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Detecting the future vulnerability of degradation of mangrove species through assessing the current status of the ecosystem

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Abstract

The second-largest lagoon in Sri Lanka possesses the largest mangrove forest which is sentenced to degradation due to various socio-economic consequences. The study focused on the patchy streamlined mangrove forests in the Puttalam lagoon. Not only the Puttalam lagoon overall extent of mangrove forests have degraded in the country. The impact of the mangrove cover reduction directly affects ecosystem services which inevitability provides negative feedback. The study aimed to identify the species composition, diversity and abundance across selected freshwater parameters as an indicator to find out the vulnerable as well as restoration prioritise areas. This study further supports to fill the gaps of previously carried out study at the same location. A field survey was carried out to collect phytogeographic data and vegetation sampling was performed along the two belt transects including three islets in the lagoon. The sample size was 10m × 5m quadrants. The total number of samples was 25. Water samples were collected at the same sample points. Shannon-Wiener diversity index was calculated for mangrove diversity. Spatial distribution maps of mangrove diversity were performed by the Inverse Distant Interpolation method (IDW) in Arc GIS. Accordingly, 15 mangrove species enumerated belonging 13 genera and 10 families in the study area. *Rhizophora mucronata, Avicennia marina, Rhizophora apiculata, Avicennia officinalis* and *Excoecaria agallocha* were the most common true mangrove species that could be seen in Puttalam estuary. High salinity preferable mangrove species; *Sonneratia alba* were enumerated towards the ocean. Spatially highest mangrove species diversity could be identified in middle areas of both transects along the lagoon periphery while lowest diversity could be identified in most areas along the periphery due to the abundance of *Rhizophora* spp and *Avicennia* spp. Thus, diversity hotspots are identified as vulnerable sites of further degradation while identifying restoration priorities. The study found ecological niche species where the conservation requirements highly emphasized.

Keywords—**Diversity, Ecological niche Gradient, Mangrove, Restoration, Vulnerable**

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1. Introduction

Mangroves are dicotyledonous woody shrubs or trees. Mangrove forests are among the most productive ecosystems in the world that exist under conditions of tides, high salinity, anaerobic soils, and high temperatures. Concerning the extreme conditions mangroves are the only group of plants which have the most developed morphological, ecological, biological and physiological adaptations to extreme conditions [1]. Mangroves are confined only to tropical and sub-tropical areas in the world. Mangroves in Sri Lanka confined only to lagoons and estuaries located around the coastal belt of the island where the tidal variation is about 0.8m and grows as a thin belt of lagoons and estuaries around the coastal belt of the country. The places where the tidal variation is greater it can grow up to 15 to 20 km inland. According to most scientific literature and administrative reports, the number of lagoons on the entire coast of Sri Lanka has been estimated as 45 [2]. Mangrove ecosystems are identified as wetland ecosystems which are important for a wide range of ecosystem services [3].

Generally, ecosystem services are divided into four sections as provisioning, supporting, regulating and cultural. Mangroves in the role of carbon sequestration and coastal protection are very important related to climate change issues. These forests are one of the most productive systems and as a result, they play a key role in nutrient cycling of coastal zones and global carbon cycling and showed to act both as source and sink areas [4,5] Its structure and productivity are crucial components of estuarine habitats that support ecosystem services such as nursery areas for fish species, prawns and crabs [6,7] and the interdependence of ecosystems; mudflats, seagrass meadows, coral reefs and salt marsh [8].

Completely or partially estuarine and coastal livelihoods are based on mangrove ecosystem. Despite their socio-economic importance, mangrove areas have declined by 30%- 50% in the past fifty years, a rate higher than most other biomes [9]. During past decade researchers have been demonstrated the widespread decline of ecosystem services and their consequences. Considering the ecosystem services and valuation mangrove ecosystem merit further attention. The number of people living within ten kilometres where mangroves are significant will increase more than now. Historically mangrove ecosystems were neglected [10]. Anyhow with the population explosion,the coastal marginal areashave been populated. The bulk of resides in developing countries in Asia, Latin America, West and Central Africa significantly have shown the consequences of demographic explosion [10]. Most of third world developing countries are located around tropical and sub-tropical areas where mangroves inhabited. Also, the above mentioned particular regions are the most mangrove dependents in the world. Residents from developing countries who live around coastal periphery use heavily mangroves ranging from small scale to large scale necessities [11]. Burgeoning populations, overexploitation of mangroves and conversion of mangroves to settlements, rice fields, salt beds, tourist resorts, and industrial facilities are some of the primary causes of mangrove degradation [12, 13]As a result, mangroves have been degraded day by day.

The Millennium Ecosystem Assessment (MEA) in 2005 shows that 35% of mangrove forests in the world have disappeared within the last two decades [14]. The early 1980s' were identified as the alarming year of mass destruction of mangroves forests in the world [14]. Sri Lankan scenario is the same. In 1968 the mangrove extent in Sri Lanka was around 8000 acres to 10000 acres 1146[15]. In 1998 Silva and Silva cited that there was a mangrove extent around 87 km^2 [16]. According to IUCN (2011) [17], Mangrove areas in Sri Lanka cover less than 0.01% of the land area, approximately 10,000 ha in extent. In a study [18], Jayatissa (2012) mentioned that the present extent of mangroves of the island has been estimated between 4000 ha to over 10,000 ha. Nearly 23 of true mangrove spp have been recorded in Sri Lanka [19].

Diversity and species abundance of mangroves have been reduced relevant to the destruction and degradation of mangroves. Many international principles and acts related to biodiversity have been introduced by international organizations as biodiversity is the primary base of ecosystem services [20]. Earth Summit in Rio 1992, in chapter 15 of Agenda 21, titled "Conservation of Biological Diversity" calls for immediate action in protecting biodiversity [21]. In April 2002, the Parties of the Convention committed themselves to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and the benefit of all life on Earth [20]. Biodiversity at genetic, species, population and ecosystem levels contributes to maintaining these functions and services. Therefore the diversity is a crucial criterion especially for sensitive ecosystems like mangroves.

The importance of the study leans towards the identification of loss of species diversity and vulnerabilities of further degradation. The Puttalam lagoon possesses the largest mangrove forest in the island situated in North-western province (Fig 1), belonging to the semi-arid climate zone. The tragedy, which the lagoon experience is the largest loss of mangroves. With the immense anthropogenic disturbances, mangroves have been survived in the area without its previous diversity. This is mainly because large scale mangrove forest clearances took place for aquaculture in the past. Though such massive clearance influenced on the extent of mangrove forests, yet, aquaculture is solely not the reason to the present distribution of mangroves as there is no direct impact on mangrove species diversity; passive restoration has already maintained diversityin somewhat extent [22]. Therefore, the current paper leans mostly towards the identification of vulnerable areas for further degradation of mangroves while recognizing restoration priorities.This can be further emphasized as an unpublished previous study which followed the same methodology in the year 2017 illustrated some of the research gaps due to the sample size and such gaps might lead to misconceptions in decision making. To achieve the objective of the study the following sub-objectives accomplished;

I. Assess the mangrove species composition, diversity and richness
II. Distinguish species diversity across basic freshwater parameters in support of the identification of habitat characteristics
III. Detect diversity hotspots, degradation vulnerable areas and restoration possible areas

