Present status of mangroves and sea grasses in the upper western border of the Puttalam Lagoon, Sri Lanka

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Abstract

A study was conducted in 2021 to gather baseline information on species composition, density and diversity of mangrove and seagrass ecosystems and structural parameters of mangroves in the upper western boarder of the Puttalam, which is a potential area for coastal development. Belt transect method was employed to measure Diameter at Breast Height (DBH), height, density and diversity of mangroves. For seagrass meadows, quadrat and transect methods were used to obtain the species coverage at four sampling stations; Uchchimunai, Bottuwadiya, Kirimudal and Mohottuwaram. Although seven true mangrove species belonging to five families were identified during the survey, several dense mangrove patches were observed in certain areas. Important Value Index (IVI) indicated that 136.60 in *Rhizophora mucronata* and 130.63 in *Ceriops tagal*. IVI=130.63 is structurally most important. *Thespesia populnea* and *Phoenix* sp. were the most abundant mangrove associates found in the mangrove lands. The results revealed that mangroves were dominated by small sized trees, showing 70% of them with thin stems (<10.0 cm) and 54% the mangroves were less than one meter height; hence the structural Complexity Index (CI) of the forest (CI = 0.16) was low. The Shannon Diversity Index (SDI), Evenness (EVI) and Dominance (DOI) were 1.22, 1.01 and 0.57 respectively. These values depicted that the mangrove forests were dominated by few major species; coincided with low species diversity. The seagrass species composition of the study area was indicated as *Oceana serrulata* (13.92%), *Cymodocea rotundata* (12.93%), *Enhalus acoroides* (9.22%), *Halodule uninervis* (2.08%), *Thalassia hemprichii* (11.68%), *Halophila decipiens* (0.07%) and *Halophila ovalis* (0.16%). The esimated values for SDI in the four sampling stations, ranged from 1.03 to 1.45 and EVI ranged from 0.64 to 0.81. This study revealed that the area is an ecologically sensitive and effective plans are essential to conserve the seagrass and mangrove ecosystems while considering future developments.

Keywords: mangroves, seagrass, diversity, species coverage, conservation

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Introduction

Puttalam Lagoon, is one of the prominet lagoons located in the Northwest coast of Sri Lanka,which provides variety of ecosystem services including fisheries, aquaculture, transport, tourism, timber and habours. It is a very productive and complex ecosystem consisting of open waters, mudflats, seagrass, mangroves and marshes. Fisheries value of magrove habitat around the Puttalam Lagoon was estimated at US$ 303,609 per annum (DFAR, 2013). The total area of the lagoon is 32,700 ha (Pathirana *et al*., 2008), which is containing two main freshwater sources namely Kala Oya and Mee Oya (Dayaratne *et al*., 1997; Pathirana *et al*., 2008). In addtion, the lagoon supports around 2,500 direct fishermen and contributes to the livelihood in the area (Ranasinghe, 2010). Importantly, to sustiain year round productive fisheries, the mangrove and seagrass ecosytems of the lagoon provide feeding, breeding and nursury grounds for economically important fin-fish and shell fish species. Neverthless, they provide vast array of ecosystem services and contributed for the balance of the lagoonal system.

Being vital ecosystems, Mangrove and seagrass play a major role as primary producers and involved in carbon seaquestration process, in the lagoon system. However, these imperative ecosytems have been threaten by globally and locally with expanding of the coastal populations and natural alterations (Orth *et al*., 2006). Recent records indicated that the declining rates of the seagrass ecosytem in the world has been incrased to 7% yr^{-1} (Waycott *et al*., 2009).

Puttalam Lagoon ecosytem has been vastly threaten due to development of the tourism, fisheries, pollution and urbanisation and combine with the natural phenomena. Inspite of the economical and ecological value, 62% of the mangrove cover has been removed for the construction of shrimp farms and salterns during the 1977 to 2015 (Weragodatenna and Gunaratne, 2015). Unfortunalty the rate of mangrove regereration for the above 38 years was only 9% (Weragodatenna and Gunaratne, 2015). Hence, timely monitoring of the status of the lagoon ecosytems such as mangroves and seagrass is an important process to encourage the sustainable utilization of the resources.

