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RESEARCH ARTICLE

Species composition, abundance and diversity of mangroves in selected sites in Amprara District in the east coast of Sri Lanka

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Abstract: Sri Lanka is gifted with about 15,670 ha of mangrove habitats which are scattered along the coastal zone of the island. However, most of the studies on mangroves are confined to the western, north-western and southern parts of the country. Although it is been neglected, Eastern province shares 28% of the mangrove cover of the country. Thus, the main objective of the current study was to determine the distribution, abundance and diversity of true mangrove species in Pottuvil, Heda oya, Ragamwela, Panama, and Okanda mangroves in the Eastern province of Sri Lanka. Mangrove vegetation was sampled using belt transects of 5 m in width laid perpendicular to the shoreline and across the water-land gradient. True mangrove species in each transect was identified and counted. Height and DBH (Diameter at Breast Height) were recorded. Relative density, relative frequency, relative dominance and the IVI (Importance value index) of the species in each mangrove ecosystem were calculated. Shannon diversity index (H'), Shannon Evenness (E') and Simpson index was used to compare the diversity between sites. Nine true mangrove species were recorded in Panama lagoon and the least number of species (3) were recorded from Ragamwela creek. Highest Shannon diversity value (H' = 1.7) was obtained for the Panama mangrove which was followed by the Heda Oya Estuary mangrove (H' = 1.1). Lowest Simpson index was recorded in Panama lagoon (0.22). Nearly half of the true mangrove species (11) that have been recorded from Sri Lanka occurs in the five study sites. They belongs to seven families and eight genera. More research is needed to understand the ecological aspects of theses mangroves as these systems have not been studied for the last thirty years. It is recommended that immediate action should be taken by the government to prevent distractive anthropogenic activities in these mangrove ecosystems.

Keywords: Mangroves, Zonation, Diversity insiders, Importance Value Index.

INTRODUCTION

Mangroves are specialized vegetation types confined to the intertidal zone of the tropical and some subtropical areas in the world (Aksarnkaae, 1993; Tomlinson, 1994; Kathiresan and Bingham, 2001). Mangrove ecosystems provide many services like protection of lives and property during coastal disasters, enhancement of fisheries and protection of biodiversity as mangroves are habitats to numerous flora and fauna, climate control through carbon sequestration and storage of carbon for long periods in soil, pollution abatement, primary production and recreation (Das and Crepin, 2017). Furthermore, mangrove ecosystems have been recognized as highly-efficient wetland systems that can be used for the treatment of urban wastewater and for remediation of heavy metal-polluted coastal environments (Liu *et al.,* 2009). Mangroves host a large array of associated floral and faunal communities by providing food, habitats and shelter for their survival (Spalding *et al*, 2010). In some descriptive studies of mangrove ecosystems, emphasis has more recently been given to their functional role in sustaining these intertidal ecosystems (Dodd, 1998). Furthermore, consolidation of sediment by mangroves reduces erosion and contributes to reduce turbidity of ocean waters which is important for coral reefs and sea grass ecosystems (Engelhart *et al.,* 2007). In terms of climate change mitigation, mangrove ecosystems play an essential role in removing atmospheric carbon dioxide and climate regulation through photosynthesis (Vo *et al.,* 2012). Thus, this ecosystem has been recognized to be of high ecological and economic importance and in general, the economic value has been calculated as in the range of USD 2,000 to USD 9,000 per hectare per year (Spalding *et al*., 2010)

Mangroves in Sri Lanka show a scattered distribution around the country in areas bordering lagoons and estuaries (Bambaradeniya *et al.,* 2002). The extent of mangroves in Sri Lanka is about 15,670 ha (Edirisinghe *et al.,* 2012) which is less than 0.03% of the total land area. Twenty-one true mangrove species (MOE, 2012) and approximately 23 mangrove associate species have been recorded in Sri Lanka (IUCN, 2009). Coastline of Sri Lanka is approximately 1,600 km long and the total extent of brackish water areas, including estuaries and lagoons, is about 158,016 ha (Perera *et al*., 2013). The eastern province consists of three administrative districts and it covers about 16% of

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the country's land mass. The Eastern province shares many natural resources such as approximately 25% of the beach (420 km), 25% of the lagoons, 28% of the mangroves, 31% of freshwater marshes, 5% of sand dunes of the country (Jayasingam, 2008).

