

APPLICATION OF REMOTE SENSING TECHNIQUES TO STUDY THE DISTRIBUTION OF MANGROVES ALONG THE ESTUARIES OF GOA

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ABSTRACT

Aerial photographs were used to study the distribution of mangroves in the estuaries of Goa during 1978-79. The total area covered by 7 estuaries in Goa including the major Mandovi-Zuari estuarine complex, is approximately 12,000 ha of which the mangrove forests occupy ca. 2,000 hectares. About 900 ha of mangroves are found in the Zuari estuary, 700 ha along the Mandovi estuary and 200 ha in the Cumbarjua Canal.

The mangrove vegetation is represented by 10 genera and 15 species. The dominant species are *Rhizophora mucronata*, *Sonneratia alba* and *Avicennia officinalis*. Other codominant species are *R. apiculata*, *S. caseolaris*, *Kandelia rheedii*, *Bruguiera gymnorhiza*, *B. parviflora*, *Aegiceros corniculata*, *Excoecaria agallocha*, *Acanthus ilicifolius* and *Derris heterophylla*. The other associated species are *Thespesia populnea*, *Clerodendron inerme*, *Halophila beccarii* and *Acrostichum aureum*.

Rhizophora mucronata, *Sonneratia alba*, *Avicennia* species are dominant in the polyhaline region while *Bruguiera parviflora*, *B. gymnorhiza*, *Acanthus ilicifolius*, *Avicennia* are common in mesohaline region. In the regions of low salinity (0.5 to 5 ‰), *Kandelia rheedii*, *Sonneratia caseolaris* are the only mangroves seen with their associate species *Acrostichum aureum*, *Cyperus* Sp. The fringing mangroves of Goa region are stable and there seems to be little human impact such as large-scale wood cutting or reclamation.

INTRODUCTION

Mangrove forests of India have been studied by Champion and Seth (1968), Navalkar (1959), Sidhu (1963), Macnae (1968), Blasco (1975), Blasco *et al.* (1974), Joshi (1976), Untawale (1978), Mathauda (1957), Qureshi (1957) and Waheed Khan (1957) for their various aspects. The total area covered by mangrove forests in Indian territory has been estimated to be 355,000 hectares (Blasco 1977). The purpose of this study was to provide data on the mangroves of the territory of Goa. Remote sensing techniques were used for the first time in India to map mangrove distribution along the Goa coast.

The union territory of Goa is situated along the central-west coast of India and extends north-south between 14°49' and 15°50' N Lat. (Fig. 1). The segmented coastline of Goa is about 120 km in length. Average precipitation during the monsoon period (June to September) is about 3000 mm while average temperature ranges between 25°C to 34°C (Fig. 2). Laterite soils of Goa contain very high percentage of iron and manganese.

Seven rivers occur along the Goa coast (Fig. 1). The Mandovi and Zuari estuaries along with the Cumbarjua canal form the largest estuarine complex in Goa (Untawale *et al.* 1973).

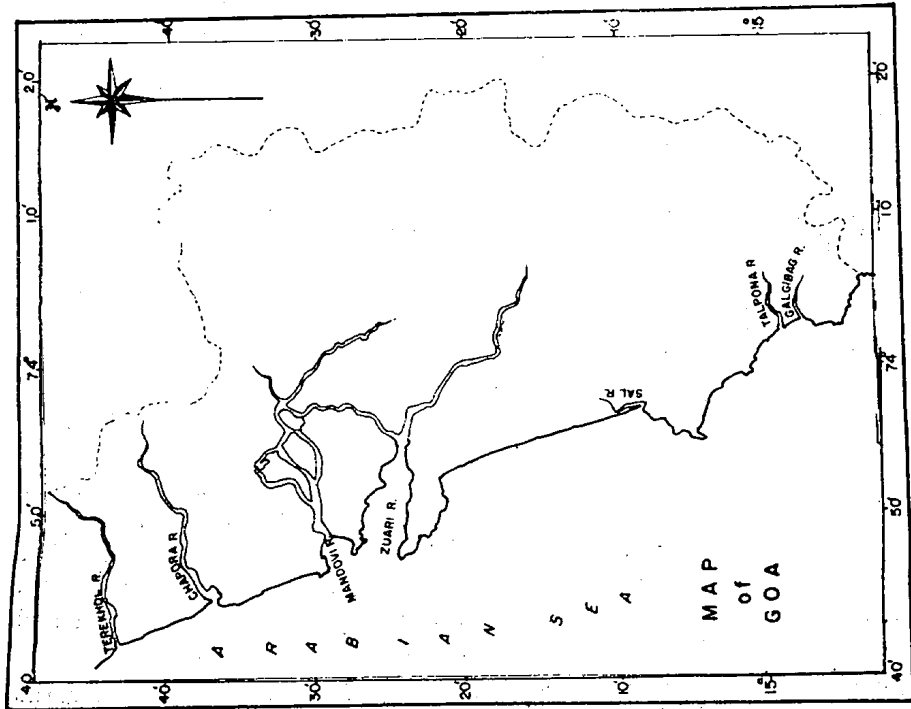


Fig. 1. Map of the Goa coast showing the estuaries.

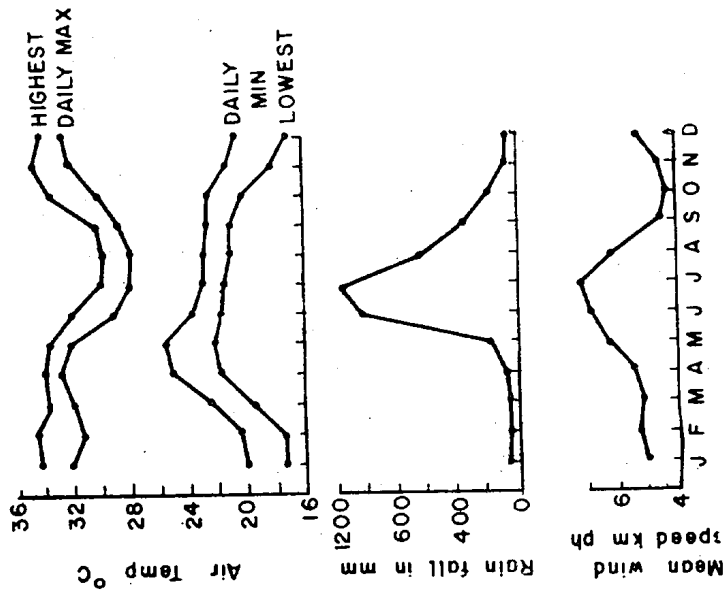


Fig. 2. Average climatological data for Goa during 1932 to 1960.

