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Ecology of Seedlings of Mangroves Species on Estuarine East Coast of India

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ABSTRACT

Mangroves are most productive ecosystems of the world. These ecosystems are subjected to various anthropogenic and climatic disturbances leading to ecological degradation both in quality and quantity. The human population living around the mangrove areas depends on these natural resources for sustaining their livelihood. Bhitarkanika mangroves in Orissa located on east coast of India occupy an area of 2021 sq. km are highly diverse but witnessing decrease in vegetation cover. The influence of tidal waves coupled with anthropogenic pressure does have impact on regeneration potential of these mangrove species of Bhitarkanika. The present study was done to assess the regeneration and seedling establishment in Bhitarkanika sanctuary by collecting data on seedling recruitment for 2 years. The seedling establishment is highest in rainy season (followed by Winter and Summer seasons) due to favorable factors of low salinity and high level of nutrients. Among the species *Excocaria agallocha* produced maximum number of seedling across all three seasons followed by *Hertiera fomes, Sonneratia apetala* and *Avecenia officinalis*. The correlation between number of seedlings and rainfall was highly significant. Old tree species in all stands are extremely limited that may be due to natural events like cyclonic storms.

Key Words: Bhitarkanika; Juveniles; Mangroves; Mature individuals; Regeneration; Population status.

INTRODUCTION

Mangroves are halophytic communities in the estuarine zones consisting of rivers, rivulets and creeks joining the sea front and forming the deltaic islands. The mangroves provide livelihood opportunities to the local population and support agriculture, fishing and prawn cultivation, wood collection and honey and other medicinal and non-timber forest produce activities in India (Datta et al. 2011). Seedling establishment is a critical stage in the life cycle of most angiosperms (Silvertown 1982). Seedling mortality and growth influence directly the spatial distribution and abundance of trees. The advanced developmental stage of viviparous mangrove seedlings which develop while still attached to the mother tree in the *Rhizophoraceae* genera is generally interpreted to be adaptive (Tomlinson 1986) and facilitate rapid establishment through rooting (Hutchings and Saengar 1987). After a period of positive buoyancy, dispersed propagules sink or become stranded, and successful rooting is the first step towards seedling establishment (Hutchings and Saengar 1987; Tomlinson and Cocks 2000). However, establishment may be hindered by tidal current and wave buffeting (Clarke 1995) or lack of shelter from water movement (Clough 1982). Consequently, large proportions (as high as 90 %) of already rooted seedlings may fail to become fully established (Delgado et. al. 1999). Pre-establishment mortality in mangroves during the first year is also considerable. Hutchings and Saengar (1987) reported 22, 36, and 72 % mortality in the first year for *Avicennia sp.*, *Ceriops sp.*, and *Rhizophora stylosa*, respectively. The possible mortality factors include herbivory, drought or salinity stress, insufficient light, damage from drifting objects, strong water movements, erosion of the substratum etc. Clarke and Hannon (1970) discussed the multiplicity of factors affecting mangroves from the stage of propagule to adult. Seedlings require a specific combination of conditions for recruitment to adult population (McKee 1996; McGuinness 1997). Two types of strategies have been discussed as regards to seedling establishment. The first one is ‘planting strategy’- which means when the propagule drops from the parent tree at low water, it can plant itself into the mud - a character especially pronounced in members of Rhizophoraceae. The other strategy is that the propagule falls in the water at high tide and then floats to another site where it settles and develops, and is termed as 'stranding strategy' (Van Speybroeck 1992). It is observed that most mangrove seedlings are light demanding and establish most readily where there are gaps in the forest canopy, i.e. not under parental tree (Tomlinson and Cox 2000).

The mangroves are more prone to tropical cyclones and other climatic disturbance. Thus, assessment of the seedling availability becomes crucial to gauge the health of the ecosystem and understand ecological processes underway. Appropriate management strategies are needed keeping in view the natural disturbances to address the issues of distribution and structure of mangrove ecosystem. Seedlings and saplings may survive the cyclone events (Wunderle 1999) or suffer from large scale mortality. Long-term regeneration studies are needed especially for mangroves of Bhitarkanika which regularly experience cyclones. Assessment of the seedling availability and information about other population parameters therefore becomes essential part of the ecosystem management. The present study was done to study the seedling recruitment for two years (1997-98) for mangrove species of Bhitarkanika Mangrove Sanctuary with an aim to generate ecological record of regeneration potential of species of Bhitarkanika.

