DIVERSITY OF HALOPHYTES ALONG SAURASHTRA COAST (GUJARAT)

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ABSTRACT :

The state of Gujarat is situated on the north-western parts of India. It occupies an area of 1,96,024 sq.km and has 1663-km-long coastline, which spreads along 13 maritime districts and one Union Territory of Diu between Kachchh and Valsad. Interestingly, Gujarat coast is characterized by typical salt marshes, salt plains, sand dunes and rocky shore found along 1663-km-long sea coast of Gujarat out of 5700-km-long Indian coast. Attempt was made to study the α –diversity Indices like Shannon's Index, Simpson reciprocal Index and Pielou's Index of halophytes growing at marshy, sandy and rocky habitats. Results showed quite low species diversity, whereas species richness was found to be low to moderate levels and species evenness in the low to moderate levels. In contrast, these measures of diversity marginally fluctuated at one marshy location, Wandi.

KEY WORDS : Halophyte habitats, α –diversity, Saurashtra coast,.

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INTRODUCTION

"Biodiversity is the variety of and among the living organisms, biological system and biological process found on Earth". The term is neolosim obtained by joining words biology, the study of life and diversity, meaning difference and variety. Biodiversity (or biological diversity) then is the diversity of and living nature (Wilson, 1988). Biodiversity is generally considered an "umbrella term" referring to organisms found within the living world, *i.e*., the number, variety and variability of living organisms (Krishnamurthy, 2004). Moreover, all measures must emphasize one or the other factor of diversity (*i.e*., species richness or species evenness), no single perfect diversity index is possible that can distil the information contained in a species abundance distribution into a single statistical number (Clarke & Warwick, 2001). Nonetheless, ecologists have invented a number of indices over the years, each of which has its own limitations (Magurran, 2004).

Similarly, to proceed very far with the study of biodiversity, we need to pin the concept down. We cannot even begin to look at how biodiversity is distributed, or how fast it is disappearing, unless we can put units on it. Therefore, various indices of diversity are designed to measure both species richness the number of species in a community and the degree of evenness or equitability of the species relative abundances (Baczkowski, 1997).

Forgoing facts generated the base of the present study, which included the objective of assessing diversity of halophytes growing along the Gulf of Kachchh and Saurastra coast and its examining habitats as a vital factor influencing halophytes diversity. These results were used for abridging relationship of halophytes diversity with that of the supporting habitats.

METHODOLOGY

Nine locations, details of which are fully described in (Fig.2) were selected in Gujarat coast from Kachchh to Diu.

Design of Twin Belt Transect:

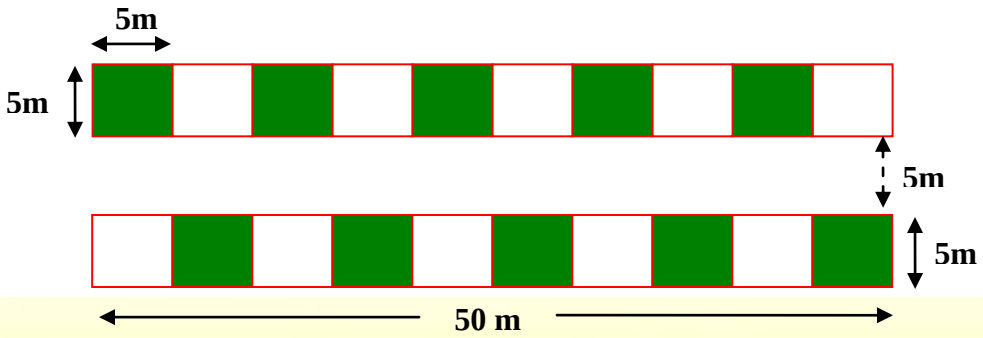


Fig. 1

Two twin belts transect (5m X 50m) (Figs.1) were laid down near to the creek or seacoast and away from the same at all selected locations. Plant species were counted in five alternative segments (5m X 5m) of either of the belts. Thus, ten sample units (5m X 5m) – quadrats - from each of twin belt transect as shown in the Fig. 1 and thereby total of 20 sample units (from 2 twin belt transects) admeasuring 500 m^2 at all sites were consider for computation of the floristic data. Preliminary observations were recorded in data sheets for further evaluation of biodiversity measures.