METHODS

An uncontrolled mosaic of photographs (Fig. 3) of the coastal area of Goa was initially prepared and studied. The photographs were taken in 1973 at a scale of 1 : 25,000. A mirror stereoscope was then used to delineate the mangrove vegetation by tracing their aerial extent onto Kodatrace. The tracings were then transferred to tracing paper which was used to prepare the final maps shown in Figs. 4, 5 and 6.

To confirm the findings from the study of the aerial photographs, field reconnaissance of the survey areas were undertaken. During survey the mangroves were sampled and the data used to determine distribution, dominance, association, density, structure, expanse and general profile of the vegetation.



FIG. 3. Satellite imagery of Goa region.

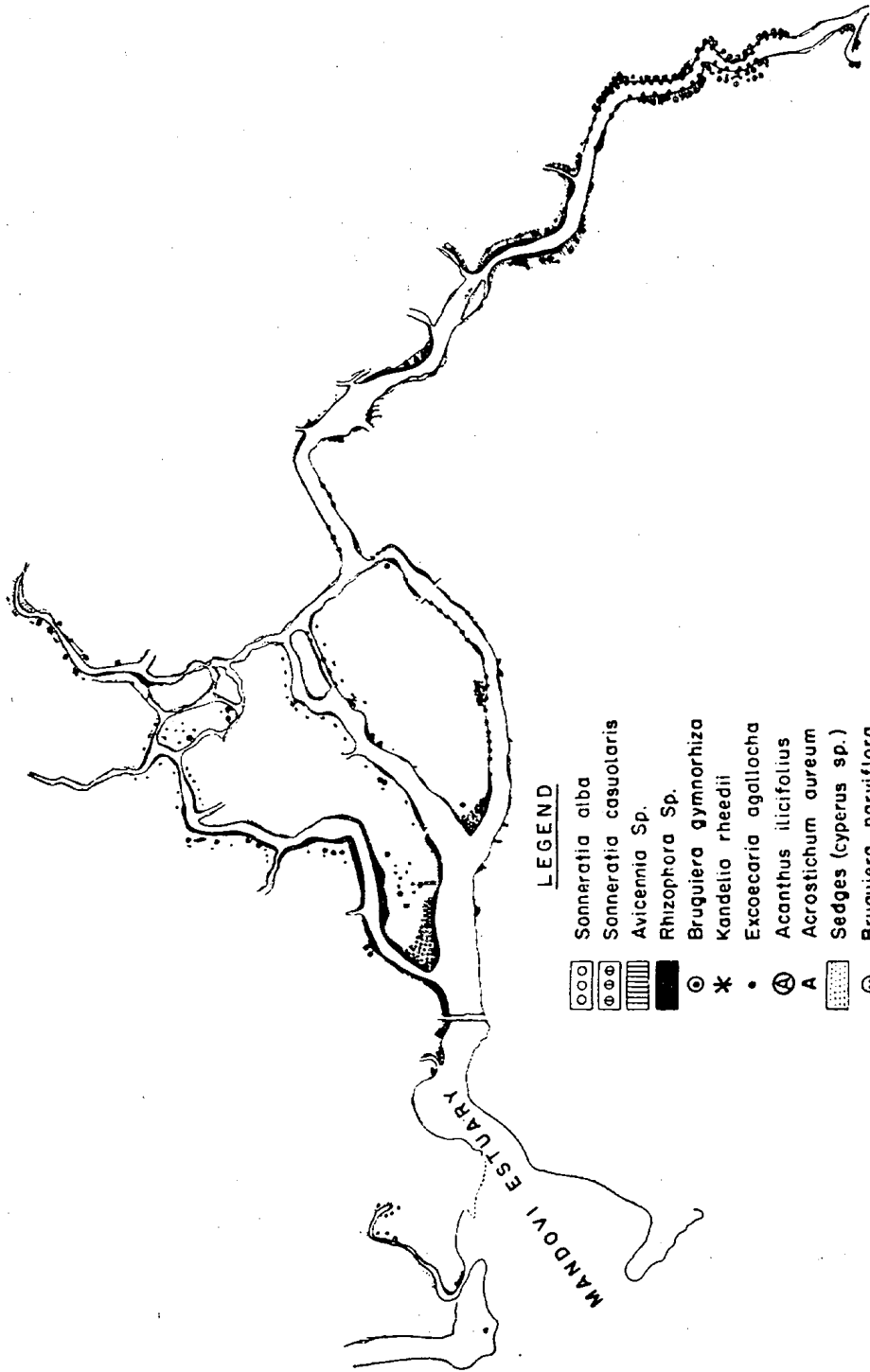


Fig. 4. Mandovi estuary showing mangrove vegetation.

