FLORISTIC DIVERSITY AND DISTRIBUTION OF BIOMASS CARBON OF SELECTED AREAS IN THE CHILAW LAGOON, SRI LANKA

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INTRODUCTION

Studies on the distribution and diversity of mangrove species within the lagoons of Sri Lanka are highly varied. The floristic diversity and abundance of species of mangroves on the island are high. Both true mangroves and mangrove associates have been identified on the island. The 2012 Red Data List records 22 species of true mangrove belonging to 12 families on the island (Jayatissa, 2012). However, a more recent review in 2021 identifies 28 species that belong to 13 families (Arulnayagam et al., 2021). In other sources, the number of species of true mangroves is indicated to range from 17 – 25 (Jayasuriya, 1991; Pinto, 2020). To date, the most acceptable documentation of species diversity and threat status of mangroves species on the island is included in the 2020 National Red List for Flora. It includes a total of 27 species belonging to 14 families. 12 of these species belong to the threatened category and this includes 4 critically endangered species (*Lumnitzera littorea, Sonneratia apetala, Xylocarpus rumphii*, and *Ceriops decandra*) and 1 critically endangered (possibly extinct) species - *Acanthus ilicifolius var. integrifolius*. Other more common species that are encountered on the island include *Rhizophora mucronata*, *Aegiceras corniculatum*, and *Sonneratia caseolaris*. Thus, the need for a more concise review of the species of mangroves reported from the island is required.

The present study was undertaken to evaluate the species diversity present within the Chilaw Lagoon. Shannon diversity index and species evenness were calculated to compare the lagoon species diversity with other sites. Along with this, studies into the biomass carbon content in the study site and the contribution of each species to the total biomass carbon pool in the mangrove forest were determined. The information generated from this study will help diffuse some confusion surrounding the species diversity in the Chilaw Lagoon and provide information on biomass carbon pools that can be applied in other studies to understand the contributions of mangrove forests to global carbon dynamics.

METHODOLOGY

The site selected for the study was the Chilaw Lagoon complex, focusing on mangrove islands in the upper region of the lagoon. The lagoon is found in Pambala 7°31'08.5"N 79°49'26.6"E on the Western coast of the island in the Puttalam District of the North-western province. The average maximum and minimum temperatures recorded were 31ºC and 24 ºC respectively. The average rainfall is between 195 mm – 30 mm. The lagoon is 29.5 km in length and 02 km wide at its broadest and has a surface area of approximately 1800 ha. The lagoon is not very deep; depths range between 0.8 – 3m and have two outlets that connect to the sea - the Northern outlet is a narrow canal of 7.8km and the Southern outlet is one of 5.5km. The total direct catchment of the lagoon is 45.3 km3 (DFAR, 2013; CEA, 1994).

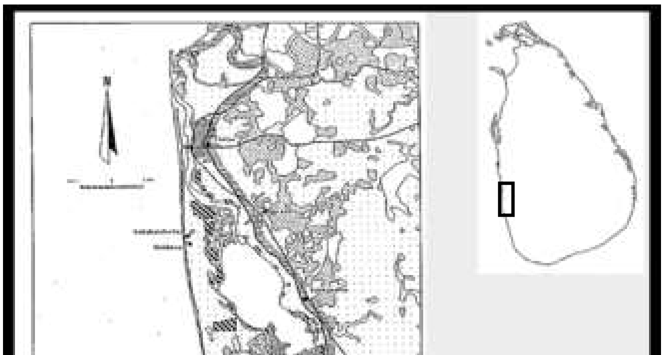

Figure 1: Map indicating study site

Four belt transects, divided into 10 m x 10 m plots were laid down in the upper region of the lagoon, focusing on the mangrove forest islands. As islands of mangrove forest were sampled, the length of the transects varied. The transects were laid down to capture the maximum level of vegetation diversity and structure.

Mangrove stands in the four study areas were visited and morphological features were recorded and species were identified. Specimens of the species which could not be identified in the field were brought to the laboratory, treated with formalin and they were subsequently identified using descriptive literature and taxonomic keys.

Shannon-Weiner's diversity index of richness and evenness was calculated using the conventional equations mentioned below. These two indexes provide an adequate description of the species composition and structure of the mangrove forests sampled.