DIVERSITY

α - diversity measures *viz.*, Shannon index (*H'*), Simpson's reciprocal index (1/D) and Pielou's evenness index (*J*) of halophytic plants were worked out, as they provide vital information about **degree of uncertainty / diversity**, species **richness** and species **evenness** at particular site.

Following measures (indices) were used for studying diversity of plants:

Shannon Index for Diversity (Smith and Smith, 2001):

$$\textbf{Diversity } H' = -\sum_{i=1}^{s} pi \log_{10} pi$$

Where, S = Number of species

pi = Proportion of individuals of the abundance of the i^{th} species expressed as a proportion of total cover.

$\log_{10}$ = log base$_{10}$

Simpson's Reciprocal Index for species richness (Smith and Smith, 2001):

$$1/D = \frac{1}{\sum (ni/N)^2}$$

Where, D = Simpson's index

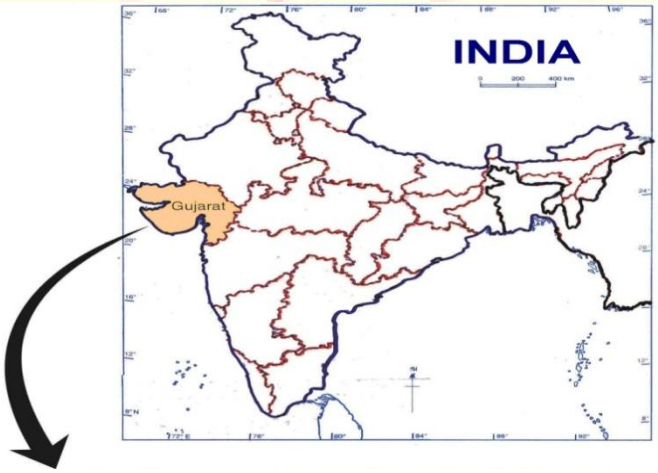
ni = the total number of individuals of i^{th} species.

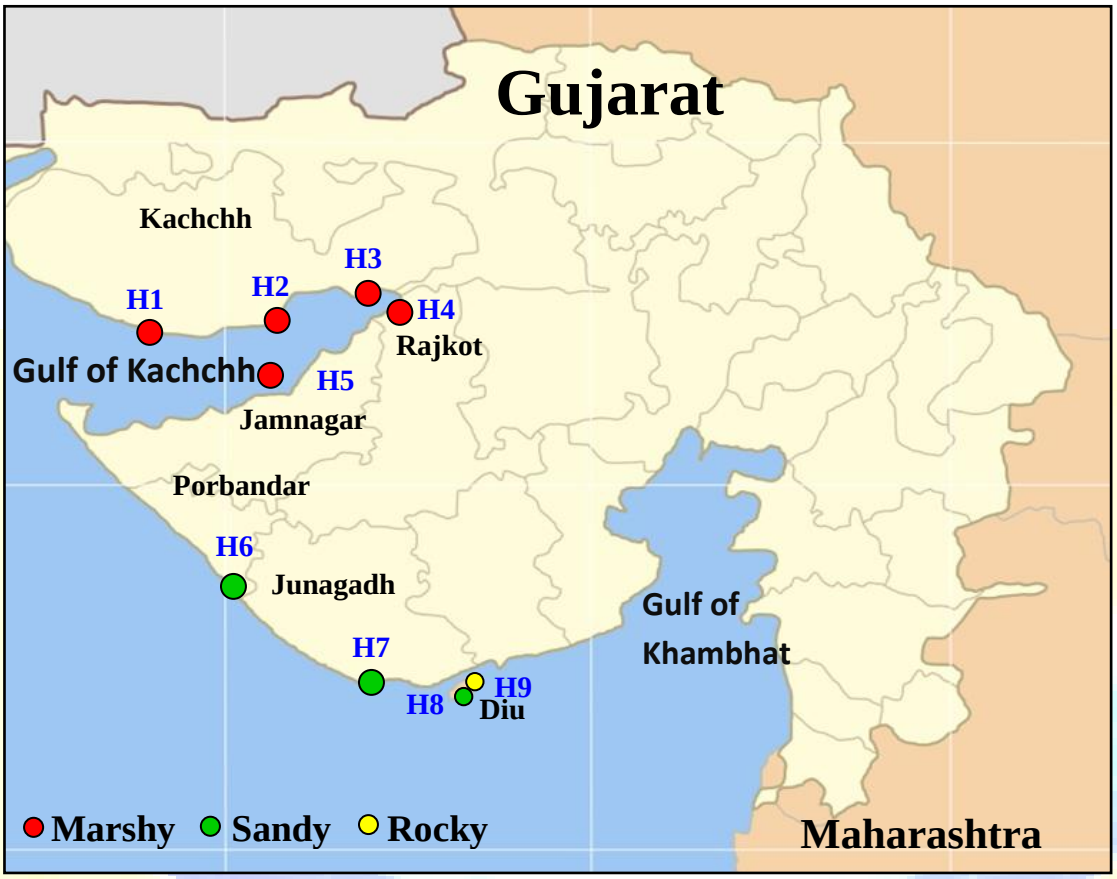
N = the total number of individual of all species.

