

The mangrove diversity of Purna Estuary, South Gujarat, India

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Abstract: The mangroves along the estuaries of South Gujarat, India, have remained largely uninvestigated. The present paper describes the mangroves of Purna estuary, Navsari district, Gujarat. They were studied by undertaking extensive field work over two years. Mangrove density maps of the area were prepared using unsupervised classification technique of IRS 1-D, LISS III satellite data for the year 2003. This locality which was devoid of any mangroves now harbors about 387 ha of mangroves, most of which is a dense forest. The highlight of this study is the occurrence of seven species of mangroves *viz.* *Avicennia marina* var. *marina*, *Sonneratia apetala*, *Acanthus ilicifolius*, *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera cylindrica* and *Aegiceras corniculatum* which makes it one of the most diverse mangrove patches in the state. Nine species of mangrove associates and six species of salt marsh are also reported from the area.

Resumen: Hay pocas investigaciones sobre los manglares ubicados a lo largo de los estuarios en el sur de Gujarat, India. El presente artículo describe los manglares del estuario Purna, distrito Navsari, Gujarat. Éstos fueron estudiados por medio de un extenso trabajo de campo desarrollado a lo largo de dos años. Se elaboraron mapas de la densidad de los manglares del área usando una técnica de clasificación no supervisada de datos satelitales IRS 1-D, LISS III para el año 2003. Esta localidad que estaba desprovista de manglares ahora alberga unas 387 ha de manglares, la mayor parte de las cuales son de bosque denso. El punto más destacado del estudio es la presencia de siete especies de manglar, que son *Avicennia marina* var. *marina*, *Sonneratia apetala*, *Acanthus ilicifolius*, *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera cylindrica* y *Aegiceras corniculatum*, lo cual hace de éste uno de los parches más diversos de manglar en el estado. También se reportan para el área nueve especies asociadas al manglar y seis especies de marisma.

Resumo: Os mangais ao longo dos estuários do sul do Gujarat, Índia, têm permanecido largamente por investigar. O presente artigo descreve os mangais do estuário do Purna, distrito de Navsari, Gujarat. Eles foram estudados efetuando um trabalho de campo extensivo durante dois anos. Os mapas de densidade do mangal da área foram preparados usando uma técnica de classificação não supervisionada de IRS 1-D, com recurso aos dados do satélite LISS III para o ano 2003. Esta localidade, que estava despida de quaisquer mangais, alberga agora cerca de 387 ha de mangais, muitos dos quais são floresta densa. O ponto saliente deste estudo é a ocorrência de sete espécies de mangal *viz.* *Avicennia marina* var. *marina*, *Sonneratiia apétala*, *Acanthus ilicifolius*, *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera cylindrica* e *Aegiceras corniculatum* o que o faz uma das manchas mais diversas no estado. Nove espécies associadas ao mangal e seis espécies do pântano salgado foram também referidas para a área.

Key words: Diversity, estuary, Gujarat, mangroves, Purna.

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Introduction

Shorelines are one of the most rapidly changing places on the Earth. As many as 3 billion people (50% of the global total) live within 60 km of a shoreline (Woodroffe 2002); huge populations inhabit areas near the coast to take advantage of valuable marine resources and to participate in seaborne trade with other nations, thus reaping socio-economic benefits. Ecologically, the coast and its adjacent areas form a unique ecosystem owing to the combined influence of both fresh and saline water. It is due to this interaction that coastal landforms support a large diversity of flora and fauna, which are crucial to the food chain. One of the important resources that the coast offers is the mangrove ecosystem, which is amongst the world's most productive ecosystems (Mitsch & Gosselink 1993; Odum *et al.* 1982). Mangroves are trees or bushes growing between the level of high water of spring tide and level close to slightly above the mean sea level (Macnae 1968). They occupy the intertidal area of coastal wetlands with significant adaptation for salt tolerance and a distinct morphology and phenology. Mangroves have immense ecological and economic importance. They not only provide socio-economic benefits to local tribes, but also provide protection to coastal areas against natural disasters and facilitate the formation of land by trapping sediments (Kathiresan 2003a).