Eventhough several studies were conducted to find the status of the mangrove and seagrass ecosystem in the Puttalam Lagoon (Jayasuriya, 1991; Dahanayaka *et al*., 2010; Ranahewa *et al*., 2018) recent studies for the upper western boundary are unavailable. Since this area of the lagoon is highy discussed for tourism based developments, the results of the present study will be useful as baseline information.

Materials and Methods

Study site:

The study was conducted at the Western boundry of the Dutch Bay area in the Puttalam Lagoon. Sampling locations are shown in Figure 1.

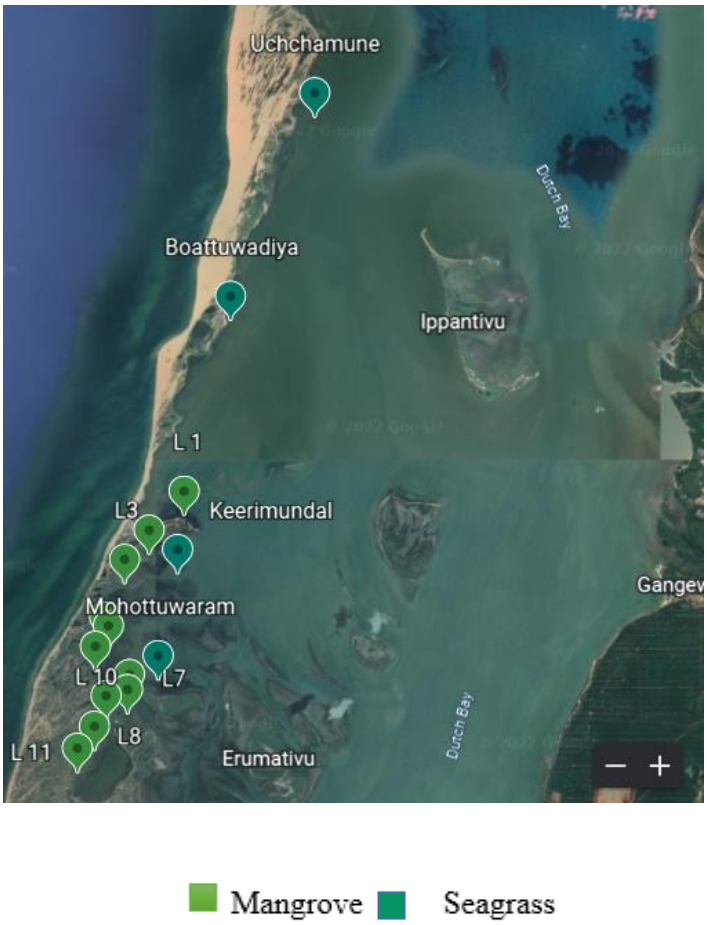


Figure 1. Map showing the study locations of mangrove and seagrass in the upper western boarder

Sampling:

Study on mangrove ecosystem was conducted in 14 sites from Karamune (L1) to Mohottuwaram area (L14). In each site 2 m wide and 50 m long belt transects were deployed from lagoon towards the land and each transect was subdivided in to 10x10 m plots. In each transect all the mangrove species were identified, counted and their Diameter at Breast Height (DBH) and heights were measured.

The seagrass coverage of the area was conducted in Uchchamunai, Kirimunda, Mohottuvaram and Bottuwadiya using the quadrate and transect method (Short and Coles, 2001). The line transect was deployed perpendicular to the shore towards and two quadrats samples were obtained within every 5 m distance, from right side and left side of the quadrat. The species was identified using guides and percentage cover was obtained using the 0.25 m^2 quadrat. The number of lines transects were depend on the area of the site. The transects were laid between 100 m distance of the study site. Apart from those observations were taken during the survey on seasonal dieback or human influence on seagrass meadows.

Data Analysis:

Dominance (DOI) and Evenness (EVI) were calculated using Shannon Wiener Index (SWI), Simpson Index (SI) and Pielou's index respectively to assess the mangrove diversity (Spellerberg and Fedor, 2003; Simpson, 1949; Pielou, 1966). Complexity Index (CI) and Important Value Index (IVI) was also calculated (BOBLME, 2015; Joshi and Ghose, 2014). In addition, mean height was used to calculate the CI (Blanco *et al*, 2001) and for this only true mangroves and woody mangrove associates were considered.

