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Salt Marsh Ecology in Karainagar, Sri Lanka

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Abstract: Salt marshes are dynamic habitat lying on a low energy coastline functioning as ecotones. Salt marshes in Sri Lanka are understudied, unexplored and less concerned for conservation. This study recorded biodiversity and ecology of Karainagar marsh plants and their influence by edaphic factors. Floral diversity was studied with 10m wide line transects at seven points perpendicular to the High Tide Line, comprising 35 quadrats. Six marsh plants of family Amaranthaceae were identified. Suaeda maritima, Halosarcia indica and Salicornia brachiata were abundantly observed. Highest Shannon Index (0.78) and lowest Simpson Index (0.41) values were recorded in Point 3. Cluster analysis classified plots into four clusters and 2D- Multi Dimensional Scaling deduced higher similarity between Points 3, 4, 5 and 7. Positive correlation between elevation and salinity (r=0.829, p=0.00) has influenced plant distribution. Pearson comparison resembled a strong statistically significant correlation between elevation and salinity (p=0.004). The flooding inundation and climatic zonation has resulted in profound increase in salinity in Karainagar. Despite their high ecological value, salt marshes are being destroyed at an alarming rate. Understanding relationship between salt marsh ecology and environmental factors is a key factor in salt marsh conservation and restoration.

Keywords: Salt marsh; Karainagar; Sri Lanka; Halophytes; Salinity; Ecology

1. Introduction

Salt marshes represent a dynamic habitat that has characteristics of both marine and terrestrial systems [10] . Salt marsh habitats are generally halophytic, arboreal and flowering plants that are predominantly observed in tropical and sub-tropical regions [1]. They are one of the productive coastal ecosystems and they provide coastal functions like flood mitigation, moderation of carbon (through carbon sequestration) [11], filtration of pollutants and sediments, and providing habitats to wildlife [6]. Salt marsh distribution is governed by environmental gradients including tidal inundation, salinity variation and interactions with other species [4]. Yet their ecology depends on various factors such as flooding frequency, soil salinity and water logging. Salinity [5] plays a major role in controlling the plant distribution. Salt marsh plants can thrive in varying salinity profiles as such they have different salt tolerant and adaptation strategies [4].

Coastal salt marshes are generally located at the land-sea interface and are critically dependent on the equilibrium between erosion, deposition and eustatism [19]. These coastal ecosystems are unique owing to the atypical conditions of their hydrodynamics and sedimentation. They are encountered on the banks of estuaries, along coasts, in blind gulf some bays and along intertidal areas [5]. They provide a wide array of services including carbon accumulation [1]; [15], nursery ground and nutrient source for fish, invertebrates and coastal birds , coastal protection [16], restoration of saline soil [2], bioaccumulation of heavy metals [3] and provision of food and medicinal resources [14]. Despite their ecosystem values, they are being destroyed due to intense anthropogenic stress including land reclamation, urban development, salt production, waste disposal and shrimp farming [15].

Sri Lankan salt marsh typically, occurs as scarce, short growth often scattered with scrub mangroves. They are widely found in almost all of the coastal cities including Jaffna; yet mostly confined to the north-western and south-eastern coasts [20]; spreading across 23,819 hectares [14]. The revised coastal zone management plan (1997) reports that Jaffna holds around 4963 ha of salt marshes. Karainagar, located 20km away from Jaffna; is one of seven islets belonging to Jaffna peninsula. It spans about ten square miles with varied diversity of coastal ecosystems. Due to several reasons, researchers are reluctant to undertake studies on Sri Lankan salt marshes. This might attribute to lack of expertise, insufficient experimental technologies or limited monitoring information. Monitoring natural saltmarsh is essential to provide reference data for restoration. Karainagar salt marsh exhibits a unique ecotone specially by lying along the semi-sheltered low energy coastline, in association with the mangrove patch. No studies have been conducted on the diversity or ecology on the Karainagar. This paper aims to develop an understanding of the salt marsh ecology in Karainagar.

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2. Materials and Methods

Study site

The assessment of ecology and diversity was conducted along a Karainagar coast (Figure 1) from December 2019 to January 2020. The study area included the Karainagar Bridge, which runs along the Palk Strait, that connects Karainagar with its motherland, Jaffna. Seven sampling points were located in the coastal stretch of the study site. The sampling sites were selected based on the representative distribution of salt marsh plants. It should be noted that Karainagar is located in the dry zone of the country.