Pielou's Index for species evenness (Smith and Smith, 2001):

$$J = \frac{H'}{H'_{max}} = \frac{-\sum_{i=1}^{s} pi \log_{10} pi}{\log_{10} S}$$

Fig. 2. Selected locations between Kachchh to Junagadh districts and Union Territory Diu along Gujarat coast.





H1 = Navinal, H2 = Wandi, H3 = Jungi, H4 = Navlakhi, H5 = Bedi bandar, H6 = Madhavpur, H7 = Mul Dwarka H8 = Gangeshwar and H9 = Sunset-point.

Where, S = the number of species

pi = the proportion of individuals of the i^{th} species or the abundance of the i^{th} species expressed as a proportion of total cover.

$\log_{10}$ = log base 10

RESULTS :

As mentioned in earlier section (Fig.1), 20 sample quadrats (5m X 5m) from 2 twin belt transects laid down at all selected habitats were considered for determining halophytes diversity. Nine locations in five districts and one Union Territory of Diu island covered almost half of the Gujarat coast from Kachchh to Diu.

SELECTED HABITATS:

As mentioned earlier (Fig. 2) showed 9 locations namely, Navinal, Wandi, Jungi, Navlakhi, Bedibandar, Madhavpur, Mul Dwarka, Gangeshwar and Sunset-point along the Gulf of Kachchh and Saurastra coast were selected for the present investigation.

The Shannon index (*H'*), based on information theory, is a measure of uncertainty (Kent and Coker, 1994; Smith and Smith, 2001). The higher the value of this index, the greater is the uncertainty, or probability that the next individual chosen at random from a collection of species containing *N* individuals will not belong to the same species as the previous one. The lower the value of *H'*, the greater the probability that the next individual encountered will be the same species as the previous one. The Shannon index value varying between 1.5 (low diversity) to 3.5 (high diversity) was used in this study.

The Simpson's index of diversity (D) considers the number of species, the total number of individuals, and proportion of the total found in each species. It is based on the number of samples of random pairs of individuals that must be drawn from a community to provide at least a 50 percent chance of obtaining a pair with both individuals of the same species. The Simpson's reciprocal index (1/D) starting with '1' as the lowest possible number indicative of low richness, and its maximum number – equal to total number of plant species occurring in a sampled area – reflective of highest degree of species richness was interpreted accordingly.

The Pielou's index (*J*) is a better appreciation of evenness or equability by comparing the relative species abundances in the community with the maximum possible evenness. The maximum possible value of *J* will be 1, when the community exhibits the maximum possible

evenness ($H = H_{max}$). The value of J will approach zero as the community becomes increasingly dominated by a single species.