The percentage cover, Shannon Diversity Index (SDI) and EVI were calculated for seagrass at each site (Aboud and Kannah, 2017). Statistical analysis was performed to find that there is a significant difference of the seagrass species cover between four sites using the R program (R Studio ver.1.4.1106). First, the data was tested for normal distribution using Shapiro test. As the data or transformed data was shown the non-normal distribution, Kruskal Wallis (Kruskal and Wallis,1953) non parametric test was performed.

$$H = -\sum_{i=1}^{s}(Pi\ X\ lnPi)$$

Where,

H = Shannon Diversity

S= Number of Species

Pi= proportion of individuals of each species

$E = H / \ln S$

Where, E= Species EVI, S= Number of Species

Results

Mangrove survey

Floristic composition:

A total of 20 mangrove and mangrove associated species were identified during the survey. This includes seven true mangrove species (Table 1) belonging to five families and three mangrove associates. This mangrove ecotype belongs to fringing forest since

it faces to the open water directly and is daily inundated by tides. However, mangrove patches were not equally distributed along the upper western boundary. They were less dense from Uchchamune to Karamune area compared to the rest.

Table 1. True mangrove species found during the survey

No	Family	Species
1	Rhizophoraceae	*Rhizophora mucronate* Lamk
2	Rhizophoraceae	*Ceriops tagal* (Perr) C.B.Rob.
3	Acanthaceae	*Avicennia marina* (Forssk.) Vierh.
4	Lythraceae	*Sonneratia alba* J. Smith
5	Lythraceae	*Pemphis acidula* J.R. Forst. & G. Forst.
6	Combretaceae	*Lumnitzerar acemosa* Willd.
7	Euphorbiaceae	*Excoecaria agallocha* L.

Mangrove distribution from lagoon towards the land are depicted in Figure 2. Accordingly, waterfront area was dominated mainly by *Rhizophora mucronata* and *Ceriops tagal*. Mangrove associates such as *Thespesia populnea* and true mangrove species such as *Pemphis acidula* and *Lumnitzerar acemosa* have increased towards the landward side.

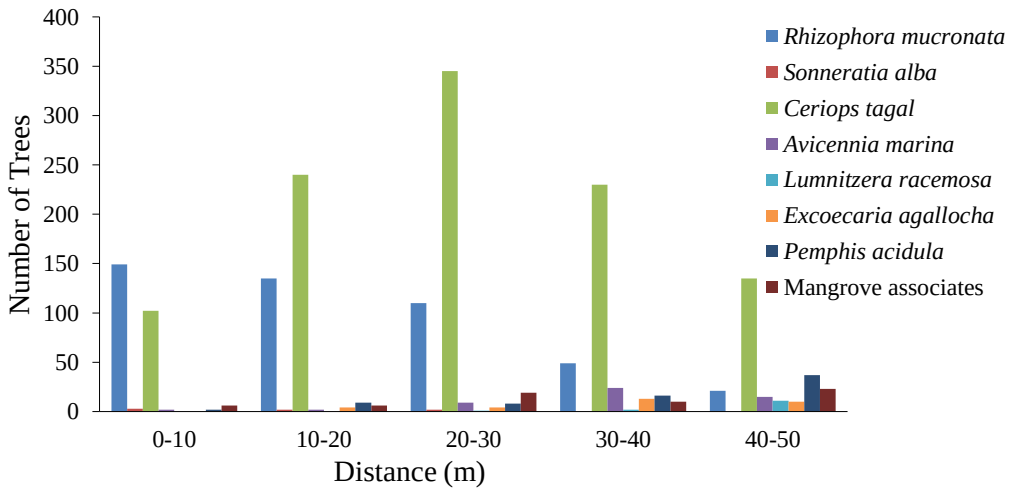


Figure 2. Distribution pattern of mangroves species from the lagoon towards the land area

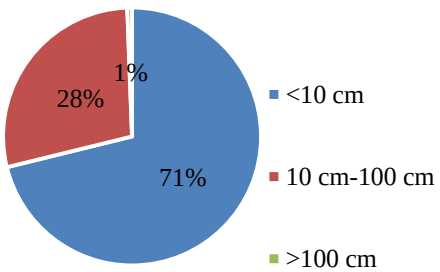
Mangrove community structure:

