

## Ecology of Mangroves in Mandovi & Zuari Estuaries & the Interconnecting Cumbarjua Canal of Goa\*

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Mangroves are absent in the mouth regions (6 to 7 km long) of both the estuaries. On either bank they have sandy beaches or rocky shores. These zones have high wave action, high salinity and low temperature. The adjoining reaches of estuaries are the zones of mangrove vegetation, extending from the lower part of the middle reaches right up to the upper reaches of these estuaries. Cumbarjua canal is also included in this zone where the wave action is weak, the sandy beaches are replaced by mudflats and the estuarine water is slightly warmer, with lower salinity and higher oxygen. The mangrove flora of these estuaries includes 31 species of 29 genera belonging to 19 families of angiosperms. Succession of species, association, dominance and other aspects of vegetation like density, adaptation and height have also been discussed.

**M**ANGROVES are widespread all along the Indian coastline and on the west coast of India in the estuarine environment many rivers form mangroves.

Macnae<sup>1</sup> has reviewed flora, fauna and other aspects of mangrove swamps. These swamps are highly productive<sup>2</sup>, however, they are not properly utilized for fish production<sup>3</sup>. Prain<sup>4</sup> has studied mangrove flora of Sunderbans. Estuarine mangroves on the west coast of India have been described earlier<sup>5-9</sup>. However, no work appears to have been done on mangroves of Goa region. General aspects of coastal lagoons and mangroves have been discussed by Chapman<sup>10</sup> and Rützler<sup>11</sup>.

### Description of Area

In Goa, the Mandovi and Zuari rivers form an important estuarine complex. They are 61.6 and 62.4 km long respectively. The total catchment areas of these estuaries cover two-thirds of the Goa territory.

The average rainfall in Goa region is 2611 mm/annum. This rainfall is not uniformly distributed throughout the rainy season, but the major part of the rainfall occurs during June to August, resulting in the heavy flooding and active erosion. It gradually decreases during the postmonsoon period. The premonsoon period is almost dry (Fig. 1).

Both these estuaries are surrounded by a hilly terrain with dense vegetation, hence the lateritic soil of these forests is rich in humus. The soil is heavily leached and become deficient in lime, potash and phosphorus, whereas the soil in river deltas is comparatively richer in these nutrients<sup>12</sup>. The high nutrient content, along with low wave action and absence of pronounced currents near the banks leads to a favourable environment for the growth of mangroves. It is seen that in the areas where such conditions prevail, the mangrove flora is rich and present in varying density in different parts of the estuarine systems. The entire system

can be classified into 3 broad categories, viz. Mandovi estuary, Zuari estuary and Cumbarjua canal (Fig. 2).

*Mandovi estuary*—The estuary is about 3 km wide at the mouth while it narrows down to 0.5 km in width upstream. In the region of the confluence the tidal action is high coupled with strong currents. It has sandy beaches on either banks at Miramar and Verem. Pronounced influence of the wave action and the current is seen up to the head of Chorao Island (6.5 km). The effect of these factors gradually decreases upstream towards Savaiverem.

*Zuari estuary*—The mouth region of the estuary is approximately 5 km wide while upstream its width narrows down to less than 1 km. Marked tidal amplitude with heavy wave action is present up to Siridao head. In this region sandy beaches interspersed with rocky portions are present from Dona Paula to Siridao head and from Vasco to near St Jacinto Island on the northern and southern banks respectively. The estuarine environment extends upstream up to Savardem (28 km).

*Cumbarjua canal*—Mandovi and Zuari estuaries are interconnected by this canal which is approximately 15 km long and 0.5 to 0.75 km wide at

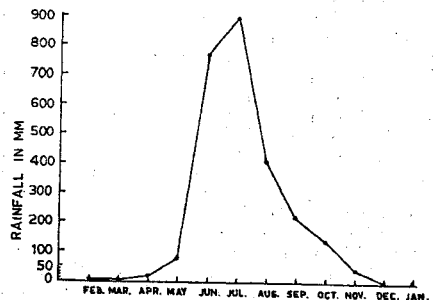


Fig. 1—Average annual rainfall in Goa during 1931 to 1960 (From Climatological Tables of Observatories in India)