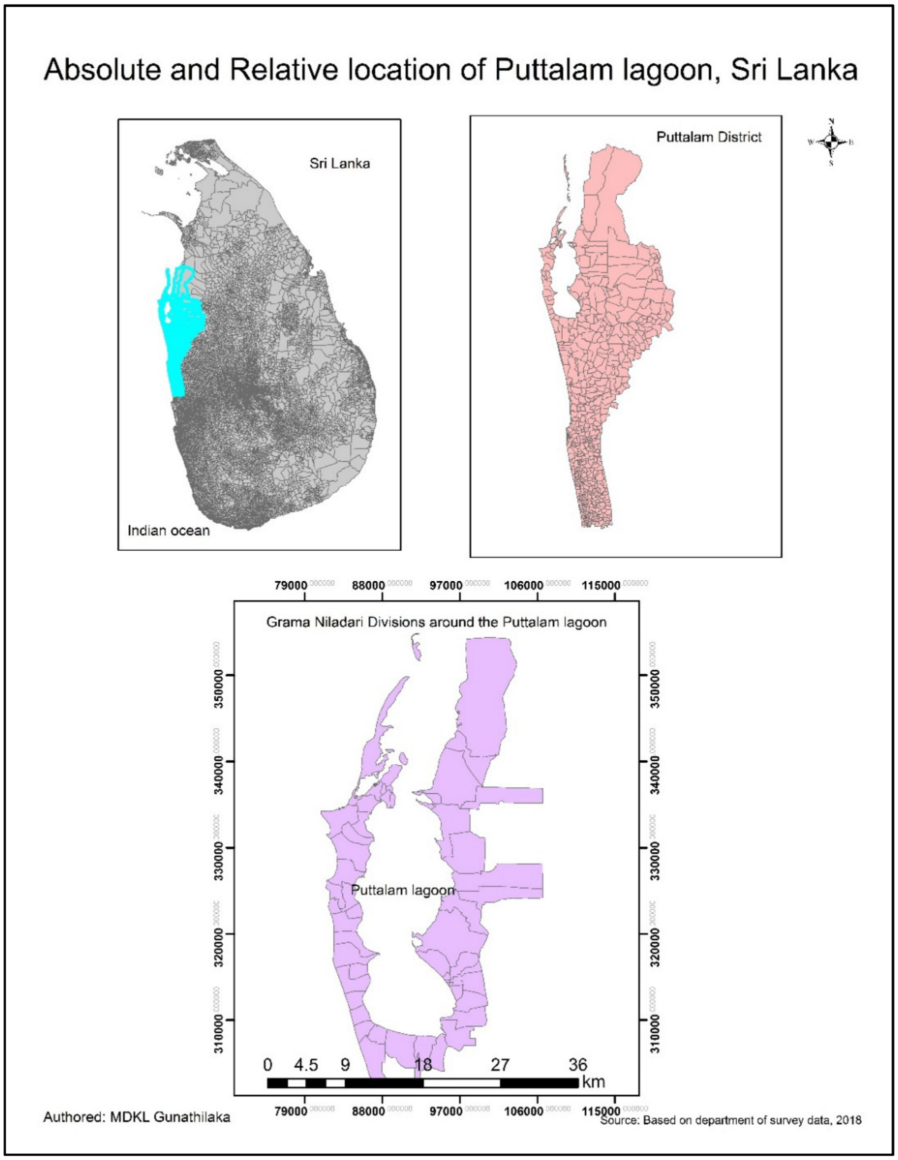

Figure 1: Location of the study area

Source: Produced by the author, 2019

2. Methodology

2.2. Data collection

The study based on primary data obtained by having a thorough vegetation survey covering the whole lagoon area. A total of 25 sample plots (Fig 2) were purposively selected. Since the mangrove shows a patchy distribution, every patch covered by the purposive sampling where the much density of mangrove patches assess by laying several plots. Vegetation sampling used systematicsampling method to identify the mangrove diversity was performed by two main belt transects including a total of three islands (Table 1). Within the belts, quadrants were laid. The sample size was 10m X 5m.In-situ testing of water for salinity, pH, Electric Conductivity (EC) and temperature sampling was carried out using portable multi-parameter water quality meter (HI98194). The location was identified with handheld global positioning system receiver; Magellan eXplorists 31

Table 1: Locations of samples

Transect	Sample ID	Number of samples
Right	R1 –R10	10
Left	L11-L22	12
Island	I23, I24 and I25	3

Phyto-geographic data were collected during the vegetation sampling. The data gathering sheet wasprepared including species name, scientific name, plant details, and diameter at the breast (DBH), height, and habitat conditions, soil and other parameters.

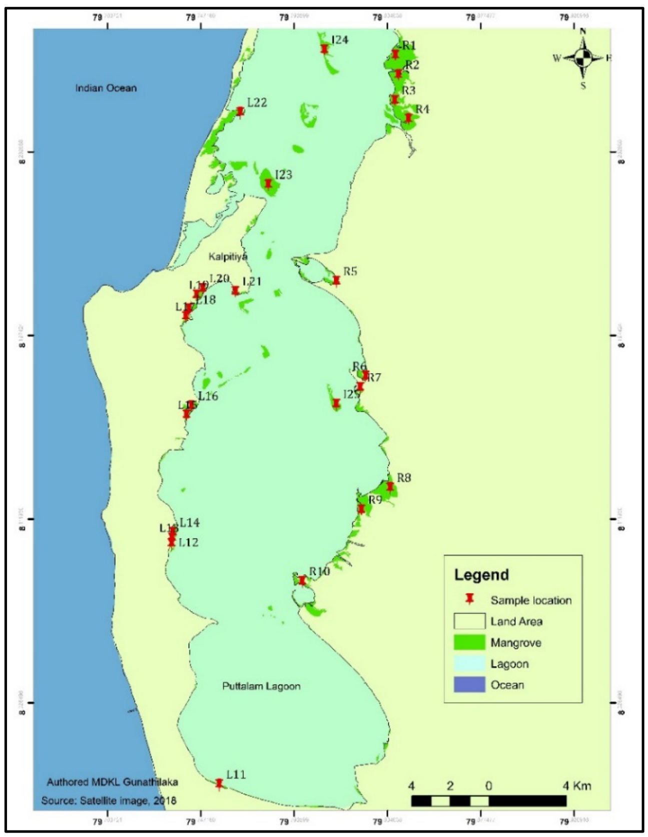

Figure 2: Locations of the sample plots

Source: Produced by the author, 2019

2.2. Data analysis

Collected vegetation data collated and analysed by Shannon- Wiener diversity index.

$$H= -\sum Pi \ln(Pi) - 1$$

The value of the 'H' is range from 1 to 5. Higher the value of 'H' higher in diversity and lower the value of 'H' lower the diversity. According to the Ejtehadi's classifications (2008) [23] , Shannon wiener index belongs to heterogeneity indices under the category of information theory indices. The equitability (EH) of Shannon index can be calculated by,

$$EH \, {}^{1}\!/_{4} \;\; H = Hmax \, {}^{1}\!/_{4} \, H - \ln S$$

Where (EH) is evenness, H is Shannon's diversity index and Hmax is the maximum value of H. Value of (EH) ranges between 0 to 1. The higher the value of (EH) indicates the less variation in the community between species. The results are presented in the form of tables, graphs and spatial maps.

The Puttalam lagoon area map was updated in the study by applying Google satellite images and Arc GIS software. Spatial analysis was done applying the Inverse Distant Interpolation method in Arc GIS 10.1 version for the calculated mangrove diversity and abundance of species which in turn used to identify hot spots and vulnerable areas. While freshwater gradients patterned against the composition of species as well as perform spatial mappings to identify the most appropriate areas for restoration and vulnerable areas of degradation.

3. Results and Discussions

3.1. Mangrove species composition, diversity and richness

A total of 15 various mangrove specieswas enumerated belonging to 13 genera and 10 families. Among them, 8 species were true mangrove species and 7 species were mangrove associates (Fig 3). Figure 3 further shows that some of the locations are composedeither of true species or associates. Mixed communities seem not much favourable in the mangrove patches. A total of 13 genera of mangroves represents755 individual mangrove species in the study area. 511(67.68%) of them belonged to true mangroves while the remaining 244 (32.32%) species were mangrove associates. When considering the distribution of species it is true mangrove species are more landward while the associates were ocean-ward (Fig 4). *Rhizophora mucronata* was the dominant true mangrove species. Next to *R. mucronata, R. apiculata* and *Avicennia* marina distribution were significant.Among the associates, *Suaeda maritima* and *Salicornia bigelovii* were more dominant towards the ocean in other words. This will much clearer with spatial analysis in the next sub-section.

No:	Species	True/Associates	Genera	Family	Samples																								
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	*Sonneratia alba*	TRUE	Sonneratia	Lythraceae	x	x																							
2	*Aegiceras corniculata*	TRUE	Aegiceras	Euphorbiaceae									x																
3	*Rhizophora mucronata*	TRUE	Rhizophora	Rhizophoraceae		x			x				x		x		x	x	x	x				x		x			
4	*Avicennia marina*	TRUE	Avicennia	Avicenniaceae		x	x						x	x		x						x	x		x		x		
5	*Rhizophora apiculata*	TRUE	Rhizophora	Rhizophoraceae			x	x		x	x	x																	x
6	*Avicennia officinalis*	TRUE	Avicennia	Avicenniaceae						x	x	x	x		x		x				x	x	x						
7	*Excoecaria agallocha*	TRUE	Excoecaria	Euphorbiaceae						x	x		x			x						x	x			x			
8	*Lumnitzera racemosa*	TRUE	Lumnitzera	Combretaceae														x											
9	*Thespesia populnea*	ASSOCIATE	Thespesia	Malvaceae														x											
10	*Hibiscus tiliaceus*	ASSOCIATE	Hibiscus	Malvaceae												x													
11	*Phoenix pusilla* synonym for *Phoenix farinifera*	ASSOCIATE	Phoenix	Arecaceae (Palmae)							x																	x	
12	*Clerodendrum inerme*	ASSOCIATE	Clerodendrum	Verbenaceae																								x	
13	*Salicornia bigelovii*	ASSOCIATE	Salicornia	Amaranthaceae																							x		
14	*Pemphis acidula*	ASSOCIATE	Pemphis	Lythraceae	x																	x			x	x		x	
15	*Suaeda maritima*	ASSOCIATE	Suaeda	Amaranthaceae						x		x	x			x	x	x							x				

Figure 3. Distribution of mangrove species within the sample plots
Source: Field survey, 2019

