

Phenology of mangroves tree species on Orissa coast, India

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Abstract: The aim of this study was to analyze various phenological characteristics of mangroves of Bhitarkanika for developing a data bank which could be of help to forest managers in planning for regeneration of species in the Sanctuary. We collected data on number of days taken by species to flower and to produce mature propagules/seeds. We also recorded all phenophases of each species and maturity characteristic of mangrove seeds in Dangmal and Bhitarkanika forest blocks of the Sanctuary. Storage life of seeds materials for various mangrove species was also tested with the help of mist chamber design. *Excoecaria agallocha* and *Acanthus ilicifolius* take only 2-3 months to produce mature hypocotyls whereas *Rhizophora mucronata*, *Bruguiera gymnorrhiza* and *Xylocarpus granatum* complete these phases between 4 and 6 months. 30 % of seeds of *Rhizophora apiculata* and *Ceriops decandra* germinated after a storage period of up to 45 days showing higher viability than other species. However, fresh seeds of a majority of mangrove species exhibited more than 65-94 % germination. Proper identification of period of collection, maturity characteristics and germination timings will aid in better regeneration of mangroves in Bhitarkanika.

Resumen: El propósito de este estudio fue analizar varias características fenológicas de los manglares de Bhitarkanika para desarrollar un banco de datos que podría ser útil para los manejadores del bosque en la planeación de la regeneración de las especies en el santuario. Obtuvimos datos sobre el número de días que toman las especies para florecer y producir semillas o propágulos maduros. También registramos todas las fenofases de cada especie y las características de la madurez de las semillas del manglar en los bloques de bosque Dangmal y Bhitarkanika del santuario. También se probó la longevidad en almacenamiento de semillas para varias especies de manglar con ayuda de un diseño de una cámara de bruma. *Excoecaria agallocha* y *Acanthus ilicifolius* tomaron sólo entre dos y tres meses para producir hipocótilos maduros, mientras que *Rhizophora mucronata*, *Bruguiera gymnorrhiza* y *Xylocarpus granatum* completaron estas fases entre 4 y 6 meses. 30 % de las semillas de *Rhizophora apiculata* y *Ceriops decandra* germinó después de hasta 45 días de almacenamiento de las semillas, mostrando una viabilidad mayor que la de otras especies. Sin embargo, las semillas frescas de la mayoría de las especies de manglar tuvieron una germinación superior a 65 - 94 %. La identificación adecuada del periodo de recolección, de las características en la madurez y de los tiempos de germinación contribuirán a mejorar la regeneración de los manglares en Bhitarkanika.

Resumo: O objetivo deste estudo foi o de analisar várias características fenológicas nos mangais de Bhitarkanika para o desenvolvimento de um banco de dados que possa servir de ajuda aos gestores no planeamento florestal no que concerne à regeneração das espécies presentes no Santuário. Foram colectados, por espécie, dados sobre o número de dias necessários para a floração e para que produzam propágulos / sementes maduras. Registram-se, também, todas as fenofases de cada espécie e as características de maturidade das sementes de mangal em Dangmal e nos blocos de floresta Bhitarkanika no Santuário. A vida de

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armazenamento dos materiais seminais para as várias espécies de mangal foi também testada com a ajuda de uma câmara de névoa concebida para o efeito. A *Excoecaria agallocha* e a *Acanthus ilicifolius* levaram apenas 2-3 meses para produzir hipocótilos maduros enquanto que a *Rhizophora mucronata*, *Bruguiera gymnorrhiza* e *Xylocarpus granatum* completaram esta fase entre os 4 e 6 meses. Verificou-se que 30 % das sementes de *Rhizophora apiculata* e *Ceriops decandra* germinaram depois de cerca de 45 dias de armazenamento das sementes e mostraram maior viabilidade do que as outras espécies. No entanto, as sementes frescas da maioria das espécies de mangal apresentaram mais de 65-94 % de germinação. A adequada identificação do período de colecta, características de maturidade e tempo de germinação ajudarão a melhor regeneração dos mangais em Bhitarkanika.

Key words: Bhitarkanika, flowering, germination, mangroves, phenology, storage life.

Introduction

The mangroves in India are spread over an area of 4448 square kilometers (FSI 2008). The state of Orissa has only 203 square kilometer mangrove area. Although the overall assessment shows no change in 2005 compared to the year 2003, several areas have shown marked decrease in quality and quantity of the vegetation cover. There is net reduction in the mangrove forest area in Orissa compared to 2001 assessment when the total mangrove area was 219 km². Causes for degradation of mangroves in Orissa are shoreline changes, settlements, conversion for agriculture and aqua culture (Upadhyay *et al.* 2002). District wise assessment indicated that mangrove forests are found only in Baleswar, Bhadrak, Jagat-singhpur and Kendrapara districts of Orissa, out of which Kendrapara alone accounted for about 86 % of total area under mangrove.