In Ampara District mangrove ecosystems have been distributed discontinuously along the shoreline. Pottuvil and Panama are two of the major lagoons in the Ampara district. They support some well-grown mangrove ecosystems (personal observations by the authors). However, majority of mangrove studies conducted in last three decade in Sri Lanka were restricted to Southern, Western and North Western provinces (Amarasinghe and Perera, 2017). After the past civil war in North and Eastern province of the country some research have been carried out in North and Eastern province by a few researches (Amarasinghe and Perera, 2017). However, most of these were restricted to Trincomalee and Batticoloa Districts. No reports available on mangroves in Ampara District except the preliminary study conducted by Prasanna *et al.,* (2017). This is may be due to poor accessibility of these mangrove areas. Thus, the objective of this study was to study the mangrove vegetation, their distribution, abundance and diversity of true mangrove species in the lagoons, estuaries and creeks in the coastal stretch of Pottuvil to Okanda in the Ampara district.

According to a preliminary study conducted by Prasanna *et al*., (2017), 16 true mangrove species have been recorded from Eastern Province and eight of those were common to all three Districts. Twelve true mangrove species had been recorded in Ampara district (Prasanna *et al*., 2017).

METHODOLOGY

Study sites

Five mangrove ecosystems located in the coastal stretch from Pottuvil to Okanda in Ampara District were studied in this project. These ecosystems were located on Eastern coastal belt of the country. The studied mangrove ecosystems were Pottuvil lagoon, Heda Oya estuary, Ragamwela creek, Panama lagoon and Okanda creek. These mangrove areas extend over about 35 km on the coastal stretch of the Eastern coast (Figure 1).

All the study sites are located in the dry zone of Sri Lanka. Seasonal rains dominate the climate with one prominent season with heavy rains from December to February (North East monsoon). Average annual rainfall of the sites range from 1200-1500 mm and mean annual temperature range from 30 – 32 ^{o}C (Jayasingam, 2008). Although, the tidal inundation of this area is very low (<75 cm), during the rainy season whole mangrove areas were submerged by flood water (personal communication and field observations). Most of the coastal belt is dominated by dry mixed evergreen forests and sand dunes (Jayasingham, 2008).

Vegetation sampling

Mangrove vegetation was sampled using belt transect method. Transects were randomly located in the mangrove vegetation from the shoreline towards land. Length of the transects were determined according to the breadth of the mangrove stand, while the width was 5 m. About 10 % of the area of each mangrove site was sampled. Each transect was divided in to 5 m x 5 m sub plots for convenience of sampling. Within each transect true mangrove species were identified and counted. Tree height and the DBH (Diameter at Breast Height) of individuals of true mangrove species were recorded. Data were collected from 608 transects laid in the above five study sites (Table 1).

Data analysis

Quantitative data were used to calculate the relative density, relative frequency (Magurran, 2004), relative dominance and the Importance value index (IVI,) of the species in each mangrove site. Furthermore, diversity indices based on species richness (Margalef Index, D_{Mg}), proportional abundance (Shannon Index H′) were computed. Species dominance was estimated using Simpson (D – 1) index and Shannon Evenness (E) was also computed. These indices were used to explain and compare the diversity of selected Mangrove ecosystems. Shannon index of each mangrove site were compared with others using Hutcheson t-test. Gamma diversity of the studied region was described.

RESULTS

Species Distribution

Eleven true mangrove species were recorded in the studied sites located in Ampara District. Only two mangrove species, *Lumnitzera racemosa* and *Excoecaria agallocha* were common to all five study sites, while *Aegiceras corniculatum, Avicennia officinalis, Bruguiera sexangula* and *Pemphis acidula* each were restricted to a single site (Table 2). Nine true mangrove species were recorded in Panama lagoon while the least number of species (3) were recorded from Ragamwela creek. *L. racemosa* was the most abundant mangrove species in Ragamwela creek, while *Avicennia marina* was the least abundant mangrove species in the same site. *E. agallocha* recorded the highest relative density in the Pottuvil lagoon, Panama lagoon and Heda Oya estuary, while *L. racemosa* recorded with the highest relative density in the Ragamwela and Okanda creek mangroves. *P. acidula, B. sexangula* and *A. officinalis* were recorded only at Panama lagoon (Table 2).