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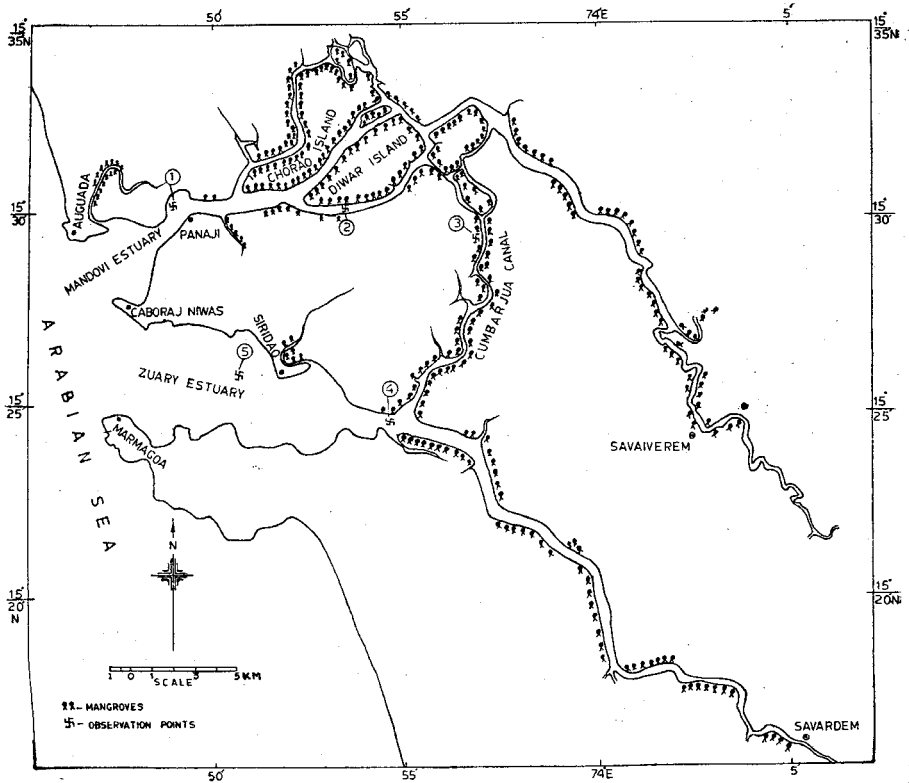


Fig. 2—Map of Goa showing mangroves in Mandovi and Zuari estuaries and interconnecting Cumbarjua canal

different places during its course. The influence of wave action and current in this canal is negligible. On either side it has mudflats and the bottom has a mixture of clay and sand in different parts.

This major estuarine system can be classified further in two different zones in relation to the mangrove vegetation (Fig. 2).

**Zone of absence**— In the Mandovi estuary, the zone from its confluence to the head of Chorao Island (6 km) is devoid of mangrove vegetation, while in Zuari there are no mangroves from the confluence region to the Siridao head (7 km). The main factors for the absence of mangroves in these parts of the estuaries are the high intensity of wave action, strong currents and a rocky or sandy substratum.

**Zone of presence**— In the Mandovi estuary the mangroves start from the head of Chorao Island and extend for a distance of 34 km, up to Savaiverem. In the Zuari estuary the zone of mangroves starts from east of Siridao head and continues till Savardem for a distance of about 28 km. In Cumbarjua canal the mangroves are present on both the banks throughout its length (Plate I, Fig. 1).

In both the estuaries beyond Savaiverem and Savardem a practically freshwater environment

is established resulting in the absence of mangroves.

In the zone of mangrove abundance, the influence of wave action and current is considerably low and the substratum is rich in humus and soft silty mud. All these factors together create a favourable environment for mangroves (Plate I, Figs. 1-4).

## Results and Discussion

### Environmental Parameters

These tropical estuaries undergo strong seasonal changes in their environment. The variations are of different magnitude at all 5 stations located in this estuarine system, but they follow a certain generalized pattern. The changes in temperature, salinity and oxygen are given in Fig. 3.

