

## THE ESTUARINE REGION

This section deals with the second ecozone: the ecology of the alluvial plains, mud flats and estuarine areas. These are specialised habitats and Goa has many of them. They are not well understood in their dynamics which is why we allow them to be disturbed and damaged, often for frivolous reasons.

The mangrove habitat is not unique to Goa, but mangroves are an important part of the coastal ecosystem. Their many ecological functions are well-known. Though there is a government order banning the felling of mangrove species, we continue to fell them when we think it is necessary for development. The Forest Department is gamely attempting to regrow mangrove species in certain areas with some measure of success.

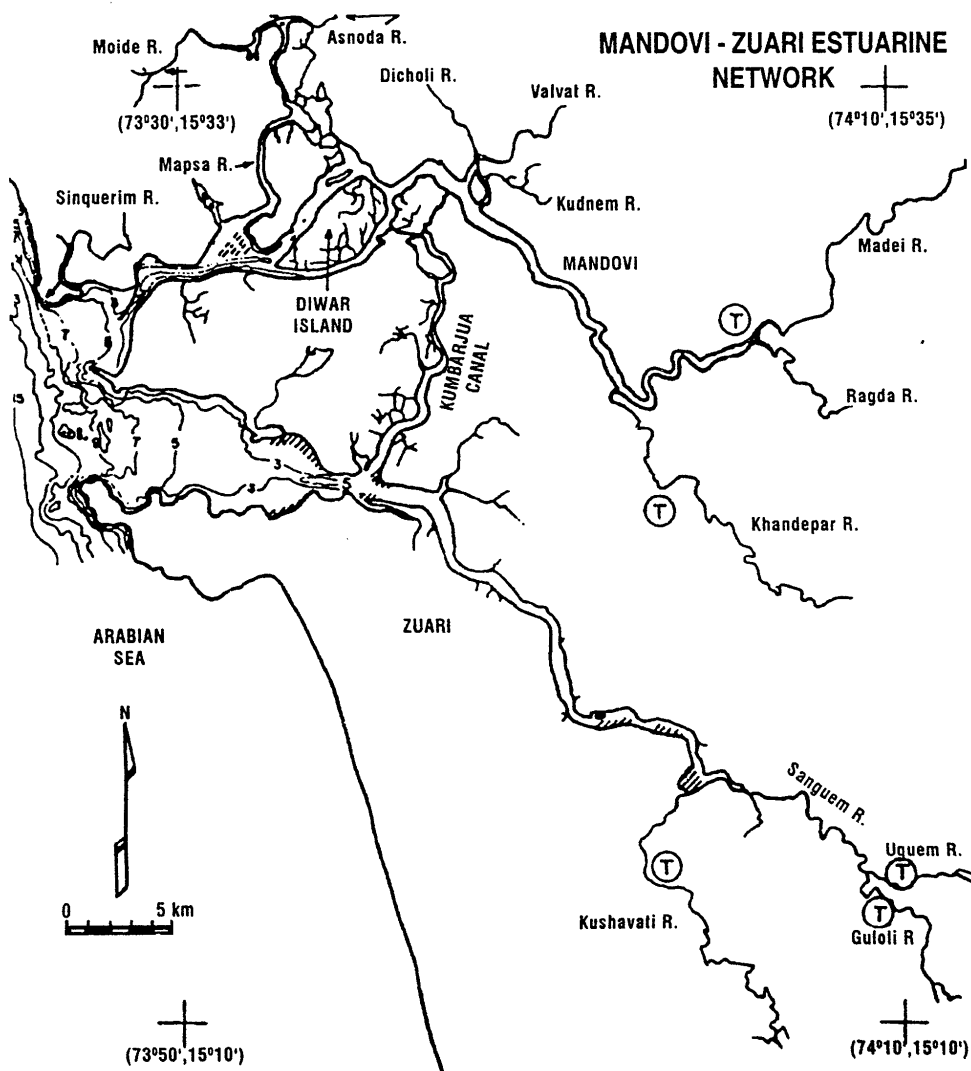
The Mandovi-Zuari estuarine complex is also little understood, which is why we have turned the mouths of these rivers into receptacles of waste, sewage and mining silt.