Diversity indices

As revealed from Hutcheson t-test, Shannon diversity values of different study sites were significantly different from each other (Table 3). Highest Shannon diversity value (H' = 1.7) and the lowest Simpson index value (0.22) was obtained for the Panama mangrove which was recorded highest number of species among all study sites, followed by the Heda Oya estuary mangrove (H' = 1.1). Above two sites were also had the highest Shannon Evenness values (Table 4). The highest Dominance value was (0.78) recorded in Panama lagoon, while the lowest (0.25) in Ragamwela creek. Shannon diversity index for the whole mangrove area is 1.43.

As explained, Highest Shannon and evenness values

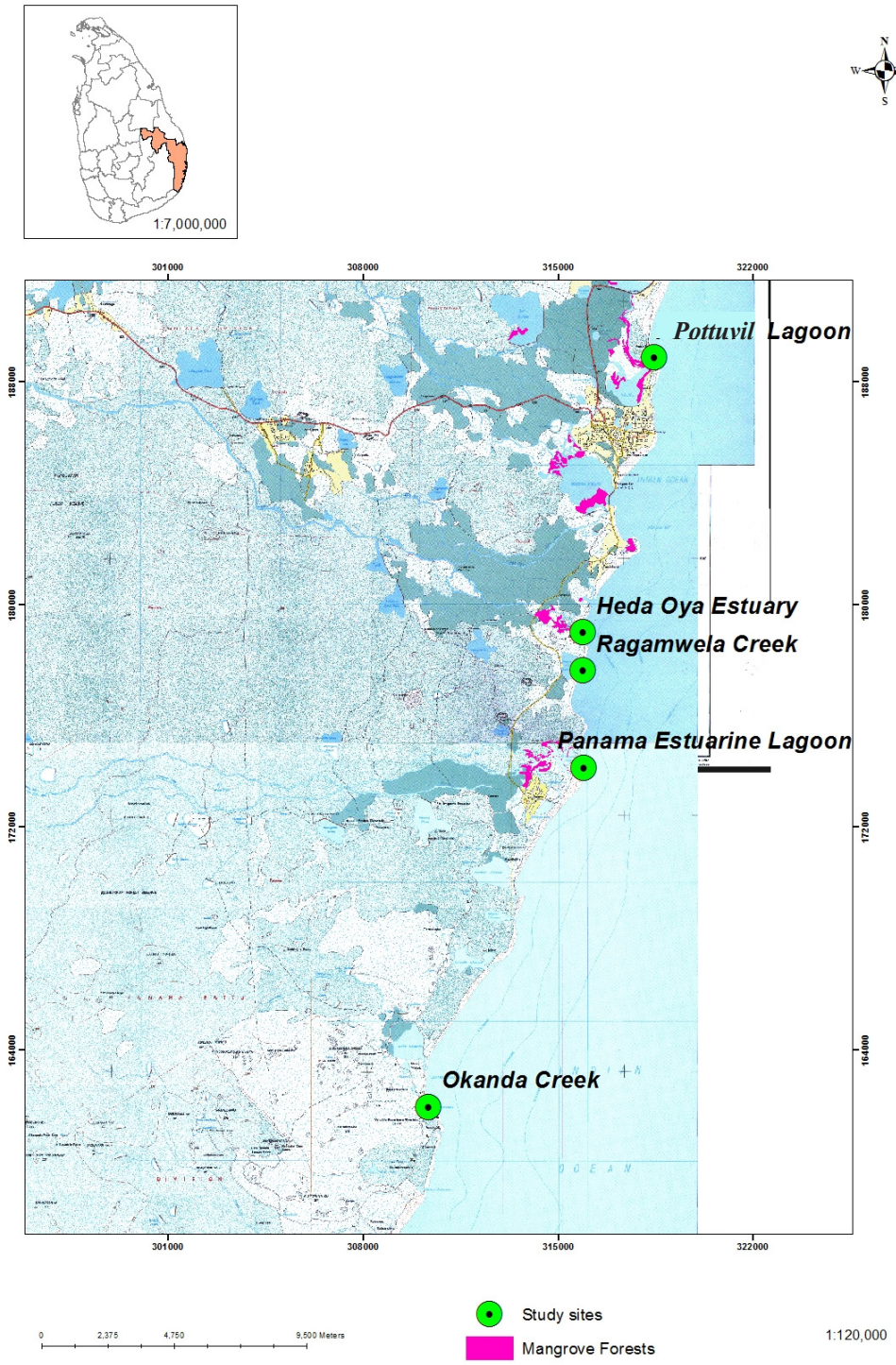

Figure 1: Location of the study sites (Modified from Survey Dept. Map).

Table 1: Study locations with number of transects studied in each location.

Study Site	No. Transects	Area covered (m²)
Pottuvil Lagoon	208	9,100 m²
Heda Oya Estuary	126	4,100 m²
Ragamwela Creek	29	725 m²
Panama Lagoon	206	12,425 m²
Okanda Creek	39	1,725 m²

Table 2: Abundance and Distribution of Mangroves in Selected Sites.

Family	Species	Pottuvil Lagoon	Heda oya Estuary	Ragamwela Creek	Panama Lagoon	Okanda Creek
Myrsinaceae	*Aegiceras corniculatum*	+++	-	-	-	-
Avicenniaceae	*Avicennia marina*	-	-	+	+	++
	Avicennia officinalis	-	-	-	+	-
Rhizophoreceae	*Bruguiera gymnorrhiza*	+++	++	-	+	++
	Bruguiera sexangula	-	-	-	+	-
	Rhizophora apiculata	-	++	-	+	-
	Rhizophora mucronata	++++	-	-	++++	+++
Sterculiaceae	*Heritiera littoralis*	+	++	-	-	-
Combretaceae	*Lumnitzera racemosa*	+++	+	++++	++++	++++