Methodology

For the assessment, random sampling method was followed. Salt marsh vegetation was studied using transects in seven randomly selected points. Each plot was installed over 5m away from any adjacent plot to avoid spatial autocorrelation [4]. Along the coastal zone, line transects of 10m were laid perpendicular to the High Tide Line (HTL). Within each transect, quadrats (1 x 1m) were laid to for the purpose of species identification (Table 1). Salt march species along the transects were identified, counted (more than 75% of the plant body inside the quadrat) and recorded.

Environmental data

Water samples were taken from the Palk Strait and tested for salinity, pH and conductivity. Data on environmental factors were collected from the Department of Meteorology, Sri Lanka. Elevation data was extracted from the Digital Elevation Model (DEM)[1].

Biodiversity analysis

Biodiversity was analyzed with the measure of species richness (Margalef Index, D_{Mg}), and dominance (1-D) [13], species diversity (Shannon Index, H') [21], and the evenness (Shannon Evenness, E) [17] of the species. The indices were used to explain the distribution and abundance of salt marshes in the selected site. All the data were analyzed with MS Excel 2016 and SPSS 17.0. Further, community structure was assessed with Primer 6 version. Cluster analysis was performed using the Bray-Curtis dissimilarity matrix. Multiple response permutation procedure was applied to check for significant difference between the clusters. 2-D Multi-Dimensional Scaling (MDS) was executed to clarify the relationship of environmental factors on the plant community distribution. Environmental data were analyzed and compared with plant distribution using Kruskal-Wallis test (α=0.05), linear regression and Analysis of Variance based on Pearson correlation.

3. Results

Species distribution

A sum of six salt marsh species belonging to family Amaranthaceae were recorded in Karainagar (Table 1). *Suaeda maritima*, *Halosarcia indica* and *Salicornia brachiata* were present in most of the points sampled while the others were scattered throughout the study site. *Suaeda nudiflora* was the least abundant in the points studied. Highest relative density was exhibited by *Suaeda maritima* and *Halosarcia indica*, throughout all the sites. The relative abundance of the salt march species at the study site is given in Figure 2.

Plant diversity

Species richness, dominance and evenness varied widely between the study points. Highest Shannon diversity value (H'=0.78) and lowest Simpson index value (0.41) was recorded in Point 3 (Table 3) which comprised of the highest number of species among all study sites, followed by Point 7 (H'=0.70). Point 3 also exhibited the highest Shannon evenness value (1.00). The highest dominance value was (0.59) recorded in Point 3, while the least (0.50) was recorded in Point 1. As explained by Table 3, the Shannon diversity index was in the range of 0.60 – 0.80 despite the fact that Simpson index was between 0.40 and 0.50.

[1] Elevation DEM can be accessed through https://en-in.topographic-map.com

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Figure 1: Map of the study area (Source: Google Earth, 2015)