Ceriops tagal was the most abundant true mangrove species with the percentage coverage of 60.04% followed by *Rhizophora mucronata* (26.50%) and *Pemphis acidula* (4.09%) whereas *Sonneratia alba* was the least abundant true mangrove species (0.40%). It was an evident that mangrove community from Karamune to Mohottuwaram area was pioneered by *Ceriops tagal* (IVI=130.63) and *Rhizophora mucronate* (IVI= 136.60). *Lumnitzera racemosa* was the least important true mangrove species (IVI=9.34) in this ecosystem (Table 2).

Table 2: Mean values of Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDo) and Important Value Index (IVI) of mangrove species and mangrove associates.

Species	RF (%)	RD (%)	RDo (%)	IVI
Rhizophora mucronata	67.74	26.50	42.36	136.60
Sonneratia alba	9.68	0.40	10.16	20.23
Ceriops tagal	58.06	60.05	12.53	130.64
Avicennia marina	19.35	2.95	4.32	26.63
Lumnitzera racemosa	8.06	0.79	0.48	9.34
Excoecaria agallocha	12.90	1.76	4.62	19.28
Pemphis acidula	25.81	4.09	4.90	34.79
Thespesia poplnea	16.13	0.91	2.96	19.99
Phoenix sp.	6.45	0.79	11.02	18.27

The mangrove stand was dominated by large number of small trees with only 29% of trees exceeding 10 cm DBH and only 3% exceeding 4 m height (Figure 3).



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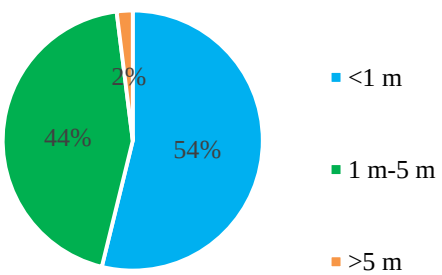

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Figure 3: Pie chart showing the Diameter (a) and Height (b) distribution of mangrove trees recorded during the survey

CI of the studied mangrove stand was 0.1577 (Table 3). Shannon diversity and Simpson dominance values of mangrove ecosystem was 1.22 and 0.57 indicating that the species dominance was medium (Table 4).

Table 3: Structural Characters of the Mangrove stand

No. of species	Basal area (m^2/ha)	Total Density (trees/ha)	Mean Height	CI
9	0.09	12944.88	1.50	0.16

Table 4: Mangrove diversity, DOI and EVI

Species Diversity	1.22
DOI	0.57
EVI	1.01

Sea grass survey:

Seven seagrass species were recorded from the study sites (Table 5). The least number of spices (5) were recorded at Mohottuvram while other three sites had six species. None of the site contained all the seven seagrass species. The average percentage area coverage by seagrasses was 50. 06% in the study sites. In addition, Figure 4 describes species-wise coverage of seagrasses in the area and the highest and lowest coverage have been obtained by *Cymodocea rotundata* (12.93%) and *Halophila decipiens* (0.07%) respectively.

Table 5: Seagrass species found during the survey

Sampling Site	Uchchimune	Bottuwadiya	Kirimudal	Mohottuvaram
Enhalus acoroides	+	+	+	+
Oceana serrulata	+	+	+	+
Cymodocea rotundata	+	+	+	+
Thalassia hemprichii	+	+	+	+
Halodule uninervis	+	+	+	+
Halophila decipiens	-	+	+	-

