

Diversity of Halophytes in Gulf of Kachchh, Gujarat

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ABSTRACT- Floristic inventory and diversity assessment are necessary to understand the present diversity status of the conservation of biodiversity. Shore lines are one of the most rapidly changing places on the Earth. The Gulf of Kachchh (GoK) is a semi-enclosed coastal indentation with predominance of mangrove ecosystems, coral reefs, associated rich marine diversity and coastal terrestrial vegetation. Halophytes are flowering plants, which are naturally found in saline habitats such as coastal swamps, coastal dunes and inland salt flats etc. Present works reveals, the diversity of halophytes in GoK. Total 27 halophytes were encountered from 13 coastal talukas and islands of GoK. Islands of GoK and Bhachau taluka are the area with highest diversity in GoK. In the present study, α diversity (Shannon diversity index, Simpson's Index, species richness, evenness index) of the halophyte community was studied. From the study of biodiversity, it was observed that highest species diversity (Shannon-Wiener diversity H') was observed in Jamnagar district and its islands, whereas species richness index (d) was highest in Devbhumi Dwarka district and its islands. Evenness index (e) was highest (0.528) in Morbi district.

Key-words- α -Diversity, Gulf of Kachchh, Halophytes, Saline habitats

INTRODUCTION

The Gujarat state is situated on the north-western parts of India. It ($20^{\circ} 2' - 24^{\circ} 41' N$ latitude and $68^{\circ} 8' - 74^{\circ} 23' E$ longitude) occupies an area of 1,96,024 sq.km and has 1663-km-long coastline, which spreads along 13 coastal districts and one Union Territory of Diu between Kachchh and Valsad. Interestingly, 1663-km-long sea coast of Gujarat is characterized by typical salt marshes (~796-km), sand dunes (~440-km) and rocky shore (~319-km) [1]. It is widely accepted now that among the various biodiversity regions, the coastal and marine ecosystems are of particular importance in terms of their utility to the human livelihood security. Salt marshes are defined as natural or semi-natural terrestrial halophytic- ecosystems [2]. The dominant flora is composed of halophytic plant such as, grasses, shrub and herbs. Salt marshes are those areas, which are periodically inundated by the sea and which contain true halophytic

and salt tolerant plants occupying an area (approximate) between the mean high water neap tide and mean high water spring tide [3].

In the last 70 years various attempts have been made to classify halophytes [4]. However, the simplest and clearest definition is probably stating that "halophytes species are those occurring in naturally saline conditions only" [5].

Halophyte plants complete their life cycle in saline habitats with unique morphological, biological and physiological characters, which distinguish them from sea grasses and mangroves. There are a few hundred halophytic plant species recorded in the world. Although voluminous information is available on general biology and eco-physiology of halophytes, only a few reports are available on diversity of this fascinating group of coastal flora [6]. Halophytes are plants of significant economic potential which can contribute tremendously toward the environmental restoration and also have industrial applications in the form of essential oils, medicinal, alcohol, fiber, latex, pulp, cosmetics etc.

Present investigations have been carried out to assess the distribution of halophytes diversity in 13 coastal talukas and islands of GoK.

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MATERIALS AND METHODS

Study Area

An assessment of halophytes flora was conducted along the GoK coast in 2011 to 2014 under Integrated Coastal Zone Management Project. The study area consisted of 4 districts (13 coastal talukas i.e. from Okha to Abdasa) surrounding the Gulf of Kachchh (22° 15' N to 23° 50' N and 68° 20' E to 68° 54' E) and its islands (Fig. 1). For the purpose of data collection the entire study area was categorized into four zones based on the district boundaries i.e. Devbhumi Dwarka, Jamnagar, Morbi and Kachchh.