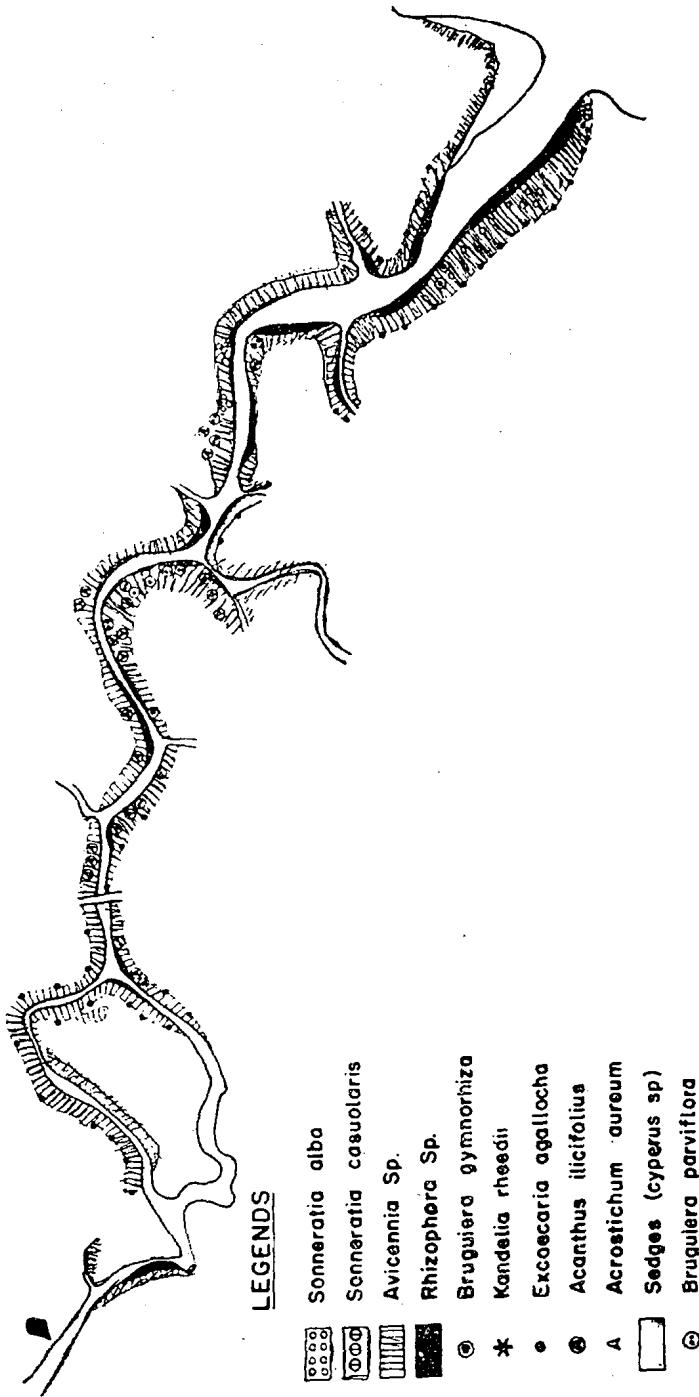


FIG. 5. Distribution of mangroves along Cumbarjua Canal.

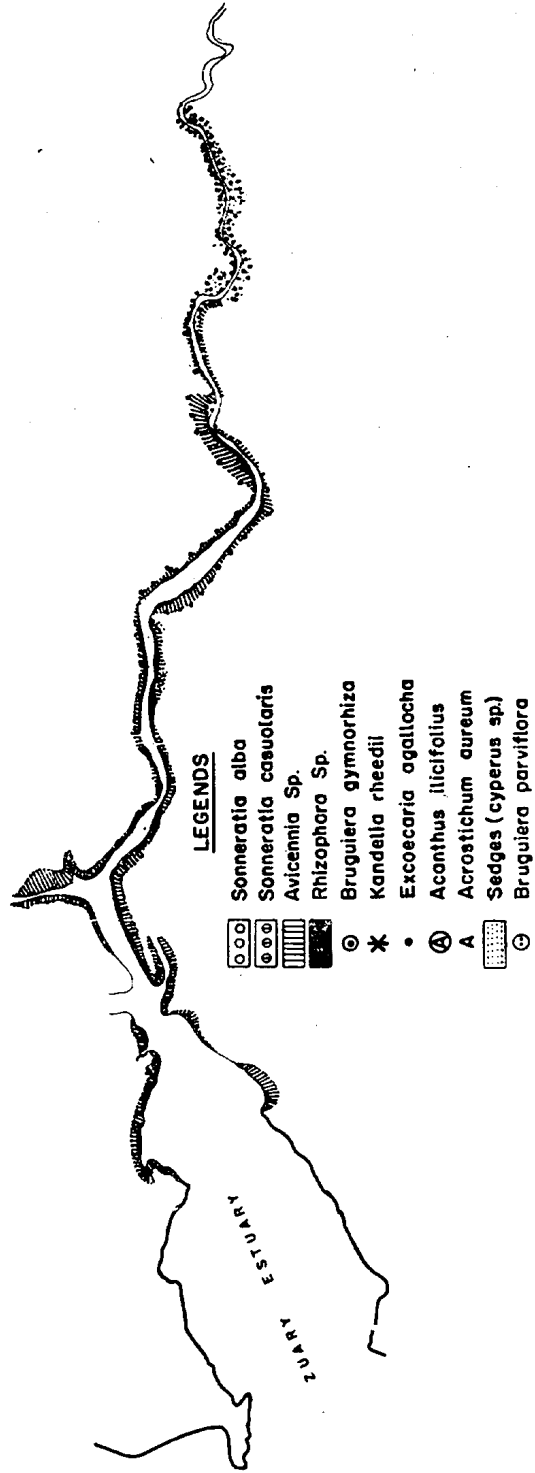


FIG. 6. Mangrove distribution along Zuari estuary.

RESULTS

The Terekhol river is on the border between Goa and Maharashtra. It is about 26 km in length and covers approximately 349 hectares of water area in Goa territory. Salinity intrudes into this river for approximately 20 km. The mangrove vegetation occurs along the river bank, covers about 30 hectares (Table 1). Zonation within the mangroves varies from the coastal region towards the headwaters while most of the mangroves occur in the bay region near the mouth of the river. Most of the mangroves in the latter area are tall and the stands are dense. In upstream areas the mangroves occur in isolated patches.