There are 18 million ha (Spalding 1997) of global mangroves inhabiting the tropical and subtropical region from 30° N and 30° S. Around 34 major and 20 minor mangrove species belonging to about 20 genera in over 11 families have been recorded globally (Tomlinson 1986). Mangroves of South and Southeast Asia form the world's most extensive and diverse mangrove system comprising 41.4% of global mangroves (Kathiresan 2003b). Indian mangroves make up 3.1% of the total global cover and are distributed along all the maritime states, except the union territory of Lakshwadeep, covering an area of about 4461 sq. km along the 7,500 km long Indian coastline (Anon. 2005b). The floral diversity of mangroves of India is comprised of 38 core mangrove species (Kathiresan 2003c).

Gujarat state, with a coastline of about 1650 km, harbours approximately 960 sq. km of mangroves supporting the second largest block of tidal forests of India (Anon. 2005b). Mangroves in

Gujarat are mostly confined to (a) Indus deltaic region i.e. Kori creek and Sir Creek area, (b) The Gulf of Kachchh, and (c) The Gulf of Cambay. Major work on the mangroves in Gujarat has been carried out by agencies such as the State Forest Department, Space Applications Centre (SAC, Indian Space Research Organisation, Ahmedabad), and Gujarat Ecological Education and Research Foundation (Gandhinagar). Eight core mangrove species have been reported by them along the Gujarat coast. However, most of their work is restricted to the Gulf of Kachchh with an emphasis on species diversity and extent (Chavan 1985; Shah *et al.* 2005; Singh 2002; Singh 2006). Preliminary observations (Singh 2002) suggest that the estuaries of south Gujarat also harbour a rich diversity of mangroves. However, they have remained largely uninvestigated, except for areas of Umargaon creek (Kothari & Rao 1991a, 1991b; Kothari & Singh 1998) and Valsad (Shah 1978). We conducted an inventory on mangrove diversity of one such un-explored area in south Gujarat, the Purna estuary mangroves, using comprehensive ground surveys coupled with preliminary remote sensing studies.

Materials and methods

Study area

The coastal wetland of Purna River is located on the southern part of Gujarat state on the western coast of India. It extends between the longitude 72° 44' E to 72° 55' E and latitude 20° 53' N to 21° 01' N (Fig. 1). The study area is covered in the Survey of India (SOI) topographical maps 46D/9 & 46 D/13. Purna is a perennial river of Navsari district in South Gujarat which originates from the Satpuras range and debouches into the Arabian Sea near Navsari. It has a mouth span of approximately 1.5 km with the tidal influence up to 26.2 km upstream (as per the SOI topographical map, 1965). The mean annual rainfall received in this region was 2492 mm (measured at Navsari station) during the year 2004 (Anon. 2005a).

The wetland comprises intertidal mudflats, mangroves, salt marsh, sand beach, dunes, tidal creeks, etc. The lower most reaches of the river form extensive mudflats. The river mouth supports numerous small islands. Tidal waters reach the mudflats through a dense creek network. It experiences semi-diurnal tides, with two high and two low tides daily.



Fig. 1. Location map of the study area.

Methods

A base map indicating the shoreline, the coastal wetland features and surrounding villages of the study area was prepared from the SOI topographical map by tracing the relevant features. Extensive fieldwork on the northern as well as the southern fringe of the Purna Estuary wetland was carried out to study the mangrove diversity. The study area was visited 8 times during 2006 to 2008. The islands at the river mouth were surveyed using boats from the nearby coastal villages. The vegetation was studied using traverses laid perpendicular to the mangrove fringe and extended till the end of the intertidal area and in the case of islands till the opposite fringe. The specimens, both mangrove and non-mangroves, were collected and labeled properly. They were brought back to the laboratory where a few samples were preserved as Herbaria and few were dissected to identify the specimens. They were identified using the mangrove identification manuals and standard Floras (Banerjee *et al.* 1989; Rajendran & Sanjeevi 2004; Shah 1978). The plants whose identity could not be confirmed were sent to experts for identification. Precise GPS locations were collected from all the field areas visited.