Lythraceae	*Pemphis acidula*	-	-		+	-
Euphorbiaceae	*Excoecaria agallocha*	++++	++++	++++	++++	++++
Total no. sp.	11	**6**	**5**	**3**	**9**	**5**

Absent = -, Less than 100/ha = + (Very Rare), More than 100/ha = ++ (Rare), More than 200/ha = +++ (Common), More than 300/ha = ++++ (Very Common) (Jayathissa *et al*., 2002)

Table 3: Hutcheson t-value and associated probability calculated for pairs of study sites.

		P values				
		Pottuvil	Hada Oya	Ragamwela	Panama	Okanda
Hutcheson t-value	Pottuvil		0.044	<0.001	<0.001	<0.001
	Hadaoya	2.0		<0.001	<0.001	<0.001
	Ragamwela	44.0	28.8		<0.001	<0.001
	Panama	36.4	22.4	98.5		<0.001
	Okanda	3.9	4.8	16.2	23.2	

Table 4: Diversity indices obtained for studied mangrove ecosystems.

	Pottuvil Lagoon	Heda oya Estuary	Ragamwela Creek	Panama Lagoon	Okanda Creek
No. of Species (S)	6	5	3	9	5
No. Individuals (N)	122504	3518	149572	2873	5426
Simpson (D)	0.44	0.46	0.75	0.22	0.52
Shannon (H')	1.041	1.09	0.41	1.66	0.91
Evenness (E)	0.581	0.68	0.38	0.76	0.57
Dominance (1-D)	0.55	0.54	0.25	0.78	0.48

Table 5: Importance Value Index of mangrove species observed in each study cite.

Species	Study Sites				
	Pottuvil	Panama	Heda oya	Ragamwela	Okanda
Aegiceras corniculatum	20.16				
Avicennia marina		83.13		3.46	61.31
Avicennia officinalis		34.39			
Bruguiera gymnorrhiza	26.19	8.54	66.47		20.82
Bruguiera sexangula		8.57			
Excoecaria agallocha	179.03	128.58	163.38	77.66	122.69
Heritiera littoralis	0.59		67.45		
Lumnitzera racemosa	19.31	64.58	9.67	274.08	194.73
Pemphis acidula		1.56			
Rhizophora apiculata		1.92	50.18		
Rhizophora mucronata	148.51	112.16			26.08