Fig. 1: Study Area GoK

Methodology

For the present study, the random sampling method was followed. In the coastal areas, line transects of 500 m were laid perpendicular to HTL (High Tide Line) to landward side by using 5x5 Km grid maps of Land use/Land cover maps (Like forest, grasslands, scrublands etc.). Distance of 5 km between two subsequent line intersects was maintained using Global Positioning System. Within each transect, quadrates were laid at the interval of 20 m for Trees and Shrubs 5m x5m and for herbs, grasses, climbers 1m x1m [7-9]. To enrich the species inventory the opportunistic coastal area at each site (areas falling outside of the quadrates) were also explored and observed species were recorded and photographed.

Collection of plant specimens was carried out to know more information on habitat and for preparation of herbarium specimens. The species were identified using published literature and different Floras [10-13].

Analysis of Bio-diversity- To measure α -biodiversity, it is necessary to measure species richness, species diversity

and the evenness of the species. Species richness is another good aspect of measuring biodiversity.

Shannon Wiener diversity index- The Shannon diversity index sampling to measure was utilized to randomly measure the individuals from an 'indefinitely large' (that is effectively infinite) population [14]. Species diversity was calculated using the equation [15].

$$H = -\sum p_i \ln p_i$$

Whereas,

H' = Shannon index of general diversity,
 p_i = Proportion abundance of the i^{th} species = (n_i/N) ,
 n_i = Number of individuals in the i^{th} species and
 N = The total number of individuals.

Simpson's index- The index of dominance of the community was calculated by Simpson's index [16] as:

$$c = \sum n_i (n_i - 1) / N (N - 1)$$

Where c = Index of dominance, n_i and N being the same as the Shannon index of general diversity.

Species richness index- Species richness S is the simplest measure of biodiversity and is simply a count of the number of different species in a given area. The index of species richness (d) was calculated by following [17] formula as-

$$d = (S - 1) / \ln N$$

Whereas,

d = Margalef Diversity Index

S = Total number of species,

N = Total number of individuals

Evenness index: The evenness (equitability) index of the community was calculated equation [18] as follows:

$$E = H' / \ln S$$

Whereas,

H' = Shannon index

S = Number of species

RESULTS AND DISCUSSION

The total of the species of 27 halophytes belonging to 23 genera and 14 families were encountered from GoK. Halophytes diversity includes 22 Dicot and 5 Monocot species.

Among 13 talukas and Islands of GoK, the highest number (21) of halophyte species diversity was found in the Islands of GoK and Bhachau taluka (20) followed by Mundra, Anjar and Khambaliya Talukas. The lowest numbers of halophyte species were observed in Lalpur Taluka (11) (Fig. 2 & Fig. 3).