TABLE 1. Physical data for the estuaries of Goa

River	River area (ha)	Mangrove area (ha)	Mangrove (%)
Terekhol	349.0	30	8.6
Chapora	711.0	100	14.0
Mandovi	5564.0	700	12.6
Zuari	5790.0	900	15.5
Cumbarjua Canal	375.0	200	53.3
Sal	302.0	30	9.9
Talpona	40.0	20	25.0
Galgibag	26.0	20	76.9
Total	13157.0	2000	15.1

Mangroves occupy only about 8.59% of the total water area of the river. Mangrove species are *Avicennia officinalis* Lamk, *A. alba* Blume, *Rhizophora mucronata* Lamk, *Acanthus ilicifolius* Linn., *Sonneratia alba* Sm., *Excoecaria agallocha* Linn. and occasionally *Aegiceras corniculata* (L.) Blume. Both *Avicennia* species were recorded near the mouth of the river where salinity is very high. *Kandelia rheedii* W. & A. is found only in upstream areas (Shinde and Mustafa 1974) where salinity is low. In areas of lowest salinity, only *Acrostichum aureum* L. occurs.

Chapora river is approximately 30 km and salinity intrusion occurs beyond Colvale which is about 18-20 km from the mouth. Total water area of the river is about 711 hectares and mangroves occupy about 100 hectares (14.06%).

Small yet numerous patches of mangroves occur in the estuary near mouth region. In the less saline upstream areas mangroves are more extensive yet limited in number.

Mangroves in this estuary are more dwarf than those observed in other Goa estuaries. Representative species are *Excoecaria agallocha*, *Avicennia alba*, *Sonneratia alba* and *Acanthus ilicifolius*. In less saline areas, upstream of Covale village, vegetation is composed primarily of *Derris* sp., *Aegiceras corniculata* and *Acrostichum aureum*. Sedges are common in which *Sonneratia alba* too grows.

Mandovi river is about 68 km long and its tributaries account for an additional 109 km. The estuarine portion is 5 km wide at the mouth and 0.5 km wide at an upstream region. The open water area in Mandovi estuarine system covers about 5564 ha. Mangrove vegetation occupies about 700 ha. The lower end of the estuary is devoid of mangroves because of the rocky substratum, strong wave action and strong tidal

currents. These conditions are unsuitable for the establishment of mangrove seedlings (Fig. 4).

Mangrove vegetation is first seen as small patches in the creeks of Mandovi estuary with denser forest occurring in areas like Chodan Island. The distribution of mangrove species according to the salinity gradient, is clearly seen in this estuary. In euhaline areas dominant mangrove species are *R. mucronata*, *A. officinalis* and *Sonneratia alba*. In polyhaline zone, *Kandelia rheedii*, *R. apiculata*, *A. officinalis* are dominant. Oligohaline regions are characterised by the presence of *Sonneratia caseolaris* (L.) Engl., *Kandelia rheedii*, *Bruguiera parviflora* Roxb., *Excoecaria agallocha* Linn. and sedges.

Several tributaries of the Mandovi estuary (Mapuca river, Narona river and Goa river) have formed islands such as Chorao and Diwar. *Avicennia*, *Rhizophora*, *Sonneratia* and *Kandelia* colonize the islands. On western part of the Chorao island, where Mandovi estuary meets the Mapuca river, an area of about 2.5 sq. km mangrove vegetation has established. *Rhizophora mucronata*, *R. apiculata*, *S. alba*, *K. rheedii* occur in rows on the outskirts of this banded area.

Zuari river and its estuarine area are the largest in Goa. Open water covers approximately 5790 ha while mangrove vegetation occupies 900 ha. The mouth region (7 km wide) of the estuary is rocky and subjected to heavy wave action while the upstream region is quite narrow (0.5 km). First 7-8 km of this estuary is devoid of mangroves because of strong wave action, current and rocky substratum. Beyond this, a small patch of mangroves is dominated by *Sonneratia*, *Avicennia* and *Rhizophora*. After the branching of Cumbarjua canal, *Sonneratia alba* is dominant along with *Avicennia*, *Rhizophora* and *Excoecaria agallocha*. Further upstream, from Borim bridge, mangrove vegetation continues on both sides of the estuary and is dominated by *A. officinalis*, *Sonneratia* spp. and a few *Rhizophora* plants (Fig. 6). In the upstream areas, sedges particularly *Cyperus* sp. occur and Sanvordem onwards, mangroves are very rare on both the banks although *Sonneratia caseolaris* and *Kandelia rheedii* continue to be present. Zuari is a negative estuary with more fresh water influence (Untawale *et al.* 1973). Salinity is very low towards upstream region as most of the glycophytes are growing along the banks after Sanvordem.

The Cumbarjua canal connects the Mandovi and Zuari estuaries and is approximately 15 km in length and 30 to 40 metres in width. It has about 375 hectares of open water area and the mud flats on either side have fringing mangroves (Fig. 5). Total mangrove area along the canal is approximately 200 hectares or 53.33% of the total area. Mangrove vegetation is quite dense and seedling establishment is common along the canal where weak wave action, slow current and suitable substratum provide ideal establishment sites. The southern part of Cumbarjua canal has a rich mangrove flora. Dominant species observed are *Avicennia*, *Rhizophora*, *Sonneratia* and *Excoecaria*. Height of *Avicennia* trees ranged approximately 15 to 20 m while *Rhizophora* ranged from 8 to 10 m (Fig. 7). *Acanthus ilicifolius* was noticed very common and ranged from 1 to 1.5 meters in height. Near Madkai, *Avicennia* is the dominant species with its height from 6-8 m. *B. gymnorrhiza* and *B. parviflora* appear along with other vegetation.

Sal, a small river in southern Goa, has 302 ha of water area. Mangrove vegetation is scattered in this estuary and covers 9.93% of the total mangrove area of Goa. *A. officinalis* is the dominant mangrove along with *Excoecaria agallocha*, *Acanthus*, *Derris*. A few plants of *R. mucronata*, *B. gymnorrhiza* and *A. coniculata* were seen. *A. officinalis* ranged from 3-5 meters in height (Table 1).