For Shannon-Weiner diversity index:

Species richness is given by:

$$H=\sum[(p_i)\times\ln(p_i)]$$

where pi = proportion of total sample represented by species I

Species evenness is given by; $\frac{H}{H_{max}}$

$H_{max} = ln(S)$ = maximum diversity possible (where S = number of species)

To determine the biomass carbon, the diameter at breast height (DBH) of plants was obtained by measuring the circumference of stems of mangrove plants (circumference > 5cm) from the same transects mentioned above. A standard tape measure was used for this purpose. Allometric equations were applied to calculate the above-ground biomass (AGB) and the below-ground biomass (BGB) of each tree. The calculated biomass was pooled and multiplied by 0.56[1] to determine the total biomass carbon (TBC) that is present in the trees. The allometric equations utilized are summarised in the table below. Where available, species-specific allometric equations were used. In all other scenarios, common allometric equations were used.

Table 1: Allometric equations used to determine biomass in mangrove species

Species	Allometric Equations		Source
	Above Ground Biomass	Below Ground Biomass	
Common Equation	$0.251\ \rho\ dbh^{2.46}$	$0.199\ \rho^{0.899}\ dbh^{2.4}$	Komiyama et al., 2005
Rhizophora muconata	$\log_e(AGB) = 6.247 + 2.64 \log_e(dbh)$		Amarasinghe & Balasubramanium, 1996
Avicennia marina	$\log_e(AGB) =$		Amarasinghe & Balasubramanium,

[1] Total biomass carbon accounts for 56% of biomass (IPCC, 2001).

	$5.551+2.153\log_e$ (dbh)		1996
Bruguiera gymnorrhiza	$0.289(dbh)^{2.327}$	$0.100(dbh)^{2.364}$	Perera et al., 2011
Lumnitzera racemosa	$0.114\ (dbh)^{2.523}$	$0.118\ (dbh)^{2.063}$	Perera et al., 2011
dbh: Diameter at breast height (cm) **ρ: wood density of the corresponding mangrove species**			

RESULTS AND DISCUSSION

A total of 213 individual trees were identified, enumerated, and DBH measured for the study. Four belt transects in each of the selected mangrove islands were surveyed. A total area of 0.15 ha (1500 m^2) was surveyed during the field visits. The average stand density of the mangrove forests amounts to 1420 trees/ha. Zonation of mangroves was observed in the islands. *R. mucornata* and *R. apiculata* were found on the outer fringes of all islands that were surveyed and other recorded species were found predominantly in the interior.

Twelve true mangrove species belonging to six families were reported from the survey sites of the Chilaw lagoon. The most common species recorded was *B. cylindrica,* of which 78 individual plants were encountered. This accounted for 36% of the mangroves that were identified in the selected site. *A. marina, R. mucronata,* and *R. apiculata* were also identified in considerable frequencies, accounting for around 14%, 13%, and 10% of recorded species. In comparison, species such as *B. sexangula* and *X. granatum* were found to be the least abundant with only one individual from both species being identified. The relative abundance of the species in the study site is indicated below in Figure 01 and a complete list of species identified is shown in Table 01. Among the species recorded were two Endangered species (*B. cylindrica* and *X. granatum*), and two Vulnerable species (*B. sexangular* and *B. gymnorhiza*). It is worth noting that 78 individuals of endangered *B. cylindrica* were recoded from the survey sites.

Table 2*:* Mangrove species identified in the survey site, their relative abundance, and threat status

Species	No. of trees	Relative abundance of species	Threat status
Bruguiera cylindrica	78	36.62	EN
Avicennia marina	30	14.08	LC
Rhizophora mucronata	28	13.15	LC
Avicennia officinalis	23	10.80	NT
Rhizophora apiculata	23	10.80	NT
Excoecaria agallocha	14	6.57	LC
Bruguiera gymnorhiza	5	2.35	VU
Aegiceras corniculatum	4	1.88	LC

Rhizophora anamalayana	3	1.41	NE[2]
Lumnitzera racemosa	3	1.41	NT
Bruguiera sexangula	1	0.47	VU
Xylocarpus granatum	1	0.47	EN

The diversity and the evenness of mangrove species in the study site were calculated assuming that the four transects were representative of the entire mangrove community in the lagoon. Accordingly, calculated Shannon's index was 1.90 and the evenness 0.76 respectively.

In relation to biomass carbon calculation, the DBH of a total of 357 plant stems was measured. The average stem density was calculated at 2380 stems/ha. The total biomass and biomass carbon content of the Chilaw lagoon were calculated to be 183 $Mgha^{-1}$ and 102.8 MgC ha^{-1} respectively. The contribution of each species to the overall biomass and carbon content in the mangrove community of the Chilaw lagoon is depicted in Table 02 below. Above-ground biomass carbon accounted for the larger portion of total biomass carbon. The above-ground biomass carbon and below-ground biomass carbon were 12.80 MgC and 2.6 MgC respectively.