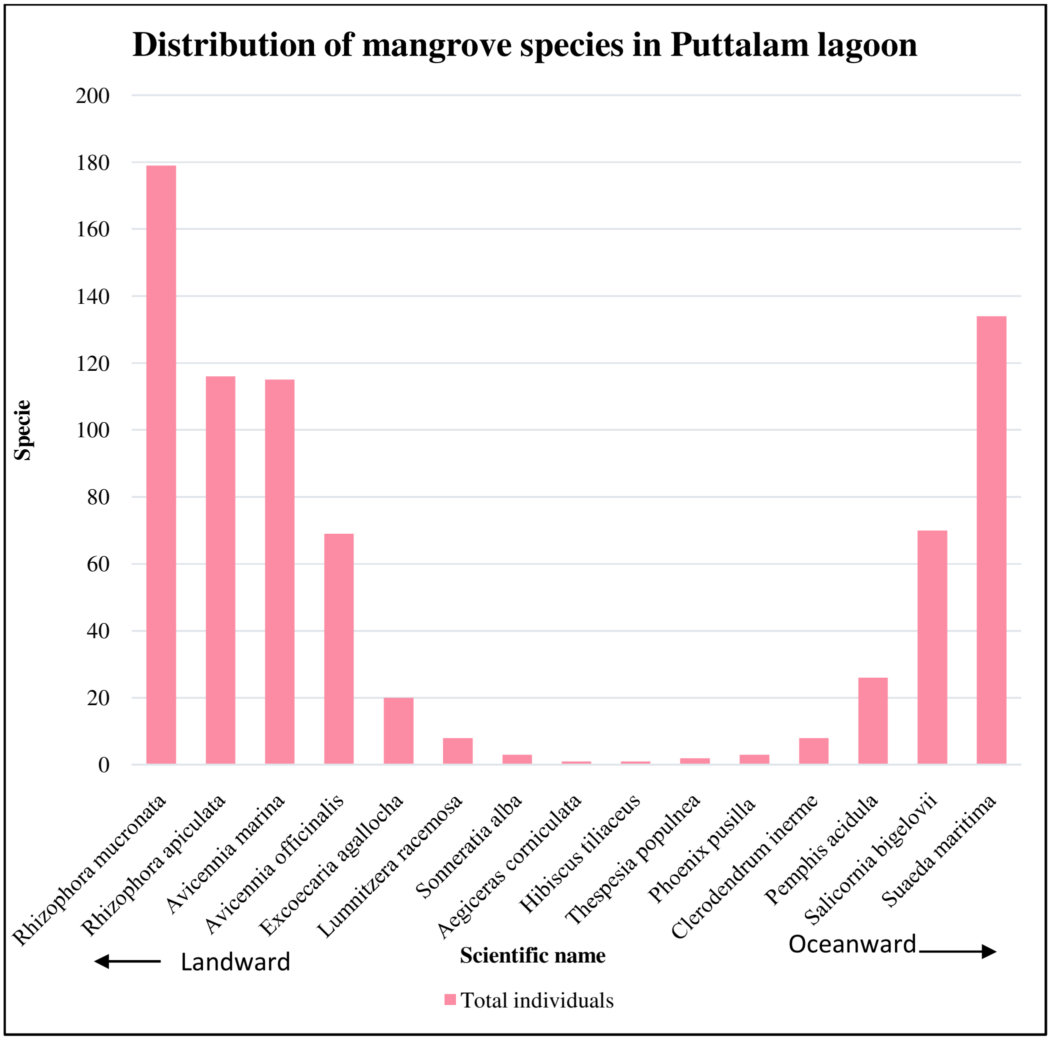

Figure 3: Mangrove species distribution in Puttalam lagoon

Source: Based on the vegetation survey, 2019

Mangrove species genera wise distribution shows *Rhizophora* and *Avicennia* as the particular genera found in the landward, enumerated about 295 and 184 individual species respectively (Fig 5). Again *Salicornia* and *Suaeda* reported as the significant genera of mangrove associates. *Rhizophoraceae*, *Avicennaceae* were the highly enumerated mangrove family which are true mangrove species. Among the mangrove associates, *Amaranthaceae* was prominent. These distribution patterns indicate that lagoon is more particular for true mangrove species especially the dominance of *Rhizophoraceae* family (Fig 6).

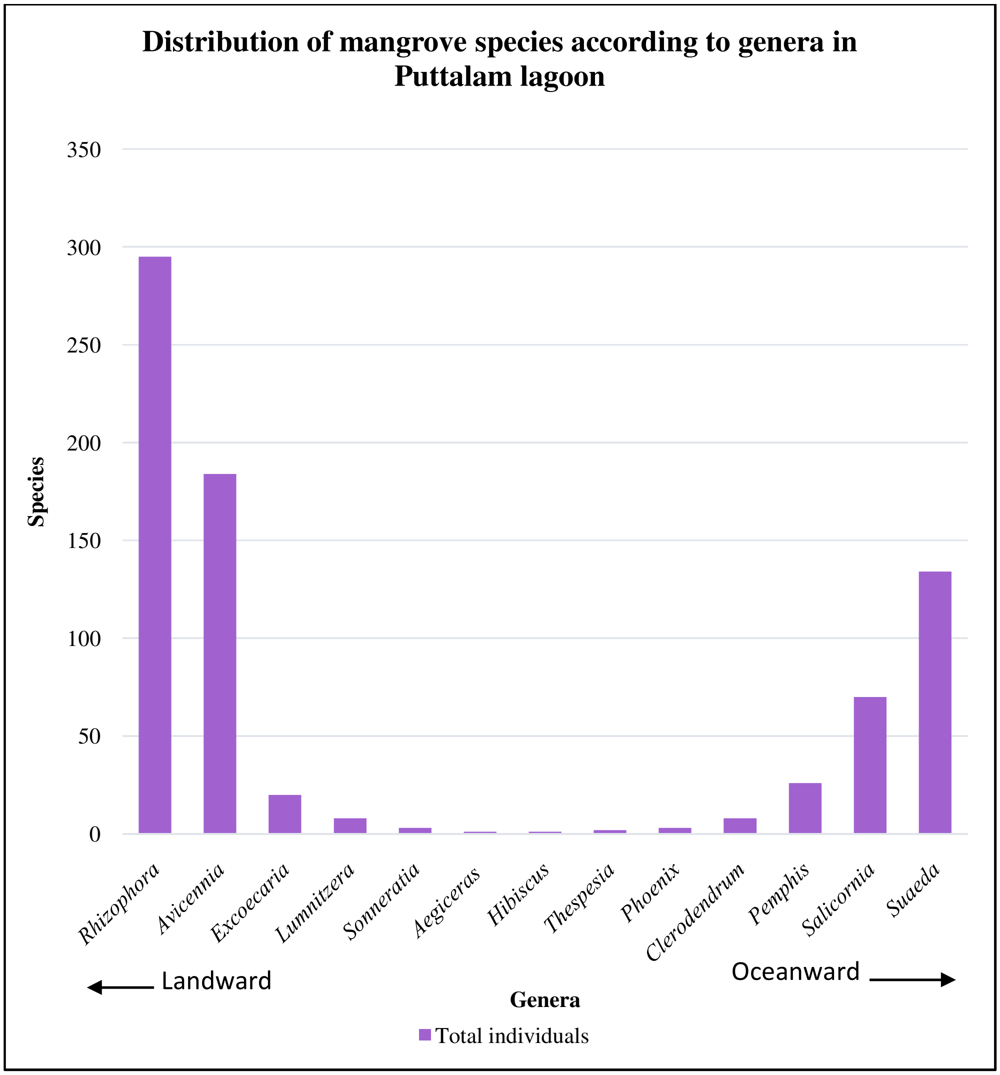

Figure 4: Genera wise mangrove distribution in Puttalam lagoon

Source: Based on the vegetation survey, 2019

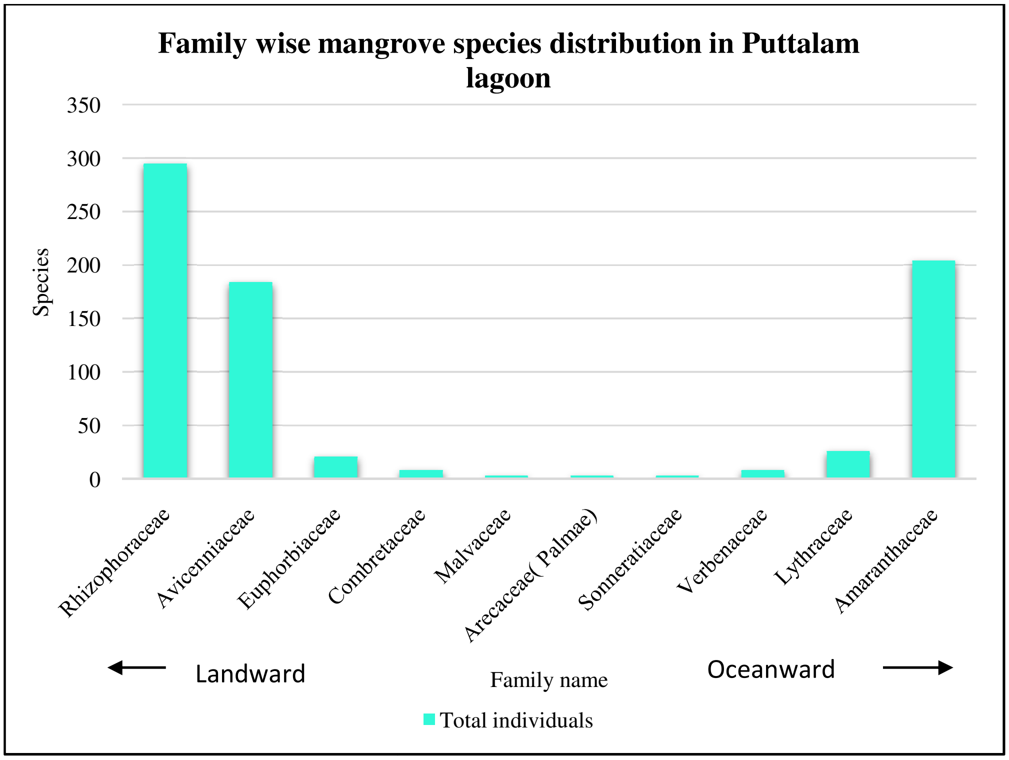

Figure 5: Family wise mangrove distribution in Puttalam lagoo
Source: Based on the vegetation survey, 2019

