



Research article

Ecological studies of mangroves species in Gulf of Khambhat, Gujarat

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Abstract: Mangrove forests are of utmost importance due to their role in preventing extreme weather events like tsunamis and cyclones etc. The present study aimed to observe the mangrove plant diversity and edaphic characteristics from Gulf of Khambhat, Gujarat. Ecological parameters and edaphic characteristics were studied for different sites *i.e.* Navsari, Surat and Bhavnagar. *Avicennia marina* was found as dominant species at all study sites. Plant species diversity shows increasing tendency with the decrease in plant density. Important Value Index, Shannon-Weaver diversity index and Simpson index of dominance of the mangrove species across the study area were also determined. The present study provides the baseline data of mangrove species and concludes the need of detail study for mangrove species in Gulf of Khambhat, Gujarat for conservation and management strategies.

Keywords: Mangrove plants - *Avicennia marina* - IVI - Plant density - Conservation.

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INTRODUCTION

Mangrove forest ecosystems are significant for the biodiversity, protection of coastal area from erosion and provision of protected nursery breeding areas for marine fauna. Ecological study of any area or habitat helps to understand the inter-relationship of all biotic (plants, microbes, other organisms) and abiotic (temperature, moisture and soil etc.) components of environment. Globally mangrove forest cover around 1,46,500.00 km² of coastline (Alongi 2008) while total mangrove cover India is about 4,662.56 km². This represents 0.14% of the total geographical area of country and 3% of the global mangrove area. Mangroves are world's most productive ecosystems, found at the interface between land and sea in tropical and subtropical latitudes. Mangrove forests are only forest on earth where land, freshwater and sea mix together. These forests are specially adapted to high salinity, extreme tides, strong winds, high temperatures, low oxygen and muddy soil (Kathiresan 2010).

Gujarat is situated in the west coast of India which is surrounded by Arabian Sea. In maritime states of India; Gujarat has largest coastal area around 28,000 km² or longest coast line around 1650 km supports variety of marine flora and fauna. The area under mangrove cover (1058 km²) along the Gujarat coast is the second largest block of tidal forest in India, next only to the Sunderbans (2155 km²) (MoEF 2013–14). This state has two gulfs out of three gulfs in India and the coastal area is spread from south Gujarat (high rainfall area about 2500 mm) to north- west of Kachchh (low rain area about 250 mm only). Different range of tides, waves, cyclones and currents in the sea affect the physical as well as the biological conditions of the marine ecosystem whereas clear cutting, hydrological changes, oil spills and climate change are creating more pressure on mangrove forests sites (Blasco *et al.* 2001). In Gujarat 1103 km² area is under mangrove which includes 175 km² moderately dense mangroves (15.86% of mangrove area of state), 928 km² open mangrove (84.13%). The present research study deals with the ecological status of mangrove species in Gulf of Khambhat, Gujarat.

MATERIALS AND METHODS

Study area

Gujarat state is situated on the west coast of India between 20°06' N to 24°42' N latitude and 68°10' E to 74°28' E longitude. It is bounded by the Arabian Sea on the west. Ghogha from Bhavnagar (21°40' N, 72°17' E), Dumas from Surat (21°4' N, 72°42' E), Dandi from Navsari (20°55' N, 72°47' E), Dahej from Bharuch were selected from Gulf of Khambhat (Cambay) are selected for the present research work (Fig. 1 & 2).



Figure 1. Aerial view of four selected sites (Source: Google Earth)