Digital LISS III satellite data obtained from the IRS P6 satellite, Path 93 and Row 57, dated 31st March, 2003 was used for generating a

mangrove density map of Purna Estuary. Image was analyzed using the ERDAS IMAGINE, 8.5. The image was geometrically corrected with the reference projection Geographic Lat/Long and Spheroid and Datum Modified Everest using GPS points collected in the field. The image was then subjected to unsupervised classification technique using the maximum likelihood classifier for mapping the wetland features. Each class was then assigned a category based on the classification system developed for the Coastal Wetland Map at SAC (Anon. 1992). This classification system basically divides coastal areas into wetland and non-wetland categories at the first level and then for the coastal wetland features it makes a distinction between vegetated wetland classes and non-vegetated wetland classes. The vegetated classes have been designated based on their fidelity to the mangrove ecosystem. The class grass has been separated out as it could be easily distinguished from the other mangrove associates due to its form and large extent. The map was subjected to contextual editing where a few classes that merged with another category were then recoded again to their correct category. The accuracy of this finalized map was assessed according to the method described by Green *et al.* (2000).

Results and discussion

Seven species of mangroves are present in the study area. These species have been listed in Table 1 with comparative information of mangrove diversity in other areas of Gujarat (Anon. 1987; Anon. 1992; Anon. 1998; Chavan 1985; Kothari & Rao 1991a 1991b; Kothari & Singh 1998; Rajendran & Sanjeevi 2004; Shah 1978; Shah *et al.* 2005; Singh 2002; Singh 2006). The mangroves are found mainly on the islands and on the estuarine fringe of the intertidal wetland where daily tidal flushing occurs. Different species of mangroves occupy different areas of the wetland. The mangrove vegetation shows the dominance of *Avicennia marina* (Forsk.) Vierh. var. *marina*. It occurs as a fringe mangrove and is seen on the high tidal mudflats as well (Fig. 2). *Sonneratia apetala* Buch. Ham. is present on most of the intertidal mudflats and grows profusely along the creeks. *Acanthus ilicifolius* L. is generally found growing along the shallow creeks as well as on the landward fringe of the intertidal area. It is also the only mangrove species in this area which grows on the hyper-saline mudflats. *Ceriops tagal* (Perr.)

C.B. Roinson and *Bruguiera cylindrica* (L) Bl. plants are present on the intertidal mudflats and behind fringe patches of *Avicennia marina*. *Rhizophora mucronata* Lam. is present dispersed along the intertidal mudflats. Plants of *Aegiceras corniculatum* (L.) Blanco were found on the edge of a creek. Small saplings of all the mangrove species were observed in large numbers except for *Aegiceras corniculatum* which indicates the good regeneration status of the mangrove vegetation.



Fig. 2. An overview of mangroves at an island of Purna Estuary.

The area also harbours a rich diversity of mangrove associates and salt marsh vegetation. Nine species of mangrove associates and six species of salt marsh are being reported in the area. They have been listed in Table 2. Some of these species show a distinct zonation in the intertidal as well as the high tidal areas of the estuary. *Salvadora persica* L. is present in the open mangrove patches as well as on the high tidal mudflats. It occupies the largest area among the mangrove associates. Extensive patches of *Derris trifoliata* Lour. have been observed all over the study area. The occurrence of this species is a new report for Gujarat. The salt marsh vegetation which comprises *Suaeda fruticosa* Forsk., *Suaeda nudiflora* (Willd.) Moq., *Sesuvium portulacastrum* L., *Salicornia brachiata* Roxb., *Arthrocnemum indicum* (Willd.) Moq., and *Cressa cretica* L. occupies the hightidal mudflats. *Aeluropus lagopoides* (L.) Trin. ex Thw. is prominently present along the intertidal and higher mudflats. *Porteresia coarctata* (Roxb.) Tateoka is seen along the fringes of the mangrove islands. *Ipomoea biloba* Forsk. occurs at several places along the sandy beaches of the wetland.