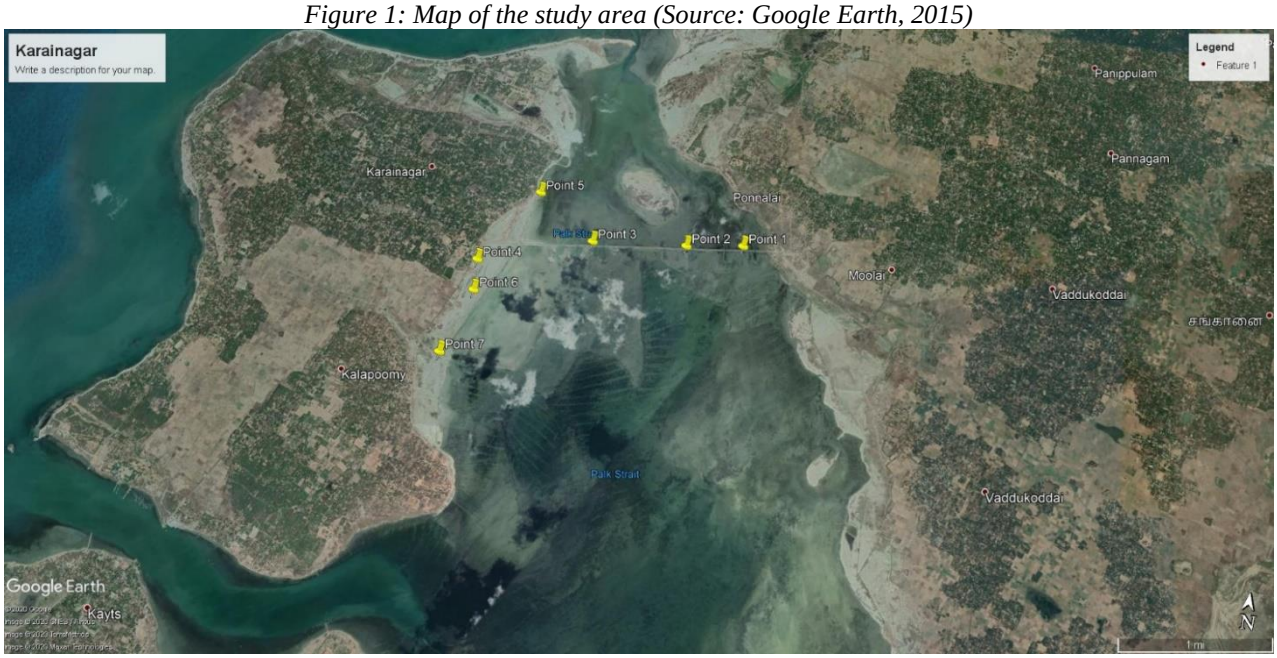

Table 1: Sampling points in the study location and number of quadrats

Sampling point	GPS location	No. of quadrats
Point 1	9°44'36.47"N, 79°55'2.34"E	3
Point 2	9°44'33.22"N, 79°54'40.96"E	4
Point 3	9°44'29.39"N, 79°54'5.39"E	6
Point 4	9°44'15.50"N, 79°53'23.52"E	5
Point 5	9°44'46.14"N, 79°53'42.10"E	5
Point 6	9°44'3.35"N, 79°53'24.55"E	6
Point 7	9°43'37.84"N, 79°53'17.07"E	6

Species distribution

Cluster analysis of plots based on plant composition identified four clusters (1-4) related to variation in environmental characteristics. *Salicornia brachiata* was dominant in cluster 1 whilst *Arthrocenum indicum* was prominent cluster 2. Cluster 3 was characterized by *S. maritima* and *H. indica*, and the rest were in cluster 4. Each cluster is clearly separated with respect to plant species. 2-D MDS showed higher similarity between Points 3, 4, 5 and 7 with relevant to the environmental factors (2-D stress=0.03, Bray Curtis similarity). The influence of salinity, elevation and soil water content was observed higher on the plant distribution and abundance than that of the other environmental factors (Figure 4). There was a statistically significant correlation between elevation and salinity (p=0.004) while no correlation between salinity and abundance (p=0.150)

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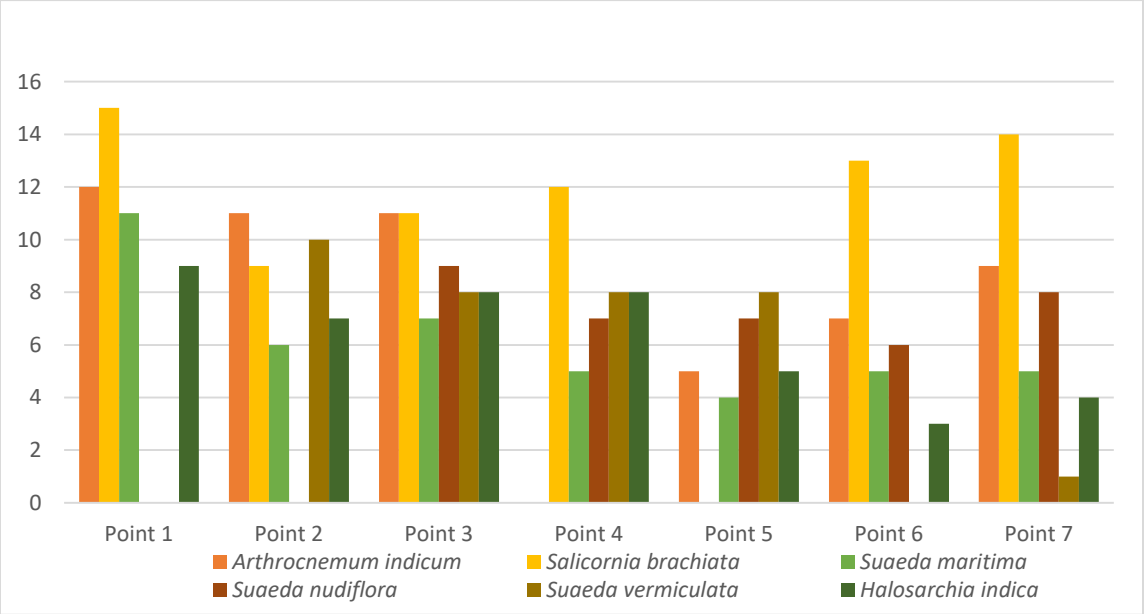