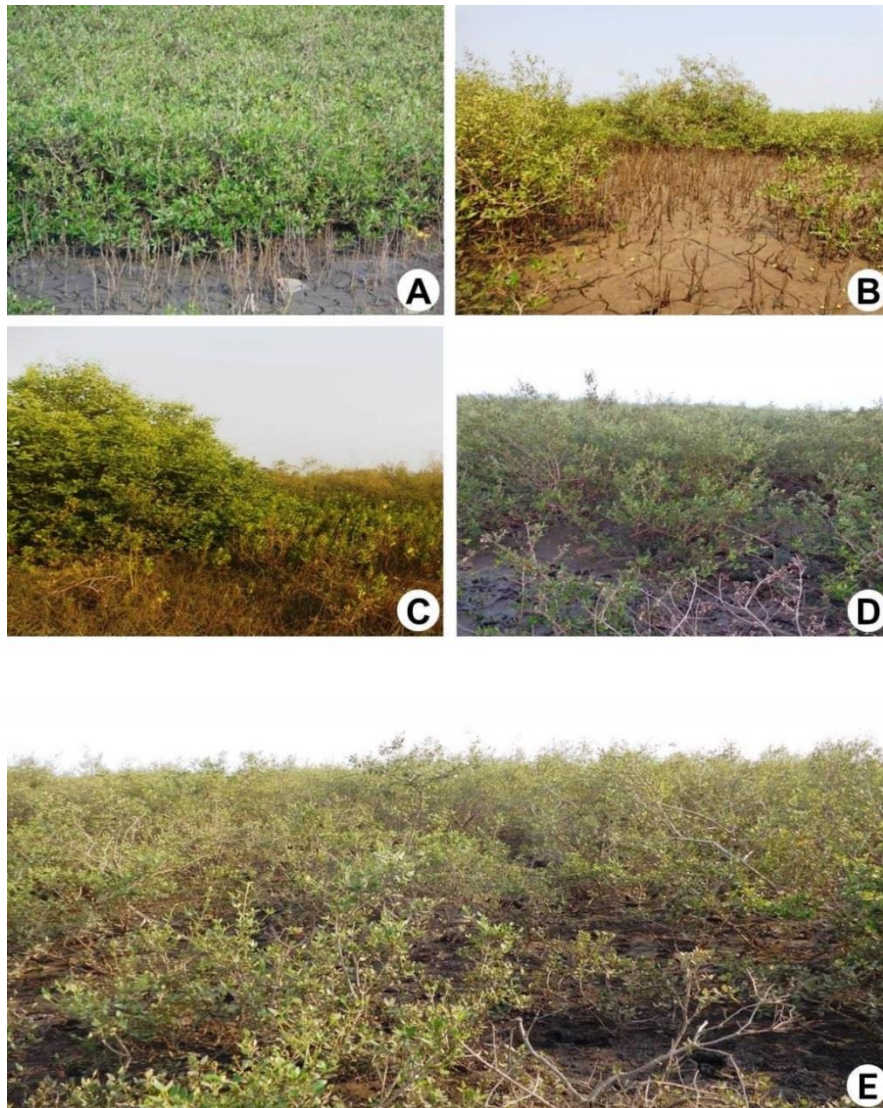


Figure 2. Habitat of mangrove vegetation: A & B, Bhavnagar; C, Navsari, D, Bharuch; E, Surat.

Field methods

The mangrove vegetation study was carried out from selected sites during low tide. Quantification of mangrove vegetation at each site was done by quadrat method. 10 quadrates (3×3m) were laid randomly at

each site and in each quadrat, total numbers of trees were counted; tree height and Girth at Breast Height (GBH) was measured for all trees. Quantity parameters like frequency, relative frequency, density, relative density, abundance, dominance, relative dominance, Important Value Index (IVI) was determined Curtis (1959). The distribution pattern of species was determined by ratio of abundance to frequency if the ratio is below 0.025 then it indicates regular distribution, between 0.025–0.050 indicates random distribution and when exceeds 0.050 indicates contagious distribution (Whitford 1949). Species diversity was determined by using Shannon index (H), Simpson's index of diversity (1-D) were calculated using standard methods (Shannon & Weaver 1963, Simpson 1949, Kerkhoff 2010).

Collection and authentication of plant samples

Plant samples (leaves, flowers, stem, seeds and roots) were collected from selected sites for authentication and preparation of herbarium. Authentication and identification of collected plant samples was done with the help of Scientist, GEER foundation, Gujarat.

Soil sampling and chemical analysis

Soil samples were collected from 0–10 cm depths from each site during October and November of the year 2014. Five sets of samples were collected from each study site and mixed together to form a composite soil sample and from which three replicate samples were brought to the laboratory. Collected soil samples were air dried and sieved through a 2 mm mesh and was subjected to routine chemical analysis. Physicochemical characteristics of soil samples were determined using standard methods (APHA 1998). pH of soil was determined using method described by Black (1973). Total organic carbon was determined using method described by Walkey & Black (1934).

RESULTS

Mangrove plant status

Table 1. Mangrove diversity of selected site of Gujarat.