It needs to be mentioned here that since it was difficult to distinguish and measure the length of intermeshing runners of grass and other species, their upright shoots were considered as an individual plants. Similarly, juvenile seedlings of mangroves occurring in sampled area were also noted as an individual plants.

Habitat 1 Navinal

Marshy site of Navinal was inhabited by 2 succulent halophytes (*Haloxylon salicornicum*; *Suaeda nudiflora*), 2 non succulent halophytic grasses (*Aeluropus lagopoides*; *Heleochloa setulosa*) and one mangrove species (*Avicennia marina*, var. *acutissima*) and their total number of individuals reached to 35, 2, 2504, 78 and 48, respectively (Table 1). *pi*denoting the ratio of *ni/N*, where *ni* is the number of individuals of the*i*th species and *N* is the total number of all individuals of all species in the sampled area, was computed. This parameter (*Haloxylon salicornicum*= 0.0131; *Suaeda nudiflora* = 0.0007; *Aeluropus lagopoides* = 0.9389; *Heleochloa setulosa* =0.0292 and *Avicennia marina* = 0.0180) reflected that a grass species *A. lagopoides* was dominant, whereas S. *nudiflora* had the least dominance at this site.

Shannon (0.129), Simpson's reciprocal (1.132) and Pielou's indices (0.184) - Table 1 - showed obviously low diversity, species richness and evenness of halophytes in the habitat, since their computed values were less as compared to normal theoretical ranges (H' = 1.5 to 3.5; 1/D = 1 to 5 for this site; and J= 0 to 1).

Habitat 2 Wandi

This marshy site supported a perennial succulent halophyte *viz.,H. salicornicum* and a

shrubby mangrove *viz*., *A. marina* and their number of individuals recorded in sampled area were 138 and 315 (Table 2). *pi* value for the former species (0.3046) was less than that of *A. marina* (0.6954) indicating dominance of the latter species in the habitat. Furthermore, Shannon index (0.267), Simpson's reciprocal index (1.733) and Pielou's index (0.887) reflected low level of diversity, but high degree of species richness and evenness as only two species grew at this location (Table 1).

Habitat 3 Jungi

Five typical halophytes were found here. The marshy site was inhabited by 4 succulent species *viz*., *Haloxylon salicornicum*; *Salicornia brachiata*; *Sesuvium portulacastrum*; *Suaeda fruticosa* and a shrubby halophyte *Salvadora persica* and their total individual number were 37, 360, 1, 10 and 1 (Table 3). *pi* values (*Haloxylon salicornicum* = 0.0905; *Salicornia brachiata*= 0.8802; *Sesuvium portulacastrum*= 0.0024; *Suaeda fruticosa* = 0.0244 and *Salvadora persica* = 0.0024) suggested that relative abundance of a succulent annual *S. brachiata* was greater than that of any other species growing at this site.

When compared with normal range of values of diversity measures, Shannon (0.195), Simpson's (1.276) and Pielou's (0.279) indices for halophytic communities occurring at this location were suggestive of relatively low species diversity, species richness and evenness.

Habitat 4 Navlakhi

Marshy site of Navlakhi was inhabited by 3 succulent halophytes (*H. salicornicum*; *S. brachiata and S. portulacastrum*), one non-succulent grass (*A. lagopoides*) and one mangrove species (*A. marina*). Their total number of individuals reached to 13, 2425, 10, 92 and 457, respectively (Table 4), whereas their *pi* values were noted as, 0.0043; 0.8091; 0.0033; 0.0307 and 0.1525. The last parameter reflected that *S. brachiata* was the most dominant halophyte in the habitat. On the other hand, relative dominance of *H. salicornicum* and *S. portulacastrum* was almost negligible. Shannon (0.263), Simpson's reciprocal (1.473) and Pielou's indices (0.377) were indicative of low diversity, species richness and evenness of halophytes at this marshy site.