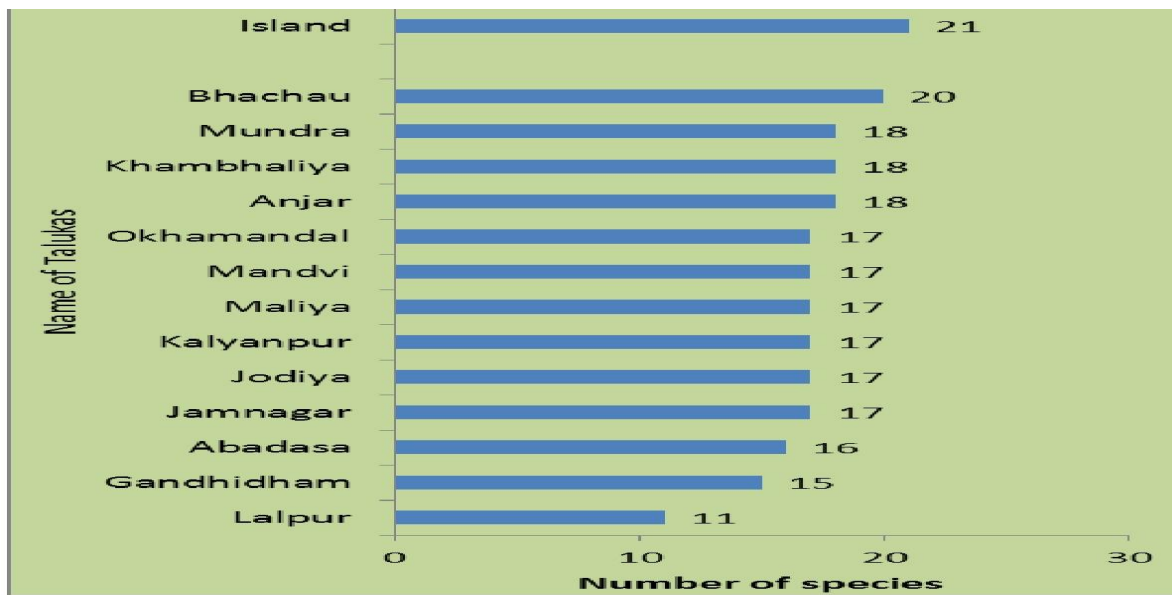


Fig. 2: Taluka and Island wise Species richness of Halophytes in GoK

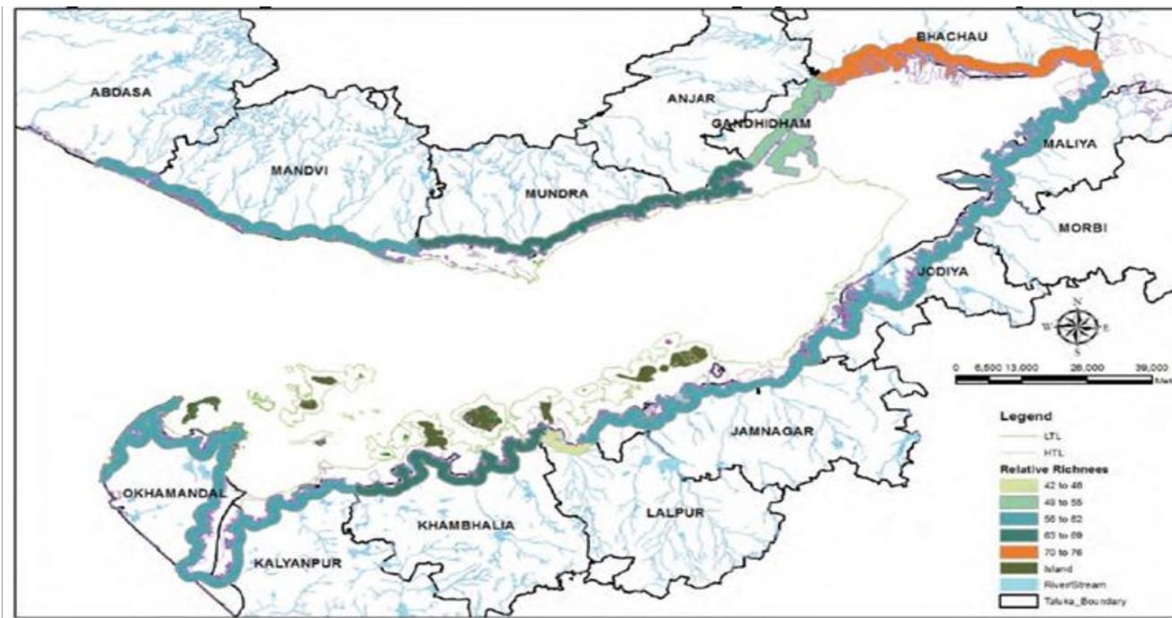


Fig. 3: Showing distribution pattern of Halophytes in the GoK (2011 - 2014)

It is widely accepted that the biodiversity of coastal flora is dependent on hydrological regime, geological and climatic conditions [19]. Although hydrology, whether it is frequency of the inundation or water source was the most important factor, remaining criteria such as, wetland morphology, vegetation type and geological locations were equally important for managing coastal ecosystem [20]. In the present study, Islands of GoK surrounded by sea water and having high saline habitat appear to support maximum halophytes diversity. However, the lowest diversity of halophytes was observed in Lalpur taluka, which has less saline area as compared to other talukas surrounding the GoK.

