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Review Article

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A REVIEW ABOUT GREEN SHIELD OF ODISHA, BHITARKANIKA

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ABSTRACT

Mangroves are extremely important bio-resources that are crucial to coastal environment. Indian mangrove vegetation covers about 6.756 sq.km along the 7516.6 km long coast line, including island territories. Majority of the mangrove habitats are now threatened by various factors such as reduction in fresh water flow, marine and coastal pollution, siltation, sedimentation and excessive salinity. The present work is focused on assessing the status of mangroves plant with special reference to Bhitarkanika. Periodical floristic surveys are needed to monitor and preserve the rich mangrove plant diversity in India. Effective governance structures, better planning for rehabilitation of degraded mangroves, education and awareness building in local communities are needed for protect and restore the valuable mangrove wetland ecosystem.

Keywords: Mangrove; Wildlife Sanctuary; Succession; Zonation.

INTRODUCTION

Mangrove is a compound word formed by Portuguese “Mangue” and English “Grove”. Mangrove ecosystem is a highly dynamic ecosystem which provide exploring flora and fauna (Roychoudhury, N *et al.,* 2017). Mangrove ecosystem is one of the world’s most species diversified and productive ecosystems. The mangrove habit is the complex of physiological adaptations enabling survival and success (Hogarth 2015). Mangrove act as nutrient sinks and protect offshore ecosystems and natural sea defense (Roy *et al.,* 2019). Mangroves are found in the intertidal regions of river deltas and backwater areas. The mangroves are taxonomically and ecologically unique group of plants colonizing the inter tidal zones along the deltas, shallow lagoons, bays and back waters in tropical and subtropical sheltered belts (Kathiresan and Rajendran, 2005). The total mangrove area in India is 4921 km^2, which comprises about 3.3% of global mangroves (FSI,2019).Mangroves Located in the five Districts of the state of Odisha, such as Baleswar (2sq km), Bhadrak (21sq km), Jagasinghpur (7sq km), Kendrapara (183sq km) (Anon *et al.,* 2013). The mangrove swamps of Odishaspread over 130sq km area and harbours many rare and interesting species (Pattnaik *et al.,* 2011). Mangrove forest of Bhitarkanika National Park is a diverse one and is typical of the Sunderbans (Barik and Chowdhury 2014). Bhitarkanika wildlife sanctuary is located in Kendrapara district of coastal state of Odisha along the East coast of India. It is situated between 20^{0}4’- 20^{0}8’ N latitude and 86^{0}45’- 87^{0}5’E longitude. It is surrounded by the Bay of Bengal on the East, the villages of Kendrapara district on the West, Baitarani and the Dhamra rivers on the North and the Mahanadi estuary on the South. The average annual rainfall is about 1,642mm and maximum rainfall is received between in the month of June to October. The climate is tropical warm and humid. The maximum temperature recorded is 41^{0}C and the minimum is 9^{0}C in the month of May and January, respectively. Mean relative humidity ranges from 70-80% throughout the year.

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METHODOLOGY

We conducted a systematic literature search was restricted between January 2000 to December 2025 to encompass both early restoration studies and recent advance in conservation. Reference list of relevant articles were also screened to identify additional sources. The review process followed the preferred reporting items for systematic review. Information collected from the local people who depend mostly on mangrove forest for day to day needs. Socio- economic data collected from different villages located around the Bhitarkanika Wild life Sanctuary. Mostly data collected from thesis (Pattnaik S, 2012).