Habitat 5 Bedibandar

This marshy habitat supported 2 succulent halophytes species *viz*., *Haloxylon salicornicum* and *Salicornia brachiata*, and interestingly 3 mangrove species *Aegiceras corniculatum*; *Avicennia marina* and *Rhizophora mucronata* and their individuals were recorded 125, 131, 2, 407 and 62 respectively. *pi* values for the said halophytes *Haloxylon salicornicum* (0.1719), *Salicornia brachiata* (0.1802), *Aegiceras corniculatum* (0.0028), *Avicennia marina* (0.5598) and *Rhizophora mucronata* (0.0853) indicated that a mangrove species *A. marina* was dominant here followed by succulent halophytes.

Furthermore, the Shannon index (0.504), the Simpson's reciprocal index (2.613) and the Pielou's index (0.722) for plant species were noted respectively. Calculated values indicated low halophyte diversity, moderate level of species richness and noticeably even distribution of species at this site.

Habitat 6 Madhavpur

Four halophyte associated species *viz.*, a facultative halophyte *Cyperus conglomeratus* and 3 strand species namely, *Halopyrum mucronatum*, *Lotus garcini* and *Sericostoma pauciflorum* were found at this typical sandy location. Their total individual number reached up to 1523, 1367, 220 and 44 (Table 6). *pi* values for *C. conglomeratus* (0.4829); *H. mucronatum* (0.4334); *L. garcini* (0.0698) and *S. pauciflorum* (0.0140) highlighted dominance of *C. conglomeratus* and *H. mucronatum* at this site because of their greater relative abundance compared to remaining 2 species. Although Shannon index (0.416) reflected low diversity of halophyte associated species here; its value was higher as compared to halophyte communities growing at foregoing marshy sites. Simpson's reciprocal index (2.346) indicated moderately high species richness. Pielou's index (0.692), too, showed highly even distribution of the said species in the sandy habitat.

Habitat 7 Mul Dwarka

Sandy site of Mul Dwarka was inhabited by one facultative halophyte *C. conglomeratus* and 2 strand species (*H. mucronatum* and *L. garcini*) and their total number of individuals were 4863, 980 and 589 respectively. *Pi* values (*C. conglomeratus* = 0.7561; *H. mucronatum* = 0.1524 and *L. garcini* = 0.0916) suggested that a facultative species *C. conglomeratus* was dominant in a community, whereas *L. garcini* had the least dominance. Shannon (0.311), Simpson reciprocal (1.657) and Pielou's indices (0.652) were indicative of low diversity, moderate species richness and comparatively even distribution of 3 halophyte associated species recorded in the sandy site.

Habitat 8 Gangeshwar

This sandy habitat supported 3 species, such as *C. conglomeratus*, *H. mucronatum* and *I. pes-caprae* and their total number reached up to 2702, 41 and 218. *pi* values for a facultative halophyte *C. conglomeratus* (0.9125) and 2 strand species *H. mucronatum* (0.0138) *I. pes-caprae* (0.0736) indicated the dominance of a facultative halophyte over strand species occurring here. Shannon, Simpson's reciprocal and Pielou's indices for halophytic community were noted as 0.145; 1.193 and 0.304, respectively and they indicated low species diversity, moderate level of species richness and low level of species evenness of halophyte associate at this sandy site.

Habitat 9 Sunset-point

Plant community structure of this coastal rocky habitat included 5 different kinds of plant species. Sunset-point was inhabited by one non- succulent halophyte (*S. madrasepatanus*), one shrubby halophyte (*Limonium stocksii*), one facultative halophyte (*C. conglomeratus*) and 2 strand species (*I. pes-caprae*, *Lepidagathis trinervis*) and their total number of individuals in sampled area were 51, 6, 327, 1003 and 480. *pi* values for *S. madrasepatanus* (0.027), *L. stocksii* (0.003), *C. conglomeratus* (0.175), *I. pes-caprae* (0.537) and *Lepidagathis trinervis* (0.257) reflected the dominance of *I. pes-caprae* here because of its greater relative abundance compared to all other species found in this area. Calculated value of the Shannon index (0.476)

was indicative low species diversity; Simpson's reciprocal index (2.596) reflected moderate species richness and Pielou's index (0.681) showed moderately high even distribution of mixed halophyte community occurring on a rocky habitat.

