

Assessing the Diversity, Biomass, and Vegetation of Mangroves in Sukol River, Oriental Mindoro, Philippines

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How to cite this article: Randy A. Quitain (2024). A Assessing the Diversity, Biomass, and Vegetation of Mangroves in Sukol River, Oriental Mindoro, Philippines. Library Progress International, 44(4), 220-226

ABSTRACT
Establishment of mangrove's data with relation to biomass, vegetation and diversity provides a proper guide to develop a management approach, and effective interventions intended for conservation as well as restoration for these trees. In order to acquire information regarding the structure, biodiversity and biomass production of mangroves a floristic assessment was conducted in the mangrove communities along Sukol River, Bongabong, Oriental Mindoro, Philippines. Twenty 10m x 10m quadrants were randomly laid inside the mangrove areas. The girth of the tree was measured at breast height or equivalent of 1.3 meter above the ground using tape measure. The assessment revealed four species of true mangrove namely: Sonneratia alba, Avicennia marina, Rhizophora apiculata and Rhizophora mucronata. The largest stem diameter and basal area recorded were exhibited by S. alba with 55.64 cm and 15.91 m2 ha-1 respectively. Vegetation analysis revealed that R. mucronata was the densest species (50.22%), while the most dominant was S. alba (82.82%). On the other hand, the diversity index was at H'=1.302 and D=0.7009. Computed biomass using allometric models from previous studies revealed that the mean aboveground biomass of the mangrove stand was 54.7 Mg ha-1. The aboveground biomass delivers requisite data to estimate the carbon sequestration of riverine mangroves. Meanwhile, the acquiring the species composition and structures with emphasis on the classification of species serves as basis for conservation strategy.
Keywords: Allometric models, diversity index, floristic assessment, vegetation analysis, Sukol River.

INTRODUCTION

In tropical and subtropical regions, mangroves are intertidal trees that can withstand the marine environment saline condition. Mangrove ecosystems are unique in terms of their location, structures, and roles. They are one of the ecosystems that has been well-studied, and several researchers around the world have numerous substantial research papers on mangroves [1]. Such areas of focus are the gaseous exchange through the root tissues and leaves for biomass, carbon stock and oxygen release, type of wetland habitat, propagation and valuation of ecosystem services[2].

Mangrove habitats have a significant homeostatic role that impact the biogeochemical cycle in addition to offering an abundance ecological benefit. Additionally, they provide a variety of goods to coastal settlements, including food, fuel, and building materials, they harbor a vast array of flora and faunal biodiversity, they buffer storms and tsunamis, and they provide indirect use value, such as water filtration, mitigation of coastal erosion, and storm protection for the community. Sea grass and coral reefs also receive nutrients from these ecosystems that are stored in their roots[3]. Mangroves are home to various wildlife, based on recent account 75% of all tropical commercial fish species thrive within these ecosystems. Nevertheless, given that locals harvest mangroves for wood, thatch, medicines, and dyes, these trees actually utilized for traditional use. They are valuable as fishing ground for fish and shellfish poachers as well as for ecotourism. Mangrove forests sequester a significant amount of carbon, making them important carbon sinks in the tropical latitudes. In the biotic setting of the coastal and intertidal habitat, they offer a broad range of ecological services [4].

Mangrove populations have annual decline of 0.16% to 0.39% worldwide over the past 20 years as a result of numerous anthropogenic activities [5]. The three main problems that mangroves confront globally are extraction, degradation, and failed succession. Mangrove forests around the world are being negatively impacted by human activities such timber extraction, aquaculture, residential development, and the production of charcoal, all of which are done without considering the consequences. Furthermore, a number of natural phenomena, including temperature, precipitation, typhoons, and sea level rise, pose a serious danger to the mangroves ecological balance and biodiversity[6].

It appears that the beginning of the industrial revolution coincided with a decrease in the numbers of these intertidal biotic components. The state of the abiotic factor affecting mangrove development is altered by industrialization. The biodiversity that inhabits the coastal zone are impacted by industrial contamination caused by the discharge of sludge and effluent into bodies of water that reach the marine environment [7]. Because mangroves act as a filter for these wastes, they can control the inorganic litter that streams carry from the uplands. The heavy metals from factories, mining sites, and agricultural land are released into streams and captured by the mangroves. These materials can build up in the mangrove structure and may have an impact on its ecological function, production, and nutrient processes [8].