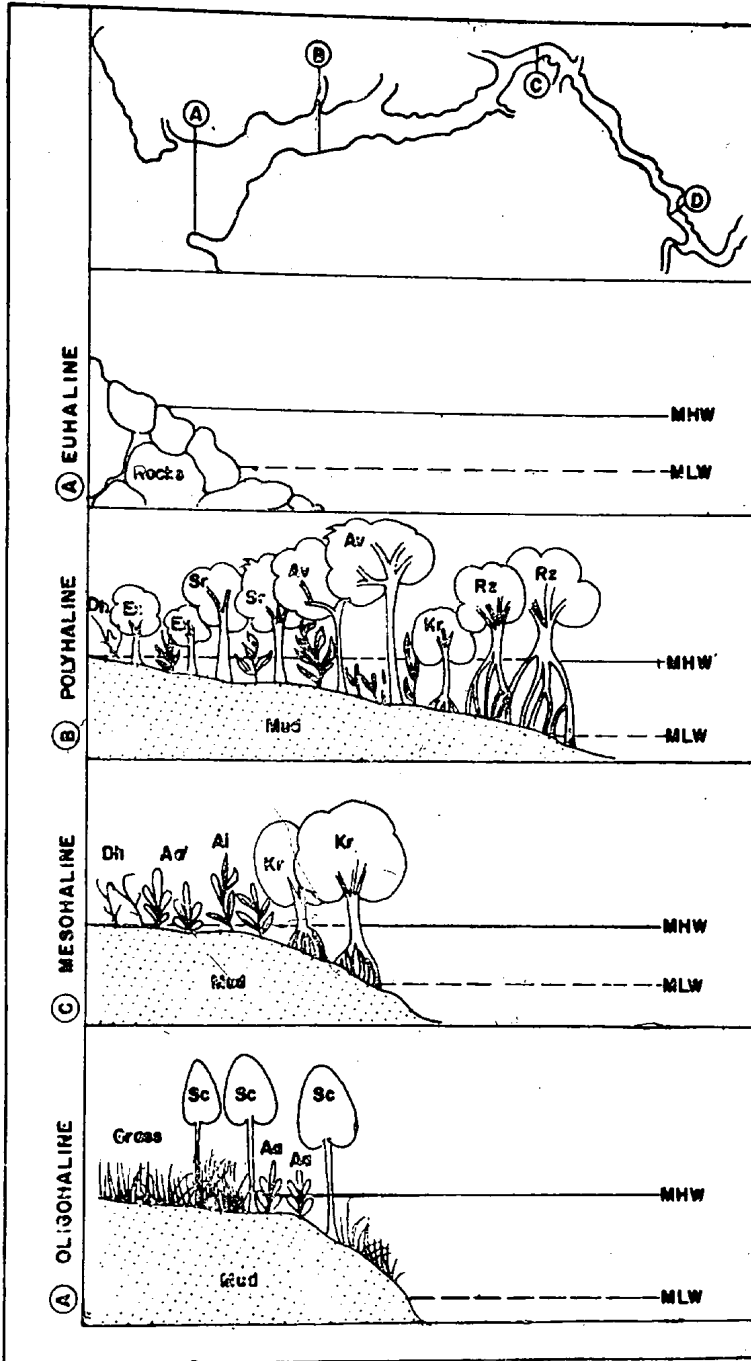


FIG. 7. Profile showing mangrove distribution along Cumbarjua canal.

MHW—mean high water level; MLW—mean low water level;

As—*Acrostichum aureum*, Ai—*Acanthus ilicifolius*, Av—*Avicennia* sp., Dh—*Derris heterophylla*, Ex—*Excoecaria*, Kr—*Kandelia rheedii*, Sr—*Sonneratia*, Sc—*S. caseolaris*, Rz—*Rhizophora* sp., Bg & Bp—*Bruguiera* sp.

The Talpona river is 9 km long and has an open water area of 40 ha. Mangrove vegetation has covered about 10 ha which is about 25% of the open water area. The dominant mangrove is *R. apiculata* which has limited distribution in other estuaries. Other common species are *A. officinalis*, *A. ilicifolius*, *D. heterophylla*, *A. aureum* while *Sonneratia alba*, *A. corniculata* and *E. agallocha* are uncommon and are mixed with other mangrove species.

Galjibag is another small river (16 km) in Goa and has approximately 26 ha of open water area. The mangrove vegetation has occupied about 20 ha, i.e., 76.9% of the total open water area. *Rhizophora mucronata* and *A. officinalis* are common and evenly distributed throughout. Other common species are *Derris heterophylla* and *Acrostichum aureum* which occur in upstream region of low salinity. In general, the mangrove vegetation is quite dense in this estuary compared to the mangroves in other estuaries of Goa.

In both the Talpona and Galjibag *Sonneratia alba* was observed towards the mouth region where salinity was high. In the region of moderate salinity *Rhizophora* species make their first appearance. Beyond this mixed vegetation of *Rhizophora* sp., *Avicennia* sp., *Excoecaria* sp., *Sonneratia* sp., *Acanthus* sp. and *Aegiceras* sp. were noticed while *Derris heterophylla* and *Acrostichum aureum* were present only in the upstream region of low salinity. In all of the estuaries studied, mangrove vegetation occurs primarily as fringing forests along banks. The total estimate of mangrove area is approximately 2000 ha as compared to a total open water area of 13157 ha in the seven riverine estuaries (Table 1).

DISCUSSION

Mangroves occur along both the east and west coasts of India. Earlier studies (Qureshi 1957, Mathauda 1957, Waheed Khan 1957 and Blasco *et al.* 1974) have provided some information on the distribution of mangroves in India. Their estimates of total mangrove cover along the Indian coast varies because of differences in sampling techniques. Estimates may also vary because of rapid rates of reclamation or destruction of mangrove area.

The total estimated area of mangrove vegetation in Goa is about 0.3 to 0.5% of the total mangrove cover of Indian coast. Goa is a territory, when compared to other states, having 3701 sq. km area of which about 0.5% area is covered by mangroves. Total 59 species of mangroves have been identified in the world of which 45 species occur in Indian mangroves (Blasco 1977). In Goa 15 species belonging to 10 genera and 7 families were reported (Table 2). The dominant mangroves were *R. mucronata*, *S. alba*, *S. caseolaris*, *A. officinalis*, *A. alba*, *E. agallocha*, *K. rheedii*, *A. ilicifolius* and *D. heterophylla*. Along the northern-central west coast of India mangroves like *R. mucronata*, *B. gymnorhiza*, *Ceriops tagal* and *S. apetala* Buch Ham. have been identified and are very common. *Kandelia rheedii* and *S. caseolaris* which are dominant in mesohaline and oligohaline zones of the Mandovi and Zuari estuaries of Goa, were not observed towards north of central west coast (Personal observations). *S. apetala* which was found along the Srivardhan coast (Personal observations) was conspicuously absent from Goa estuaries. Similar to polyhaline regions of the Waghota estuary at Vijaydurg, *R. mucronata* and *B. gymnorhiza* were common in the polyhaline zone along the Goa coast. However *Ceriops tagal* rarely appears in the polyhaline zone in Terekhol estuary. It has been observed that many rhizophoraceae grow better in polyhaline region (Walsh 1967).