The combined results of α - diversity for halophyte communities growing at 9 different habitats (Table 1) revealed quite low species diversity, whereas species richness was found to be

Table 1. α -diversity measures for halophyte vegetation at 9 different habitats along half of Gujarat coast.Values of respective diversity index are mentioned in parenthesis.

Habitats	*S	Species diversity (*H'*)			Species richness (1/D)			Species evenness (J)		
		*L	*M	*H	L	M	H	L	M	H
Navinal	5	✓ (0.12)	-	-	✓ 1.13	-	-	✓ 0.18	-	-
Wandi	2	✓ (0.26)	-	-	-	-	✓ 1.73	-	-	✓ 0.88
Jungi	5	✓ (0.19)	-	-	✓ 1.27	-	-	✓ 0.27	-	-
Navlakhi	5	✓ (0.26)	-	-	✓ 1.47	-	-	✓ 0.37	-	-
Bedi bandar	5	✓ (0.50)	-	-	-	✓ 2.61	-	-	✓ 0.72	-
Madhavpur	4	✓ (0.41)	-	-	-	✓ 2.34	-	-	✓ 0.69	-
Mul Dwarka	3	✓ (0.31)	-	-	-	✓ 1.65	-	-	✓ 0.65	-
Gangeshwar	3	✓ (0.14)	-	-	-	✓ 1.19	-	✓ 0.30	-	-
Sunset-point	5	✓ (0.47)	-	-	-	✓ 2.59	-	-	✓ 0.68	-

***S** = Total number of species; *L = low; *M = moderate; *H = high

low to moderate levels, but for the Wandi site, where it was high. Species evenness in the last habitat was also noticeably higher than remaining locations, where it ranged from low to high levels.

These findings interestingly show that halophyte vegetation growing along half of the Gujarat coast from Kachchh to Diu is characterized by variations in species diversity, richness and evenness at different habitats. The present investigation underlines the urgent needs to conserve halophyte communities not because of the rarity of the species, but also because of their low degree of diversity and relative abundance, before they really become either endangered or extinct in India.

DISCUSSION:

Magurran, as early as 1988, suggested that biodiversity happened to be an important measure for the evaluation of ecosystems. Diversity of plant communities is highly valued now, since these ecosystems are being increasingly threatened by the current environmental crisis.

The Shannon index derived from a mathematical formula is also applied to biological systems (Mandaville, 2002). It is preferred over other diversity indices and its values vary between 0.0 – 5.0. Results between 1.5 to 3.5 are indicative of normal biological system and the index value exceeding 4.5 are rare. Values above 3.0 indicate that the structure of habitat is stable and balanced; while, the values under 1.0 suggest that habitat structure is being seriously degraded by many factors including climatic change, anthropogenic pressure and pollution (Turkmen and Kazanci, 2010).

The present investigation on diversity of halophyte occurring along upper half of Gujarat coast between Kachchh to Diu island (Table 1) showed quite low diversity in five marshy locations *viz*., Navinal (H1 = 0.129), Wandi (H2 = 0.267), Jungi (H3 = 0.195), Navlakhi (H4 = 0.263) and Bedi bandar (H5 = 0.504). As described elsewhere in the thesis, halophytic communities at these sites comprised of true halophytes and mangroves.

A few reports on Indian halophytes also showed remarkably low diversity. Shukla (2007) reported that salt marsh vegetation found at four marshy locations on Diu island off Gujarat coast had low diversity of 0.060 to 0.645. Low value of 0.181 was also recorded by Vyas (2007) for one marshy site at (Sonrai Creek) and by Talekar (2009) for two other sites at Mingalpur = 0.252 and Rahtalav = 0.290 in 'Bhal'. These reports support our findings.

Further syudies on diversity of halophytes along the second half of Gujarat coast between Amreli to Valsad districts, too, reflected similar characteristic (Pawar, 2012). His data suggested low floristic diversity varying between 0.035 to 0.343 in eight marshy locations, supporting our findings.