## THE MANDOVI-ZUARI ESTUARINE ECOSYSTEM

The Mandovi and the Zuari are two estuaries located in Goa on the west coast of India; they join the Arabian Sea. The main channels of these estuaries are each about 50 km long and they are connected by a narrow channel, the Cumbarjua canal. At the upstream end, both estuaries receive freshwater from the rivers, which originate in the Western Ghat mountain ranges. A number of rivers/rivulets join the two estuaries. The Mandovi, the Zuari, the Cumbarjua canal and the rivers/rivulets form a network, which is used extensively for transport of goods (mainly iron ore), for fishing, and for dumping domestic and industrial waste. The increase in population and industrial activity in Goa during the last few decades has increased the dependence of the state on the network. Simultaneously, issues related to the health of the estuarine network and to its ability to absorb additional impacts have gained importance. Addressing these issues requires an understanding of the hydrodynamics of the network. A first step towards this goal is the understanding of propagation of tides because they dominate the advective field. Earlier studies have accumulated considerable data on the seasonal cycle of hydrography and of

the chemistry of the estuarine network. Little, however, is known about propagation of tides in the network. Hence, a study based on observations and mathematical modelling was initiated. In this article, we describe the observations made as a part of the study, and infer prominent characteristics of tidal propagation. Though tides dominate the advective field, another process, the effect of the influx of freshwater brought in by rivers and rivulets that join the network, also needs to be considered. The freshwater enters primarily at the upstream end of the channels. Many points along the channels also receive freshwater. The influx is high during the south west monsoon (June-October), when most of the annual precipitation occurs over the catchment area, decreasing rapidly after the withdrawal of the monsoon. However, even during the dry season, at the upstream end of the channels the water is fresh.

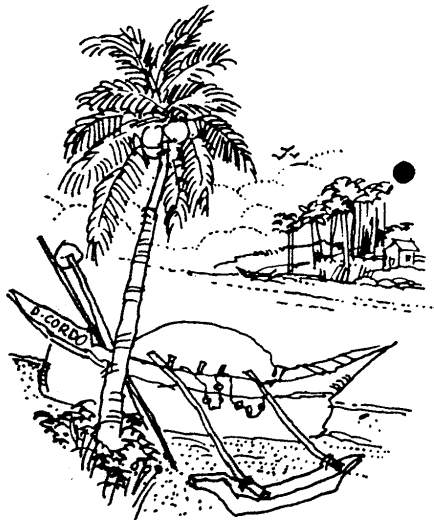
**A Physical description of the Mandovi-Zuari estuarine network** — The Mandovi is widest, approximately 4 km, at the Aguada Bay. The 4 km-long stretch of the Bay is on average marginally deeper than the rest of the estuarine channel, the average depth in the Bay being about 5 m. River Siquerim joins the Bay. The 6 km long stretch upstream of the Bay is on an average 750 m wide



and 5 m deep. The Mapusa river joins the Mandovi at the upstream end of this stretch. Farther upstream, Diwar Island, approximately 11 km long, bifurcates the Mandovi into two channels. Before rejoining at the upstream end of the island, the two channels lead into an extensive network of narrow channels in a marshy area. The Cumbarjua canal joins the Mandovi about 4 km upstream of the Diwar island. The 30 km stretch of the main channel of the Mandovi, from the eastern edge of the Diwar island to Ganjem, gets progressively narrower and shallower in the upstream direction. Rivers Dicholi, Valvat, Kudnem and Khandepar join the Mandovi along this stretch. Khandepar is the largest of the four rivers and is fed by the river Dudhsagar at its upstream end. The locations up to which tidal influence is felt on these rivers are noted in figure. During the dry season, in the main channel of the Mandovi, tidal influence is seen only till a little upstream of Ganjem. Farther upstream the channel bifurcates into the rivers Madei and Ragda. The Mapusa river, which joins the Mandovi at Penha de France, has at its upstream end the rivers Asnoda and Moide. The Mapusa river and its tributaries are joined by a large network of small rivulets, which often flow through marshy areas.