Species Name	Vernacular name	Family	Status in various sites				
			Bhavnagar	Surat	Navsari	Bharuch	
True mangrove	<i>Avicennia marina</i> (Forsk.) Vierh var. <i>acutissima</i> Mold.	Tivar, Tavarian	Avicenniaceae	+	+	+	+
	<i>Bruguiera gymnorhiza</i> (L) Lam	Tavar	Rhizophoraceae	-	-	+	-
	<i>Sonneratia apetala</i> Buch.-Ham	Motitavar	Lythraceae	-	+	+	-
	<i>Acanthus ilicifolius</i>	Kantaliyo	Acanthaceae	-	-	+	-
Mangrove associates	<i>Ipomoea pes-carpae</i> (L.) Sw.	Maryada-vel	Convolvulaceae	-	-	+	-
	<i>Sesuvium portulacastrum</i> (L.) L.	Shore purslane	Aizoaceae	+	+	+	-
	<i>Salvadora persica</i> L.	Toothbrush tree	Salvadoraceae	-	+	-	-
	<i>Suaeda</i> sp.	Seepweeds	Amaranthaceae	-	+	-	-

Note: +, indicates presence; - indicates absence.

The patterns of mangroves and associated species distribution in selected study area depict little variation in the species composition (Table 1). At Bhavnagar a total of 886 plants representing two species were identified within 90 m² area survey. *Avicennia marina* (Forsk.) Vierh (Avicenniaceae) showed the highest density (87.5 plants/90m²) with 83.33% relative frequency 99.99% relative dominance and 282.09 important value index. Other species recorded with their ecological parameters is presented in table 2. Only two species (*Avicennia marina* and *Sonneratia apetala* Buch.-Ham.) were found at Surat site. The maximum number of species was recorded at Navsari site such as *Avicennia marina*, *Sonneratia apetala*, *Bruguiera gymnorhiza* (L.) Lam., and *Acanthus ilicifolius* L. (Fig. 3). Only one species (*Avicennia marina*) was recorded at Bharuch site.

Avicennia marina has been found common in all selected sites exhibiting maximum density at Bhavnagar (87.5 plants/90m²) Among all species the mean height was maximum of *Sonneratia apetala* (230.86 cm) followed by *Avicennia marina* (127.28 cm) and *Bruguiera gymnorhiza* (109.82 cm). *Avicennia marina* is dominating species at all selected sites with higher important value index at all sites. In general the distribution pattern of all species was contagiously distributed at all study sites except *Sonneratia apetala*, which showed random pattern of distribution at Surat and Navsari site. The Shannon-Weaver diversity index and Simpson