Similarly, Kunza and Pennings (2008) found low diversity in Georgia salt marshes in the U. S. fluctuating between 0.15 to 0.41. Furthermore, El-Sheikh *et al.* (2006) also noted low diversity varying between 0.02 to 0.35 for five vegetational groups in salt marshes of northern coast in Kuwait.

However, Judd and Lonard (2002) recorded a little higher values of the Shannon index of 0.731 to 0.883 for halophyte vegetation along the Brackish and salt marsh in the Rio Grande Delta in Texas. While describing diversity of plant communities in the South-west Saudi Arabia along Red sea coast, Hegazy *et al.* (1998) observed low diversity of 0.60 for halophyte growing in coastal areas and comparatively greater diversity of 1.8 for flora on salt affected sandy flats.

Perry and Atkinson (1997), who worked on four marshes on the York and Pamunkey rivers in Virginia, found low plant diversity on Goodwin islands (0.668), Catlett islands (0.542), Taskinas creek (0.647) and slightly higher diversity of 1.351 in Sweet Hall marsh.

Likewise, plant diversity in National Park in Kuwait (El-Sheikh and Abbadi, 2004) was comparatively low (0.70) in salt marshes than that in non-saline depressions (0.85), ridges (1.05) or in coastal desert plain (0.78).

Thus, results of this investigation along with other studies suggest that the diversity of halophytic flora occurring at five marshy habitats along the upper half of Gujarat coast from Kachchh to Jamnagar, obviously matches with that of plant communities growing in Georgia marshes in U. S., northern coast of Kuwait, South-west Saudi Arabia, as well as with those on Diu island, 'Bhal' wetlands and along the lower half of Gujarat coast in India. Nevertheless, halophyte vegetation found on sites in Rio Grande Delta in Texas, York and Pamunkey rivers in Virginia and in National Park of Kuwait appears to be little more diversified.

The second major flora covered under this investigation and comprising of facultative halophytes and strand species at three sandy and one rocky habitats, were characterized by low diversity (H6 = 0.416, H7 = 0.311, H8 = 0.145 and H9 = 0.476, Table 1).

These findings are supported by other studies also. For instance, as reported by Shukla (2007), diversity of halophyte communities occurring in sandy location at Vanakbara on Diu island was low (0.328). The Shannon index for plant species growing on three sandy habitats along the Arabian Sea coast was also suggestive for low (0.234 to 0.671) diversity. Thus, floristic diversity in sandy habitats on Diu Island and Porbandar coast is in conformity with the present investigation.

El-Sheikh *et al.* (2006) recorded low diversity of 0.80 for coastal sandy drifts plant communities along northern coast of Kuwait. According to Galal and Fawzy (2007), diversity of seven groups of sand dune flora in the Nile Delta, Egypt was as follows: (VG – A = 3.4, VG – B = 2.9, VG – C = 3.2, VG – D = 1.5, VG – E = 3.1, VG – F = 2.9 and VG – G = 3.0). Thus, most of the Nile Delta sand dune flora appears to be highly diversified. Moreover, Isermann (2005) recently observed low (0.45) to high (1.77) diversity for sand dune plant communities along Baltic Sea coast of Germany.

While summing up the present data collected for the upper half of Gujarat coast, with reference to plant diversity of terrestrial ecosystems of India, the halophytes or salt marsh flora are highly fragile and least diversified. It will be of interest to add here that Indian tropical forests are marked by noticeably very high diversity reaching up to 3.84 to 4.56 (Singh *et al.*,

1994). Himalayan grasslands 1.75 to 2.63 (Reshi *et al.*, 2009). Moreover, Hegazy *et al.* (1998) had earlier concluded that inland vegetation adjacent to salt marshes in South-west Saudi Arabia, had remarkably high diversity of (3.9) as compared to halophyte flora found in the area. All these reports collectively suggest that diversity of halophytes occurring in Gujarat and in other countries is really low, as compared to forests, grasslands and other ecosystems of the globe.

CONCLUSION:

α- diversity measures viz., Shannon index (H'), Simpson's reciprocal index (1/D) and Pielou's evenness index (J) (Table, 10) were suggestive of quite low diversity, but noteworthy high degrees of species richness and evenness at selected sites.

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