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Vegetation Structure and Species Distribution Pattern of Mangrove Species in Bhitarkanika Ecosystem, Orissa, India

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Abstract: Indian east coast in West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and the Andaman and Nicobar islands supports various types of mangrove formations such as deltaic, estuarine, backwater and sheltered, insular bay types. The present study is an effort to collect ecological information on zonation of mangrove species based on phytosociological methods at four forest sites in Mangrove Ecosystems of Orissa coast. A total of 16 species were recorded at Thakurdia site, 20 tree species at Dangmal site, 24 tree species at the Bhitarkanika forest site and 17 tree species at Kakranasi forest site. The Bhitarkanika site has the highest number of species among all the four study sites. This block along with Dangmal is in the core area of the Bhitarkanika wildlife sanctuary. Availability of fresh water through Bhitarkanika (Maipura) and Brahmani rivers and saline water from sea help wide range of niches for different species to occur and, thus, species diversity is the highest in this mangrove ecosystem. A clear zonation pattern so characteristically reported by authors from different mangrove forests of world is absent in the study area. The mangrove species in study area occur as 'ecological mosaics' scattered over the forest blocks. Such mosaic formations could be linked to the very dynamic nature of the forest blocks in the study area with ecological functions such as tidal inundation, seed/propagule dispersal etc. operating equally throughout the area. *Rhizophora* and *Kandelia* species which are characteristic of the riverbank vegetation were seen deep inside the forest blocks, thus adapting to different type of niches. The riverbank-like niche is provided by innumerable creeks that criss cross the forest blocks and thus favouring these species that grow on the banks. Based on these habitat types a new classification of mangrove forest types of Bhitarkanika forest ecosystem has been proposed through present study.

Key words: Bhitarkanika sanctuary, coastal ecosystem, mangroves, species, zonation.

Introduction

Identifying patterns of species distribution and abundance and determining the mechanisms underlying these patterns continue to be major focus of community ecologists. The halophytic trees and shrubs of tropical coastal forests (typically mangroves) exhibit pronounced zonation of species (Snedaker, 1982). Strong zonation is defined as the ordering of species, or groups of species, at a given location. Certain species are noted to occupy the seaward fringes of swamps, whereas others occur more commonly in the upland reaches, albeit with considerable overlap (Smith, 1992). Such zonation has been attributed to interspecific differences in tolerance of edaphic factors that co-vary with tidal elevation (Ellison et al., 2000), sorting of dispersed propagules during stranding, interspecific competition and frequency dependent preferences of seed predators. Attempts have been made to review the zonation schemes based on frequency of inundation, salinity of the soils, and the

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generic name of the dominant mangrove trees of the Indo west pacific region. Clear pattern of zonation with the constituent species is difficult to find in the forests. Instead, vegetation composition usually shows some overlap between zones. Zonation of mangrove species across gradients such as salinity, tidal inundation etc. has been studied by various authors (Blasco, 1975; Amarasinghe and Balasubramaniam, 1992). Kenneally (1982) observed that frequency of tidal flushing, soil type, soil salinity, drainage, and plant-animal interaction are the major factors that appear to determine the survival of individual species and thus zonation.

Curtis (1933) and Rao et al. (1972) described mangrove communities according to the salinity of the water and salt tolerance of plants. Salinity-based habitat zonation was suggested by Untawale (1984). Quereshi (1957) observed zonation pattern linking with regularity and duration of tidal flooding. Blasco and Aizpuru (1997) opined that any classification system for the mangroves of India should utilize the criteria of physiognomy and structure which could easily be used for vegetation mapping purposes and should reflect the different aspects of degradation and reconstitution following human and animal interferences under given salinity and flooding conditions. Banerjee and Rao (1990) studied distribution in terms of near or away from the riverbanks purely based on visual observations. We carried out the zonation study in Bhitarkanika mangrove sites in four forest blocks. The study aimed at species mapping in the study area by following ecological sampling methods and to explore the pattern of zonation in mangrove species of this area.