Table 1. Mangroves of Purna Estuary vis-à-vis mangroves of other region of Gujarat (compiled from various sources).

Mangroves	Occurrence		
	Purna	GUK	Gujarat
Avicenniaceae			
<i>Avicennia alba</i> Blume	-	P	P
<i>Avicennia marina</i> (Forsk.) Vierh.	P	P	P
<i>Avicennia officinalis</i> L.	-	-	P
Sonneratiaceae			
<i>Sonneratia apetala</i> Buch. Ham.	P	-	P
Rhizophoraceae			
<i>Ceriops tagal</i> (Perr.) C.B. Roinson	P	P	P
<i>Rhizophora mucronata</i> Lam.	P	P	P
<i>Rhizophora apiculata</i> Bl.	-	-	Extinct
<i>Bruguiera gymnorrhiza</i> (L.) Lamk.	-	-	Extinct
<i>Bruguiera cylindrica</i> (L.) Bl.	P	-	Extinct
Myrsinaceae			
<i>Aegiceras corniculatum</i> (L.) Blanco	P	P	P
Acanthaceae			
<i>Acanthus ilicifolius</i> L.	P	-	P

GUK = Gulf of Kachchh, P = Present; minimum one stand

Table 2. Mangrove associates and salt marsh halophytes of Purna Estuary.

Species
<i>Aeluropus lagopoides</i> (L.) Pellegrin
<i>Arthrocnemum indicum</i> (Willd.) Moq.
<i>Caesalpinia crista</i> L.
<i>Canavalia gladiata</i> (Jacq.) DC.
<i>Clerodendron inerme</i> (L.) Gaertn.
<i>Cressa cretica</i> L.
<i>Derris trifoliata</i> Lour.
<i>Ipomoea biloba</i> Forsk.
<i>Porteresia coactata</i> (Roxb.) Tateoka
<i>Salicornia brachiata</i> Roxb.
<i>Salvadora persica</i> L.
<i>Sesuvium portulacastrum</i> L.
<i>Suaeda fruticosa</i> Frost.
<i>Suaeda nudiflora</i> (Willd.) Moq.
<i>Thespesia populinea</i> (L.) Sol. Ex Corr.

The coastal wetland map prepared from LISS III satellite imagery (2003) indicates the total wetland area, including water and non-vegetated areas, to be near 4870 ha (Fig. 3). Mangrove

vegetation covers an area of about 388 ha. Of this, dense mangroves occupy about 303 ha while sparse mangroves cover an area of about 85 ha. The extent of the other categories has been indicated in Table 3.

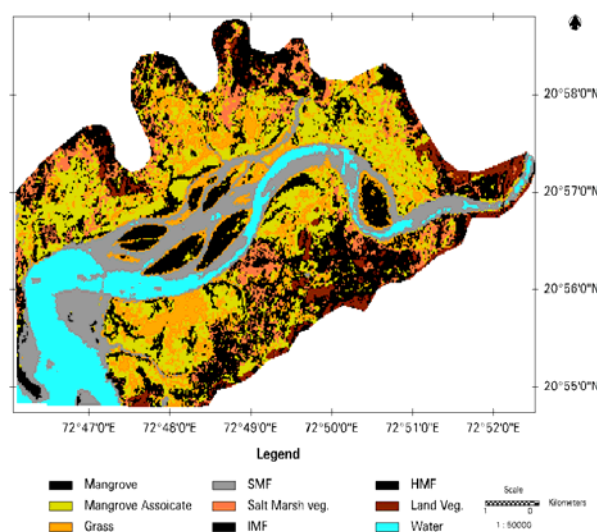


Fig. 3. Coastal wetland map; Purna estuary - 2003 (Prepared from analysis of LISS III satellite data).