**Temperature**— The confluence regions of the two estuaries are the zones where mangroves are absent. They have slightly lower temperatures as compared to the zones of mangrove vegetation. During different seasons, the difference in the mean seasonal temperature is of the order of 1°C. Amongst the zones of mangrove vegetation, in Cumbarjua canal the waters are still warmer. The temperature



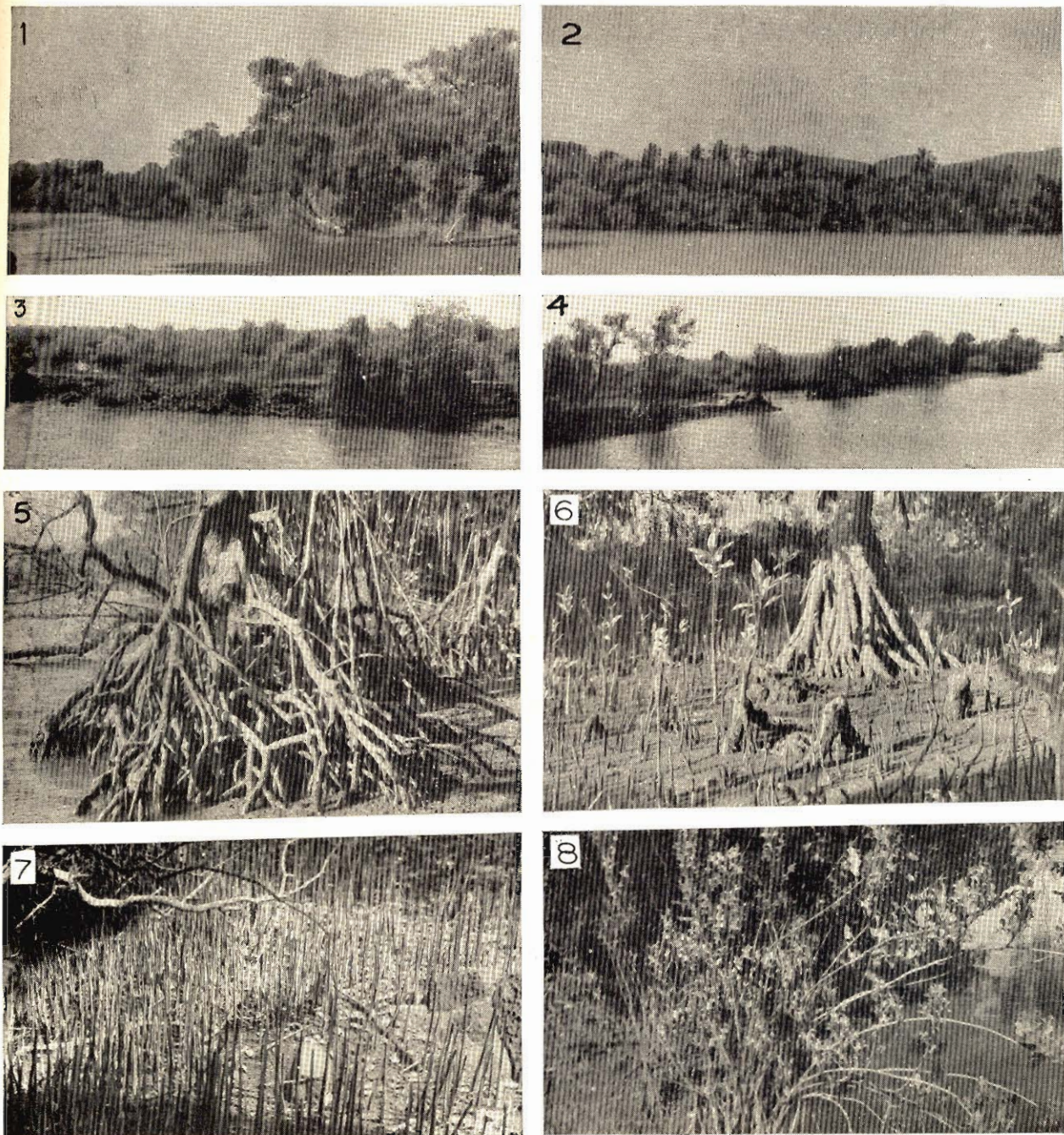


Plate I—Mangroves in Zuari and Mandovi estuaries and in Cumbarjua canal [Fig. 1: Dense and tall vegetation in Cumbarjua canal. Fig. 2: Mangrove vegetation in Zuari estuary. Fig. 3: Beginning of mangrove zone in Mandovi estuary. Fig. 4: Beginning of mangrove zone in Zuari estuary. Fig. 5: Prop roots of *Rhizophora mucronata*. Fig. 6: Knee roots of *Brugiera* sp. Fig. 7: Pneumatophores of *Avicennia officinalis*. Fig. 8: *Acanthus ilicifolius*, a member in association]

ranges from 27.7° to 30.2°C (mean temp., 28.9°C). It appears that there may not be significant temperature differences amongst the areas where the mangroves are present, but the zones where mangroves are absent have distinctly lower temperatures (Fig. 3).