Study Site and Methodology

The state of Orissa has a geographical area of 1,55,707 sq. km., with an actual forest cover of 47,107 sq. km. (30.3%) with mangrove forests area of only 195 sq. km. Thus, the percentage of mangrove forests to geographical and actual forest cover is 0.125% and 0.414%, respectively. The Bhitarkanika mangrove forests is located at 20°4′- 20°8′ N latitude and 86°45′- 87°5′ E longitude, in the north-eastern coastal plain of Kendrapara district in Orissa, India. Bhitarkanika is a wildlife sanctuary with 672 sq. km. area out of which mangrove forests constitute approximately 130 sq. km. and remaining areas are water bodies, villages, uninhabited private land and other revenue land. The area is located in the combined interconnected delta of the rivers Mahanadi, Brahmani and Baitarani (Mishra et al., 2005). Located in the estuarine environment created by Brahmani and Baitarani, these mangrove forests are rich in species diversity, and are fairly dense and tall like Sunderbans (Selvam, 2003). The human population of villages within the boundaries of the sanctuary as well as surrounding it has been growing very fast due to heavy influx of outside population. A total of 81 villages surround the mangrove forests and the population increase is attributed as one of the reasons for decreasing mangrove cover (Upadhyay et al., 2002).

Four forest blocks in the Bhitarkanika wildlife sanctuary were selected for carrying out vegetation survey. The total area of Bhitarkanika forest block is 1712 ha, Dangmal 636 ha, Kakranasi 310 ha, and Thakurdia 272 ha (Chadha and Kar, 1999). These sites experience tide of semi-diurnal type. The mean sea level in the region is about 1.66 metres. Because of the influence of the high tidal amplitude in the area, Bhitarkanika is a tide-dominated coastal plain estuary. Due to variation in freshwater flow and tidal water penetration, water salinity within the mangrove wetland varies from 2 to 6 parts per thousand (ppt) during the peak monsoon season, 18 to 30 ppt during winter season and 25 to 32 ppt during summer months (Sarma et al., 1997). The study site experiences a high tidal range with strong bi-directional current, funnel shaped river channels with extensive tidal flats.

Soil and Geology

The soil sediments are divided into two categories, indicating recent or sub-recent forms named as 'newer alluvium' and Pleistocene forms named as 'older alluvium'. The recent sediments are presented by sand, silt, and clay with assorted boulders and pebbles. They are dark and loosely compacted with high moisture content. The Pleistocene deposits comprise clay, sand, silt, and 'kankar', with locally cemented pebbles and gravels. They are reddish brown due to high degree of oxidation (Banerjee and Rao, 1990). The soil parameters at different tidal levels of Bhitarkanika during January 1994 to June 1995 were investigated by Sarma et al. (1997) for Bhitarkanika and Dangmal sites. The organic matter content ranged from 1.886% to 2.076%, sand content from 1.639 to 1.676%, silt from 59.8 to 62.73% and clay from 35-46%.

Phytosociological Analysis

The vegetation sampling was done following Misra (1968), Kershaw (1973), Cintron and Novelli (1984) and Snedaker and Snedaker (1984). Zonation study was performed by laying line transects only. Five line transects were laid in each of the forest blocks, and the total transect length for each line was 500 metres. The lines were drawn perpendicular to the main river line with the help of a prismatic compass to keep the line straight. Distance between the lines was 750 metres to 1 kilometre. The plant species touching the line as well as plants occurring directly beneath the line or nearest plant on either side of the rope were recorded. All the plants including ground flora, shrubs and climbers and trees were recorded. The rope lines were pre-marked at one metre interval so as to enable quick recording.

Climate

The region experiences tropical monsoon climate with well marked winter (October to January), summer (February to May) and rainy (June to September) seasons. The maximum temperature is in summer i.e. months of April and May and the minimum in winter during the month of January. The relative humidity ranges from 70% to 84% across the year. Rainfall is around 16,423.4 mm per annum and maximum rainfall is received between June and October. Wind speed during March to June is over 20 km per hour, and the predominant wind direction is from south and south-west. High wind speed is observed during April to September. The most important weather phenomenon is the prevalence of tropical cyclones. The mean track of the cyclone passes over this region. Tidal amplitude in the Baunsagada River passing through the study area ranges from 1.5 to 2.5 metres in summer months to 3 to 5 metres during monsoon months whereas tidal amplitude reaches 3-4 metres in summer months to 5-6 metres during rainy season in the Bhitarkanika River.