In this respect, the diversity of mangrove species ranges from 0 to 1.4 indicating a lower to lower moderate diversity of mangrove species in the lagoon. Sample nine reported for the highest diversity. Six, seven, twelve, nineteen and twenty-first sample plots show the next reported highest diversity in the area (Fig 7.A).Figure 7. B illustrates the species abundance in which, several plots reported for a very lower abundance of species; sample twenty-three, twenty-one, eighteen, twelve, eleven and seven particularly described an abundance of 0.79-0.98; closer to one means the abundance of species is lower and found one or two abundant species. Except sample twenty-three and eleven, other sample plots which the abundance was low, in contrast, stated for the higher in diversity. It implies that higher the diversity lowers the abundance; higher in number, which indicates the less variation in the community between species. According to the field observations (2016), the sample plots in which the abundance of species is lower always represented a different composition of species.

However, even with results like sample twenty-three and eleven, it is possible to state that extreme cases could also be identified. Sample twenty-three possess a moderate diversity where the abundance is very low in number. In contrast, the sample eleven demonstrated a lower diversity in which the abundance was reported for the very low category.

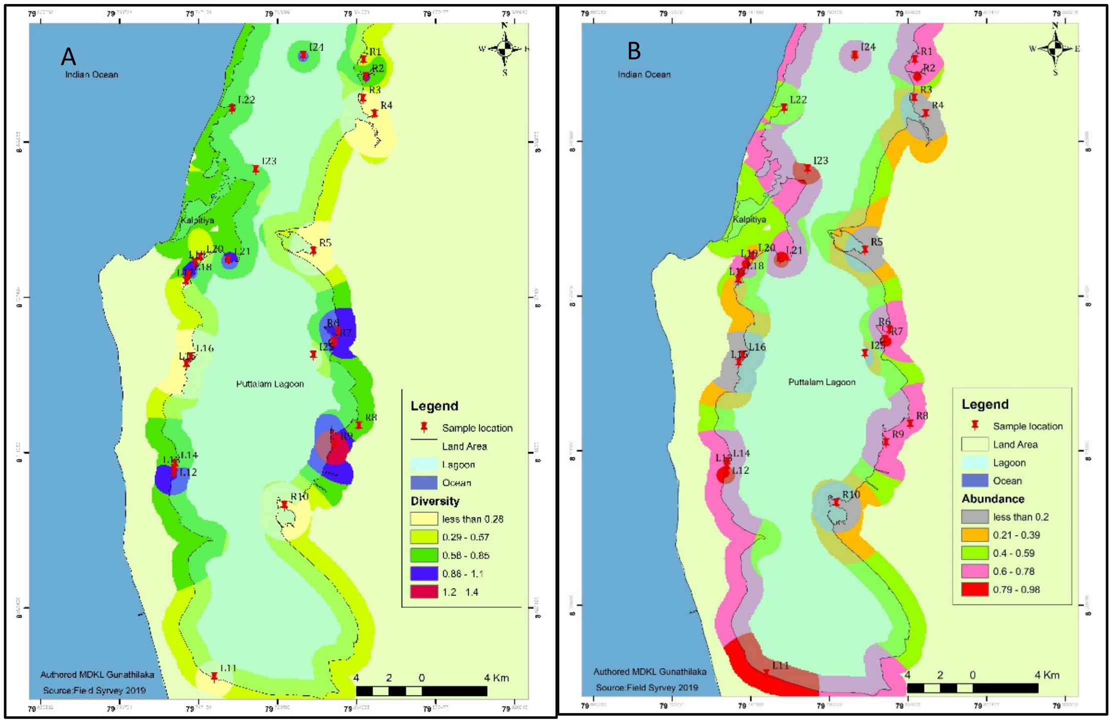

Figure 6: Mangrove species diversity (A) and abundance (B) in Puttalam lagoon

Source: Based on the vegetation survey, 2019

On the other hand, some of the sample plots revealed that lower the diversity higher the abundance of species. If for instance, sample three, four, five and ten in the right side periphery of the lagoon reported very lower diversity and very high abundance of species (Fig 7).

Kala Oya estuary (R3 and R4), Karativue (R5), Matti aru (R10), Daluwa-Mampuri (L11), Kurugngnampitiya – Palakudawa (L15, L16 and L17) areas have shown very lower diversity of mangroves. R3 and R4 samples plots are at the proximity of the outlet of Kala Oya estuary where *R. apiculata* is dominant. Sample five (R5) and ten (R10) consisted only of *R. mucronata* and *A. marina* respectively (Fig 3). Lower diversity solely consisted of true mangrove species (Fig 7, 8 and 9). Mangrove restoration has been implemented where the diversity reported as lower; Sample 15 (L15) and 16 (L16) which could be recognized easily. *R. mucronata* species were highly enumerated in the western periphery of the lagoon as a product of past mangrove restoration efforts (Field observation, 2016).

3.2. Species diversity across basic freshwater parameters

Figure 8 and 9 shows the distribution of true and associate mangroves across the salinity gradient of the Puttalam lagoon area. The salinity of Puttalam lagoon range between 6 to 30 ppt (parts per trillion). The highest salinity level computed as 29.6 ppt recorded in sample two (R2) in the right periphery while the lowest salinity as 6.9 ppt existed in sample 8 (R8) in the same periphery of the lagoon. Sample two, three, four, five and ten (R2, R3 R4, R5 and R10) confined only true mangrove species in the right periphery of the lagoon (Fig 8). The highest amount of mangrove associates recorded in sample one and nine. *Sonneratia alba* prefers high saline levels and found in sample 2 and 3 (R2 and R3) and moderately high salinity level prefer *Avicennia* species and *Rhizophora* species calculated in sample plot ID two, three, nine, ten, twelve, eighteen, nineteen, twenty-one, twenty-three (R2, R3, R9, R10, L12, L18, L19, L21, I23) and two, three, four, nine, ten, twelve, twenty-five (I25) respectively. Where the salinity is high the composition of mangrove associates are dominant than true species. However, sample 23 (I23) have shown low salinity with a large composition of mangrove associates. Therefore, this evidence demonstrates which the salinity preference of mangrove species is varied. Besides, the tolerance level of salinity of *Suaeda* spp is ranged between low to moderate in number, is proved from the sample plot six and nine (Fig 3).