**Salinity**—Salinity is the most important factor in the estuarine environments. The salinity at station Nos. 1 and 5 is higher. In the zone of mangrove vegetation the salinity varied from 1 to 34.5‰. Further, there are sharp seasonal differences during the monsoon, postmonsoon and

premonsoon. In the monsoon the salinity becomes very low, because of heavy rains (Fig. 3).

**Dissolved oxygen**—During the monsoon period, due to freshwater influx, the variation in dissolved oxygen increases (range, 3.3 to 5.5 ml/litre). In this season sharp differences are noticeable between the zones of mangrove vegetation in lower reaches and the zones where mangroves are absent, which correspond with the mouth areas of the estuary. The mouth zone has lower dissolved oxygen as compared to the zones of mangrove vegetation. In the former, dissolved oxygen varied around



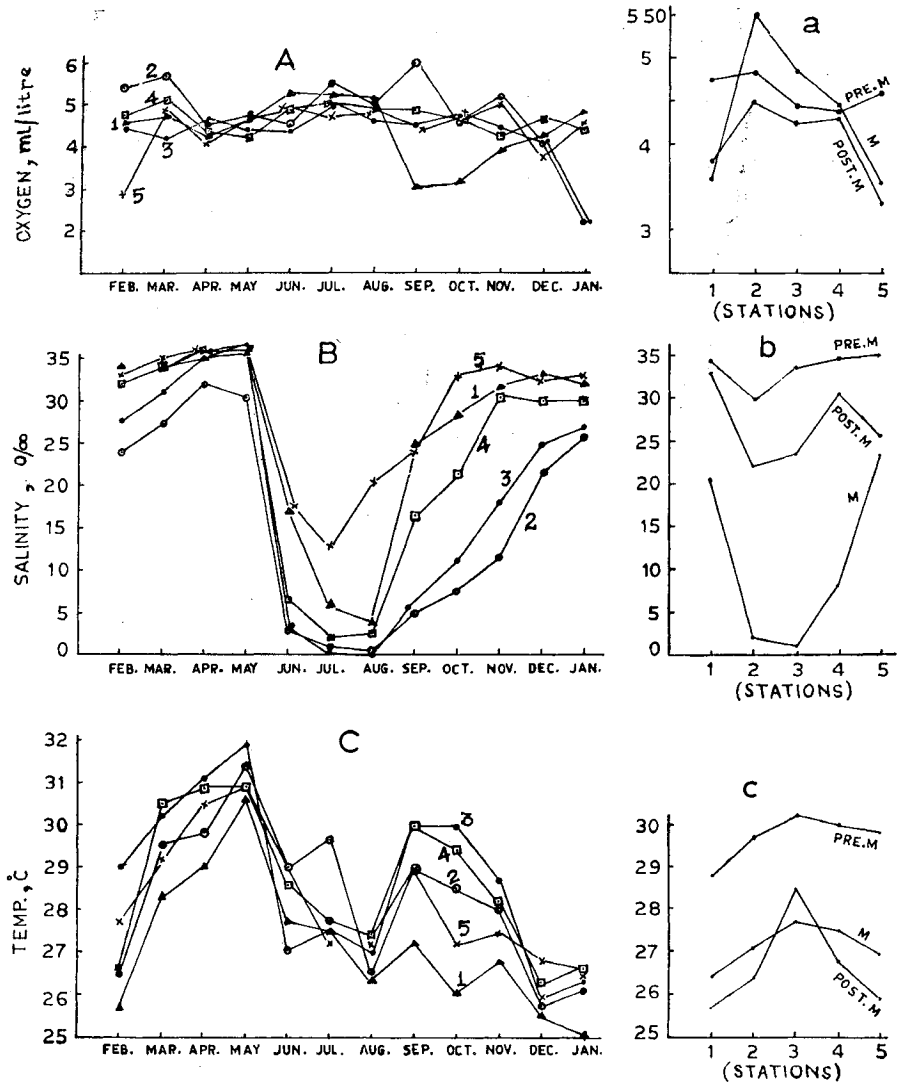


Fig. 3 — Seasonal variations in oxygen (A), salinity (B) and temperature (C) around mangrove swamps during 1971-72 [Curves 1 to 5 represent data for station Nos. 1 to 5. a, b and c represent generalized picture of oxygen, salinity and temperature respectively for premonsoon (Pre.M), monsoon (M) and postmonsoon (Post.M) for station Nos. 1 to 5]

3.6 ml/litre and in the latter from 4.5 to 5.5 ml/litre (Fig. 3).