Studies on mangroves of Gujarat have largely focused on the Gulf of Kachchh. 11 different species of mangroves have been reported from the state of Gujarat so far (Anon. 1987; Anon. 1992; Anon. 1998; Chavan 1985; Kothari & Rao 1991a 1991b; Kothari & Singh 1998; Rajendran & Sanjeevi 2004; Shah 1978; Shah *et al.* 2005; Singh 2002; Singh 2006). They have been listed in Table 1 along with the mangrove diversity of Purna River. Out of these, 3 species (*Rhizophora apiculata*, *Bruguiera gymnorrhiza*, *Bruguiera cylindrica*) are considered to be extinct by some workers (Singh 2002; Singh 2006) leaving the mangrove diversity of Gujarat to be 8. Precise information on mangrove distribution and diversity for any estuarine area in south Gujarat is lacking. Currently available information includes the presence of *Sonneratia apetala* at river Tapi (Singh 2002; Singh 2006), *Bruguiera cylindrica* in the Umargaon creek (Kothari & Rao 1991a, 1991b; Kothari & Singh 1998), and *Rhizophora mucronata* at sea coasts near Bulsar (now Valsad) (Shah 1978). In addition to this, the general occurrence of *Acanthus ilicifolius* in the estuarine area of South Gujarat has also been reported (Singh 2002; Singh 2006). No other mangrove

species are reported to occur along the south Gujarat coast.

Table 3. Area occupied by different wetland categories in Coastal wetland map- 2003 (Prepared from analysis of LISS III satellite data).

Class	Area (ha)
Vegetated Wetlands	
Mangrove	387
Mangrove Associate	1063
Grass	707
Salt marsh vegetation	375
Land vegetation	196
Nonvegetated Wetlands	
Water	486
Mudflat	1654
Total	4868

The mangroves of the Purna River are found in an estuarine environment. Such an environment supports relatively high diversity as the mangrove vegetation here is governed by fresh as well as saline water input (Anon. 1998). Earlier works have mentioned the Purna River Estuary as the largest single patch of mangroves in South Gujarat (Singh 2002; Singh 2006) with the occurrence of salt marsh vegetation (Anon. 1992). However, information regarding mangrove species diversity, density as well as precise extent is lacking for the survey area. We observed 7 mangrove species, 6 species of salt marsh, and 9 species of mangrove associates (Table 2) in the study area. The Marine National Park and Sanctuary, Gulf of Kachchh, Gujarat, which is considered to be the most diverse mangrove patch in the state presently has 6 mangrove species only (Singh 2002; Singh 2006). This makes the Purna Estuary one of the most diverse mangrove patches of the state.

The Survey of India topographical maps from 1965, showed no mangroves in our survey area. Also the Forest Survey of India (FSI) report of 2003 (Anon. 2005b) reports a mangrove area of 100 ha for the entire Navsari district. Our analysis of satellite data for the year 2003 shows presence of approximately 387.17 ha of mangrove forest. The mangroves in this area have migrated and established naturally, and presently show substantial diversity and density. Looking at the expanse of the intertidal area, this can be a major mangrove plantation site or a site for natural regeneration of mangroves. Though the mangrove area has reached such a condition naturally, they

are presently under considerable threat due to the rapid industrial development in the area. Reclamation of mangrove wetlands for aquaculture and salt pans industries also poses a serious threat to this vegetation. With the growing threat to the coastal areas from the ever-increasing population as well as natural hazards like tsunamis, it becomes even more important to protect mangroves, which have repeatedly proved their significance. Such a rich and diverse mangrove patch on the Purna Estuary deserves thus conservation and protection.

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