During the year 1920 the Philippines was covered by 400,000–500,000 hectares of mangroves but declined to 120,000 hectares in 1994. The occurrence of this depletion was due to over exploitation by coastal dwellers, conversion to agriculture, salt ponds, industry and settlements[9]. It is obvious that mangrove ecosystems have been declining for some time due to both natural and human causes. In order to mitigate the depletion, mangroves need to be properly conserved and managed. For restoration initiatives across regions, it is vital to comprehend the growth pathways, nutrient cycling, and devolution of energy toward their associates. In addition to floristic and faunistic studies, there should be a growing effort to evaluate the mangrove ecosystem in terms of bioremediation, economic valuation, and biomass production [10].

Due to the decline of mangrove ecosystems, it is imperative to comprehend their biological and ecological components for conservation strategy. To determine the species composition of the current mangrove structures, mangrove evaluation is required, with a focus on classifying species for conservation purposes. Determining the production of the vegetation stand is important to comprehend the dynamics of the cycling of nutrients and organic matter in mangroves, especially the carbon sequestration activity. For intervention programs like forest restoration and rehabilitation projects, accurate data on biomass output will be crucial. Furthermore, information about the species variety and composition of the current mangrove structures may be used as the foundation for creating an efficient plan for managing these natural resources. The mangrove ecosystems across the world need to provide more baseline data in order to obtain knowledge that can be utilized for economic value in support of sensible policy and decision-making.

The objective of this study was to determine the species composition and variety of mangroves in Sukol River, Bongabong, Oriental Mindoro, as well as to acquire baseline data regarding the abundance and variability in biomass production at the species level. Moreover, discussed the characteristics that define the overall community structure of the mangrove area in terms of species composition, relative abundance, frequency, and dominance.

METHODS

The study was conducted in the mangrove area near Bongabong, Oriental Mindoro's Sukol River (about at 12.744302N, 121.48938E; see Figure 1). The mangrove site had characteristics of brackish water, riverine areas, and intertidal zones. Within the mangrove area, four transects were placed 25 meters apart and parallel to one another, dividing the twenty 10 m × 10 m quadrants vertical to the river. Primavera's mangrove field guide was used to identify specific plant species [11].

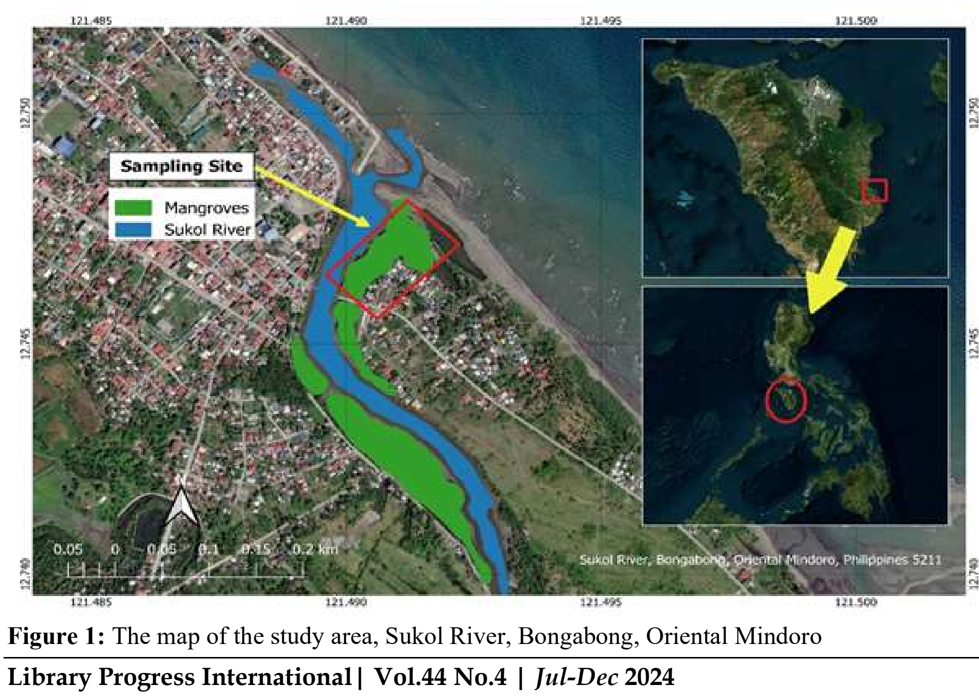

Figure 1: The map of the study area, Sukol River, Bongabong, Oriental Mindoro

The Sukol River mangroves taxonomic profile and community structure were determined using the following parameters: height, crown, relative frequency, relative density, and DBH (diameter at breast height). Furthermore, diversity indices for mangrove vegetation were determined using the Shannon-Weiner (H) Index formulas [12].