The 36 species of halophytes were reported from India in the “book Monograph on Indian Halophytes” [13]. Present study reported 27 species of halophytes from GoK (Gujarat), among them two species viz. *Haloxylon recurvum* Bunge ex Boiss. and *Zygophyllum simplex* L., were not reported in the book [13]. *Zygophyllum simplex* L. was reported as halophyte in the book “Halophytes as a resource for livestock and for rehabilitation of degraded lands” [21]. *H. recurvum* Bunge ex Boiss and *Z. simplex* was reported as Indian desert halophytes in the book “Contributions to the ecology of halophytes” [22]. Thus, these two species were incorporated as halophytes in the present study.

Similarity among the Talukas of GoK based on halophytes species distribution through Bray Curties similarity measure

Considering the occurrence of the halophyte species and its composition, of Jamnagar, Jodiya, Kalyanpur, Maliya and Mandvi talukas were found to have the highest similarity

with each other *i.e.* 94%. Species composition of Okhamandal taluka showed 92% similarity of halophytes composition with Kalyanpur, Jamnagar and Jodiya taluka. The detailed similarity among the studied areas is given in Fig. 4.

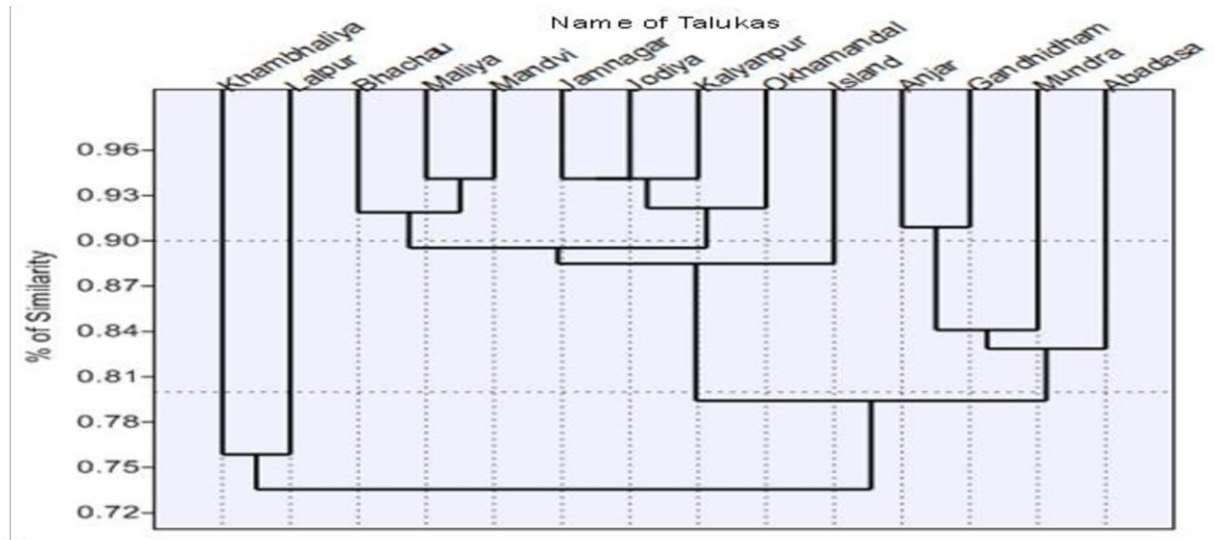


Fig. 4: Similarity among the Talukas of GoK based on halophytes species

Halophytes Diversity in GoK

Calculating biodiversity is a large part of determining the health of an ecosystem. The Shannon-Wiener Index (H') and Simpson's index (c) were used to determine, which community is more diverse. The Simpson's Index (c) employs data regarding the proportion of the species, while the Shannon-Wiener Index (H') includes information on species evenness and richness. These indices take quantitative numbers and express them in qualitative terms. Shannon-Wiener diversity index preferred over other diversity indices and its values vary between 0.0–5.0 [23]. Results between 1.5 to 3.5 were indicative of normal biological system and the index value exceeding 4.5 were rare. Values above 3.0 indicate that the structure of the habitat was stable and balanced; while the values below 1.0 suggest that habitat structure is being seriously degraded by many factors such as climate change, anthropogenic pressure and pollution. From the present biodiversity study it was observed that the highest species diversity (Shannon-Wiener diversity) was observed in Jamnagar district and its islands (1.859) followed by Devbhumi Dwarka district and its islands (1.817), Morbi district (1.664) and Kachchh district (1.633) (Table 1). Thus the coastal areas of GoK has been revealing Shannon-Wiener diversity index in between 1.6 to 1.8, which indicate normal biological system and there is no degradation of habitat structure.