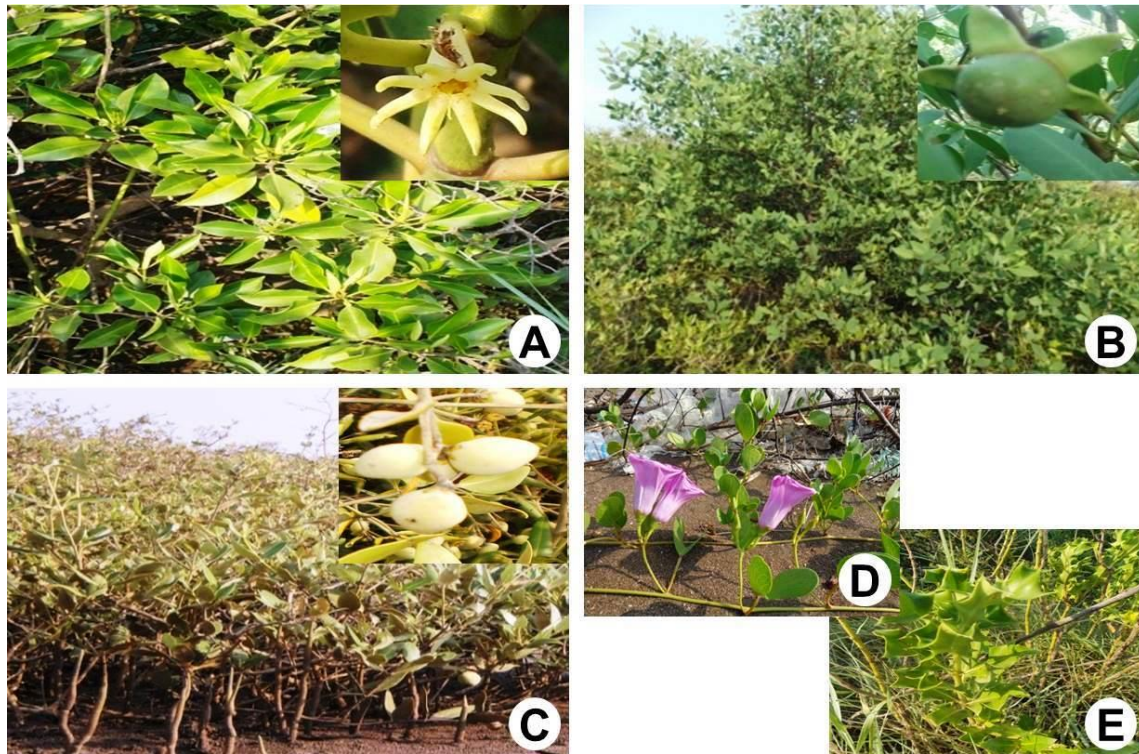


Figure 3. Some mangrove plants: **A**, *Bruguiera gymnorhiza* (L.) Lam.; **B**, *Sonneratia apetala* Buch.-Ham.; **C**, *Avicennia marina* (Forsk.) Vierh; **D**, *Ipomoea pes-caprae* (L.) R.Br.; **E**, *Acanthus illicifolius* L.

index of dominance was analyzed for dominance and species diversity (Shannon & Weaver 1963, Simpson 1949). The Shannon-Weaver index showed highest diversity at Navsari site (1.20) followed by Surat (0.20), Bhavnagar (0.07) whereas Simpson index of diversity (1-D) was higher in Navsari (0.66) followed by Surat (0.09), Bhavnagar (0.03) and the value of this index ranges between 0 and 1, the greater the value, the greater the plant diversity. Result shows that Navsari site have been found with more diversity than other sites (Table 3 & 4).

Table 2. Vegetation characteristics of different selected sites.

Site 1 Bhavnagar											
	Density (plants/90m ²)	Relative density (%)	Abundance (plants/90m ²)	Relative Abundance (%)	Frequency (%)	Relative Frequency (%)	Mean Height (cm)	Total Basal area (cm ² /90m ²)	Relative Dominance (%)	A/F ratio	Important value index (IVI)
<i>Avicennia marina</i>	87.5	98.76	87.5	94.09	100	83.33	71.68	471.59	99.99	0.88	282.09
<i>Sesuvium portulacastrum</i>	1.1	1.24	5.5	5.914	20	16.66	3.30	0.006	0.001	0.28	17.91
Site 2 Surat											
<i>Avicennia marina</i>	13.7	95.14	13.7	88.67	100	71.43	86.87	61.63	96.83	0.13	263.39
<i>Sonneratia apetala</i>	0.7	4.86	1.75	11.32	40	28.57	77.01	2.02	3.17	0.04	36.60
Site 3 Navsari											
<i>Avicennia marina</i>	14.9	43.44	14.9	40.27	100	27.03	127.28	122.39	44.74	0.15	115.21
<i>Bruguiera gymnorhiza</i>	3.9	11.37	4.88	13.18	80	21.62	109.82	27.56	10.07	0.06	43.07
<i>Sonneratia apetala</i>	3.1	9.04	3.44	9.31	90	24.32	230.86	119.63	43.73	0.04	77.09
<i>Acanthus illicifolius</i>	12.4	36.15	13.77	37.24	100	27.03	63.75	-	-	0.14	-
Site 4 Bharuch											
<i>Avicennia marina</i>	18.5	100	18.5	100	100	100	114.6	43.09	100	0.185	300

Table 3. Diversity indexes of selected mangrove sites.

Diversity indexes	Bhavnagar	Surat	Navsari
Shannon-Weaver Index (H)	0.07	0.20	1.20
Simpson index of Diversity (1-D)	0.03	0.09	0.66

Note: At Bharuch site only single species *Avicennia marina* was recorded in selected sampling area.

Table 4. Species diversity of different mangrove sites.