STUDY SITE

The study site is located at 20° 4' to 20° 8' N Latitude and 86° 45' to 87° 5' E Longitude on the eastern coast of the state of Orissa, India. The Mangroves in India are spread over an area 4639 sq. km of which only 221sq. km mangrove area lies in Orissa (FSI 2009). Although various assessments indicate an increase in mangrove forests, there is a decline in both quality and quantity of the vegetation cover. Various reasons given for degradation of mangroves in Orissa include shoreline changes, settlements, conversion for agriculture and aqua culture (Upadhyay et al. 2002). Vegetation survey was done in 4 forest blocks of the Bhitarkanika wildlife sanctuary. The total area of Bhitarkanika forest block is 1712 ha. Dangmal is 636 ha., Kakranasi is 310 ha., and Thakurdia is 272 ha. (Chadha and Kar 1999). These sites experience tides of semi diurnal type. The mean sea level in the region is about 1.66 meters. The influence of the high tidal amplitude on the ecology of the area, thus, is significant and may affect the establishment pattern of seedlings of mangrove species in this area.

CLIMATE

The region comes under the tropical monsoon climate with three pronounced seasons: winter (October to January), summer (February to May) and rainy (June to September). The maximum temperature is recorded during April and May and the minimum temperature in January. The relative humidity ranges from 70% to 84% through the year. The predominant wind direction is from south and south-west with wind speed of 20 km hr^{-1} from March to June. Rainfall is around 16423.4 mm per annum and maximum rainfall is received between June to October. Important weather phenomenon in this region is the prevalence of tropical cyclones and the mean track of the cyclone passes over this region (Singh and Panda 1999). Rainfall conditions (1642.34 cm yr^{-1}) decide the sequence of mangrove distribution 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. These 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.

PHYTOSOCIOLOGICAL ANALYSIS

The data on structural parameters of tree and seedling layers were collected by quadrat method for mangrove species of four blocks at Bhitarkanika, Thakurdia, Kakranasi and Dangmal sites located in Bhitarkanika Mangroves forest ecosystem in Orissa. In the above four forest blocks, sampling was done by methods described in Misra (1968). Thirty 1x1 m quadrats were laid out at each site. Each site was divided into 6 segments of 1 km each along tidal line from the riverbank. A line transect was laid towards landward side from the water line. In each segment, six 1x1 m quadrats were laid randomly at 0, 50, 100, 150, 200 and 250 m interval towards the land-ward side for phytosociological analysis. The number of individuals of all species were enumerated and height of trees was measured. Structural parameters like density, abundance and frequency were calculated for the mangrove species in Bhitarkanika. Data wew collected in winter, summer and rainy seasons and the seedlings were inventorized to establish the intensity of biotic factors in size classes of <30 cm, 30-60 cm and 60-90 cm heights at each site for the years 1997 and 1998. Statistical analysis was done to find out the relation between various abiotic parameters and seedling establishment at the study sites.

RESULTS AND DISCUSSION

The Rivers and Mangroves of Bhitarkanika

Several Rivers form a network of water flowing system in and around Bhitarkanika sanctuary. The Bhitarkanika sanctuary is bounded by River Dhamra in the north, Hansua in the west and Bay of Bengal on the east and south. Tidal amplitude in the rivers and creeks in Bhitarkanika such as Khola (which receives tidal water from both ends) ranges from 1.5 to 2.5 m in summer months to 3 to 5 m during monsoon months in the Baunsagada River. The sanctuary encompasses 35 km sea coast known as 'Gahirmatha Coast' from Dhamra mouth to Barunei, the mouth of River Hansua. The area has about 200 km of water body inside the sanctuary. It is located in the deltaic region of the river Brahmani, Baitarani, and their tributaries. The estuarine Rivers-Brahmani, Baitarani, Kharasrota, Dhamra, Pathasala, Maipura, Hansua, and Hansina during their course flow into the Bay of Bengal which are further criss crossed by numerous creeks, channels, and nallahs, thus providing the peculiar ecological niche for the growth and development of rich and varied mangrove life forms, both flora and fauna along with their associates. There are more than 180 villages in and around the sanctuary and the population has been growing very fast. Heavy influx of refugees and settlements due to other reasons has led to clearing of mangrove forests. The population increase is attributed as one of the reasons for decreasing mangrove cover in the area.