TABLE 2. *Distribution of mangroves in different estuaries of Goa*

Species	Terekhol	Chapora	Mandovi	Zuari	Cumbarjua	Sal	Talpona	Galjibag
<i>Rhizophora mucronata</i>	++	+	+++	+++	++	++	++	++
<i>R. conjugata</i>	—	—	—	—	—	—	+++	—
<i>R. apiculata</i>	—	—	++	—	+	—	—	—
<i>Bruguiera gymnorhiza</i>	—	—	++	+	++	+	—	—
<i>B. parviflora</i>	—	—	+	+	+	—	—	—
<i>Kandelia rheedii</i>	—	+	+++	+++	++	—	—	—
<i>Ceriops tagal</i>	+	—	—	—	—	—	—	—
<i>Avicennia officinalis</i>	++	++	++	++	+++	++	++	++
<i>A. marina</i>	—	—	+	+	+	—	—	—
<i>A. alba</i>	+	+	+	+	+	+	—	—
<i>Acanthus ilicifolius</i>	++	++	+++	+++	+++	++	++	++
<i>Sonneratia alba</i>	++	+	+++	+++	+	+	+	+
<i>S. caseolaris</i>	—	—	++	+	++	+	—	—
<i>Excoecaria agallocha</i>	++	++	++	++	++	+	+	+
<i>Aegiceras corniculata</i>	+	—	—	—	—	++	+	—
<i>Derris heterophylla</i>	++	++	+++	+++	+++	++	++	++
<i>Acrostichum aureum</i>	++	++	++	++	++	++	++	++

— Absent + Rare ++ Common +++ Dominant

Few plants of *Avicennia marina* were observed in polyhaline region of the Mandovi and Zuari estuaries. However, the same species were abundant in the polyhaline region of Vasai river towards west coast off Bombay (Untawale 1980).

Based on the distribution, mangroves are classified as coastal mangroves, mangroves growing along the creeks and mangroves growing along the banks of the estuaries. Along the Goa coast, mangrove distribution, in general, is of fringing type (Untawale and Parulekar 1976). On the basis of salinity gradient and substratum, the following type of successional patterns were observed in the mangroves of Goa.

Euhaline zones towards mouth of the estuary are characterised by high salinity (40 to 30‰) and strong wave action. The substratum is usually rocky and sandy, which is unfavourable for the establishment and growth of mangrove seedlings. Consequently mangroves are absent from this zone (Fig. 7).

The polyhaline zone is characterised by moderate salinity (18-30‰) and minimum wave action. Substrate are of usually sandy clay which favours establishment of mangrove seedlings. *Sonneratia alba*, *R. mucronata*, *A. officinalis*, *A. alba*, *A. ilicifolius* are the most common member in this zone. Species like *A. marina*, *B. gymnorhiza* and *B. parviflora* are also present (Fig. 8).

Salinity in the mesohaline zone ranges from 5 to 18‰ and wave action is feeble. The substratum is generally silt clay (Table 3). Common species of this zone are *S. alba*, *K. rheedii*, *R. mucronata* and *E. agallocha*. *Aegiceras corniculata* is an infrequently associated species (Fig. 7).

The oligohaline zone of the upstream have salinity below 0.5‰ (Table 3) which favours the growth of glycophytes in the exclusion of mangroves (Untawale 1980).

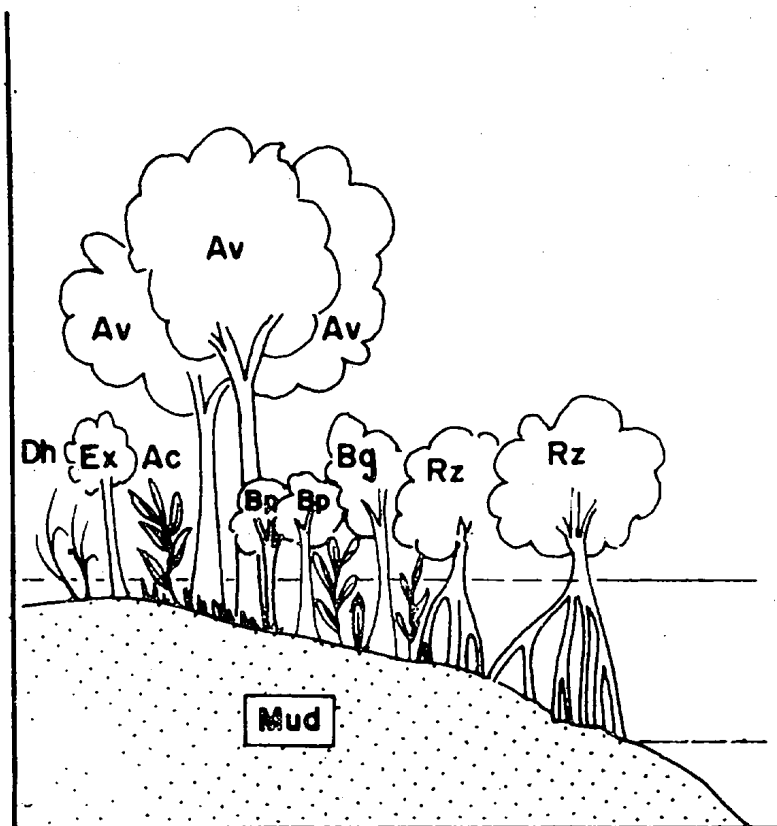


FIG. 8. Distribution of mangroves along salinity gradients. Symbols as in Fig. 7

TABLE 3. Distribution of the mangroves in relation to substratum, salinity and pH