Results and Discussion

The species recorded at various sites are given in Figures 1-4 with predominant locations in Bhitarkanika sanctuary. *A. corniculatum, A. rotundifolia, C. decandra, H. fomes, L. racemosa, P. paludosa,* and *S. caeseolaris* tend to form pure zones in many areas without much of species associations. The total annual average freshwater discharge of the Mahanadi and Brahmani rivers alone is 32,956 m^3/s. In comparison to this, Sunderbans mangroves (Ganges and Brahmaputra rivers) have an annual average discharge of 1,13,776 m^3/s; Godavari mangroves (Godavari river) 29,207 m^3/s; Krishna mangroves (Krishna river) 14,775 m^3/s. Pichavaram and Muthupet mangroves (Cauvery river) have an annual average discharge of 2,641 m^3/s. The Gulf of India, Gulf of Khambat, and the Andaman and Nicobar Islands do not have any major river (Selvam, 2003). The Sunderbans and Orissa mangroves have four dry months in a year whereas the mangroves areas in South and West of India have 6-8 dry months in a year. The Bhitarkanika mangroves receive a substantial amount of freshwater inflow, much higher than southern mangrove areas on east coast. The number of species and biomass is high in the mangrove wetlands which receive more fresh water through river discharge and where rainfall is high and number of dry months is less. These mangroves have a dominance of species that are less saline-tolerant (Blasco, 1975; Selvam, 2003). The Bhitarkanika sanctuary shows high estuarine species diversity.

From the figures showing species zonation for each of the forest blocks, two distribution ranges have been

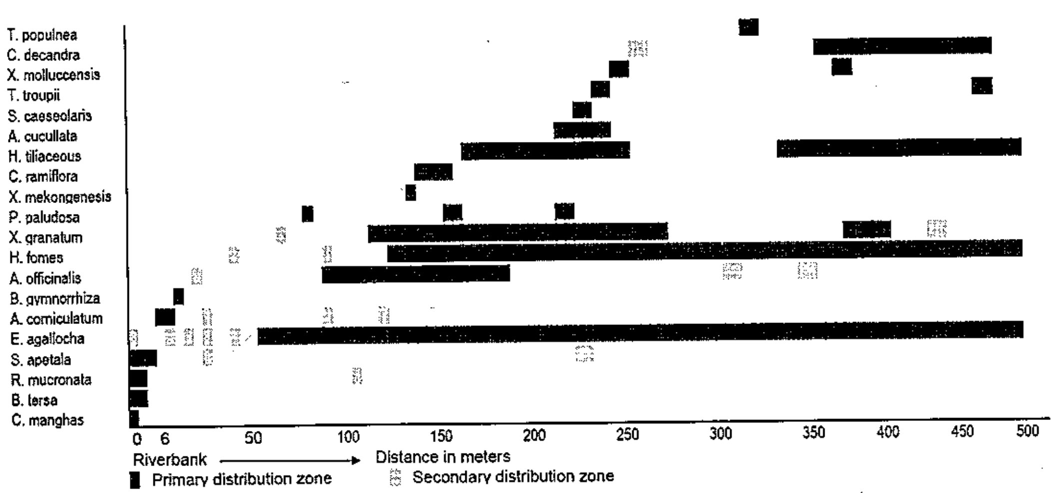

Figure 1: Zonation Diagram of Bhitarkanika.