Vegetation Ecology

Table 1 provides details of phytosociological parameters of seedlings of the species in forest block of study area. Various Diversity indices are given in Table 2. Seedlings of 24, 21, 24 and 23 species were recorded in Dangmal, Bhitarkanika, Thakurdia and Kakranasi forest blocks respectively. *E. agallocha* had the highest density in all the forest blocks followed by *H. fomes*. *T. populnea H. littoralis*, *S. maritima*, and *X. granatum H. tiliaceous* had the least density in Dangmal forest block. Highest frequency was recorded Dangmal forest block for H. *fomes* followed by *E. agallocha*. *M. wighitiana*, *P. coarctata*, *S. maritima*, and *X. granatum*. All the species exhibited contagious distribution in all the forest blocks except H. *fomes* showing the tendency of random distribution in Dangmal and Bhitarkanika blocks. *X. granatum, S. maritima, P. coarctata, M. wighitiana, H. littoralis, T. populnea*, and *H. tiliaceous* were least frequent species in the Dangmal area.

Shannon Wiener Diversity Index was highest for Thakurdia and lowest for Bhitarkanika forest block. The Concentration of Dominance values were the lowest for Thakurdia and highest for Bhitarkanika. The Evenness Index exhibited a pattern similar to that for the Shannon Wiener Diversity Index. The richness index was highest for Dangmal block and Beta diversity for Kakranasi and Thakurdia blocks (Table 2).

Seasonal Changes in Seedling Recruitment

From the above it is observed that maximum numbers of seedlings are produced in the rainy season followed usually by winter and summer (Table 3). The above pattern was observed across all the four forest blocks for both the years, i.e. 1997 and 1998. Maximum number of seedlings recruitment (across all seasons in both the years) was observed in Bhitarkanika forest block, followed by Thakurdia, Kakranasi and Dangmal blocks. Kathiresan et al. (1996) reported that luxuriant growth of mangrove seedlings takes place towards the monsoon month, because of low salinity and high levels of nutrients during these periods. They found about 5-fold more seedling growth and about 4-fold higher leaf sprouting in monsoon than those of summer months. Luxuriant mangrove forests are bestowed with either high annual direct precipitation and/or high surface water runoff from upland watersheds (Snedaker 1984). In the Bhitarkanika and Dangmal Forest Blocks, *E. agallocha* produced maximum number of seedlings across all the three seasons followed by *H. fomes, S. apetala* and *A. officinalis*. Seedlings of *X. granatum* and *R. mucronata* were absent or minimal in number during summer in Dangmal area and seedlings of *C. decandra* were absent during the rainy season in Bhitarkanika. *E. agallocha, S. apetala, C. decandra* and *A. corniculatum* had maximum number of seedlings during rainy season in the Thakurdia and Kakranasi Forest Blocks. *H. fomes,*

Table 1. Phytosociological parameters of seedlings layer at study sites in Bhitarkanika Sanctuary. (D= Dangmal; B= Bhitarkanika; T= Thakurdia; K= Kakranasi)