Halophila ovalis	+	-	-	-
Number of species	6	6	6	5

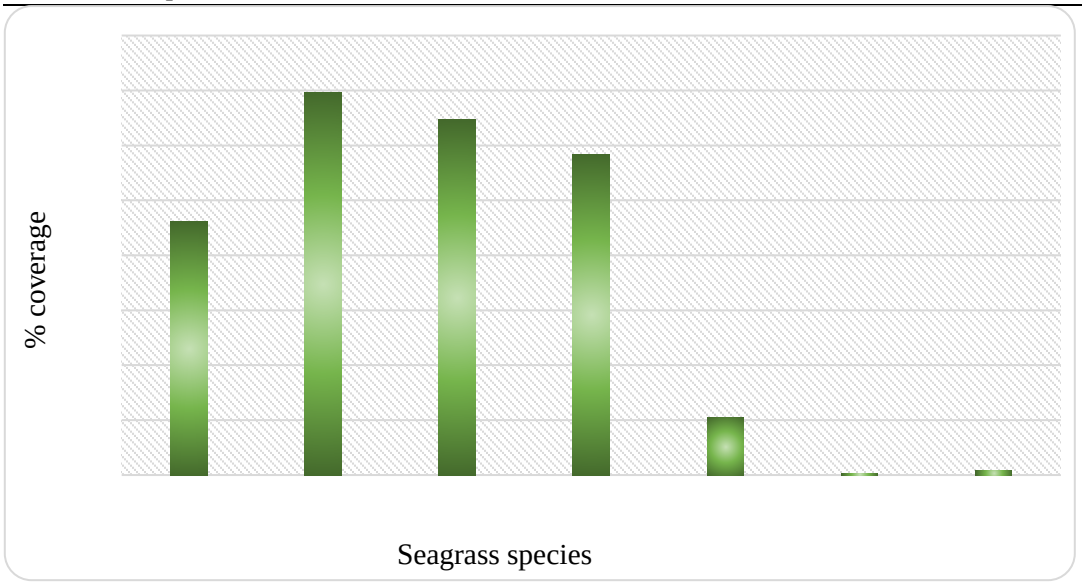

Figure 4. Percentage of cover of the seagrass species in upper Western border of the Puttalam Lagoon

Oceana serrulate (18.81%) was the most abundant seagrass at Uchchimune area, while *Halophila ovalis (0.65%)* covers a least area *Cymodocea rotundata* coverage in Bottuwadiya area is conspicuously high compared to the other sites (34.13%). Kirimundal area contains highest coverage by *Oceana serrulata* (21.48%) which is the highest coverage of the species of the upper Western boundary of the lagoon. *Halophila decipiens* (0.17%) obtain the lowest coverage in Kirimundal. Mohottuvaram contains conspicuous high coverage of *Thalassia hemprichii* (15.0%), while *Cymodocea rotundata*, obtain lowest coverage (0.38%) (Figure 5).

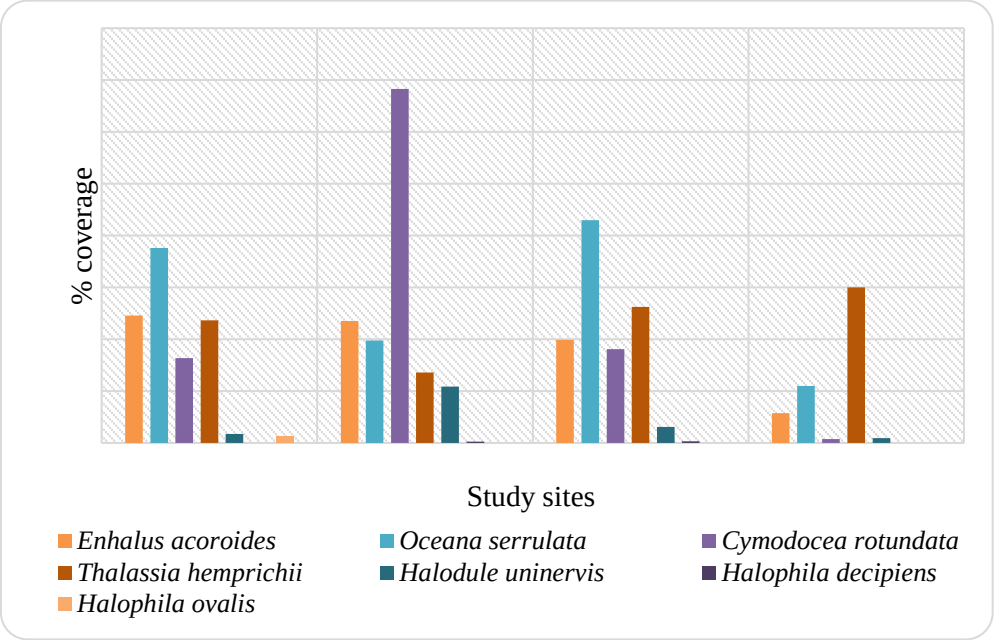

Figure 5. Percentage of coverage of the seagrass species in the study sites

The Shannon Indices of the area ranged from 1.03 – 1.45 where Mohottuvaram showed the lowest value of 1.03 (Table 6). However, according to the statistical results, there was no significant difference between the sites in terms of the seagrass species cover (Table 7).