The Simpson's Index measures the probability that two individuals chosen at random will be the same species.

Because of this, the range for the Simpson's Index (c) is from Zero to One. Zero is the least diverse and one is the highest level of diversity attainable with this index [24]. From Simpson's index (c), it was observed that Jamnagar district and its islands (0.804) were highly diverse followed by Devbhumi Dwarka district and its islands (0.786), Morbi district (0.754) and Kachchh district (0.747) (Table 1).

The study came with an index of dominance in 0.252 to Kachchh district, 0.245 for Morbi district, 0.214 for Devbhumi Dwarka district and 0.196 for Jamnagar district (Table 1). It was reported that greater the value of index of dominance the lower the species diversity and vice versa in the scale of 0 to 1 [25]. Thus, as highest index of dominance was observed in Kachchh district, the diversity was lowest in that region. Lowest index of dominance was observed in Jamnagar district and its islands thus the diversity was highest in that region.

Since heterogeneity contains two separate ideas-species richness and evenness- it was only natural to try to measure the evenness component separately [26,27]. Evenness describes how equally individuals are distributed amongst the species. Pielou's evenness index (e) was highest (0.528) in Morbi district followed by Jamnagar district and its islands (0.494), Devbhumi Dwarka district and its islands (0.0.647) and Kachchh district (0.365) (Table 1).

Margalef species richness index (d) was highest in the Devbhumi Dwarka district and its islands (1.519) followed by Kachchh district (1.373), Jamnagar district and its islands (1.262) and Morbi district (1.085) (Table 1).

Table 1: Various diversity indices of Halophytes in GoK

Diversity indices	Devbhumi Dwarka District and its islands	Jamnagar District and its islands	Morbi District	Kachchh District
Shannon-Wiener index (H')	1.817	1.859	1.664	1.633
Simpson's index (c)	0.786	0.804	0.754	0.747
Dominance (1/c)	0.214	0.196	0.245	0.252
Evenness index (e)	0.410	0.494	0.528	0.365
Species richness (d)	1.519	1.262	1.085	1.373