Sites	Bhavnagar	Surat	Navsari	Bharuch
Species Name	<i>Avicennia marina</i>	<i>Avicennia marina</i>	<i>Avicennia marina</i>	<i>Avicennia marina</i>
	<i>Sesuvium portulacastrum</i>	<i>Sonneratia apetala</i>	<i>Sonneratia apetala</i>	
		<i>Salvadora persica</i>	<i>Bruguiera gymnorrhiza</i>	
		<i>Suaeda</i> sp.	<i>Acanthus illicifolius</i>	
		<i>Sesuvium portulacastrum</i>	<i>Ipomoea pes-caprae</i>	
			<i>Sesuvium portulacastrum</i>	
Total species	2	5	6	1

Edaphic characteristics

Soil characteristics of different selected sites have been presented in table 5. Soil mean temperature was recorded from 29.9–33.5 °C. pH ranges from 8.37 to 8.68. Similarly, the values of electrical conductivity were from 4.25 mS.cm⁻¹ to 12.28 mS.cm⁻¹. In this study it was found that more water contents were present in soil at Navsari than Bhavnagar and Surat.

Table 5. Physicochemical characteristics of different mangrove sites.

Soil parameters	Navsari			Surat			Bhavnagar		
	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE
Temperature (°C)	29.9	0.581	0.259	33.5	0.757	0.338	32.5	1.155	0.516
pH	8.376	0.034	0.015	8.680	0.147	0.066	8.396	0.096	0.043
EC (mS/cm)	4.248	0.190	0.085	6.626	1.755	0.785	12.282	4.228	1.891
M.C. (%)	60.1	3.021	1.351	23.7	6.485	2.90	44.2	0.932	0.417
O.Carbon (%)	0.17	0.02	0.01	1.09	0.07	0.04	1.52	0.04	0.02
O.M. (%)	0.29	0.04	0.02	1.88	0.12	0.07	2.62	0.07	0.04
Total Nitrogen (%)	2.438	--	--	1.208	--	--	4.734	--	--
Av. Phosphorous (%)	0.019	4.73	2.73	0.011	0.58	0.33	0.022	3.61	2.08
Sulphate (%)	0.081	0.012	0.007	0.111	0.003	0.002	0.119	0.001	0.001
Cl (ppm)	12.23	0.02	0.013	18.24	0.44	0.253	38.16	1.05	0.604
Total Hardness (mg CaCO ₃ /kg)	265.33	2.31	1.33	538.67	4.62	2.67	1588	41.57	24.00

Note: SD, Standard deviation; SE, standard error; n, 3; Av., Average.

DISCUSSION

Gujarat has second largest area of mangroves in India (1058 km²). About 99.4% mangrove forest area is represented by three mangrove areas; Gulf of Kachchh (15.2%), Gulf of Khambhat (10.1%) and Kachchh district including Kori creek (74.1%) and remaining 0.6% in Valsad and Navsari district. Even with fewer mangroves area Gulf of Khambhat was reported to have rare mangrove species. The Gulf of Khambhat includes Bharuch, Surat, Navsari and Bhavnagar districts mainly. Therefore coastal area Ghogha from Bhavnagar, Dumas from Surat, Dandi from Navsari, and Dahej from Bharuch has been selected for ecological study. In present study total eight species (*Avicennia marina* (Forsk.) Vierh, *Bruguiera gymnorrhiza* (L.) Lam., *Sonneratia apetala* Buch.-Ham., *Acanthus illicifolius*, *Ipomoea pes-caprae* (L.) R.Br., *Sesuvium portulacastrum*, *Salvadora persica* and *Suaeda* sp.) were recorded from Gulf of Khambhat which includes both true mangrove and associate species. Fourteen species of mangrove have already been reported *i.e.* *Avicennia marina* (Forsk.) Vierh, *Avicennia officinalis* L., *Avicennia alba* Bl., *Aegiceras corniculatum* (L.) Blanco, *Ceriops tagal* (Perr.) Robinson, *Ceriops decandra* (Griff.) Ding Hou, *Excoecaria agallocha* L., *Sonneratia apetala* Buch.-Ham., *Acanthus illicifolius* L., *Bruguiera cylindrica* (L.) Bl., *Bruguiera gymnorrhiza* (L.) Savigny, *Lumnitzera racemosa* Wild, *Rhizophora mucronata* Lamk., *Kandelia candel* (L.) Druce (Bhatt *et al.* 2011). The abundance to frequency ratio indicated that most of the species were contagiously distributed except *Sonneratia apetala* at two sites (Surat and Navsari), which showed random distribution pattern. Smith (1957), Kershaw (1973), Kumar & Bhatt (2006) have also reported contagious distribution in natural vegetation. In most of places landward

mangrove are under pressure due to clearing of mangrove plants for fodder and conversion of mangrove area to other forms of land use (Farnsworth & Ellison 1997, Ashton & Macintosh 2002).