Species	Density				Ferquency (F)				Abundance (A)			
	D	**B**	**T**	**K**	**D**	**B**	**T**	**K**	**D**	**B**	**T**	**K**
Excoecaria agallocha L.	2.90	6.83	2.50	2.87	46.67	80.00	16.67	43.33	6.21	8.54	2.00	6.62
Heritiera fomes Buch.-Ham.	2.17	3.33	1.60	1.07	60.00	73.33	30.00	26.67	3.61	4.55	5.33	4.00
Acanthus ilicifolius L.	0.63	0.90	0.87	0.33	16.67	26.67	16.67	10.00	3.80	3.38	5.20	3.33
Phoenix paludosa Roxb.	0.23	0.83	0.50	0.33	13.33	26.67	13.33	16.67	1.75	3.13	3.75	2.00
Brownlowia tersa (L.) Kosterm	0.30	0.53			10.00	16.67			3.00	3.20		
Bruguiera gymnorrhiza (L.) Lamk	0.40			0.10	13.33			3.33	3.00			3.00
Rhizophora mucronata Lamk.	0.23	0.03	0.33	0.37	6.67	10.00	13.33	13.33	3.50	3.00	2.50	2.75
Sonneratia apetala Buch.-Ham	1.17	2.27	1.17	1.07	16.67	30.00	23.33	23.33	7.00	7.56	5.00	4.57
Hibiscus tiliaceus L.	0.03	0.07	*0.73*	*0.07*	3.33	3.33	*20.00*	*3.33*	1.00	2.00	*3.67*	*2.00*
Avicennia officinalis L.	1.03	1.30	0.47		16.67	6.67	10.00		6.20	4.33	4.67	
Dalbergia spinosa Roxb.	0.23	0.67	0.10		10.00	20.00	3.33		2.33	3.33	3.00	
Ceriops decandra (Griff.) Ding Hou	0.27	0.30	1.80	1.77	13.33	10.00	30.00	40.00	2.00	3.00	6.00	4.42
Caesalpinia crista L.	0.13		0.30	0.20	6.67		6.67	10.00	2.00		4.50	2.00
Cyanometra ramiflora L.	0.97	1.13	0.17	0.07	23.33	30.00	3.33	3.33	4.14	3.78	5.00	2.00
Acrostichum aureum L.	0.27				13.33				2.00			
Cerbera manghas L.	0.10	0.10			6.67	10.00			1.50	1.00		
Intsia bijuga (Colebr.) O. Kunt.	0.10				6.67				1.50			
Thespesia populnea (L.) Sol. ex Correa	0.07	0.60	0.10		6.67	23.33	3.33		2.00	2.57	3.00	
Heritiera littoralis Dryand.	0.07	0.03			3.33	3.33			2.00	1.00		
Aegiceras corniculatum (L.) Blanco	0.17		1.17	1.67	10.00		16.67	26.67	1.67		7.00	6.25
Myriostachya wightiana (Nees ex Steud.) Hook.f.	0.20				3.33				6.00			
Porteresia coarctata (Roxb.) Tateoka	0.10		0.13		3.33		3.33		3.00		4.00	
Salicornia maritima Wolff & Jefferies	0.07			0.10	3.33			3.33	2.00			3.00
Xylocarpus granatum Konig	0.70	0.90	0.53	0.13	3.33	26.67	10.00	3.33	2.00	3.38	5.33	4.00
Xylocarpus moluccensis (Lamk.) Roem	0.05					20.00				2.50		
Sonneratia caseolaris (L.) Engl.		0.37		0.30		6.67		6.67		5.50		4.50
Xylocarpus mekongensis Pierre		0.10		0.07		6.67		3.33		1.50		2.00
Kandelia candel (L.) Druce		0.10	0.30	0.07		6.67	13.33	3.33		1.50	3.00	2.00
Rhizophora apiculata Bl.		0.07		0.07		3.33		3.33		2.00		2.00
Salvadora persica L.			0.33	0.33			16.67	16.67			2.00	2.50
Avicennia marina (Forsk.) Vierh.			0.67	0.73			16.67	20.00			4.00	3.67
Lumnitzera racemosa Willd.			0.43	0.47			6.67	6.67			6.50	7.00
Aegialitis rotundifolia Roxb.			0.77	0.67			13.33	10.00			5.75	6.67
Pongamia pinnata (L.) Pierre			0.07				3.33				2.00	
Avicennia alba Blume			0.27	0.20			3.33	3.33			8.00	6.00
Tamarix troupii Hole			0.07				3.33				2.00	

Table 2: Diversity Indices of Seedlings in the study sites

Forest Block	Diversity Index	Concentration of Dominance	Evenness Index	Richness Index	Beta Diversity
Dangmal	1.070	0.123	0.336	3.913	6.660
Bhitarkanika	1.007	0.155	0.330	3.097	3.533
Thakurdia	1.214	0.078	0.381	3.749	6.742
Kakranasi	1.113	0.107	0.354	3.685	6.752

Table 3. Seedling Density in different seasons recorded in all four forest blocks of Bhitarkanika (W= Winter; S= Summer; R=Rainy).