Table 6. Shannon Index values of the sites

	Uchchimune	Bottuwadiya	Kirimudal	Mohottuvaram
SDI	1.45	1.37	1.43	1.03
EVI	0.812	0.766	0.798	0.639

Table 7: Kruskal Wallis test results

	Chi squared	df	P value
Kruskal Wallis	1.8702	3	0.5998

Discussion

Mangrove survey

IUCN (2012) had reported 13 true mangrove species and 18 mangrove associates in Puttalam Lagoon. However, during the present study seven true mangrove species and 13 mangrove associate species were found from the study area. Present study is confined to the upper areas of the lagoon where certain mangroves only tolerate in this area. Also, in Puttalam Lagoon both riverine and fringing mangroves were observed and forest CI was 0.1577. The IUCN study was conducted in mainland where the fringing mangrove are dominant and are less complex than the riverine mangroves (Amarasinghe and Balasubramaniam, 1992; IUCN, 2012).

Historical studies showed that *Rhizophora mucronate* and *Avicennia marinaas* the most dominant species (Amarasinghe and Balasubramaniam, 1992; IUCN 2012; Ranasinghe 2010; BOBLME 2015), in Puttalam Lagoon. However, present study reported *Ceriops tagal* as the most dominant species in Upper western boundary with percentage density of 60%. Contribution of *Rhizophora mucronata* to the total density was 26%. However, in terms of IVI both *Rhizophora mucronata* and *Ceriops tagal* were the pioneering species in the lagoon with IVI of 136.60 and 130.63 respectively. Reason for this variation was although there are large number of *Ceriops tagal* species, their diameter was low and hence the percentage dominance was lower than the *Rhizophora mucronata*. *Rhizophora mucronata* population was more mature than the *Ceriops tagal* population in the studied area.

Clear zonation of mangroves could be observed during the present study with *Rhizophora mucronata* and *Ceriops tagal* being the prominent waterfront species. This is due to the fact that *Rhizophora mucronata* cannot tolerate wide salinity range (Amarasinghe and Balasubramaniam, 1992). Salinity in the Puttalam Lagoon is highly variable factor and Arulananthan *et al.*, 1995 records that average salinity level of the Puttalam Lagoon was 37 psu. *Lumnitzerar acemosa* and *Pemphis acidula* are on the landward side. IUCN (2012) also recorded that the mangrove zonation in the Puttalam Lagoon with *Rhizophora mucronata*, *Rhizophora apiculata*, *Sonneratia alba* and *Bruguiera cylidrica* as waterfront species. Present study did not record *Rhizophora apiculata* and *Brugiera cylindrica* from Karamune to Mohottuwaram; because present study considered only the upper western boundary and these species may not distributed equally around the lagoon. Although *Sonneratia alba* was recorded its' percentage density is too low (0.39%).

Sea grass survey

Even though the past records stated eight seagrass species in the Puttalam lagoon area (Jayasuriya, 1991; Ranahewa *et al*., 2018), the study revealed only seven species in the