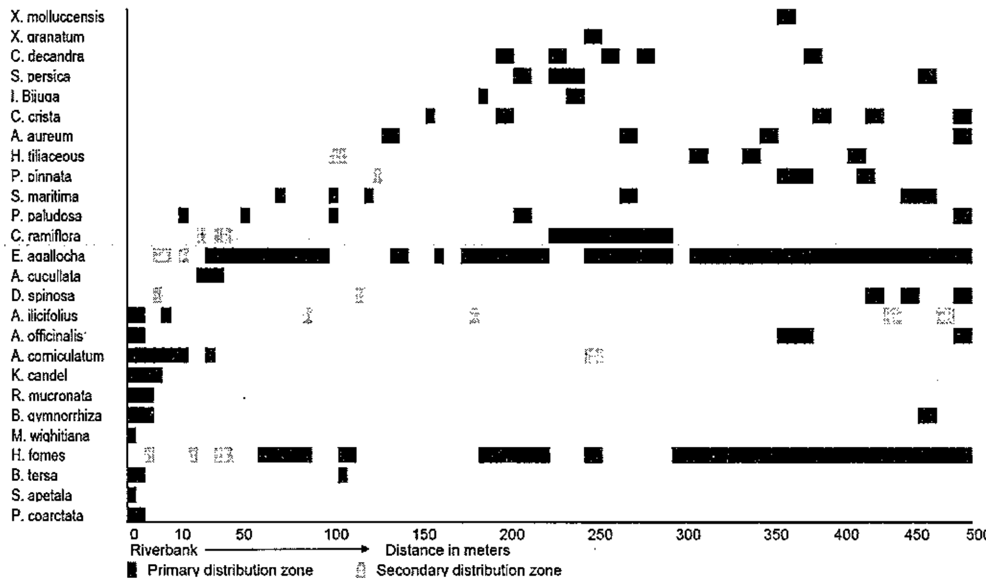

Figure 2: Zonation Diagram of Dangmal.

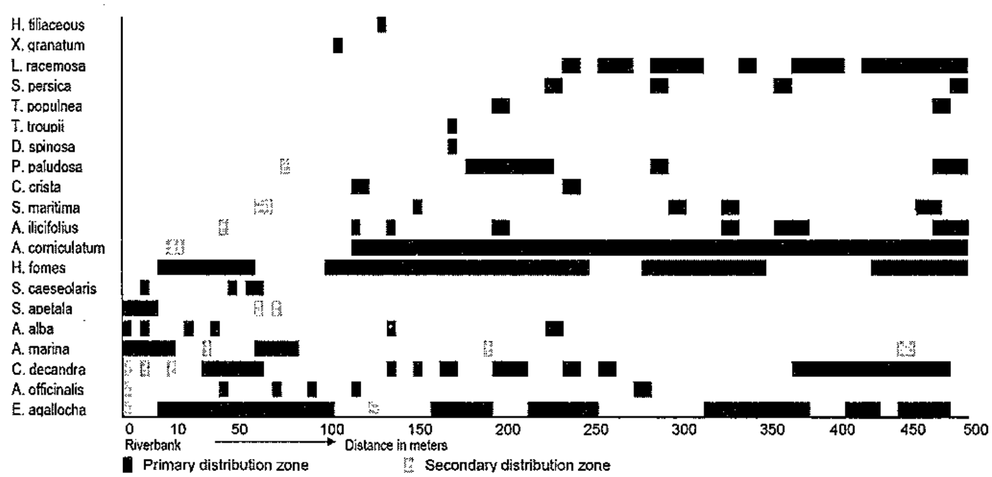

Figure 3: Zonation Diagram of Thakurdia.