Present study revealed that Avicenniaceae is most dominant mangrove family in all selected sites *Avicennia marina* was the most frequent, most abundant and most dominant species in all selected sites. Average GBH of selected mangrove species ranged from 0.28 cm to 22 cm. A similar kind of work has also been reported where Avicenniaceae was the dominant mangrove family with 100% frequency and 72.55% relative frequency. Average GBH of mangroves was 21.69 cm. Studies also showed that *Avicennia marina* can withstand more harsh environmental conditions such as high salinity, high temperature etc (Lunar & Laguardia 2013). It was found that mean height of *Avicennia marina* was maximum at Navsari (127.28 cm) followed by Bharuch (114.6 cm), Surat (86.87 cm) and Bhavnagar (71.68 cm). Among all species the mean height was maximum of *Sonneratia apetala* (230.86 cm) followed by *Avicennia marina* (127.28 cm) at Navsari site and then by *Avicennia marina* (114.6 cm) of Bharuch site and *Bruguiera gymnorhiza* (109.82 cm) of Navsari site. In this study it was observed that where plant density is more there plant mean height is less. This may be due to the reason that higher density of *Avicennia marina* at Bhavnagar may cause reduction in plant growth due to competition for limited resources (Volin *et al.* 2005, Li *et al.* 2014).

Soil mean temperature was recorded in the range between 29.9°C to 33.5°C. A similar study has been done where mean temperature of soil was recorded 31.87°C at degrading mangrove habitat and 28.26°C at luxuriant mangrove habitat (Kathiresan 2002). The pH was recorded 8.37 (Navsari), 8.39 (Bhavnagar) and 8.68 (Surat) which is supported by study of Rao & Rao (2014). Study showed that alkaline pH (8.35–8.79) in similar type of habitat. pH have been reported from 7.11–8.52 in Pondicherry mangroves (Satheeshkumar & Khan 2009). In present study it was found that more water contents were present in Navsari mangrove soil than Bhavnagar and Surat mangrove soil. The moisture contents (mean values) were 23.7% (Surat), 44.4% (Bhavnagar) and 60.1% (Navsari). High moisture content at Navsari can either be due to freshwater input of Purna river or frequent tidal inundation (Ashton & Macintosh DJ 2002). It has been observed that 44.4% moisture content is more suitable for plant density at Bhavnagar site where as on other sites with less and more moisture content plant density was less. Kathiresan (2002) also found moisture content 31.49% at degrading sites and 42.2% at luxuriant mangrove habitat. Total nitrogen was recorded from 1.21% to 4.7%. Similar results were observed by Hossain *et al.* (2012), where total nitrogen has been reported from 0.057% to 0.158% in Sunderban mangrove soil whereas available nitrogen at same site was reported from 0.504 to 2.016 $\mu\text{g.g}^{-1}$. Available nitrogen has been reported from 29.4 to 81.2 ppm (Rao & Rao 2014). Available phosphorous was found maximum at Bhavnagar (0.022%) followed by Navsari (0.019%) and Surat (0.011%). Available phosphorous of mangrove soil has been reported 3.32 ppm to 5.89 ppm (Rao & Rao (2014). Phosphates have been reported 0.06 mg L^{-1} by Dogiparti *et al.* (2014). The values of organic carbon were observed 0.17% at Navsari, 1.09% at Surat and 1.52% at Bhavnagar site and it has been found that with increase in organic carbon plant density is also increasing. Organic carbon has been reported 4.28% and 3.12% at two mangrove areas of Andhra Pradesh (Dogiparti *et al.* 2014). The organic matter was recorded from 0.29% to 2.62%, which shows similar results studied by Satheeshkumar & Khan (2009) where organic matter has been reported from 0.94% to 3.94% in mangrove soil.

CONCLUSION

Present study revealed that Avicenniaceae is only dominant family in the Gulf of Khambhat coastal area, Gujarat and due to anthropogenic disturbance *i.e.* clear cutting, hydrological changes, oil spills and climate change are creating more pressure on mangrove forests in these sites and the other mangrove species either present in very low number or disappeared from that site. The distribution pattern of mangrove species at Gulf of Khambhat is mostly contagious. Availability of eight species but in less number indicated that in near future the coastal region will be dominated by monotonous species (*Avicennia marina*). Other species regeneration should be focused while making conservation plans. This study will provide baseline for further study in this area and for development of conservation as well as management strategies for mangrove species.

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