selected area. However, among the ~60 seagrass species reported in the world (Short *et al.,* 2007) and 15 seagrass species are recorded in Sri Lanka (Udagedara and Dahanayaka, 2020), seven tropical seagrass species have been recorded in the upper western boundary of the Puttalam Lagoon indicate a seagrass hot spot of Sri Lanka. The *Syringodium isoetifolium* or the Spaghetti seagrass could not be found. The complete loss of the seagrass species, *Syringodium isoetifolium*, could be occurred due to the changes in the sediment structure of the lagoon, thus, alternation of the benthic environment (Hanington *et al*.,2014). Also, the shallowing of the lagoon due to high sedimentation makes the high irradiance cause a destructive effect on the seagrass species, making them vulnerable in the lagoon environment (Fokeera -Wahedally and Bhikajee (2005). The highest abundance was recorded from the species, *Cymodocea rotundata* (10.88%), which conspicuous coverage could be observed in Bottuwadiya area (34.13%) but the species obtained least coverage in Mohottuvaram area. Also, the species *Halophila ovalis* only recorded in Uchamunai area (0.65%). Considering the water quality of the area, Uchamunai area directly influence by the seawater as it is located in the edge of the lagoon mouth and contain vast array of salinity fluctuation. The *H. ovalis* was not found in the sites located in the lagoon ward, this may indicate the origin of the *H. ovalis* from the marine area rather than the lagoon (Benjamin *et al*., 1999). Further, the stress generated due to high temperature on the plant can be avoided using the high salinity (Ontoria *et al*., 2020). Hence, they may prefer the seaward area of the lagoon. Similarly, *Halophila dicipiens* recorded minor values only reported in Bottuwadiya and Kirimundal area as 0.13% and 0.17% respectively.

As a stenohaline species indicated by Dawes *et al*., 1989, *H. decipens* only survive in the particular lagoon environment. Even though *Cymodocea rotundata* dominant in studied area it gets comparatively low value (0.38%) in Mohottuvaram while the highest coverage was recorded by *Thalassia hempichi* (15%). The species can be specific to sediment characters of the habitat. Hence, the difference in the species cover can be occurred due to sediment variations. (Thangaradjou and Kannan, 2007; De Boer, 2007; Ayeshya *et al*., 2019). Mohottuvarama located in sheltered area due to the nearby islands, which cause the low water current and high sedimentation. During the survey, the observations taken into account as Mohottuvarama area possess muddy sediment while Uchchamunai to Kirimundal contain sand- silty sediments. The variation of the species composition and coverage of the four sites of the Western boarder of the lagoon could be due to the water quality and sediment variations (Ranahewa *et al*., 2018; Livingston *et al*., 1998).

This evidence also has been proven by the diversity indices which Mohottuvaram gets lowest diversity and EVI (1.03 and 0.639). Considering the diversity indices of the four sites, which vary from 1.45- 1.03, it implies a moderate species diversity. According to

the statistical analysis there is no significant difference between the seagrass coverage of the four sites in upper western boarder of the lagoon.

However, the impacts on the seagrass meadows influence by both anthropogenic and natural activities of the area according to the observations taken during the seagrass survey. Lagoon has overwhelmed by high fishing activities, shrimp farm, aquaculture activities in recent decades (De Silva *et al*., 2017; Pathirana *et al*., 2008; Jones *et al*., 2018), which cause to the destruction of seagrass meadows via fishing gears, boat mooring and propelling, fish cage development etc. The local fishermen conducting some conventional fishing practices which were prohibited destructive fishing methods (fyke nets, hand operated trawling) were investigated during the survey. These activities have invaded the seagrass meadows and cause to the uprooting of the plants. On the other hand, habitat fragmentation and erosions of the bed could be observed which destruct the growth and spread of the seagrass meadows over the lagoon (Apostolaki *et al*., 2007). The alternation of water qualities via aquaculture activities, effluents and also from the natural phenomena such as current, high rain fall events induced the growth and the metabolisms of seagrass (Campbell and McKenzie, 2004; Lirman and Cropper, 2003). Further, according to the observations taken during the survey seasonal dieback of the seagrass meadows could be noticed which occur due to the exposure to the direct sunlight with the tidal fluctuations. Nevertheless, as the area have high potential to expand the tourism activities and related infrastructure development the seagrass meadows of the area would be highly threaten. As a seagrass hot spot, upper western lagoon needs to be monitored for further loss of the ecosystem and encourage sustainable utilization of lagoon resource.

Recommendations

Our study revealed a temporal difference of seagrass and mangrove composition and coverage in the upper Western boarder of the lagoon. These can be due to anthropogenic activities and/or natural phenomena, such as weather events and variation of environmental conditions. As a tourism hot spot and the area has high potential to expand human oriented activities, the upper Western lagoon needs to be monitored to ensure the sustainable utilization of the lagoon resources.

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