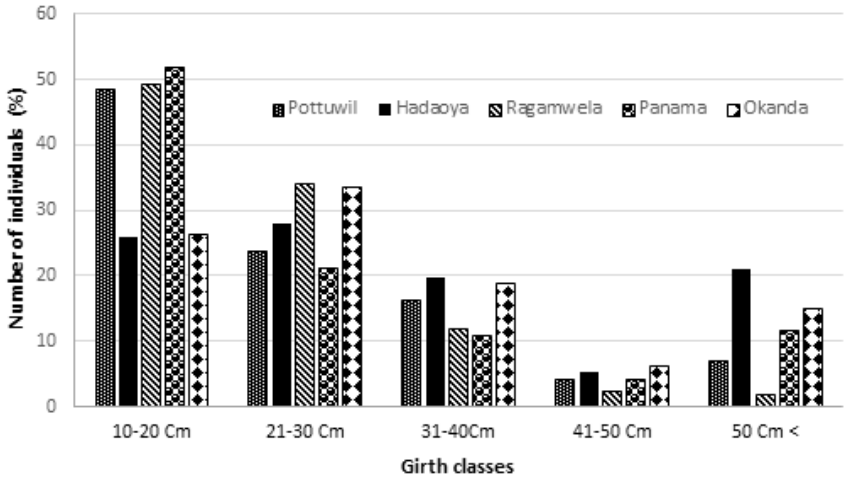

Figure 2: Girth classes distribution of individuals of mangrove species in each study site.

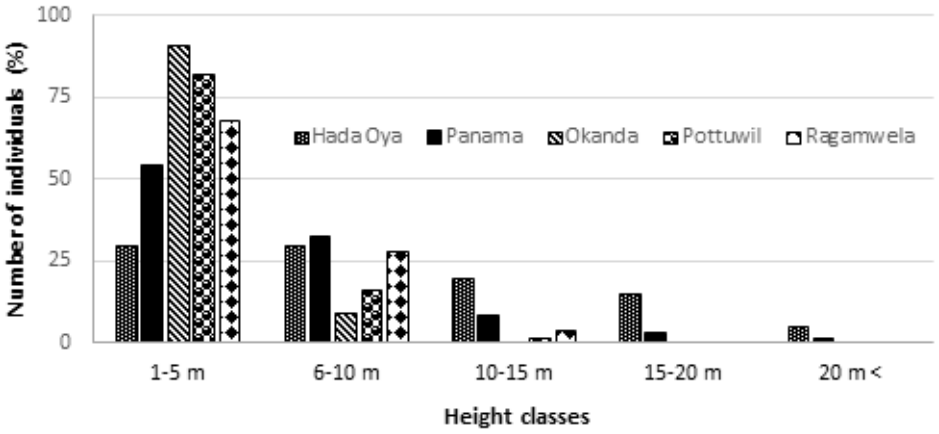

Figure 3: Height classes distribution of individuals of mangrove species in each study site.

were obtained in Panama lagoon. The least Shannon H' and evenness (E) was recorded in Ragamwela creek at 0.41 and 0.38, respectively. Though the species richness was same in both ecosystems namely, Hada Oya estuary and Okanda creek, the diversity and evenness could be changed with the number of species present in the sampling site and with stand tree density (Krishnanantham *et al*., 2015). Simpson's Index of Diversity (1-D) is between 0.75 - 0.22 among all study sites. The lowest Simpson's Index of diversity has been recorded in the Panama lagoon, while the highest value has been recorded in Ragamwela Creek. The lowest Simpson's Index of diversity has been recorded in the Panama estuarine lagoon, while the highest value has been recorded in Ragamwela Creek.

Importance Value Index

IVI for species was calculated for the five sites separately and for all the mangrove areas together enabling comparison with other mangrove areas in Sri Lanka. Among all observed mangrove species the highest IVI was obtained for *L. racemosa* in Ragamwela creek (274.08) while the lowest IVI was recorded for the *H. littoralis* (0.59) in Pottuvil lagoon. IVI of *E. agallocha* in Heda Oya estuary, Panama lagoon and Pottuvil lagoon mangroves were relatively high. *L. racemosa* recorded highest IVI in Okanda creek and Ragamvela creek (Table 5).