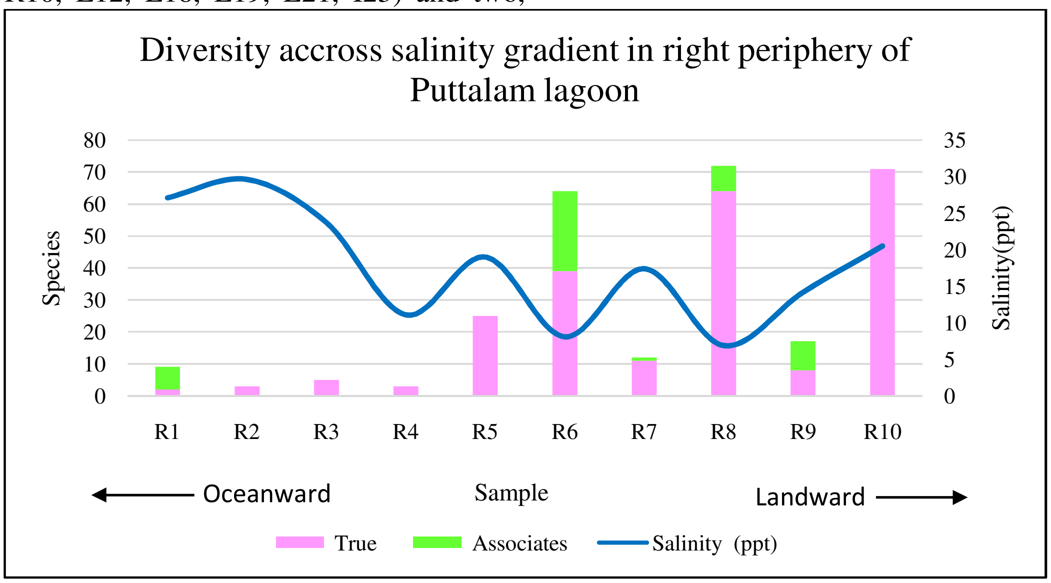

Figure 7: Mangrove diversity across the salinity gradient

Source: Based on the vegetation survey, 2019

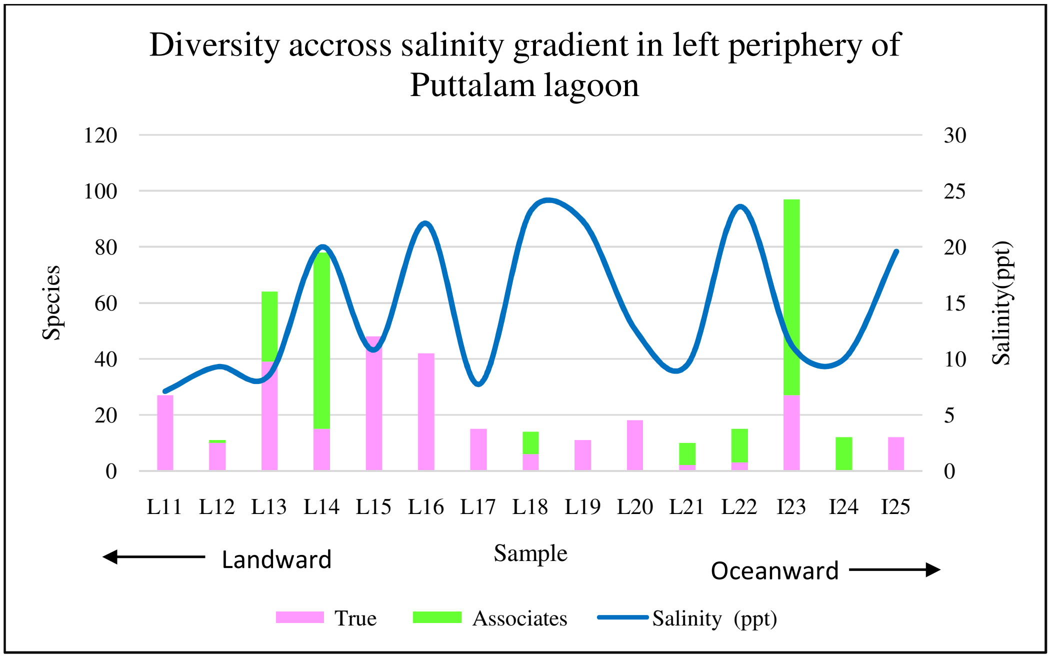

Figure 8: Mangrove diversity across the salinity gradient

Source: Based on the vegetation survey, 2019

The salinity level of the left periphery fluctuates between 7ppt to 24ppt making significant variations (Fig 9).Sample eleven, fifteen, sixteen, seventeen, nineteen, twenty and twenty-five (L15, L16, L17, L19, L20 and L25) were solely confined to true mangrove species.Sample twenty-four which is an island close to the outlet of the lagoon have recorded only mangrove associates while a large number of mangrove associates enumerated in sample fourteen (L14); which is located landward, and sample twenty-three (23I) areas. Again the significance of *Suaeda* spp could be seen in sample 14. Further, sample 14 is a place where a large number of sediment patchesexisted as effluents of aquaculture ponds which proves the lower to moderate salinity preference of the species.

When comparing the spatial distribution of salinity and diversity of Puttalam lagoon (Fig 10) low salinity levels; 12-16ppt characterisevery high diversity of mangrove species. Spatially very high salinity level was recorded towards the ocean. Salinity level between 12 to 16 ppt prefers *R. mucronata* and *R. apiculata* very well while *A. officinalis* prefer very low salinity levels range between 6.9 to 11ppt.

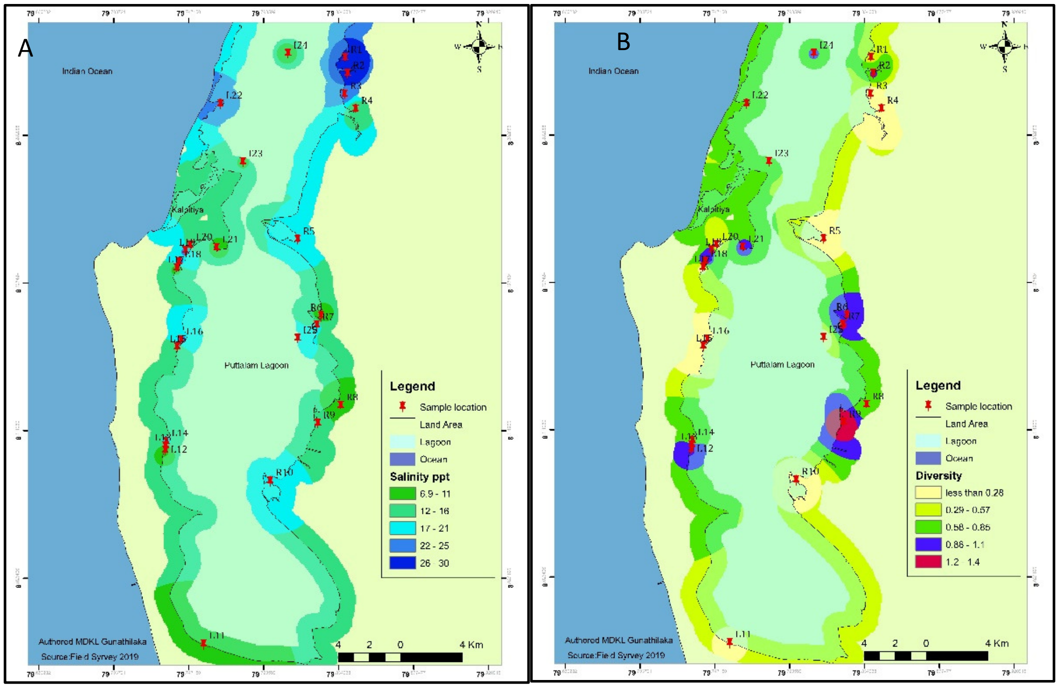

Figure 9: Spatial distribution of salinity (A) and mangrove diversity (B)

Source: Based on the vegetation survey, 2019

Sonneratia alba prefers very high salinity levels which were highly restricted only to high saline zone and enumerated at sample 1 and 2 (R1 and R2) located in Kala Oya estuary. Accordingly, Kala Oya estuary can be recognized as an ecological niche for rare and very rare species. Demonstrating the uniqueness of species distribution, Kala Oya estuary is well appropriated for high salinity preferring *Pemphis acidula*, which is a valuable medicine that has the potentiality to exterminate dengue larval within 24h and have strong antibacterial quality [24] . Except for the outlet of the lagoon, completely the area have lower to moderate salinity levels (Fig 10 A). *Aegiceras corniculata* prefers high salinity levels [25], however, the enumerated lone species existed in sample 9 (R9) where salinity level range from 12 to 16 ppt. Though salinity tolerance of *Excoecaria agallocha* ranged from high to moderate salinity [26] levels, the species enumerated plots distributed within low salinity stages. Mangrove associates enumerated where the salinity level ranges from 6.9 to 16ppt. Hence, the salinity tolerance level of mangrove species different from species to species.