Table 3: Contribution of each species to biomass and biomass carbon content of total biomass

Species	No. of individuals	Total biomass (Mg)	Total Organic C (Mg)	% Biomass/carbon contribution
A. corniculatum	4	0.11	0.06	0.41
A. marina	30	4.21	2.36	15.27
A. officinalis	23	8.05	4.51	29.21
B. cylindrica	78	9.23	5.17	33.50
B. gymnorhiza	5	0.05	0.03	0.20
B. sexangula	1	0.02	0.01	0.06
E. agallocha	14	1.32	0.74	4.78
L. racemosa	3	0.07	0.04	0.25
R. apiculata	23	1.16	0.65	4.22
R. mucronata	28	2.31	1.29	8.37
R. anamalayana	3	1.01	0.57	3.68
X. granatum	1	0.01	0.01	0.04

[2] *R. anamalayana* is a hybrid species which is not listed in the National Red List 2020. It is included here as it still contributed to the diversity in the lagoon.

CONCLUSIONS/RECOMMENDATIONS

Twelve species of mangroves belonging to four families were identified from the lagoon. This number of species recorded is similar to Cooray et al., (2021), Jayasundara et al., (1999), and Jayasuriya (1991) who identified 10 species, 13 species, and 15 species respectively within the Chilaw lagoon. The most common species identified in the study was *B. cylindrica* (accounting for 36% of species that were encountered). *A. marina, R. mucronata, and R. apiculata* also occurred in considerable frequencies, accounting for around 14%, 13%, and 10% of recorded species. Previous studies carried out in the Chilaw lagoon, show differences in dominant mangroves. *E. agallocha* was reported to be the most common species encountered by Jayasuriya (1991), and Nigamuni & Subasinghe, (2015). Jayasundara et al., (1999) have reported *A. officinalis* as the most abundant mangrove species in the lagoon and contrary to findings in the present study, showed that *B. cylindrica* is the least abundant species in the lagoon. Amarasinghe & Perera (2017) identified *L. racemosa* as the most abundant species encountered in the Chilaw lagoon. Cooray et al., (2021) identified *R. apiculata* and *R. mucronata* as co-dominating species in the lagoon complex.

Diversity indexes are ideal tools for comparative studies on species diversity. Shannon index indicates the degree of diversity of species present in a site, relating to the proportion of species in the sample. Thus, in comparison to indexes such as Simpsons index, it is considered to be more suited for comparative studies[3] (Morris et al., 2014). Shannon diversity index and the evenness of diversity of the Chilaw lagoon were 1.09 and 0.67 respectively. When comparing Shannon's indexes calculated elsewhere; Negambo Lagoon indicates a value of 2.32 (Nigamuni & Subasinghe, 2015), Puttalam Lagoon, 0.76 (Nigamuni & Subasinghe, 2015), and Mandaitivu and Arali was 2.02 and 1.79 respectively (Arulnayagam, 2021). This indicates that the diversity in the Chilaw Lagoon is comparatively high. However, Nigamuni & Subasinghe (2015) reported the Shannon index for the Chilaw lagoon as 2.18. The discrepancy could be due to differences in the species composition, dominance, and other flora characteristics of the limited area which was surveyed during field studies.

Field studies of the present investigation were only carried out in the upper islands of the lagoon as these areas were found to be the most susceptible sites to impacts of rising sea levels. Similarly, Jayasundara et al., 1999, restricted their study sites to the lower region of the lagoon, thus additional studies covering sites throughout the lagoon would provide a more accurate and holistic representation of the flora of the lagoon.

In regard to biomass carbon the largest contribution to biomass carbon is from *B. cylindrica*, the highest species recorded (78 individuals). *B. cylindrica* contributed biomass and biomass carbon content of 9.23 Mg and 5.17 MgC respectively, representing 33.50% of the calculated proportion. *A. officinales* was the second-highest contributor to the biomass and biomass carbon amounting to 29.21% of calculated stocks (8.05 Mg of biomass and 4.51 MgC). *B. gymnorhiza, B. sexangula*, and *X. granatum* represented the lowest number of species recorded and also the lowest contributor to the biomass and carbon stock. The findings can help shape future programs of restoration and replanting to determine which species of mangroves may be grown to ensure maximum carbon capture and storage.

[3] Simpson's index relies more on dominance and gives more weight to dominant species.

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