Height and girth class distribution of the mangrove species

Except for Heda Oya and Okanda mangrove sites, all the other mangrove sites consist of > 40 % of the individuals in the girth class 10 -20 cm (Figure 2). In the Heda Oya and Okanda mangroves, ~ 40 and 35 % of the individuals, respectively were in the girth class category 31-40 cm or above. A similar situation could be seen when the height class distribution was considered. Except in Heda Oya, > 50 % individuals in all the other sites were within the height class of 1-5 m (Figure 3). In Heda Oya ~ 40 % individuals were in the height class of 10-15 m or above, whereas, only 30 % of the individuals of mangroves in Heda Oya were in the 1-5 m height class.

DISCUSSION

Nearly half of the true mangrove species (11) recorded in Sri Lanka occurs in the five study sites (Table 2) and they belong to eight genera and seven families. All sites

are situated in the same geographic as well as in the same climatic region. However, species distribution showed considerable differences. This may be attributed to differences of these mangroves with respect to their hydrology, soil salinity variations and other edaphic factors (soil nutrition, texture, bulk density etc.). Mangrove ecosystem in associated with Panama lagoon was the most diverse system among all the study sites (Table 4). Thus, this particular mangrove community can be identified as one in a higher successional stage because around 40% of plants were exceeding 20 cm of girth and less disturbed site than the other studied sites. Same factor is revealed from the tree height measurements of individuals. Further, Panama mangrove harbors both high salinity preferring as well as low salinity preferring species as it is an lagoon as well it is connected with the Wila Oya which is a branch of Hada Oya in the upper area. Although, *Sonneratia caseolaris* has been recorded as a common mangrove species in mangroves of Ampara District (Prasanna *et al*., 2017), we did not encounter this species in any of the five study sites.

Species richness and diversity in five selected sites were significantly varied from one another as revealed by the Shannon diversity index (Table 3, $p < 0.05$). This could also be attributed to the differences is hydrology that can affect seed/ seedling dispersal and therefore, the variability of seed rain characteristic to each study site, soil salinity and degree of human interference. However, according to the survey *L. racemosa* and *E. agallocha* were recorded in all five sites, while *P. acidula* was recorded only from Panama lagoon mouth. During the study, Considerable number of individuals of dead *P. acidula* plants were also observed and this is probably due to the changes of wave patterns due to the high speed heavy naval boats operating in the lagoon and recently constructed artificial water breaker in the right bank of lagoon mouth. *P. acidula* is naturally found on sandy substratum close to the beaches/ sea, mouths of lagoons and estuaries. According to our field observations remaining living trees are also not in good condition and thus this species could be wiped out from this site. Unfortunately, this is the only known site of *P. acidula* in the Ampara District of the east coast of Sri Lanka.

Species diversity of the study sites of the Ampara district is lower than that of the sites in Kala Oya estuary (1.34 - 1.76) as reported by Perera *et al*., (2013) except for that of the Panama lagoon which has a similar diversity to sites in Kala Oya estuary. Further, the species diversity of all the study sites have higher diversity and evenness than those reported for Irakkandy lagoon in Batticoloa (H'= 0.86 and E = 0.54 as reported by Krishananantham *et al*., 2015), except for the Ragamwela creek which recorded the lowest diversity during the current study. Diversity indices indicated that diversity of the study area is moderate and similar to that observed in the Western dry zone mangroves of Sri Lanka. Shannon diversity index calculated for the mangroves in the whole study area was higher than that of Irakkandy lagoon (Krishananantham *et al.,* 2015) and it is similar to those recorded for Kala Oya estuary by Perera *et al.* (2013).