Figure 2: Abundance of salt marsh species recorded in the study area

Table 2: Relative abundance of species and their distribution in the study area

Species	Family	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
Arthrocnemum indicum	Amaranthaceae	✓	✓	✓	x	✓	✓	✓
Salicornia brachiata	Amaranthaceae	✓	✓	✓	✓	x	✓	✓
Suaeda maritima	Amaranthaceae	✓	✓	✓	✓	✓	✓	✓
Suaeda nudiflora	Amaranthaceae	x	x	✓	✓	✓	✓	✓
Suaeda vermiculata	Amaranthaceae	x	✓	✓	✓	✓	x	✓
Halosarcia indica	Amaranthaceae	✓	✓	✓	✓	✓	✓	✓

✓ - Present, x – Absent

Table 3: Diversity indices of salt marsh species in the study area

Diversity index	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
Shannon Index (H)	0.60	0.69	0.78	0.69	0.69	0.65	0.70
Simpson index (D)	0.50	0.45	0.41	0.45	0.45	0.46	0.43
Margalef Index (D_{max})	1.79	2.44	2.88	3.11	2.73	2.60	3.09
Evenness (E)	0.99	0.98	1.00	0.98	0.98	0.92	0.89
Dominance (1-D)	0.50	0.55	0.59	0.55	0.55	0.54	0.57

Plant distribution patterns relation to soil salinity were on contrary to those with respect to elevation. Regression analysis between elevation and salinity showed positive correlation (r=0.829, n=35, p=0.000) whilst correlation of salinity with plant distribution was negative and did not show a statistical significance (r=0.355, n=35, p=0.090).

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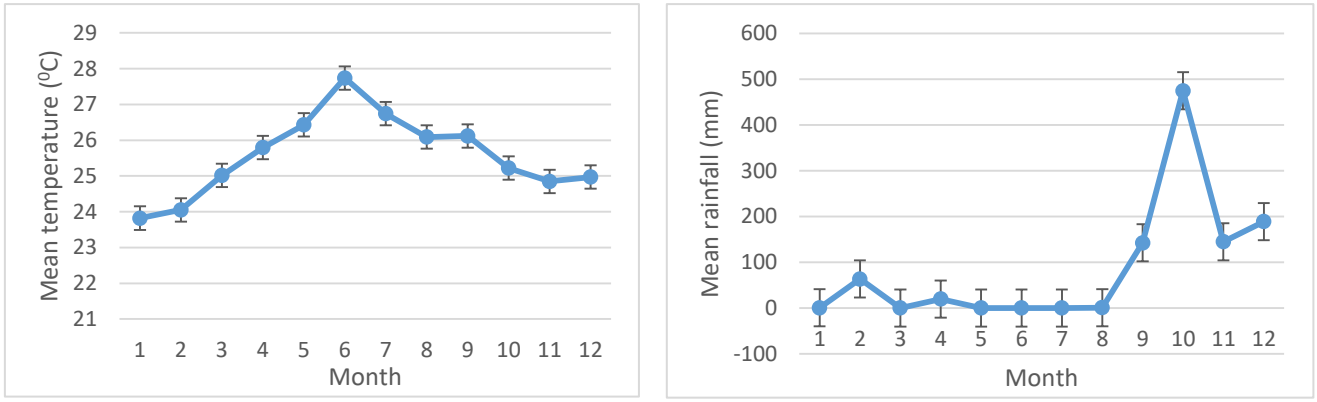

Figure 3: Mean annual temperature (left) and rainfall (right) of Karainagar. (Source: Meteorological Department, Sri Lanka