Zone	Salinity ‰	pH	Substratum	Mangrove species
Euhaline	30—40	7—8	Rocky, sandy	No mangroves
Polyhaline	18—30	6.7—8	Silty clay	<i>Sonneratia alba</i> , <i>Rhizophora mucronata</i> , <i>Rhizophora apiculata</i> , <i>Kandelia rheedii</i> , <i>Bruguiera gymnorhiza</i> , <i>Bruguiera parviflora</i> , <i>Avicennia officinalis</i> , <i>Avicennia alba</i> , <i>Excoecaria agallocha</i> , <i>Acanthus ilicifolius</i> , <i>Derris heterophylla</i>
Mesohaline	5—18	6.5—7.5	Silty clay	<i>Rhizophora mucronata</i> , <i>Rhizophora apiculata</i> , <i>Bruguiera parviflora</i> , <i>Avicennia alba</i> , <i>Kandelia rheedii</i> , <i>Bruguiera gymnorhiza</i> , <i>Avicennia officinalis</i> , <i>Excoecaria agallocha</i> , <i>Acanthus ilicifolius</i> , <i>Derris heterophylla</i>
Oligohaline	0.5—5	6—7.5	Silt	<i>Kandelia rheedii</i> , <i>Sonneratia caseolaris</i> , <i>Acrostichum aureum</i> , <i>Cyperus sp.</i> , <i>Acanthus ilicifolius</i> , <i>Derris heterophylla</i>
Limnetic	0.5	6—7.5	Silt	<i>Sonneratia caseolaris</i> , <i>Acrostichum aureum</i> , <i>Cyperus Sp.</i>

Luxuriant growth of *Kandelia rheedii* (Fig. 9) and *Sonneratia caseolaris* (Fig. 10) has been observed along the estuaries of Goa coast. *K. rheedii* which is on verge of extinction according to Blasco (1975), appears in abundance in the Mandovi and Zuari estuaries, particularly in the upstream regions. Similarly *S. caseolaris* has a very limited distribution along the Indian coast, yet was found growing in the upstream regions of both the estuaries. Joshi (1976) and Bhosale (1978) have reported the occurrence of stray *K. rheedii* along the Vashisti river near Chiplun, but about *S. caseolaris* there seems to be no report along the central west coast. Mangrove flora of Goa consists only of two *Sonneratia* species, i.e. *S. alba* and *S. caseolaris*. *Sonneratia apetala* occurs along the northern central west coast. *S. acida* reported by Bhosale (1978) and Joshi (1976) apparently does not occur in Goa. Other mangrove species like *C. tagal* and *Lumnitzera racemosa* which occur abundantly along the Maharashtra coast (Joshi 1976) were not observed from Goa.



FIG. 9. *Kandelia rheedii* -a mangrove species on the verge of extinction, growing along the Mandovi estuary.

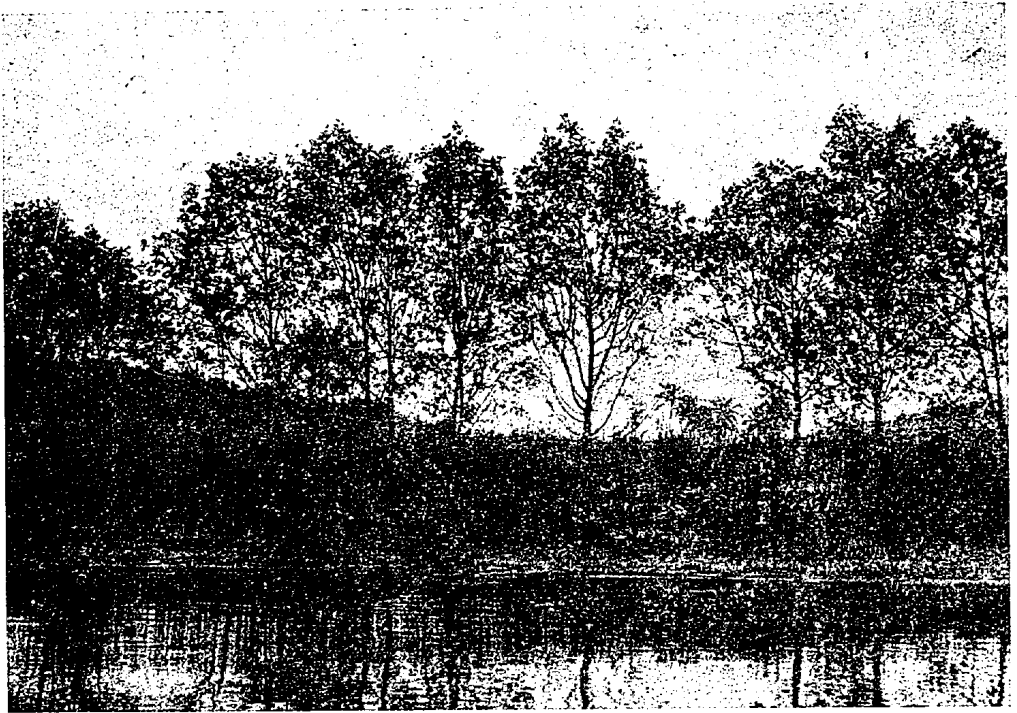


FIG. 10. Growth of *Sonneratia caseolaris* in the upstream region of Mandovi estuary.