Species	Bhitarkanika			Dangamal			Thakurdia			Kakranasi		
	W	S	R	W	S	R	W	S	R	W	S	R
Excoecaria agallocha	39500	355000	88500	21000	20000	42000	18000	15000	40000	23000	20500	33000
Heritiera fomes	37500	31000	47000	14500	13000	24000	20000	12000	12500	12500	12500	20500
Sonneratia apetala	12000	10000	35500	11000	4500	35000	7000	10000	18500	7500	9500	19500
Xylocarpus granatum	11000	6000	10500	1000	0	2000	8000	2500	9500	0	0	0
Cynometra ramiflora	13500	15000	15000	5000	5500	3000	0	0	0	0	0	0
Rhizophora mucronata	6000	4000	10000	4000	1500	4500	0	0	0	0	0	0
Avicennia officinalis	4500	9000	19500	2000	4500	20000	2500	3500	3000	0	0	0
Phoenix paludosa	6000	5500	6000	3000	4000	1500	6000	4500	3500	4000	2000	4000
Ceriops decandra	3000	3500	0	500	4000	2000	16500	9500	26500	11500	17500	26000
Lumnitzera racemosa	0	0	0	0	0	0	6000	1500	2500	6500	8500	4000
Avicennia marina	0	0	0	0	0	0	13500	6000	13000	6500	7000	10000
Aegiceras corniculatum	0	0	0	0	0	0	11500	11500	21000	10500	11000	14500
Aegialitis rotundifolia	0	0	0	0	0	0	0	0	0	1500	2000	4000

Table 5. Details of recruitment of seedlings in different height classes in the three seasons in Bhitarkanika (W= Winter; S= Summer; R= Rainy).

Site	Season	Height class in cm (1997)			Height class in cm (1998)		
		<30	30-60	60-90	<30	30-60	60-90
Bhitarkanika	R	226	32	49	225	30	6
	W	47	44	70	17	45	83
	S	60	50	61	20	68	41
Dangmal	R	157	18	24	151	13	15
	W	10	53	26	13	48	22
	S	3	27	38	19	32	36
Thakurdia	R	137	19	51	129	29	33
	W	37	45	46	61	46	27
	S	28	52	47	31	33	18
Kakranasi	R	142	22	29	115	16	35
	W	17	45	27	46	53	34
	S	22	37	50	28	46	47

L. racemosa and *A. marina* had the maximum number of their seedlings during winter at Thakurdia site. In Kakranasi Forest Block, *H. fomes, A. marina* also had more seedlings during the rainy season and *A. rotundifolia* had maxmum seedlings during winter. Kakranasi had more seedlings than other forest blocks during summer.

Across all forest blocks, maximum number of seedlings per ha was recorded for *E. agallocha, H. fomes* and *S. apetala* at Dangmal and *S. apetala* and *C. ramiflora* in Bhitarkanika, *C. decandra* and *A. corniculatum* at Takurdia. *C. decandra* at Kakarnasi also produced higher number of seedlings per ha. Lowest seedling recruitment was observed in *S. maritima, K. candel, H. littoralis, T. populnea* and *C. manghas a*t Dangmal, *C. manghas, H. tiliaceous*, and *R. apiculata* at Bhitarkanika, *S. caeseolaris, X. mekongensis, P. pinnata* at Thakurdia and *P. pinnata, D. spinosa, K. candel* and *T. populnea* in Kakarnasi blocks (Table 4).

Table 4. Number of seedlings per hectare in four sites of Bhitarkanika across all seasons.