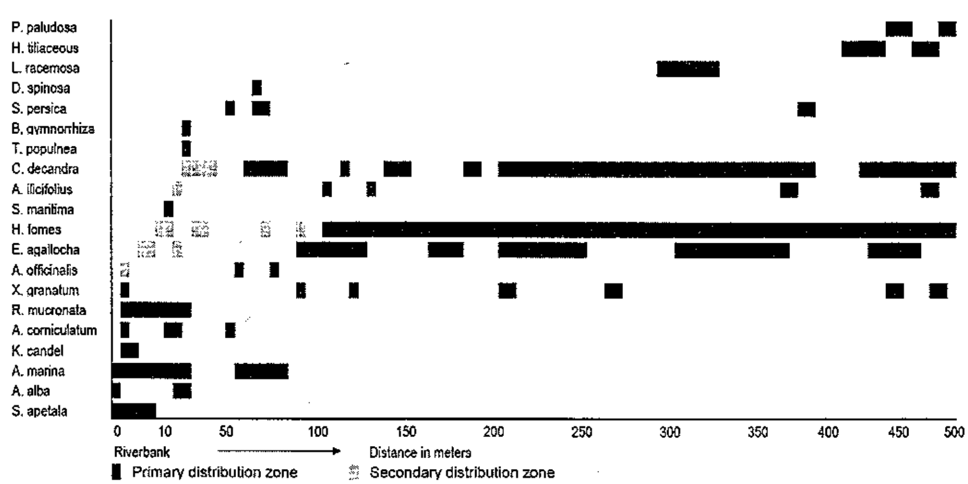

Figure 4: Zonation Diagram of Kakranasi.

identified, the 'primary distribution zone' where it showed maximum presence (in all the transects put together), and the 'secondary distribution zone', where the main range of species occurrence does not take place. Zonation diagram of Dangmal shows that 11 species occur within a distance of 12 metres from the riverbank out of a total 26 species recorded through transect lines. These species are *Porteresia coarctata* (the wild rice variety), *S. apetala, B. tersa, Myriostachya wighitiana, B. gymnorrhiza, R. mucronata, K. candel, A. corniculatum, A. officinalis, Acanthus ilicifolius* and *Phoenix paludosa*. Among the species *E. agallocha* and *H. fomes* exhibited wide occurrence range starting from 20 metres to 500 metres (*E. agallocha),* 60 metres to 500 metres (*H. fomes).* However, the distribution ranges of both the species were not continuous and were fragmented into five or more patches of different lengths. Similar fragmented pattern of distribution was also seen for many other species indicating diverse niches that are small in geographical spread in the forest block. In Bhitarkanika forest block, of the 20 species that were encountered through transects, six species were found distributed up to distance within 12 metres only from the riverbank viz., *C. manghas, B. tersa, R. mucronata. S. apetala, A. corniculatum* and *B. gymnorrhiza*. The highest range of distribution (extent of distribution over a large patch of area) is seen in case of *E. agallocha* and *H. fomes*. *A. officinalis, H. tiliaceous, X. granatum* and *C. decandra* have the next greater range of distribution. Distribution of *A. officinalis* ranges from 80 to 190 m, *X. granatum* from 110 to 280 m, *H. tiliaceous* in two patches from 160 to 250 m and again from 330 to 480 m, and *C. decandra* from 350 to 460 m from the riverbank. A total of 11 species which include *C. manghas, B. tersa, B. gymnorrhiza, X. mekongensis, T. populnea, T. troupii* and *C. ramiflora* etc. had a very limited distribution range.

Species zonation in the Thakurdia forest block was extremely fragmented with most of the species scattered in the forest block. The species encountered in the riverbanks were also distributed widely in other pockets of this forest block, thereby clearly defying any specific affinity to the ecological scopes or niches provided in the riverbanks. *A. corniculatum* exhibited continuous presence from 110 metres till 500 metres. *E. agallocha, C. decandra,* and *H. fomes* with highest IVI values in the block showed wide distribution ranges although in fragmented patches. A total of 20 species were recorded in Kakranasi forest block. Six species occurred within 10 metres from the riverbank viz., *S. apetala, A. alba, A. marina, K. candel, A. corniculatum* and *X. granatum*. *H. fomes, C. decandra* and *E. agallocha* had high occurrence bands, with the presence fragmented in case of *E. agallcoha* and *C. decandra* and continuous in case of *H. fomes*. *Phoenix paludosa* showed limited distribution i.e. at the extreme end of the transects (440-500 metre range). *B. gymnorrhiza, T. populnea, S. apetala, K. candel, X. granatum* and *Suaeda maritima* etc. had narrow distribution in a limited range of 2-10 metre across the entire forest block.