Tropical plant communities with their high level of species diversity display phenological events staggered in time and space, which are, governed both by biotic and abiotic factors (Stiles 1978). The plants may either stagger their phenological activity to avoid competition for pollination and disperser agents or may opt for clumping of phenological activity to attract the pollinators and dispersers or to swamp the predators by producing the vulnerable organs in concentrated burst (Schaik 1986). Understanding of such behaviour of the communities is useful in evolving proper management strategy. Information on phenology is useful in predicting the interactions of plants and animals to the changing environment (Bhat & Murali 2001). Description of various phenological events of plants is helpful in understanding of

ecosystem functioning (Janzen 1967). Only a few studies have been carried out on phenological events of mangrove species in different regions of the world (Duke *et al.* 1984; FAO 1994). Some earlier studies on the Orissa mangroves by Banerjee *et al.* (1989) and Banerjee & Rao (1990) gives only limited information on flowering and fruiting periods of different species. This study was carried out to investigate the phenological events, seed viability and seed germination of mangrove trees species in Bhitarkanika Sanctuary.

Material and methods

Study site

The study site is within the Bhitarkanika Sanctuary (Upadhyay & Mishra 2008) and is located between 20° 4' - 20° 8' N and 86° 45' - 87° E. The study area (Fig. 1) falls under tropical monsoon climate with three pronounced seasons, *viz.* winter (October-January), summer (February-May) and rainy (June-September). Maximum temperature is recorded in April-May and minimum in January. The relative humidity ranges from 70 - 84 % throughout the year. Predominant wind direction is from South and South West with higher wind speed during March to June above 20 kilometer per hour. Average annual rainfall is around 1642 cm with maximum rainfall received during June to October. The most important weather phenomenon in this area is prevalence of tropical cyclones. Two blocks, *viz.* Dangmal and Bhitarkanika were selected for studying phenological events of mangrove tree species. The data on structural parameters of tree and seedling layers were collected by quadrat method for two years (1997 and 1998) in Bhitarkanika and Dangmal

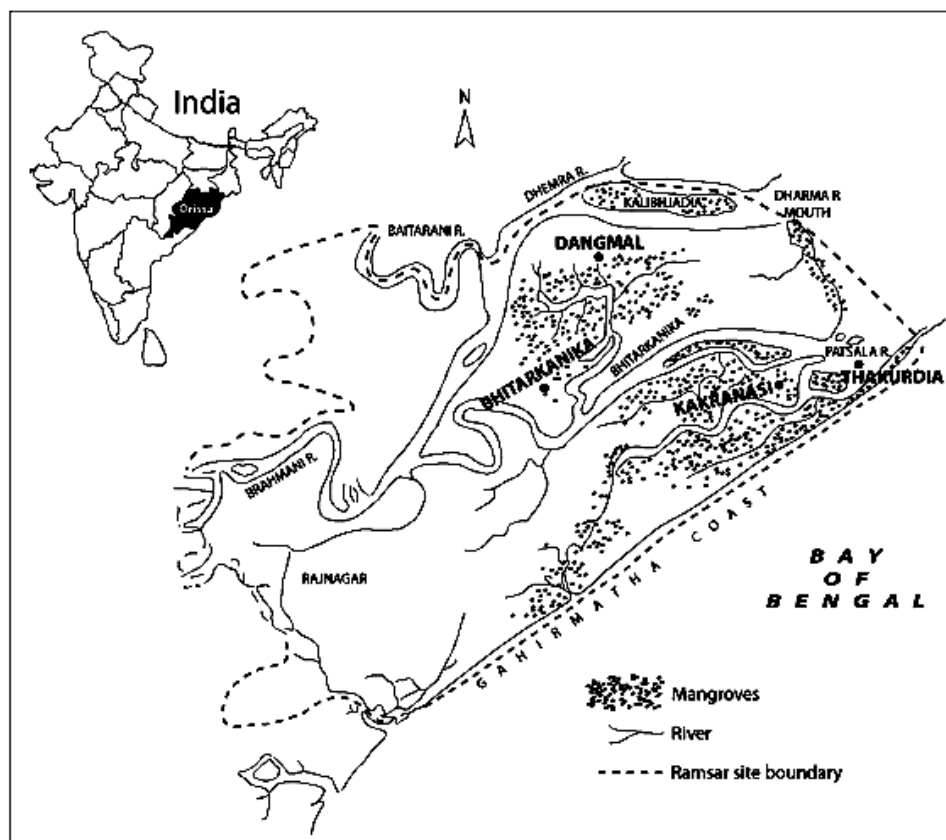


Fig. 1. Location of study sites in Bhitarkanika sanctuary (reported from Upadhyay *et al.* 2008).