$$\mathrm{H}' = -\sum_{i=1}^{k} Pi \log Pi$$

Using a tape measure, the tree's girth was measured at breast height, approximately equivalent to 1.3 meters above the ground. Split large stems were regarded as two distinct trees which considered also for separate measurement. Meanwhile, measurements of *Rhizophora* species were taken above the most noticeable prop root. Prior research reports employed DBH (diameter at breast height) and TH (total height) as independent variables in allometric equations to determine the biomass of mangrove species above ground. The study utilized allometric models instead of total tree height in the field, with DBH as the only independent variable [13]. Given the nature of the investigation, DBH was suggested as an independent variable for allometric models.

$$\sqrt{Biomass} = 0.48DBH - 0.13$$

The number of sampling units where a certain species was present referred to its frequency. The degree of dispersion of each species within a specific habitation was referred to as the frequency of mangrove vegetation. The mangroves shrubbery state was expressed as a percentage of occurrence. The following formulas were used to measure the frequency and relative frequency of species in the research area.

$$\text{Frequency} = \frac{No.of\ occurences\ of\ species}{Total\ no.of\ site\ samples\ taken} \text{ x } 100$$

$$\text{Relative Frequency} = \frac{No.of\ occurences\ of\ particular\ species}{Total\ no.of\ occurences\ of\ all\ the\ species} \text{ x } 100$$

The species resilience in the environment were their density and abundance, which were typically assessed. Density was the number of individuals per sampling unit, whereas abundance was the quantity of individuals occurring per sampling unit. The Important Value Index (IVI) for mangroves was determined by adding the relative frequency, relative abundance, and relative density for each species. The index was created to characterize each species achievement with a single value in terms of dominance and ecology [14].

$$\text{Abundance (A)} = \frac{Total\ number\ of\ inviduals}{Number\ of\ Sampling\ units\ of\ occurence} \text{ x } 100$$

$$\text{Relative Abundance} = \frac{Abundance\ of\ a\ particular\ species}{Sum\ of\ the\ abundance\ of\ all\ species} \text{ x } 100$$

$$\text{Density} = \frac{Total\ no.of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Total\ no.of\ quadrats\ sampled} \text{ x } 100$$

$$\text{Relative Density} = \frac{Density\ of\ a\ particular\ species}{Sum\ of\ the\ densities\ of\ all\ species} \text{ x } 100$$

$$\text{IVI} = Relative\ frequency + Relative\ abundance + Relative\ density$$

The researcher used an improvise PVC pipe markers fixed in the sampling quadrats as reference location for the next sampling activity.

RESULTS

Mangrove Diversity Index

In studies that experimentally manipulate species diversity, it is often species richness that is varied among treatments. The species richness of the mangroves in Sukol River were high with 227 species (see Table 1). A total of four species were recorded which represent true mangrove species, with the mangrove sites diversity index described as relatively high. The diversity index of Sukol River was at H'=1.302 and D=0.7009. The plots studied in the study area were mature and diverse.

Table 1: The Mangroves Species of Sukol River, Bongabong, Oriental Mindoro

Scientific Name	Family Name	Local Name	Tree Density
Avicennia marina	Avicenniaceae	Api-api	8
Rhizophora apiculata	Rhizophoraceae	Bakhawang Lalaki	12
Rhizophora mucronata	Rhizophoraceae	Bakhawang Babae	114
Sonneratia alba	Sonneratiaceae	Pagatpat	93
Total			N=227

Mangrove Biomass Production

By counting the plant on sample plots of an identified area was a practical means of deriving density estimates. For this study area, *Rhizophora mucronata* were the dominant species because of high total number tree estimation per hectare. Highest mean stem diameter recorded was exhibited by *Sonneratia alba* with 67.54 cm. Calculations using the allometric models revealed that the total estimated aboveground biomass of mangroves in Sukol River was 54.7 Mg ha^{-1}. Estimation at species level showed that *Sonneratia alba* demonstrated the highest biomass production among the other mangrove species at 45.64 Mg ha^{-1} (see Table 2).