Zonation pattern indicates that *E. agallocha* and *H. fomes* are distributed evenly throughout the forest area in a wide range of niches. *B. tersa, R. mucronata* and *C. manghas* on the other hand have specific distribution range within four metres from the river banks. *Xylocarpus granatum* and *X. molluccensis* primarily colonize the interior midsections of the forest blocks. The clear zonation patterns so characteristically reported by authors from different mangrove forests is absent in the study area. Most of the species occur as 'ecological mosaics' scattered over the forest blocks. Such mosaics may be because of the dynamic nature of the forest blocks in the study area with ecological functions such as tidal inundation, seed/propagule dispersal etc. operating equally throughout the area. We refer the study of Kumaran et al. (2004) in which they explored pneumatophores of *Avicennia* and Palynoflora of *Avecennia, Aegialitu, Excoecaria, Rhizophora* and *Sonneratia* from lignite beds in Konkan in Maharashtra well above 37 m msl. The study indicated that there could have been higher sea level strand during Miocene-Pliocene along west coast of India. Diverse distribution of mangrove species on east coast without a clear zonation with their presence from shore line up to 500 m on hinterland defying all zonation hypotheses could perhaps be explained through such studies.

Quantitative studies carried out on the riverine estuaries in eastern and northern Australia and in Hinchin Brook Island, north eastern Australia by Bunt and Bunt (1999) and Bunt and Stieglitz (1999) also did not show any clear cut zonation of mangrove distribution patterns in any of the sites. Ellison et al. (2000) stated that Sunderbans mangrove forests of Bangladesh did not show any zonation pattern across intertidal area at any scale. There was no pattern of zonation at local (individual transect), landscape (within blocks) or regional (within north south lines) scale in the above area. It was concluded that interspecific competition or propagule dispersal may be more important than edaphic variables in controlling the size and relative abundance of co-occurring species. Because mangrove species vary in their tolerances to underlying edaphic gradients and considerable overlap among species occurs, discrete zones are difficult to identify (Ellison and Farnsworth, 2001). From the present and studies referred above it can be concluded that clear mangrove zonation pattern does not occur in Bhitarkanika.

Observations showed that some peculiar formations occur in the forest blocks. For example, *Rhizophora* and *Kandelia* species which are characteristic of the riverbank vegetation were observed deep inside the forest block. This is not because of the species adapting to a different type of niche, but the niche favourable to the species is provided elsewhere also for initiating colonization and growth. The riverbank-like niche is provided by innumerable creeks that criss cross the forest blocks which favour the species that grow on the banks. In Andaman and Nicobar Islands, *Rhizophora apiculata, R. mucronata* and *R. stylosa* grow as pioneers on coral reefs and exposed rocks and exhibit stunted growth because of lack of soil and soil nutrients (Balachandra, 1988). *P. coarctata, M. wighitiana* (with adventitious root systems), *A. marina, A. alba, B. tersa, S. apetala, R. mucronata* and *K. candel* etc. growing on the riverbanks and showing affinity towards frequent inundation, and loose soil are the early-colonizer and soil binder species.

The overall pattern of vegetation distribution in the present study is similar to the findings reported by Banerjee and Rao (1990). They have divided the habitats as (1) Vegetation of the estuarine banks; and (2) Vegetation that occurs in the inner estuarine banks. Thom (1984) classified mangroves on a regional scale based on three groups of dynamic factors: (i) geophysical—changes in sea-level, climatic conditions and tidal properties of a region, (ii) geomorphic—character of sedimentation, dominance of particular processes—wave or river, tidal or river etc., and (iii) biological factors. Blasco and Aizpuru (2002) described four physiognomic (on the basis of height and number of strata) types of mangrove forests of India: (i) tall dense mangrove forests, (ii) low dense mangrove forests, (iii) low open mangrove forests, and (iv) low discontinuous mangrove thicket. Analysing the vegetation characteristics of Bhitarkanika, it can be said that the study area (all the four blocks) has the second type of mangrove structure. Rainfall conditions also seem to decide the sequence of mangrove distribution in the different zones in the tidal region. During successive tidal floods the salt water inundates the land surface and the subsequent exposure of the soil substratum evaporates the water from these salt-mixed solutions. This results in thick salt crust on the soil surface and these salt crusts inhibit or limit the regeneration and growth of the mangroves. Frequent rainwater flushing helps in washing off the surface and leaching down the salt particles and makes the land suitable for growth of mangroves. A different type of classification is proposed through the present study due to the distinctiveness of vegetation and habitats that were observed in mangroves of Bhitarkanika. These ecological habitats covered in the study can be broadly classified as:

A. The *high sedimentation forest:* Part of the Thakurdia and Kakranasi forest blocks is closer to the Maipura mouth near the beginning of the Baunsagada river. This region has high wave action, high accretion rate and annual average salinity is 27.81 (Sarma et al., 1997). Inundation frequency is twice daily and most parts of the forest are at an elevation equal to or 0.5 metres above MSL.