During the postmonsoon period, the conditions are almost uniform in all the zones and the dissolved oxygen values fluctuate between 3.1 and 5.2 ml/litre. It is thus seen that in the postmonsoon period amplitude of variation becomes slightly narrower as

compared to monsoon months, however, the difference is not very appreciable. During the premonsoon period the values vary from 3.3 to 4.4 ml/litre. Dissolved oxygen in the zones of abundance at station Nos. 1, 3 and 4 is higher. Thus the dissolved oxygen values show seasonal variations in different zones.

Environmental data for oxygen, salinity and temperature for monsoon, postmonsoon and premonsoon period indicate a generalized picture (Fig. 3a, b and c respectively). In all these seasons, in the zones of mangrove vegetation, located in lower reaches of the estuaries and in the canal, the temperature is slightly higher, the salinity lower and the dissolved oxygen higher.

**Nutrients** — Phosphates and nitrates have an important role on plant growth in these environments<sup>13</sup>. These are studied for a period of 1 yr at each station. The mean values for different seasons are given in Fig. 4.

Phosphate concentration in both the zones during the monsoon and postmonsoon periods is of the same order and the values are around 0.5 to 1.25 µg at/litre. Later during the premonsoon months their value increases and ranges between 1.2 and 1.5 µg at/litre.

Nitrate is present in low concentration at all the stations during the monsoon months. The values increase during the postmonsoon period and decrease again in premonsoon period.

Further it is seen that throughout the year in the mouth region of these estuaries, where mangroves are absent, the nitrate values are lower, but phosphates do not show such concentrations.

**Floral Composition**

Principal dominant species in the zone of mangroves in the two estuaries are: *Avicennia officinalis*, *Rhizophora mucronata*, *Sonneratia caseolaris* and *Bruguiera* sp. The common plants in association with the dominant species are *Acanthus ilicifolius*, *Aegiceras corniculata*, *Clerodendron inerme*, *Vitex trifolia*, *Pongamia pinnata*, *Cocos nucifera* along with

a few grasses like *Sporobolus*, *Diplanchnie* and *Chloris*. Apart from these associations, the individual species sometimes form pure colonies. Detailed enumeration of species found in the mangrove swamps of both the estuaries is as follows:

Family	Species
Sterculiaceae	1. <i>Heritiera littoralis</i> Dry.
Papilionaceae	2. <i>Erythrina variegata</i> var. <i>orientalis</i> Merr.
	3. <i>Pongamia pinnata</i> Benth.
	4. <i>Derris trifoliata</i> Lour.
Caesalpiniaceae	5. <i>Caesalpinia nuga</i> (L.) Ait.
Rhizophoraceae	6. <i>Rhizophora mucronata</i> Lam.
	7. <i>Bruguiera conjugata</i> (L.) Merr.
	8. <i>B. parviflora</i> Wight & Arn.
Combretaceae	9. <i>Lumnitzera recemosa</i> Willd.
Sonneratiaceae	10. <i>Sonneratia caseolaris</i> Engl.
Turneraceae	11. <i>Turnera ulmifolia</i> var. <i>angustifolia</i> Willd.
Goodeniaceae	12. <i>Scaevola frutescens</i> Krause syn. <i>S. koenigii</i> Vahl
Myrsiniaceae	13. <i>Aegiceras corniculata</i> Blanco
Apocynaceae	14. <i>Cerbera manghas</i> L. ( <i>Cerbera odollam</i> Gaertn.)
Asclepiadaceae	15. <i>Lepladmedia reticulata</i> Wight.
Convolvulaceae	16. <i>Breweria cordata</i> Bl.
	17. <i>Ipomoea grandiflora</i> Lam.
	18. <i>Operculina turpethum</i> (L.) Silva Manso
Acanthaceae	19. <i>Acanthus ilicifolius</i> L.
Verbenaceae	20. <i>Premna integrifolia</i> L.
	21. <i>Vitex trifolia</i> L.
	22. <i>Clerodendron inerme</i> (L.) Gaertn.
	23. <i>Avicennia officinalis</i> var. <i>tomentosa</i> L.
Euphorbiaceae	24. <i>Excoecaria agallocha</i> L.
Palmae	25. <i>Cocos nucifera</i> L.
Cyperaceae	26. <i>Cyperus malaccensis</i> Lam.
	27. <i>C. rotundus</i> L.
	28. <i>Fimbristylis polytrichoides</i> Vahl
Graminaeae	29. <i>Sporobolus maderaspatanus</i> Bor.
	30. <i>Diplanchnie fusca</i> (L.) Beauv.
	31. <i>Chloris quinguesetica</i> Bhide