Distribution of *E. agallocha* in Panama and Pottuvil lagoons is more extensive than in the other mangrove areas. Bark of *E. agallocha* contains a poisonous latex, which irritates skin and eyes if they come into contact and it may even cause blindness (Kathiresen, 2015). Therefore, wood of this species is not used as firewood. Leaves of *E. agallocha* were not preferred as fodder by wild animals and other livestock species such as cows and goats (Mathiventhan and Jayasingam, 2012). This species has the ability to grow in waters edge with high salinity as well as a back mangrove with low salinity. Further, this plant is also observed in muddy substrata as well as in sandy soils. According to Feller and Sitnik (1996), some mangrove species have double distribution; a broad capacity to tolerate environmental conditions and consequently, they may be abundant in two different zone in the same ecosystem. This must be the reason for high density of *E. agallocha* in all the study areas. On the other hand, unusual abundance of *E. agollocha* may also be because that other species in the ecosystem have been utilized (cut) by people for various purposes and *E. agallocha* is left behind as it is not used due to the reasons discussed above.

The importance value index (IVI) is very important to compare the ecological significance of species (Lamprecht, 1989). It indicates the extent of dominance of a species in the structures of a forest stand (Curtis and McIntosh, 1951). It is specified that species with the greatest importance value are the dominants of the forest. Accordingly, *L. racemosa* and *E. agallocha* are the most important mangrove species in all the major mangrove areas in Ampara District. An IVI value of 174.58 has been reported in Batticaloa lagoon for *E. agallocha* by Perera and Amarasinghe (2014). It was slightly lower than the value obtained at Pottuvil lagoon (179.03), while slightly higher than that observed in all the other study sites (Figure 4.1). In the same study, Perera and Amarasinghe in 2014 have recorded, IVI as 88.08 for *R. mucronata* in Batticaloa lagoon which was less than the IVI reported in the present study for *R. mucronata* at Pottuvil lagoon (148.51), Panama lagoon (112.16), while higher than the Okanda creek (26.08). Perera and Amarasinghe (2014) have also reported IVI values of *R. mucronata* and *A. marina* as 87.73 and 63.94, respectively in the Uppar lagoon in the east coast of Sri Lanka.

According to the study, the mangrove ecosystems in the Ampara district were highly diversified. However, all the study sites were under various kind of anthropogenic pressure. The man made canal through the lagoon mouth, which is used to move large naval boats in Panama lagoon is undesirable for the health of the lagoon, specifically to the mangrove vegetation. It might change the natural hydrology and chemical parameters of the lagoon and caused a change of the distribution of mangrove species and disturb life cycle of crustaceans such as shrimps and crabs. This man-made canal keeps the lagoon open to the sea throughout the year. All those have provided habitats for large number of faunal species especially Pottuvil and Heda Oya mangrove are the only mangrove ecosystems in the country where elephants are residing as nearby villagers confirmed that elephants inhabit this mangrove patch for more than three months a year. Therefore, it is

necessary to take immediate action to provide proper legal protection through forest protection ordinance by declaring all those mangrove ecosystems as conservation forest or at least forest reserves.

REFERENCES

Aksarnkaae, S. (1993), *Ecology and Management of Mangroves*, The International Union for Conservation of Nature and Natural Resources (IUCN), Bangkok, Thailand, 176.

Amarasinghe, M.D. and Perera, K.A.R.S., (2017), Ecological Biogeography of Mangroves in Sri Lanka, *Ceylon Journal of Science*, **45**:119-125.

Amarasinghe, M.D. and Perera, K.A.R.S., (2017), Historical Biogeography of Sri Lankan Mangroves, *Ceylon Journal of Science*, **46** (Special Issue), 111-117.

Bambaradeniya, C.N.B., Ekanayake, S.B., Kekulandala, L.D.C.B., Fernando, R.H.S.S., Samarawicrama, V.A.P. and Priyadarshana, T.G.M. (2002). *An Assessment of the Status of Biodiversity in the Maduganga Mangrove Estuary*, Occasional papers of IUCN Sri Lanka, **1**:49.

Curtis, J.T. and McIntosh, R.P. (1951). An Upland Continuum in the Praine Forest Border region of Wisconsin. *Journal of Ecology* **32**:476-496.

Das, S. and Crepin, A. S., (2017). Mangrove can provide Protection against Wind Damage During Storms. *Journal of Estuarine, Coastal and Shelf Science* **134**:98-107.

Dodd, R.S., Radii, Z. A., Fromard, F. and Blasco, F. (1998). Evolutionary diversity among Atlantic coast mangroves. *Oecologia* **19**:323-330.