It is observed that the height of the mature propagules of mangroves and the tidal amplitude play an important role in the distribution of mangrove species (Fig. 11). The production of number of seeds or propagules in different mangrove species is correlated to the size of seeds or propagules. The rhizophoraceae members produce larger sized propagules but in less number. In *Avicennia* where the size of the seeds is reduced, production is more. The extreme case is seen in *Derris*, *Excoecaria* and members of Graminae

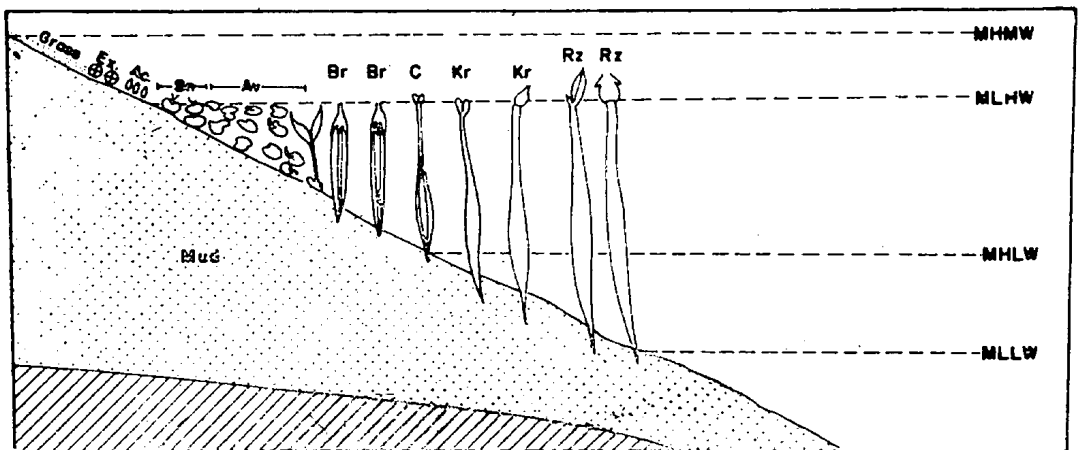


FIG. 11. Distribution of mangroves in relation to length and weight of propagules and tidal levels.

and Cyperaceae where the seed size is very small and the number is much more as compared to other plants.

The estuaries of Goa flow in directions determined by the regional geomorphology. At several places these estuaries have U-shapes (Fig. 12). In these areas velocity of the

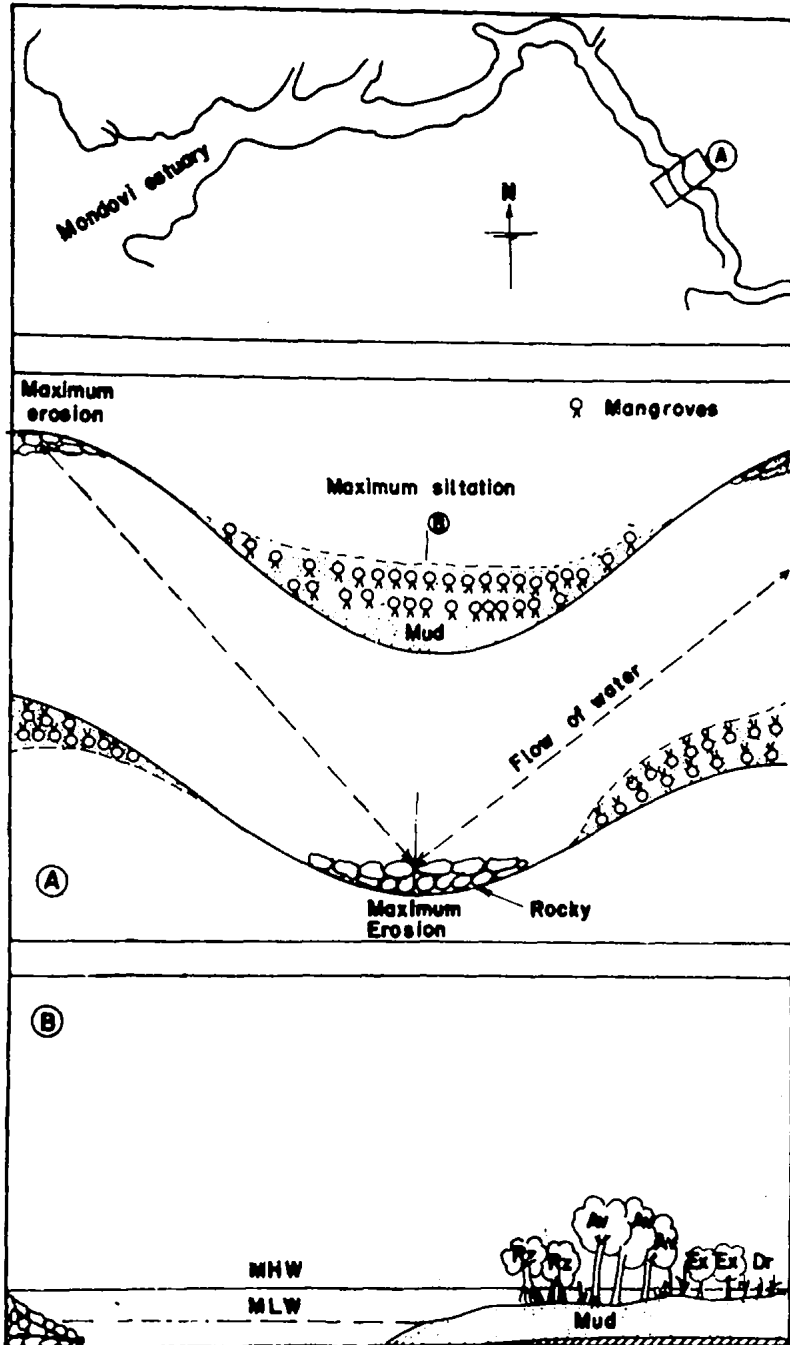


FIG. 12. Zones of erosion, accretion and mangrove establishment along the estuary.

water current is greater and the rate of erosion is maximum. As a result the establishment of mangrove seedling does not take place in such areas. In areas where eroded sediment is deposited, mangrove propagules readily get established and result into extensive dense mangrove vegetation.

Mangroves are very important coastal ecosystems (Heald and Odum 1970, Chapman 1978) and many are experiencing increasing stress such as indiscriminate cutting, reclamation and pollution. If properly managed, many mangrove areas could be used for aquaculture purposes (Parulekar and Verlenkar 1980). Before many of these types of exploitation activities are initiated, detailed exploration of mangrove vegetation along the Indian coast is urgently required. There is need to standardize survey techniques and this study has shown that remote sensing technique (using aerial photography and satellite imagery) could be effectively used to survey mangrove forest in India.

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