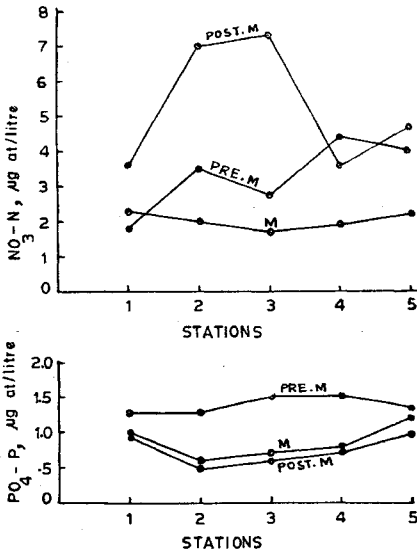


Fig. 4 — Distribution of phosphates and nitrates in mangrove swamps of Goa during 1971-72 [Pre.M, premonsoon; M, monsoon; and Post.M, postmonsoon]

Though the same species are found in both these estuaries, they show remarkable differences in their growth and density in some parts of Mandovi and Zuari estuaries and Cumbarjua canal. In the canal the average height and the growth of mangroves is more than in any part of the estuaries (Plate I, Fig. 1). Similarly the number of rows of the plants on either banks is more in Cumbarjua canal as compared with the estuaries.

**Succession of Species**

*R. mucronata*, commonly known as red mangrove, is the species which establishes itself first on the banks. Usually the mangrove swamps are protected by *R. mucronata* with supporting root system, which form the front row towards water-front. These trees grow up to 6-8 m high and have very dense canopy of the fleshy leaves (Fig. 5).

Thus the red mangroves create an essential environment for the black mangroves — *A. officinalis*. *Avicennia*, soon after the seedling stage, develops a horizontal root system, which gives rise to another special type of aerial roots — pneumatophores. These roots occupy a vast area helping in the formation of a suitable substratum by trapping silt. Meanwhile the shoot system also develops into a dense canopy. Decayed leaves of these plants also play an important role in the enrichment of the substratum. The root systems of *Rhizophora* sp. and *Avicennia* sp. give additional support to the plant. Thus the plants can sustain high wave action and

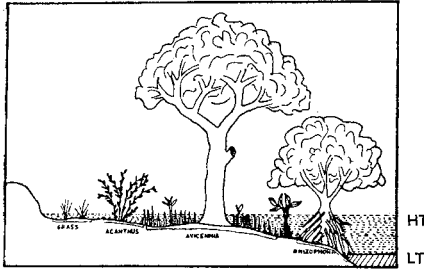


Fig. 5 — Diagrammatic representation of typical species succession in a mangrove swamp

ultimately prevent erosion. Diagrammatic representation of typical species succession in these estuaries is shown in Fig. 5.

**Association** — After the establishment of these high trees, shrubby bushes, herbaceous species and climbers make their appearance. *A. uicifolius*, *A. corniculata*, *V. trifolia*, *C. inermis* are some of the species which form associations. Also some of these species form their own single species colonies in the mangrove swamps (Plate I, Fig. 8). Apart from these associations, in the muddy substratum around the mangroves sometimes grow patches of blue-green algae (*Nostoc* sp.). Rising pneumatophores also show the presence of diatoms while the pools beneath mangrove trees are rich in plankton.

In different parts of the estuaries a cross-section from water-front side towards the land show different species. A typical pattern of zonation is shown in Fig. 5.

In the places where mangroves extend over a wide part of a bank, the *Rhizophora* are seen towards the water-front. This species is comparatively shorter than *Avicennia* and develops a typical root system. The edge of their canopy correspond to the level of highest high water-mark. Towards the landward side *Rhizophora* are succeeded by *Avicennia*. These are taller trees having a root system occupying an extensive area. In succeeding generations depending upon the favourable condition they slowly encroach towards the land and also extend further towards the water-front.