Species	Bhitarkanika	Dangamal	Thakurdia	Kakranasi
Excoecaria agallocha	54500	27667	24333	25200
Heritiera fomes	38500	17167	14833	15167
Acanthus ilicifolius	9667	4167	5833	3500
Phoenix paludosa	5833	2833	4667	3333
Brownlowia tersa	2667	4333		
Bruguiera gymnorrhiza		3000	1167	1167
Rhizophora mucronata	6667	3333	3833	2000
Sonneratia apetala	19167	16833	11833	12167
Hibiscus tiliaceus	333	1167	5667	3333
Avicennia officinalis	11000	8833	3000	
Dalbergia spinosa	7667	2000	1000	333
Ceriops decandra	2167	2167	17500	18333
Caesalpinia crista		2000	2500	4000
Cyanometra ramiflora	14500	4500		
Acrostichum aureum		5333		
Cerbera manghas	667	333		
Intsia bijuga		500		
Thespesia populnea	5167	333	500	167
Heritiera littoralis	833	333		
Aegiceras corniculatum		3333	14667	12000
Myriostachya wightiana		1000		
Porteresia coarctata		500	667	
Salicornia maritima		333		500
Xylocarpus granatum	9167	1000	6667	3500
Xylocarpus moluccensis	2500			
Sonneratia caseolaris	2167		500	2167
Xylocarpus mekongensis	833		333	667
Kandelia candel	13333	333	2000	333
Rhizophora apiculata	333			833
Salvadora persica		667	1667	3000
Avicennia marina			10833	7833
Lumnitzera racemosa			3333	6333
Aegialitis rotundifolia			5500	7167
Pongamia pinnata		1167	333	333
Avicennia alba			1333	1500
Tamarix troupii		500	333	
TOTAL	195668	115665	144832	135166

The Bhitarkanika forest block produced maximum number of seedlings per hectare followed by Thakurdia, Kakranasi and Dangmal. Although in terms of total number of species encountered during the seedling survey, a reverse order was observed with Dangmal having maximum number of species (28 species) and Bhitarkanika the least (21 species). Table 5 provides details of recruitment of seedlings in different height classes in the three seasons. Seedlings were classified into <30 cm, 30-60 cm, and 61-90 cm height classes for the study years 1997 and 1998. There are sharp differences in the seedling recruitment in winter season between both the years. More seedlings were added in winter season in the year 1998 at Thakurdia, Dangmal and Kakranasi sites, whereas Bhitarkanika site had more recruitment in winter in the year 1997. There was no marked difference in seedling number in both the years for summer season in Kakranasi site. Seedling recruitment was low in summer season of 1997 at Dangmal site. Number of seedlings in height class 25-50 cm declined in 1998 at Bhitarkanika and Thakurdia sites compared to 1997 (Table 5). Correlation coefficient (r) between rainfall (mm) and number of seedlings in the four blocks during 1997 and 1998 indicates a highly significant positive relationship (r^2 = 0.960-0.999, $p < 0.01$).

The Correlation coefficient (r) between Shannon Wiener Diversity and Concentration of Dominance for the four forest blocks exhibited a highly significant inverse relationship (r^2 = -0.765 - -0.856, $p < 0.01$). This indicates that the species diversity tends to decrease with increase in dominance. The correlation coefficient (r) calculated between Shannon Wiener Diversity and Evenness Index across all the forest blocks was significant (r^2 =0.981; $p < 0.01$). However, the relationship of the Shannon Wiener Diversity with the Richness Index as well as with the Density across all the forest blocks was not statistically significant. Similarly, the relationship between the Evenness Index and Richness Index across all the forest blocks was also not significant.

The phytosociological study of the seedling layer indicates that seedling establishment is more in rainy season at all sites. The factors favouring higher number of seedlings in rainy season are presence of low salinity and higher level of nutrients. Kathiresan (2002) also reported that in Pichavaram mangroves seedling growth is five fold in rainy season. Highest number of seedlings observed in the present study for *E. agallocha and C. decandra* at all sites seem to confirm the hypothesis (Blasco and Aizpuru 1997) that successive cyclones are likely to destroy the oldest and largest trees and favour abundant regeneration and rapid seedling development of these highly dynamic species. In all the study sites, very old mangrove stands are extremely limited. Local destruction of mangrove and cyclonic storms may be the predominant factors for the rare occurrence of old trees.

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