blocks located in Bhitarkanika Sanctuary in Orissa. A total of 30 quadrats each 10 m x 10 m in size were sampled randomly covering an area of 3000 m² at each site. Thus, a total of 60 quadrats covering an area of 6,000 m² were studied across two sites. On the basis of data obtained from quadrat samples on the structural parameters, only dominant species, exhibiting higher Importance Value Index (IVI), were selected for phenological study. Data on various phenophases on selected mangrove species were collected through observation of individual trees at an interval of 15 days on these sites during the two years of study. A tree species was considered to be passing through peak of a particular phenophase if three out of five sub-samples (branches) from the tree were found in that particular phenophase.

The freshly fallen seeds were collected from the ground, due care was taken to collect only mature/healthy seeds showing no physical deformity and discarding immature seeds or seeds eaten by crabs, etc.

Seed germination was studied *in situ* under field conditions by using specially designed moist chamber (2.5 m x 3 m) with a covering of blue polythene sheet and an entry door covered with a flap. The door was kept closed except while making observation. A total of 100 seeds of each species were placed in a mist chamber in the field except *Xylocarpus granatum* for which 50 seeds were placed in the field. Water was sprayed on seeds using a pump operated sprayer inside the chamber every day in late afternoon to maintain moisture. Seed germination was observed every day up to 105 days under field conditions.

Results and discussion

The predominant flowering and fruiting months for selected mangrove and associate species in Bhitarkanika and Dangmal forest blocks are given in Table 1. The flowering in mangrove species occurs throughout the year (FAO 1994) with majority of flowering during the rainy season. *Aegicer*

Table 1. Period and duration of flowering of mangrove and associate species in Bhitarkanika Sanctuary.

Species	Family	Commencement of flowering	Duration of seed production (months)
<i>Avicennia alba</i> Bl.	Avicenniaceae	September	
<i>Avicennia marina</i> (Forsk.) Vierh.			3
<i>Acanthus ilicifolius</i> L. Blanco	Acanthaceae	March	1
<i>Aegialitis rotundifolia</i> Roxburgh	Plumbaginaceae	March	2
<i>Sonneratia caeseolaris</i> (L.) Engler	Sonneratiaceae		
<i>Sonneratia apetala</i> Buch-Ham.	Sonneratiaceae		
<i>Aegiceras corniculatum</i> (L.) Blanco	Myrsinaceae	August	3
* <i>Amoora cucullata</i> Roxb.	Meliaceae	August	2
* <i>Brownlowia tersa</i> (L.) Kostorm.	Tiliaceae	May	2
* <i>Thespesia populnea</i> (L.) Soland ex Correa	Malvaceae		
<i>Ceriops decandra</i> (Griff.) Ding Hou	Rhizophoraceae	March	3
<i>Heritiera fomes</i> Buch-Ham.	Sterculiaceae		
<i>Cynometra ramiflora</i> L.	Caesalpiniaceae	April	2
<i>Excoecaria agallocha</i> L.	Euphorbiaceae	July	2
* <i>Hibiscus tiliaceus</i> L.	Malvaceae	February	2
<i>Kandelia candel</i> (L.) Druce	Rhizophoraceae	August	4
<i>Bruguiera gymnorrhiza</i> (L.) Lamk.	Rhizophoraceae		
<i>Phoenix paludosa</i> Roxb.	Arecaceae	April	1
* <i>Pongamia pinnata</i> (L.) Pierre	Papilionaceae	June	3
<i>Rhizophora apiculata</i> BL.	Rhizophoraceae	June	5
<i>Rhizophora mucronata</i> (L.) Lamk.			
* <i>Tamarix troupii</i> Hole	Tamaricaceae	July	1
<i>Lumnitzera racemosa</i> Willd.	Combretaceae		
<i>Xylocarpus granatum</i> Koen	Meliaceae	September	6
<i>Xylocarpus mekongensis</i> Pierre			

* Associate mangroves.