Table 2: Checklist of Halophytes

Botanical Names / Sites	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<i>Aeluropus lagopoides</i> (L.) Thwaites	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Arthrocnemum indicum</i> (Willd.) Moq.	√	×	×	×	×	×	×	×	×	×	×	×	×	×
<i>Artiplex stocksii</i> (Wt.) Boiss.	×	√	×	×	×	×	×	×	×	×	×	×	×	√
<i>Cressa cretica</i> L.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Cyperus conglomeratus</i> Rottb.	√	√	√	√	√	√	√	√	×	×	√	√	√	√
<i>Halopyrum mucronatum</i> (L.) Stapf	√	√	√	×	√	√	√	×	×	√	√	√	√	√
<i>Haloxylon recurvum</i> Bunge ex Boiss.	×	×	√	×	√	√	√	×	×	√	√	√	√	√
<i>Haloxylon salicornicum</i> (Moq.) Bunge ex Boiss.	√	√	√	√	√	√	√	×	×	√	√	√	√	√
<i>Heliotropium curassavica</i> L.	×	×	√	×	√	√	√	√	√	√	√	×	√	√
<i>Ipomoea pes-caprae</i> (L.) R. Br.	√	√	√	√	√	√	√	√	√	√	√	√	×	√
<i>Juncus maritimus</i> Lam.	×	×	×	×	×	×	√	√	×	×	×	×	√	√
<i>Limonium stocksii</i> Kuntze	×	×	×	×	×	×	×	√	×	×	×	√	×	√
<i>Lotus garcini</i> DC.	√	×	×	×	×	×	×	√	×	×	×	√	×	×
<i>Prosopis juliflora</i> (Sw.) DC.	√	√	√	√	√	√	√	√	√	√	×	√	√	√
<i>Salicornia brachiata</i> Miq.	×	×	√	×	√	√	√	√	×	√	×	×	√	√
<i>Salvadora persica</i> L.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Sericostoma pauciflorum</i> Stocks ex. Wight	√	√	√	√	×	×	×	×	×	√	√	×	×	√
<i>Sesuvium portulacastrum</i> (L.) L.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Sporobolus maderaspatanus</i> Bor	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Suaeda fruticosa</i> Forssk. ex. J.F.Gmel.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Suaeda nudiflora</i> Moq.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Tamarix dioica</i> Roxb.	×	√	√	√	√	×	×	×	×	√	√	√	√	√
<i>Tamarix stricta</i> Boiss.	×	×	√	×	×	√	×	√	×	×	×	×	×	×
<i>Trianthema portulacastrum</i> L.	×	√	×	√	×	×	×	×	×	×	×	√	×	×
<i>Trianthema triquetra</i> Rottler & Willd.	×	√	×	×	×	×	×	√	×	×	×	×	×	×
<i>Urochondra setulosa</i> (Trin.) C.E.Hubb.	√	√	√	√	√	√	√	√	√	√	√	√	√	√
<i>Zygophyllum simplex</i> L.	×	×	√	×	×	×	×	×	×	×	×	×	×	×
Total	16	18	20	15	17	17	17	18	11	17	17	18	17	21

Abadasa (1), Anjar (2), Bhachau (3), Gandhidham (4), Jamnagar(5), Jodiya(6), Kalyanpur (7), Khambhaliya (8), Lalpur (9), Maliya (10), Mandvi (11), Mundra (12), Okhamandal (13), Island (14), √=Present, ×= Absent

PLATE-I



1- *A lagopoides*, 2- *A stocksii*, 3-*H mucronatum*, 4- *L stocksii*, 5-*P juliflora*, 6- *S brachiate*, 7- *S persica*, 8- *S pauciflorum*, 9- *S portulacastrum* 10- *S maderaspatanus*, 11- *S fruticosa*, 12- *S nudiflora*, 13- *T dioica* 14- *T stricta*, 15- *T portulacastrum*, 16- *T triquetra* .

PLATE-II



17-*A indicum*, 18-*C cretica*,
19-*C conglomeratus*, 20-*H recurvum* , 21-*H salicornicum* , 22-*H curassavica*, 23-*I pes-caprae* , 24-*L garcini* , 25-*Z simplex* , 26-*U setulosa*, 27-*J maritimus*

Fig. 5: Twenty-seven Halophyte plant species of Gulf of Kachchh (GoK) showed in Plate I and II Photographs

CONCLUSIONS

The GoK is very rich in floral diversity. The present study reveals the presence of a total 27 species of halophytes. Diversity of halophyte plant community is highly valued now, since these ecosystems are being increasingly threatened by the current environmental crisis. The coastal area and islands of GoK have shown that the halophytes diversity is medium and indicate that the habitat structure showing normal biological system and there is no degradation of habitat structure. The present study will serve as a primary input towards monitoring and sustaining the phyto-diversity of halophytes in the coastal areas of GoK. Study on floristic distribution and diversity of halophytes will be useful to the conservation researchers, scientists and coastal zone managers for effective management of the coastal ecosystem of GoK.

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