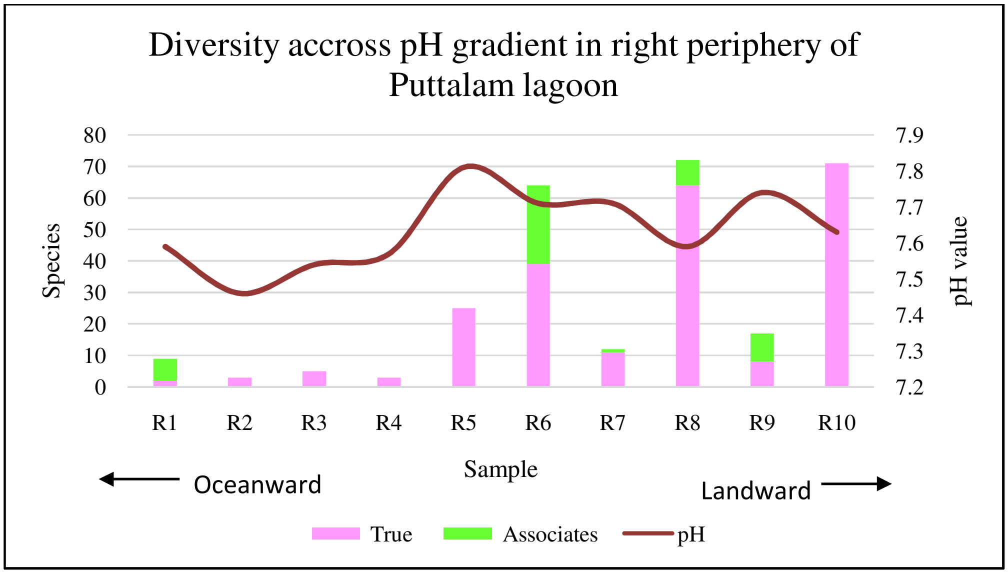

Figure 10: Diversity across the pH gradient

Source: Based on the vegetation survey, 2019

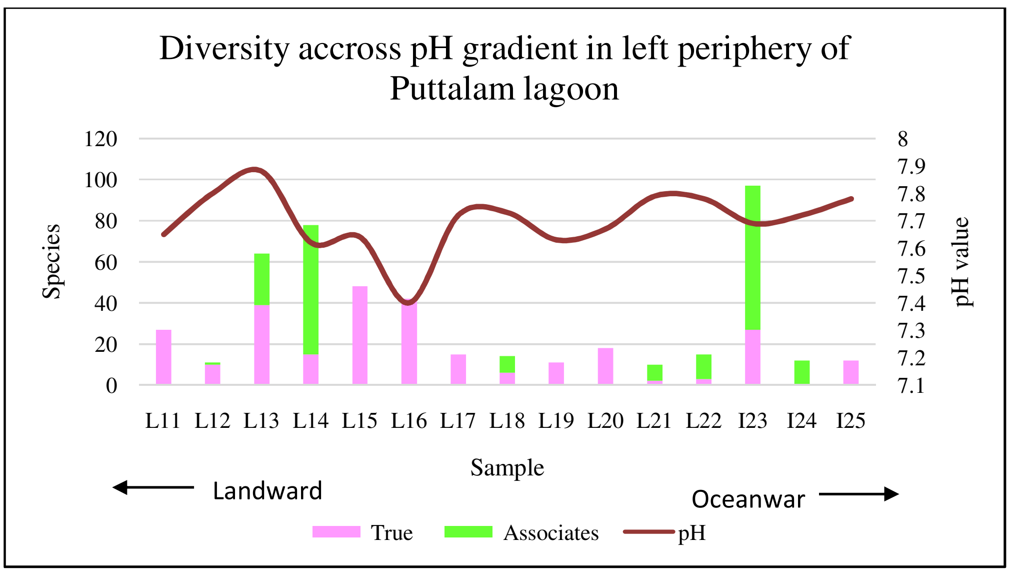

Figure 11: Diversity across the pH gradient

Source: Based on the vegetation survey, 2019

The pH gradient in the lagoon is ranged from 7.4 to 7.88. The freshwater influx to the lagoon makes moderate levels in pH in the lagoon water body. Where the mangrove associates were dominants reported a pH of 7.6 or over. The lowest pH is 7.4 and the highest is 7.81 in the right periphery (Fig 11) while the 7.88 highest pH reported for the left periphery (Fig 12) where the lowest value is same as right periphery. The spatial distribution of pH value shows that the outlet of the Kala Oya has recorded normal pH as in the freshwater. Spatially the highest pH value

(Fig 13) could be identified in the right periphery of the lagoon (R5) were more artificial shrimp ponds have existed. In the left periphery, sample twelve, thirteen, fourteen and twenty-one reported the highest pH, where commercial crab cages have existed thus, and the lagoon water body polluted in the particular area. In sample twenty-one, high pH may be due to the dry fish making process that takes place at the proximity of the sample plot. All residuals and effluents were removed directly to the lagoon.

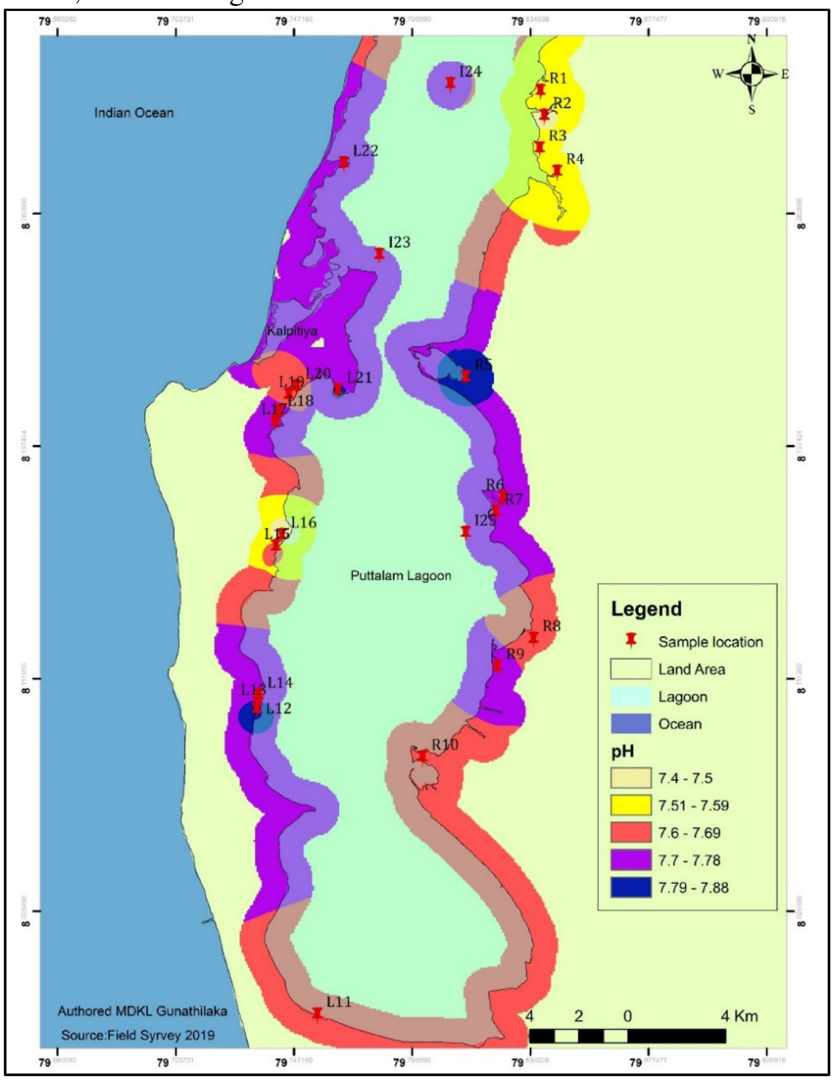

Figure 12: Spatial distribution of pH

Source: Based on the vegetation survey, 2019

Electrical Conductivity reflects the capacity of water to conduct electrical current and is directly related to the concentration of salts dissolved in water. Therefore, a significant difference between the salinity gradient and EC gradient is difficult to recognize. Both highest and lowest EC values recorded in the right periphery of the lagoon (Fig 14). Relative to the salinity gradient in the left periphery of the lagoon, EC gradient has shown a dramatic increase with salient stability of EC values at sample sixteen, seventeen, eighteen and nineteen (L16,L17,L18 and L19) where solely true mangrove species were enumerated (Fig 15) except at sample eighteen, in which one single mangrove associate species;*P. acidula* and eleven true mangrove species recorded.Previously restored areas commonly display a low electric conductivity in the lagoon water. Furthermore, most of the mangrove degraded areas identified with very low EC levels in the lagoon water.