corniculatum, *Aegialitis rotundifolia*, *Ceriops decandra*, *Heritiera fomes*, *Lumnitzera racemosa*, *Phoenix paludosa* and *Sonneratia caeseolaris* tend to form pure zones in many areas and not many other associates are seen in those areas. Flowering duration of the various mangrove species are given in Table 2. Duration of fruiting ranges from 1 - 6 months. The *Xylocarpus* species flowers continuously for a prolonged period and an individual plant was observed in different stages of flowering and fruiting, e.g. flower bud initiation, flowering, fruit initiation, intermediate and mature fruits etc., at one time. While in *L. racemosa*, *Tamarix troupii*, *P. paludosa* and *Acanthus ilicifolius* flowering takes place in unison across stands for a very short period, other species such as *Heritiera fomes* and *Sonneratia* spp. also flowers at a particular period

with small temporal deviation from stand to stand. Species that flower during winter are *H. fomes*, *A. ilicifolius* and *C. decandra*.

There is some information available on phenology of mangrove species (see FAO 1994). According to the report, *Rhizophora mucronata* has the flowering period spanning over winter and summer months. *Bruguiera gymnorrhiza* produces flowers in the summer and rainy periods (FAO 1994). In Costa Rica, *Rhizophora harrisonii* produces mature propagules mainly during June and July. In Sierra Leone, West Africa, the main fruiting season of *Rhizophora racemosa* coincides with the beginning of the rainy season in May - July. Similarly, in Malaysia, fruiting in *Rhizophora* occurs during June to December (FAO 1994). Most species in Myanmar flower and bear fruits several

Table 2. Seasonal variations in flowering duration of mangrove species of Bhitarkanika during 1997 and 1998*.

Species	Days from bud initiation to flower	Days from flower to mature fruit/hypocotyls	Total no. of days for flowering & fruiting	Period of flowering & fruiting
<i>Rhizophora mucronata</i>	54	93	147	5 th Feb - 10 th July
<i>Excoecaria agallocha</i>	13	26	39	5 th June - 25 th July
<i>Sonneratia apetala</i>	25	59	84	10 th Jan - 15 th April
<i>Aegiceras corniculatum</i>	20	50	71	20 th May - 15 th Aug
<i>Xylocarpus granatum</i>	30	84	113	20 th May - 15 th Sep
<i>Heritiera fomes</i>	23	65	88	10 th Dec - 20 th Mar
<i>Avicennia officinalis</i>	27	73	100	20 th May - 30 th Sep
<i>Acanthus ilicifolius</i>	14	34	49	15 th Jan - 25 th Mar
<i>Ceriops decandra</i>	34	69	102	20 th Dec - 15 th Mar
<i>Bruguiera gymnorrhiza</i>	35	70	106	15 th Apr - 20 th Aug

* Values are average of observations on 15 - 25 sample trees and 5 number of sub samples (branches) on each tree.

months earlier in the drier and stressed sites than in moist sites. Flowering and fruiting occur during May to Mid July on the drier sites and during July and mid-August in the lower intertidal zone in *A. corniculatum* (FAO 1994). The mangrove species of Bhitarkanika, viz. *S. apetala*, *H. fomes*, *A. ilicifolius* and *C. decandra* initiate their flowering activities in winter (Dec-Jan) and complete the fruiting stage by March-April. All other species exhibited initiation of flowering in summer (April-May) and completed their fruiting phase in Rainy season (July-September) except for *E. agallocha* and *R. mucronata*. *E. agallocha* took only two months period (June-July) and *R. mucronata* took more than five months (February-July) to complete these two phenophases.

In tropical moist forests, ripening of the fruits takes place in a single peak before monsoon suggesting that survival of seeds and seedlings is critically dependent on moisture availability (Bhat & Murali 2001). However, no such event is seen in mangroves which indicate that rainfall is not the only source of moisture for all the species. Since most of the propagules and seeds of mangroves directly fall into the river systems or marshy ground below, the moisture need may be met from there. Chapman (1976) observed that mangroves do not rely absolutely on rainfall for survival because they can extract fresh water from the sea through salt excreting glands. However, the amount of rainfall influences mangroves in two ways: (1) rainfall determines the rate of weathering and the

amount of silt brought to the mangrove swamps and (2) high rainfall reduces the incidence of hyper salinity.