Table 2: The Species-specific Mean Aboveground Biomass of Mangroves in Sukol River

Mangrove Species	Tree Density	Stem Diameter at Breast Height(cm)			Mean Aboveground Biomass(Mg ha^{-1})
		Min.	Max.	Mean DBH	
Avicennia marina	8	2.93	11.39	6.49	0.372
Rhizophora apiculataz	12	5.79	19.77	10.52	1.31
Rhizophora mucronata	114	2.86	20.37	7.40	7.38
Sonneratia alba	93	1.27	67.54	22.11	45.64
Total	N=227				54.7

The highest density of *Rhizophora mucronata* of 114 trees has relation to the type of substrate appropriateness. *Rhizophora mucronata* was very suitable growing at sandy loam substrate type at mangrove area. Next highest density was for *Sonneratia alba* of 93 trees and *Rhizophora apiculata having* 12 trees, the lowest density plant was *Avicennia marina* of 8 trees (see Table 2).

Mangrove Vegetation

Vegetation data revealed that the species of *Sonneratia alba* has an Important Value Index (IVI) of 148.79%, followed by *Rhizophora mucronata* (95.32%), *Rhizophora apiculata* (39.13%) and *Aviccenia marina* (16.75%). Among these species, two belongs to the family *Rhizophoraceae*, then the remaining were *Sonneratiaceae* and *Aviceniaceae* (see Table 3). The results of the analysis suggest that *Sonneratia* species dominated the area of Sukol River.

Table 3: The Vegetation Analysis of the Mangroves in Sukol River, Bongabong

Species	Tree Density	Number of Occurences	Basal Area (m^2 ha^{-1})	R Den	R Freq	R Dom	IVI	Rank
Avicennia marina	8	8	0.14	3.52	12.5	0.73	16.75	4
Rhizophora apiculata	12	20	0.5	5.28	31.25	2.6	39.13	3
Rhizophora mucronata	114	20	2.66	50.22	31.25	13.85	95.32	2
Sonneratia alba	93	16	15.91	40.97	25	82.82	148.79	1
Total	227	64	19.21					

The abundance of saplings and seedlings gives an indication of the natural regeneration occurring. The highest total of saplings recorded was 176 for *Sonneratia alba* while 756 seedlings for *Rhizophora mucronata*.

DISCUSSION

Diversity Index Analysis

Diversity within mangrove communities present in the Sukol Rivers can be assessed through two key metrics, their richness and evenness. Richness refers to the number of different species present in a community, while evenness measures how evenly individuals are distributed among those species. For instance, in the study site, one mangrove community may exhibit higher richness, indicating a greater variety of species, whereas maybe another shows higher evenness, suggesting that the species present are more uniformly represented. The relationship between the Diversity Index and Evenness Index is influenced by the density of mangroves at various stations in the study site, with communities that host a higher number of species typically achieving a relative diversity index. Conversely, Sukol mangrove areas characterized by high evenness can demonstrate a larger diversity index compared to communities with similar richness but lower evenness. This interplay highlights the complexity of mangrove ecosystems and the importance of both richness and evenness in understanding their impact in the estuarine environment. The structural complexity of mangrove sites is reflected in several aspects, including the arrangement of roots, the height and density of the trees, and the layering of vegetation. The intricate root systems of mangrove in Sukol River, which can be above or below the water, provide shelter and breeding grounds for various marine species, while the canopy formed by the trees creates micro habitats that support both terrestrial and aquatic organisms. Additionally, the diversity of species present in the study site contributes to the overall complexity, as different plants and animals interact within this environment. This multifaceted structure in the river not only enhances biodiversity but also plays a key role in coastal protection, carbon storage, and water filtration, making mangroves essential for both ecological health and human communities[15][16][17].