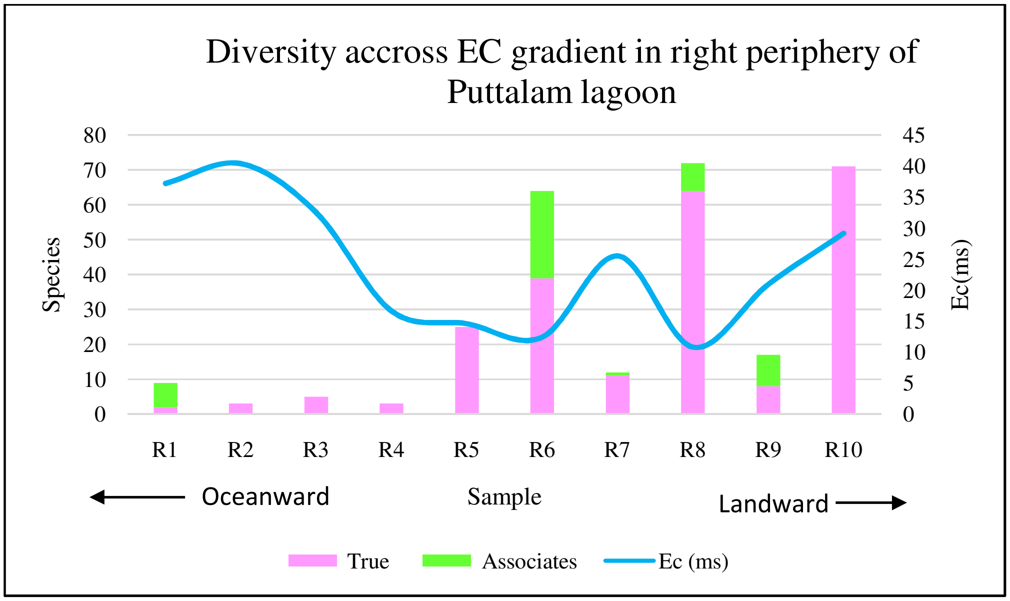

Figure 13: Diversity across EC gradient

Source: Based on the vegetation survey, 2019

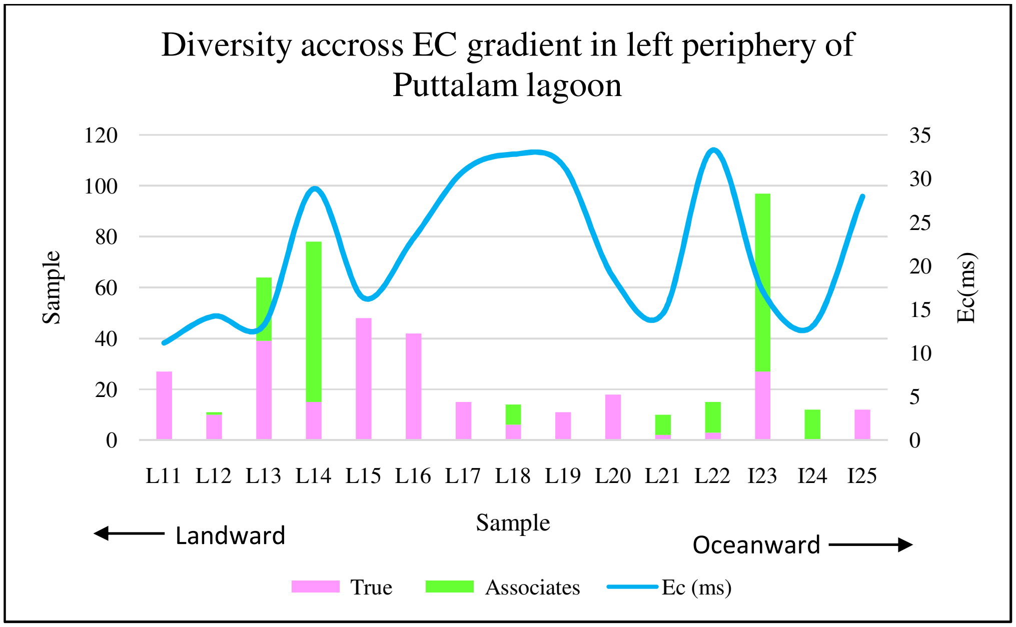

Figure 14: Diversity across EC gradient

Source: Based on the vegetation survey, 2019

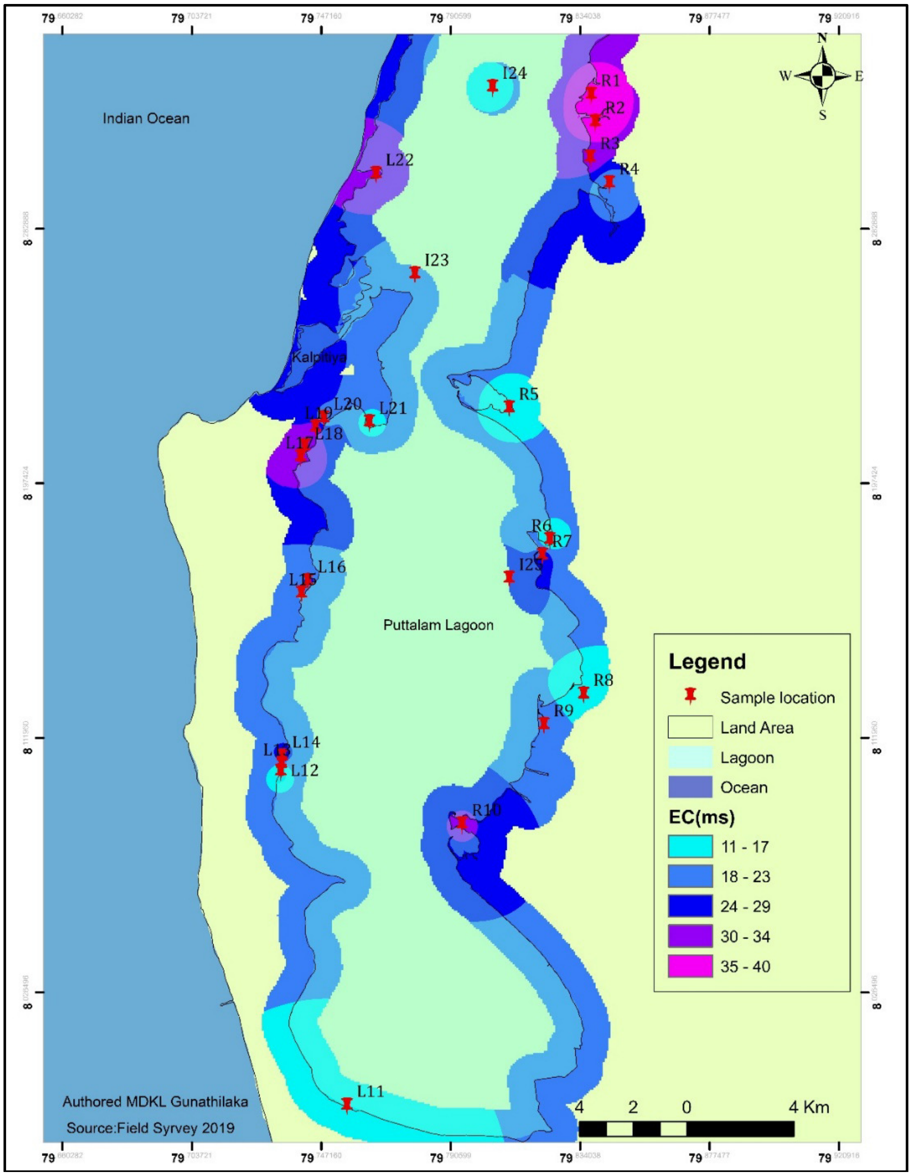

Figure 15: Spatial distribution of EC

Source: Based on the vegetation survey, 2019

The spatial distribution of EC further, illustrates that the Kala Oya estuary (Fig 16) in the right periphery has reported for the highest EC value along with the least values in three sample plots. Besides, figure 16 depicts that there is no particular connection with the diversity of species and the EC values. For example, lower the diversity reported higher EC values (R1 and R2 and R10), higher the diversity lower the EC (R9), lower the diversity lower the EC (R5), higher the diversity higher the EC (L18).

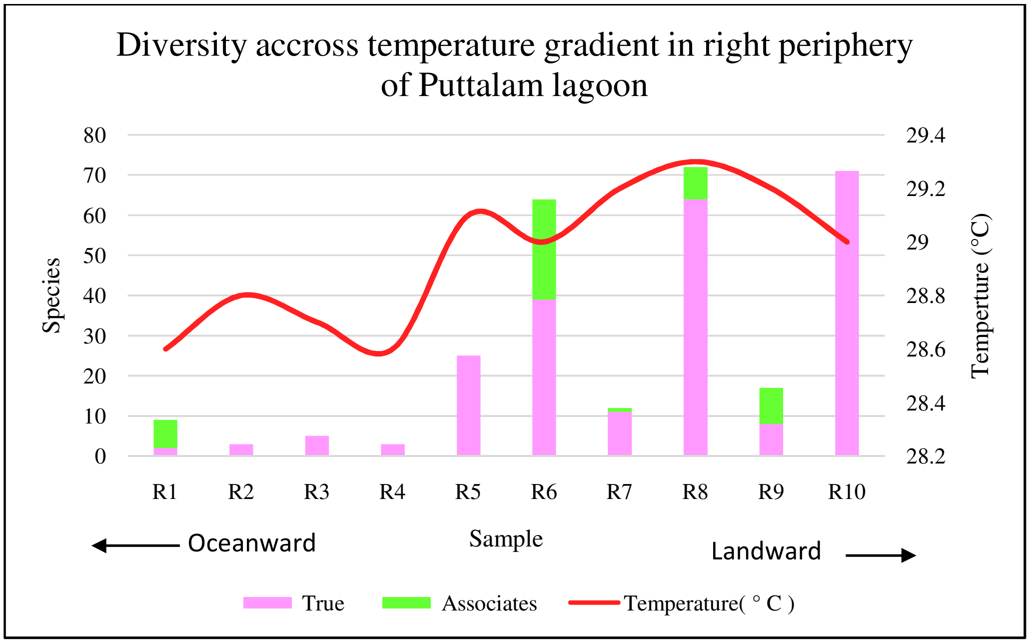

Figure 16: Diversity across the temperature gradient

Source: Based on the vegetation survey, 2019

The temperature of the Puttalam lagoon is high in the dry season as the area located in the semi-arid climate zone of Sri Lanka. However, the temperature varies with the beginning of Inter-Monsoons and South-Western monsoons. This study fund temperature values ranged between 28.6 ° C to 29.4 ° C (Fig 17 and 18).The right periphery of the lagoon conveyed relatively high-temperature values while the temperature of the left periphery fluctuates significantly (Fig 17 and 18). However, the highest temperature value recorded in the left periphery of the lagoon as 29.4° C (Fig 18).