However, in this area along the banks, both the estuaries have agricultural fields and the bunds of these fields are under constant care and maintenance. These act as barriers for further landward extension of mangroves. Further extension of these zones, as reported by Battistini<sup>14</sup>, is not present in these estuaries.

**Adaptation** — All mangrove species have adopted the suitable root systems to grow in adverse conditions. They show different type of root systems in different plants. Here the tap root is not very deep and hence unable to support the tree. Therefore, special root systems are developed which grow horizontally covering an extensive area (Plate I, Figs. 5-7).

In *R. mucronata* the oblique prop roots give additional support to the plant as a result of which these species can grow in the zone of wave action. *A. officinalis* and *S. caseolaris* are characterized by

the presence of horizontal root system spread over an extensive area for mechanical support. It further gives rise to aerial roots or pneumatophores, to perform function of respiration (Fig. 5). *Bru-guiera conjugata* and *B. parviflora* develop typical knee roots which come out of the substratum (Plate I, Fig. 6).

The root systems of all these species are submerged under water during high tide and exposed completely at low tide.

These mangrove plants are characterized by viviparous germination. They fall in the soft mud and soon develop a root system.

## Discussion

In this study ecological conditions in different parts of the two estuaries which provide favourable and unfavourable environment for mangrove growth have been investigated. These two estuaries are very different from each other. Mandovi is a positive estuary where freshwater influence is greater while Zuari is a negative estuary which has predominantly marine influence<sup>13,15</sup>.

The mouths of these estuaries lie in close proximity and are separated only by a very narrow ridge but earlier studies have shown that they are very different biologically and ecologically<sup>16</sup>. These two estuaries differ considerably in the amount of freshwater run-off, the intensity of waves and other hydrological factors. In spite of these differences in the mouth zone of both these estuaries conditions are unfavourable for mangrove vegetation. The common adverse factors for mangrove growth are the type of substratum on the banks, intensive wave action, strong current and predominantly marine characteristic of the waters. These prevent the settlement and growth of mangrove seedlings.

Towards the lower reaches of both these estuaries in station Nos. 2, 3 and 5 the environment changes. The wave action becomes weaker and modifies the environment. The sandy beaches are replaced by mudflats and mangrove vegetation starts in this region. First *Rhizophora* sp. which can sustain high wave action are seen in first row towards water-front. Towards the upper region of the estuary the influence of tide action decreases further and a second row of *Avicennia* sp. is seen along the banks. Sometimes along with the *Avicennia* sp. some associated species also grow (Plate I, Fig. 8).

Gradually towards upper reaches the mangrove becomes more extensive and dense. These conditions are further modified in Cumbarjua canal, where the wave action is comparatively less and the banks have mudflats. Thus the environment is most favourable for mangrove growth. Though the canal has most favourable environment for mangrove, it does undergo considerable seasonal fluctuations in the environment. These are brought about during monsoon months due to heavy rainfall, most of which comes within a short period of two months during June and July (Fig. 2).

The changes brought about due to the influx of fresh waters in different parts of the estuaries are broadly characterized by salinity (Fig. 3). In spite of these fluctuations it is seen that at any time of the year Cumbarjua canal, as compared to the mouth region of both the estuaries, has lower salinity, higher oxygen and lower temperature (Fig. 3). The seasonal variations are also seen in the concentration

of phosphates and nitrates. Phosphates are rich in Cumbarjua canal during premonsoon months and nitrates are rich in postmonsoon months. During monsoon months the concentration of both phosphates and nitrates become low. It is thus seen that in spite of seasonal variations in hydrography and nutrients that in any season they do not become limiting factors. Thus Cumbarjua canal presents most favourable environment for mangrove growth in this area. These get established and stabilized during non-monsoon months and therefore during monsoon months at least for short periods mangroves can stand variations in salinity from almost fresh water to marine conditions.

Towards the upper reaches beyond Savardem in Zuari estuary and Savaiverem in Mandovi estuary when freshwater conditions prevail almost throughout the year the mangroves are absent.

In both the estuaries and Cumbarjua canal in spite of favourable environment, the landward extension of mangrove is checked on either banks due to constant building of bunds for agricultural purposes.

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