B. The *sheltered middle mangrove forest:* Larger parts of the Thakurdia and Kakranasi forest blocks do not experience wave action, and salinity values are lower than the earlier zone A. Extensive channels of creeks and sloppy banks (1-3 metre height) are peculiar characteristic of this area. Inundation is regular and reaches out to large parts of the forest block through creeks. Highest elevations (above 4-5 metres from MSL) in these forest blocks get inundated only during high spring tides.

C. The *riverine mangrove forest:* Dangmal and Bhitarkanika forest blocks can be grouped in this category. These blocks have high influence of freshwater inflow from the surrounding rivers. Riverbanks are high and the areas have more erosion than sedimentation except in some parts where the river takes a turn and opposite banks get marginal sedimentation. Extensive channels of creeks are present throughout the region. The annual average salinity is 6.77 (Sarma et al., 1997). Large parts of the forest blocks are inundated daily through the main channel as well as the array of channels and creeks that are present. In Bhitarkanika block, many areas are at an elevation of 10-12 metres above MSL and are thickly vegetated by dry evergreen forests. Areas lower than these get inundated during high spring tides and silt deposition increases the height resulting in further land building.

In high sedimentation forests, *S. apetala*, *A. alba* and, *A. marina* exhibited most gregarious formations on sea front side followed by *A. corniculatum*, forming pure patches in this area. *Rhizophoraceae* members such as *R. mucronata* and *K. candel* are also seen though lacking good growth and well developed stilt roots. Sheltered middle mangrove forests of Thakurdia and Kakranasi have prevalence of full grown individuals of *R. mucronata, A. marina, S. apetala, S. caeseolaris* etc. These are followed by *H. fomes, C. decandra, E. agallocha* and *L. racemosa* all forming pure patches either singly or in association with another one or two species. The blocks also show pockets as well as bands which experience desiccation due to lack of frequent flooding and are habitated by species such as *Suaeda spp, Sesuvium portulacastrum, T. populnea, H. tiliaceous, Dalbergia spinosa, Caesalpinia crista, Salvadora persica* etc. *Phoenix paludosa* occurs in pockets with compact soil and high salinity value especially in 'troughs' that capture tidal water and thus probability of salinity values increasing over a period of time due to evaporation and absence of regular flushing. Riverine mangrove forests are dominated by *P. coarctata* and *M. wighitiana* along with *A. ilicifolius, S. apetala, B. tersa, A. officinalis* etc. forming the river bank vegetation. The areas beyond 12-20 metres from the riverbanks show steep climb with higher elevation. It is the high tidal amplitude that is seen in the surrounding rivers that ensures inundation of large parts of the forest area. Species such as *H. fomes, B. gymnorrhiz, I. Bijuga, C. manghas, Xylocarpus* spp., etc. are seen in this area. The high elevation and drier parts are occupied by *Suaeda* spp., *Thespesia populnea, Hibiscus tiliaceous* etc.

Apart from continuing with several unexplored research fields in mangrove area in India, we need to educate the people on the importance of mangroves. Mosaics and patches of mangroves much beyond high water line are easily accessible to people for cutting. Orissa mangroves are more prone to such pressure. Further, Bhitarkanika mangroves and its importance could be understood from the experience of super cyclone of 1999 as almost all villages around Bhitarkanika sanctuary were spared while over 10,000 people died in other villages on Orissa coast which were not having the shield and protection of mangroves on shoreline (IUCN, 2005). Research, education and awareness, and proper protection and management shall be the only tool to protect large coastal population from disasters like Tsunami and super cyclone which of late have become so frequent and devastating in all parts of the world.

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