R. mucronata takes longer time for producing mature hypocotyles followed by *X. granatum* and *A. officinalis*. In the Andamans, *Rhizophora mucronata* takes average 154 days for its floral bud to reach the stage of mature propagule. In the present study, far less time is taken by *E. agallocha*. Total period taken from bud initiation to flower is higher for *R. mucronata* and lowest for *E. agallocha*. These species exhibited the same pattern for total period from flower initiation to formation of mature propagule. *B. gymnorrhiza* takes 35 days for producing full flowers from bud initiation. *R. mucronata* and *X. granatum* took maximum time to complete the flower to mature propagule pheno phase. Lesser time was taken by *E. agallocha* and *A. ilicifolius* to complete this phase.

There are only few studies on mangrove phenological aspects in Goa and Andamans Island in India. There is similarity in the period of flowering in most of the mangrove species of Bhitarkanika and Andaman Islands. Species such as *E. agallocha*, *A. corniculatum*, *X. granatum*, *B. gymnorrhiza* and *A. ilicifolius* take similar time to complete the phases of floral bud to mature hypocotyls in Bhitarkanika as well as in Andamans Island. *A. officinalis* takes 150 days in Goa, 101 days in Bhitarkanika and 93 days in Andamans to produce mature fruits. Details on storage life of

Table 3. Effect of storage period on germination of seed materials of mangrove (and associated species) in Bhitarkanika Sanctuary.

(Day on which maximum germination occurred/percent germination)

Species	Storage period of seed (in days)							
	0	15	30	45	60	75	90	105
<i>Pongamia pinnata</i>	6/65	10/15	8/12	9/7	-			
<i>Kandelia candel</i>	12/71	11/68	13/45	10/21	-			
<i>Bruguiera gymnorrhiza</i>	8/75	6/45	8/31	7/15	8/14	6/5	7/6	-
<i>Avicennia officinalis</i>	5/45	-						
<i>Heritiera fomes</i>	17/80	18/7	-					
<i>Rhizophora apiculata</i>	4/94	7/85	6/60	9/34	12/26	-		
<i>Xylocarpus granatum</i>	19/90	26/46	28/18	-				
<i>Ceriops decandra</i>	7/84	11/76	12/45	15/29	12/7	-		
<i>Excoecaria agallocha</i>	13/24	14/8	-					
<i>Cynometra ramiflora</i>	12/46	14/26	12/12	-				
<i>Acanthus ilicifolius</i>	4/24	5/29	5/3	-				
<i>Aegiceras corniculatum</i>	14/84	17/64	21/15	-				
<i>Aegialitis rotundifolia</i>	8/74	10/60	15/28	-				
<i>Lumnitzera racemosa</i>	8/63	11/42	14/6	-				

(-) No germination observed.

seeds/hypocotyles of different mangrove species are given in Table 3. The seed collection periods may easily be identified for good quality of seed/hypocotyl on the basis of mature seed characteristics which will aid in achieving higher rates of seed germination and survival. The mature hypocotyl of *Rhizophora* species can be identified by prominent maturity zone near collar and distinct root initiation. Mature fruits of *Xylocarpus* species exhibit woody dry look and show cracks near ridges. Mature fruits of *Bruguiera* and *Sonneratia* species are reddish yellow/gray in colour.

The findings of the present work may be useful in restoration initiatives requiring collection of healthy planting materials. Further, seed predation is an important determinant of the structure and composition of mangrove forests as propagules are food for crabs and insects (Smith 1987). Early collection of seeds for regeneration may avoid damage of seeds by animals. The sedimentary macro faunal taxa density has been reported as 4821-6160, 2321-6071, 402-1741, 491-1473 and 44-223 m⁻³, respectively for Polychaeta, Brachiura, Tanaidacea, Gastropoda and Nemertine taxa in Dangmal and 3526-4196, 669-2767, 803-2053 and 133 - 178 m⁻³, respectively in Bhitarkanika for Poly-

chaeta, Brachiura, Tanaidacea and Nemertine Taxa (Sarma 1997). Higher seed viability was observed in case of *Rhizophora apiculata* and *C. decandra* as approximately 30 % of total seeds germinated after 45 days of storage. However, *A. officinalis*, *Heritiera fomes*, *Excoecaria agallocha* lost seed viability within 15 days of storage period. The seeds of *Pongamia pinnata*, *Kandelia candel*, *Bruguiera gymnorrhiza*, *Heritiera fomes*, *Rhizophora apiculata*, *Xylocarpus granatum*, *Ceriops decandra*, *Aegiceras corniculatum*, *Aegialitis rotundifolia* and *Lumnitzera racemosa* exhibited 65 - 94 % germination with no storage period. This indicates that successful regeneration of above mangrove species could be achieved by sowing the fresh matured seeds/hypocotyls.

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