Knowing the diversity of the following species of mangroves at the study site, *Avicennia marina, Rhizophora apiculata*, *Rhizophora mucronata* and *Sonneratia alba* and where most likely the type of environment these mangrove species grow and tribe can be of help to analyze their structural complexity, including their importance in the riverine system. *Rhizophoraceae* are known for their protruding roots above the water's surface that serve multiple functions. Primarily, they provide stabilization in the soft, muddy substrates of intertidal zones, preventing erosion and facilitate gas exchange allowing the plants to thrive in challenging conditions. Meanwhile, the *Aviceniaceae* complexity arises from their unique root systems, which consist of extensive aerial roots that provide stability in soft, muddy substrates and facilitate gas exchange in waterlogged soils. Additionally, the leaves of *Aviceniaceae* are equipped with specialized salt glands that help in osmoregulation, allowing these plants to expel excess salt while retaining essential nutrients. The *Sonneratiaceae* possess specialized adaptations, such as prop roots and pneumatophores, which facilitate gas exchange and stability in riverine substrate. The architecture of *Sonneratiaceae* species is characterized by a unique arrangement of branches and leaves that maximizes sunlight absorption while minimizing water loss, allowing them to thrive in harsh conditions.

Biomass Production Analysis

The forest stands have relatively high biomass production. Outstandingly, large girthed species of both *Sonneratia alba* and *Rhizophora mucronata* dominates the area. The mangrove site was located along the main town of Bongabong, Oriental Mindoro making it an ideal space for possible carbon loading. Mangroves throughput and contribution to other biological processes in the coastal area yields ecosystem services aggregating its economic use and non-use value that benefits the heterotrophic level, directly and indirectly. They were also important to estuarine fisheries, because of the detritus and dissolved organic carbon contributed to estuarine food webs and their roots provide shelter for juveniles. The ecological functions of mangroves are nursery ground for fish larvae and fries. This was related to the availability of organic matter and detritus in the mangrove ecosystem that enter to the water utilized by aquatic organisms. Mangrove density influence the abundance and fish diversity in water around of mangrove area. The increased one unit of mangrove density would increase the fish diversity due to the available nutrients from organic materials trapped within the mangrove area[18].

On another hand, analysis of substrate showed that the substrate type was terrestrial sandy-clay. The species of *Sonneratia alba* prefer to grow at sandy-clay substrate. These mangrove trees density indicated that the inter-tidal forest in Sukol River was still in good condition.

Vegetation Analysis

The cross-sectional area of a single stem with the bark delineates the basal area. Usually, the breast height or sum of the cross-sectional areas of all stems in a stand are measured to get the basal area and expressed in per unit of land area. The total basal area implicates that the species has extensive diameter. If the diameter of tree is wider, total basal area will also increase, *Avicennia marina* has the record of the total lowest basal area that only occurs in one plot and low of distribution. The data suggests that the total number of seedlings per hectare showed a good regeneration potential. The tree sapling and seedling similarity matrices were positively correlated. The tree species number and seedling richness were associated the same suggesting that species were abundant in the presence of their mother trees.

The reasons for mangrove seedling remaining close to their mother trees could include poor dispersal of seedlings (such as weak tidal movement and canopy shape) and the presence of a suitable environmental habitat. The number of non-exclusive mangroves were negatively correlated with the trees, saplings and seedlings. This suggests that they were found in different habitats. The environmental conditions required by the seedlings and saplings or the non-exclusive member in some way inhibit or out compete the mangroves.

Implications

Research studies regarding diversity index and vegetation analysis of mangroves may deliver conservation campaigns for the existing ecosystem capable of supporting the fringing and riverine communities. In addition, creation of basic principles, guidelines for information dissemination, training modules and environmental awareness campaign becomes effective with new research data. On the other hand, assessment of existing mangrove areas is important in order to determine both the aboveground and belowground compartments which are pre-requisite for carbon loading estimation. Moreover, mangrove vegetation analysis includes models for computation of diversity indices which help researcher to test the homogeneity of the species.

CONCLUSIONS

Information regarding diversity index and species composition of the mangroves of Bongabong describes the structural complexity of the mangrove sites. Mangrove species dominating the area belongs to the family *Rhizophoraceae, Aviceniaceae, and Sonneratiaceae*.

On the other hand, mangrove ecosystem along the Sukol River, municipality of Bongabong, Oriental Mindoro has exhibited a relatively high biomass production. Prevalence of large girthed mangrove species are significant evidence of productivity. This indicator suggests their potential as carbon sink which is a relevant strategy for climate change mitigation.

ACKNOWLEDGEMENT

The author would like to acknowledge the Research, Extension and Development (RED) Unit of the Mindoro State University in granting internal fund for this research study.

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