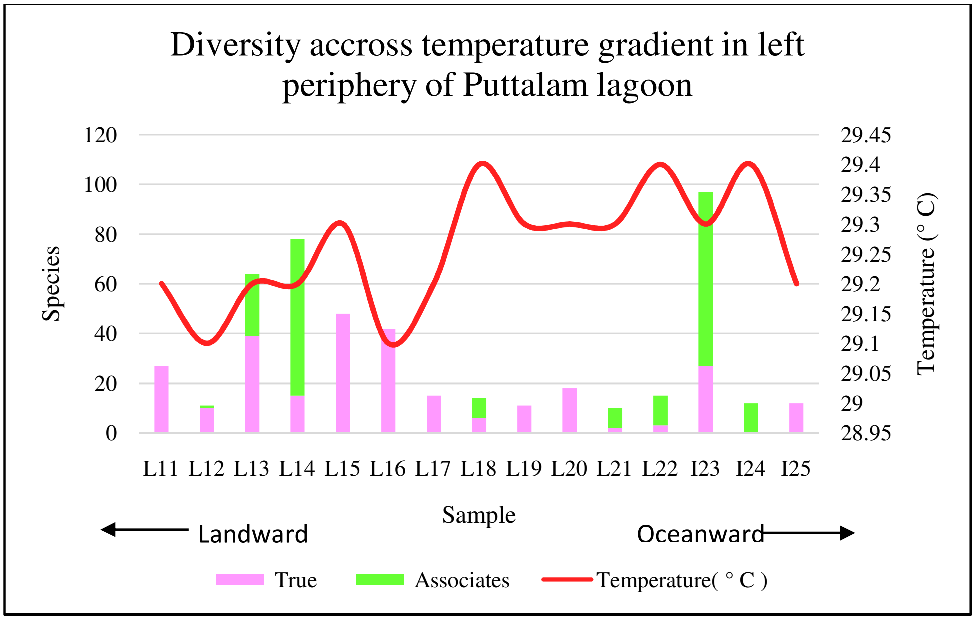

Figure 17: Diversity across the temperature gradient

Source: Based on the vegetation survey, 2019

The spatial distribution of temperature in the lagoon water body (Fig19) shows that lower temperature values recorded only in Kala Oya estuary. When comparing the diversity and temperature of Puttalam lagoon, lower diversity areas relatively shows high to moderate temperature values. In contrast, two belt transects at the outlet of the lagoon demonstrates two different patterns of temperature. Left periphery temperature increased towards the ocean while the right periphery decreased the temperature, due to the freshwater out-flux.

Considering the three islands, the following sum up can be stated (Table 2). Sample twenty-three reported for a significance of mangrove associates while sample twenty-four confined only to associate species.

Table 2: Status of islands

Island	Diversity	Abundance	Salinity (ppt)	EC (ms)	pH	Tem. ŸC
I23	Moderate	Very low	Low	Low	7.7-7.78	29.21-29.4
I24	Moderate	Low	Low	Very low		
I25	Low	High	Moderate	Moderate		29.01-29.2

Source: Based on the vegetation survey, 2019

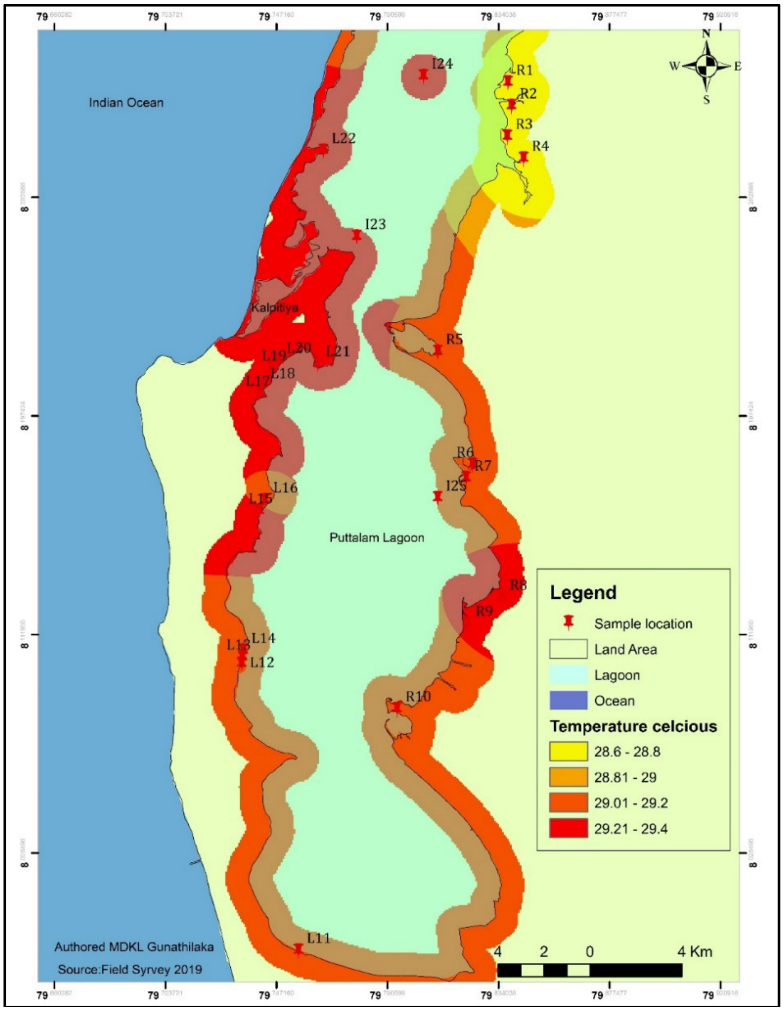

Figure 18: Spatial distribution of temperature

Source: Based on the vegetation survey, 2019

3.3 Mangrove restoration priorities and further degradation vulnerability

The spatial distribution of mangroves shows the dominance of one particular species; *R. mucronata*. This dominance indicates that encroachment of *Rhizophora*may be possible to produce a threat to the diversity of nearest localities consists of relatively high diversity. Hence, the areas which have the threat of *Rhizophora* can be identified as critical areas which require more conservation measures with restoration. Sample two (R2) in Kala Oya estuary, sample thirteen and fourteen (L13 and L14) can be recognized as highly threatened areas while sample nine (R9) identified as vulnerable areas. Sample three and four which are located at the mouth of the Kala Oya estuary have an abundance of *R. apiculate*. Though the area is identified as one of the largest extents of mangroves in Sri Lanka, now it has become vulnerable to reduce the diversity of species. And also the threat can be increased up to the upper parts of the estuary towards the ocean and the whole area will become a colony of *R. apiculate* and rare species in the area will be threatened. Therefore, it is very important to restore mangrove in Kala Oya estuary. Sample twelve is also vulnerable if the encroachment further extended. Since the lagoon areas show a lower to moderate diversity, there is a great possibility to decrease the diversity further. This encroachment is two way; natural and anthropogenic.

The *R. mucronata* has a high potential to survive in the moderate to high saline environments, thus, stakeholders used to select the specie for restoration. In that sense, the anthropogenic contribution to the *Rhizophora* encroachment may possible to reduce. Though *R. apiculata* has the same tolerance level of salinity [27] it is technically not appropriate for restoration in the area as the plant further increases sedimentation through the prop root system, consequently increases the extent of mudflat surfaces in the area. The area has already enough mudflat surfaces. *R. mucronata* enumerated in Sample 5 (R5) in Karative and nearest areas can be used as restoration sites to reduce the abundance of species and to increase the diversity of species. Sample 11(L11) consisted mostly of *A. officinalis* and vulnerable for further loss of diversity. So the area can restore with same salinity preference species such as *A. marina*. The sole extent of *A. marina* in sample 10 (R10) existed due to deforestation in the purpose of the salt industry in Seguwanthive. The restoration and conservation of mangroves in the area have become quite impossible with the expansion of commercial salt pans.The impact of the loss of diversity or rare species are not concerned for species selection and have the vulnerability of extinction of some species; *Scyphiphora hydrophyllacea* (very rare), *Cynometra iripa* (very rare), *A. corniculata* (rare), *S. alba* (rare) and *P. acidula* (very rare).

On the other hand, there are a few ecological niches identified in the area. Sample one and two are well suited for high saline species and their distribution was highly restricted to one and two sample plots; *S. alba.* This could be stated as a fundamental ecological niche of *S. alba* in the Puttalam lagoon area.*P. acidula* distribution further emphasizes another fundamental ecological niche located in sample one, twenty-two and twenty-four.The other niche possibly to emphasize as a realized ecological niche located at sample nine. *A. corniculata* prefers high salinity levels, and well established and adapted in sample nine where the salinity levels reported as lower. Accordingly, two true mangrove species and an associate species found to have ecological niches which are considered as rare and very rare species respectively. These niches are vulnerable for loss of diversity and in that perspective, the more attention on conservation and restoration of mangroves essential in the endangered areas.

4. Conclusion and Recommendations

It is clear mangroves in the second largest lagoon have been decreased by its previous extent and the study was able to find out that the diversity of mangrove species also decreased in the area. Encroachment of abundant species has become a threat to the diversity of mangroves. Demarcations of buffer zones and critical areas of vulnerability should be existed to protect the ecosystem. Apart from restoration priorities in the lagoon, mangrove conservation can be implemented on a smaller scale to a larger scale. Empowering rules and regulations related to mangrove conservation are necessary for the area. Regular observations are highly necessary to manipulate anthropogenic impacts on the mangrove ecosystem, thus required a mechanism to monitor the human behaviour in consumption of the ecosystem. Besides, environmental education and awareness programs should be implemented more than now to clarify how important the mangrove ecosystem. Community-based restoration program in the area has to be launched with more advanced underlying goals; win-win approach. Consequently, both the ecosystem and residents will be able to have benefits. Especially coastal semi-arid zone like Puttalam should pay significant attention to environmental conservation and ecosystem restoration as the area is vulnerable for sea-level rise due to global warming. One possible way to respond, at least to contribute in a small scale is conserve mangrove ecosystem in the area.

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