4. Discussion

Salt marshes can grow in a wide range of habitats from coarse sandy and muddy bottoms in the intertidal area [8]. However, the coastal area of Karainagar is relatively a simple band of salt marsh plants. Although there are few (six) salt marsh species at the study site, the diversity was high as explained by the diversity indices. Higher number of individuals (54) were recorded from point 3, which also exhibits highest values for species diversity (0.78), evenness (1.00) and dominance (0.59) whilst lower value for Simpson index (0.41)This represents one of two sites where all the species were recorded. On contrary, Point 7 even though had lower number of individuals than that of Point 3, it was highly diversified. As explained by Figure 2, *Suaeda maritima* and *Halosarcia indica* had shown their abundance throughout the site where as *Suaeda nudiflora* has not been seen throughout. This could be attributed to species resistance, to the influence by edaphic factors such as climate or salinity. Accordingly, it becomes obvious that the marsh plants that grow well in favor of extreme conditions would colonize salt marshes.

This salt marsh was found associated with a small mangrove patch at the site. Thus, its succession could be influenced by the stress by competition posed by the adjoining woody halophytes; mainly for nutrients, water and light. In addition, tropical salt marshes are frequently inundated by seawater [7]. This can have a profound influence on the stability, abundance and diversity of the salt marshes.

Gul & Khan, 1995 have notified that succession of salt marsh plants is highly dependent on salinity, peat accumulation and competition whereas, primary productivity could be influenced by edaphic factors including salinity and climate. Karainagar belongs to the dry zone of the country; with a mean temperature of 25.5^{o}C and mean rainfall 86.24 mm annually (Figure 3). The coastal area is extremely dry throughout the year which results in over evaporation of , and with less number of freshwater influx (since lack of freshwater rivers) [18], both resulting in an elevated salinity, that is slightly lesser than sea water. (Table 1).

Tidal patterns according to the elevation has a profound influence on the marsh plants distribution [9]. The mean elevation of the study site is 5.58m, which suggests tidal inundation, flooding frequency would be high at times, and plant may not survive them. In addition, tidal flooding leads to depleted soil oxygen and consequently results in anaerobic conditions [4]; which would have influenced the distribution of marsh plants in the study area.

Even though, halophytes can tolerate salt stress, particular species differ in salt ranges. Salinity has a prominent influence on halophyte distribution [12]. Salt marshes experience twice-daily flood and ebb tides, with daily variation in tidal height. The time of seawater saturation therefore depends on elevation. As elevation increases, the aerial exposure and drying time increase, leading to high soil salinity [4].

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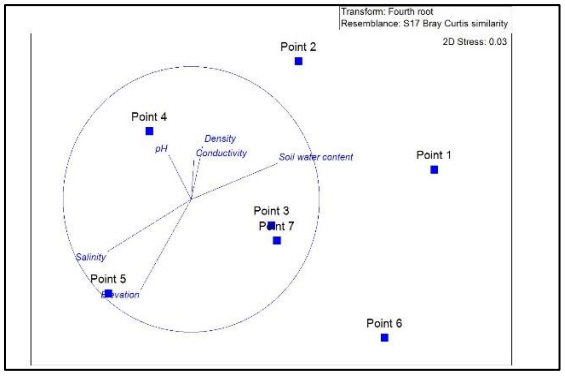

Figure 4: 2-D Multi-Dimensional Scaling (MDS) of the site

Table 4: Environmental factors measured at the study site

Variables	Mean, SD*	Standard error	Range
Salinity (ppt)	33.15,0.64	0.25	32-34
pH	7.88,0.07	0.03	7.8-8.0
Conductivity (S/m)	3.32,0.17	0.07	3.1-3.5
Density (g cm-3)	1.08,0.09	0.04	1.02-1.21
Elevation (m)	5.58,1.4	0.53	4-7
Soil water content (%)	27.43,1.5	0.27	25-30

*SD-Standard Deviation

5. Conclusion

Six halophyte species belonging to Amaranthaceae family were identified from the Karainagar salt marsh that showed different distribution ranges and distribution relative to elevation and salinity gradients. Highest diversity was observed on Point 3 followed by Point 7. Positive correlation of elevation with salinity has a profound influence on plant distribution at the salt marsh. The quantitative field data would provide a basic information to promote salt marsh conservation and restoration.

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