The Zuari estuary is bigger than the Mandovi. The 10 km stretch upstream from the mouth of Zuari is approximately 5 km wide and 5 m deep: It is known as Mormugao Bay. At the upstream end of the Bay the channel narrows to a width less than one km. The 30 km long channel from Cortalim to Sanvordem narrows progressively. It is less than 50 m wide at Sanvordem. The Kushawati river (also known as Paroda) joins the Zuari 4 km downstream at Sanvordem. The 10 km long stretch of the main channel from Sanvordem to Sanguem is also known as the Sanguem River. At Sanguem two rivers, Uguem and Guloli, join to form the Sanguem river. During the dry season, the effect of tides is felt at Sanguem and possibly as far as 4 km upstream in the Uguem river and 1 km in the Guloli. In the Kushavati, the tidal influence appears to be present up to about 8 km upstream of the point where it joins the Zuari. During the wet season, the flow at Sanguem is dominated by river run-off.

S.R. Shetye et al



## MANGROVES: INTRODUCTION

Mangroves (salt-tolerant forests) are a significant component of the Goan bio-region. Due to the topography (the Western Ghats begin a short distance from the coast, the estuarine regions are not very large), the occurrence of mangroves in Goa is not as deep as when compared with the east coast of the country. Nevertheless, Goa's mangroves are fairly extensive, with about 0.5 per cent of the state's area being covered by them. They are to be found mainly along the estuaries.

Goa is drained by seven major rivers, of which the Mandovi and the Zuari—with the Cumbarjua canal—form the largest estuarine complex. A 1982 National Institute of Oceanography (NIO) study reveals that the total area covered by these unique salt-tolerant tree species is to the order of 2000 hectares, of which 700 ha are to be found along the Mandovi, 900 ha. along the Zuari, and 200 ha. along the Cumbarjua canal, with the remainder along the other five major rivers. More precise data is now available in Jagtap's doctoral dissertation on the same subject.

**Mangrove Types** — Mangroves are generally distributed along the West Coast of India, and Goa is no exception. Blasco (1975) in his *Monograph on the Mangroves of India*, does not mention any area under mangroves in Goa. However, Vartak (1973) makes a distinction between 'low' mangroves occurring on soft tidal mud, and 'tree' mangroves distributed in the river deltas and in well protected muddy areas. The former consist of dense and low crooked shrubs of *Avicennia officinalis*, *Ceriops candolleana* and *Sonneratia acida*. With increased interference by man, this formation has been reduced to a low thicket, mainly with *Acanthus ilicifolius*.

The tree mangrove is a closed formation of moderate height consisting of *Rhizophora mucronata*, *Bruguiera conjugata*, *Sonneratia apetala* and *Aegiceras majus*.

Discussing the mangrove swamps of the Mandovi estuary, Dwivedi and others (1975) point out that the Orda swamp situated on the tributary of the Mandovi is subject to weak wave action and tidal currents favouring deposition and decay of litter, enriching the substratum in organic matter. There is low concentration of dissolved oxygen in the habitat. *Avicennia officinalis* which has breathing roots (pneumatophores) for gas exchange is dominant. This species is twice as high at Orda as at Ribandar.

The fringing mangrove at Ribandar is situated along the mainstream of the Mandovi estuary. Wave action and tidal influence are greater and the substratum is hard. These factors favour the growth of *Rhizophora mucronata* and *Sonneratia apetala* as dominant species.

**Fauna of the Mangrove Ecosystem** — Dwivedi et al recognised the following five zones for describing the vertical as well as the horizontal distribution of the fauna of the mangroves of Goa, India.

1. **Littorina Zone:** Extends upwards of Highest High Water of Spring (HHWS) and corresponds with the High Tree Zone of Berry (l.c) and is comparable with the littorinid zone of the rocky intertidal region (Stephenson and Stephenson; 1949). The dominant organism is the periwinkle gastropod *Littorina* spp.