Edirisinghe, E.A.P.N., Ariyadasa, K.P. and Chandani, R.P.D.S. (2012). Forest Cover Assessment of Sri Lanka, *The Sri Lankan Forester* **34**: 1-12.

Engelhart, S.E., Horton, B, Roberts, P.D.H., Bryant, L.C. and Corbett, D.R. (2007), Mangrove Pollen of Indonesia and Its Suitability as a Sea-Level Indicator. *Journal of Marine Geology* **242**:65-81.

Feller, I.C. and Sitnik, M., (1996), *Mangrove Ecology,* Smithsonian Institute, Washington, 1-13.

IUCN, International Union for Conservation of Nature (2009). *Mangroves: A resource book for secondary school teachers.* Colombo: IUCN Country office, iv + 48.

Jayasingam, T., (2008). Eastern Province Biodiversity Profile and Conservation Action Plane, Biodiversity Secretariat, Ministry of Environment and Natural Resources, X+63.

Jayathissa, L.P., Dahdauh, F, Koedam, N., (2002), A review of the floral Composition and Distribution of mangrove in Sri Lanka, *Botanical Journal of Linnaean Society*, **138**:29-43.

Kathiresan, K., Bingham, B.L., (2001), *Biology of Mangrove and Mangrove Ecosystem*, Center for Advances Studies in Marine Biology, **40**:81-251.

Kathiresan, K., (2015), *Biology of Mangroves*, International, Training Cause on Mangrove Biodiversity and Ecosystems; Training Manual, Center for Advance Studies on Marine Biology, Annamalei University, Parangipetthai, India, 753.

Krishnanantham, K., Seneviratne, Y.B.M.C.J. and Jayamanne, S.C. (2015). A preliminary study on vegetation structure and mangrove diversity in Irakkandy lagoon, Trincomalee. *Journal of tropical Forestry and Environment,* **5**:59-70.

Lamprecht, H., (1989). *Silviculture in the tropics Tropical Forest Ecosystems and their Tree Species Possibilities and Methods for their long-term utilization*, T2Verlagsgesells chaftmbH, postatch 1164, D6101, RoBdort, Federal Republic of Germany. 296.

Liu, Y., Tam, N.F.Y., Yang, J.X., Pi, N., Wong, M.H. and Ye, Z.H., (2009). Mixed Heavy Metals Tolerance and Radial Oxygen Loss in Mangrove Seedlings. *Marine Pollution Bulletin* **58**:1843-1849.

Magurran, A.E. (2004). *Measuring Biological Diversity*. Wiley-Blackwell, Hoboken, NJ, USA, X+179

Ministry of Environment, (2012), *The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna & Flora*; Ministry of Environment, Colombo, Sri Lanka, viii + 476.

Perera, K.A.R.S. and Amarasinghe, M.D. (2014), Effect of Vegetation Structure on Carbon Assimilation Capacity of Mangrove Ecosystems in the East Coast of Sri Lanka, *Journal of Coastal Development* **17**:1410-5217.

Perera, K. A. R. S., Amarasinghe, M. D. and Somaratna, S. (2013). Vegetation Structure and Species Distribution of Mangroves along a Soil Salinity Gradient in a Micro Tidal Estuary on the North-western Coast of Sri Lanka. *American Journal of Marine Science* **1**: 7-15.

Prasanna**,** M. G. M., Ranawana, K. B. Jayasuriya, K.M.G.G., Abeykoon, P., Ranasinhe, M., (2017), Mangrove Species Distribution, Diversity and Present Status in The North and East Coast of Sri Lanka, *Journal of Wild Lanka*, of Wildlife Conservation of Sri Lanka, 90-98 ,

Spalding, M., Kainuma, M., Collins, L., (2010) *World Atlas of Mangroves*, ITTO. ISME, FAO, UNEP, WCMC, UNESCO, -MAB and UNU-INWEH. 319.

Tomlinson, P.B., (1994), *The Botany of Mangroves*, Cambridge University Press: xii + 419pp.

Vo, Q.T., Kuenzer, C., Quang Minh Vo, Q.M., Moderd, F. and Oppelt, N. (2012), Review of valuation methods for mangrove ecosystem services. *Journal of Ecological Indicators* **23**:431-446.