ECOLOGICAL ADAPTATION

Mangrove exhibit a variety of adaptation in morphology, anatomy and physiology to survive in a hostile environment which is marked with water logged soils and high salinity regime frequented by storm and tidal surge (Roychoudhury *et al.,* 2015). The mangroves are specialized plants which can tolerate salinity. Their adaptation to salinity condition becomes possible due to their resistance to concentration of salt and secretion of salts from their leaves. Mangroves vary both in their salinity tolerance and the degree to which salinity may be necessary to maintain their growth (Ellison and Farnsworth, 2001). Adaptation to salt tolerance is of three types that is salt excluders, salt secretors and salt accumulators (Ong and Gong, 2013). The salt excluders are from the members of the genera like Rhizophora, Bruguiera and Ceriops of the family Rhizophoraceae. The species in the genera Acanthus, Aegialitis, Aegiceras and Avicennia have salt- secreting glands on the leaf surface. The species like Sonneratia, Xylocarpus and Excoecaria are the salt accumulators (Ong and Gong, 2013). The mangrove plants in the forests are adapted to harsh environments like marshy anoxic anaerobic soil and fluctuating salinity of the water bodies by developing several morphological and anatomical features (Nandy *et al.,* 2007). Seeds of some mangrove species germinate on the trees before they are disseminated. They produce a spear like hypocotyls which when dislodged, get embedded into mud and develop anchoring roots. Various types of root adaptations of mangroves in the habitat are lenticels (Bruguieraspp), Pneumatophores root, inverted wedge like projections on the ground from the underground (Sonneratia spp.and Avicennia spp.) knee roots (Bruguieraspp), cable roots (Avicenniaspp), and stilt roots, which are aerial and act as anchoring structure to withstand wave action (Rhizophoraspp) (Ong and Gong, 2013). Many mangroves have stilt roots, the plants breathe in oxygen through the pores of pneumatophores during prolonged time of submergence of the root system. Mangroves synthesize osmotically active metabolites, specific salt inducible proteins and regulate water fluxes and support scavenging oxygen radicals to avoid this adverse condition (Jithesh *et al.,* 2006). Their habitat continued to disappear globally at a rate 0.66% per year during the period 2000-2005 (FAO, 2007). Mangrove forest coastal ecosystems provides several beneficial functions, both to terrestrial and marine resources (Barbier *et al.,* 2016). Due to their valuable contribution in biomass, carbon sinks as well as a numerous other benefits for biodiversity of mangrove forests ecosystem are considered as a valuable ecological and economical resources worldwide (Himes-Cornell *et al.,* 2018). Forest soil reserves much higher organic carbon including varying proportion of active organic carbon fractions and stable organic matter, referred to as humus in comparison to agriculture and other land use (Mandal *et al.,* 2014). Mangrove forests contain significant amount of carbon stocks and are one of the sources of carbon emissions (Houghton *et al.,* 2009). Mangrove forests rank among the world's most carbon-dense ecosystems, 85% of which is stored belowground (Kauffman et al., 2020). Soil characteristics depend on forest types rather directly affected through forest biodiversity (Myo, K. k. *et al.,* 2016). The plant composition may alter the soil physical and chemical properties, which in turn disturbs land efficiency (Sing, B *et al.,* 2011). The soil texture variations are ranging from sandy loam to clay loam. The regenerating capacities of frequent growing species and water lodging make somewhat the soil acidic (Mishra *et al.,* 2017). Mangroves of bhitarkanika is the second largest viable mangrove ecosystem in India after Sundarbans. Adequate protection has been given to its rich floral and faunal diversity by declaring it as a Wildlife Sanctuary in the Year 1975. Out of the total Sanctuary area of 672sq kms, the core area comprising of 145sq kms was notified as a National Park in 1998 (Thatoi, 2004). In India, Mangrove extends over 4992km^2 of which Odisha hosts 259.1 km^2 as of 2023 (FSI, 2023). Ecological monitoring in bhitarkanika National Park, confirms that mixed species belts, especially *Avicennia marina* + *Rhizophoramucronata*, achieve the greatest surge attenuation owing to their complex root-canopy structure (CIFOR-ICRAF, 2025). *Heritierafomes* is a dominant species in the mangroves of Bhitarkanika indicating suitable habitat conditions for growth of the species. *Bruguieraparviflora* and *Bruguieragymnorrhiza* are representatives of non-secretor true tree mangroves with widespread large-leaf which are known to own differential limits for salt tolerance (Sevam *et al.,* 2002).

FLORISTIC STUDY

Mangroves are well-known diversified vegetation ranging from large trees to small shrubs with highly specialized morphological and physiological adaptations to thrive in flooded and saline habitats (Panda *et al.,* 2017). The mangroves thrive in such environment where normal flora cannot exist due to their highly specialized morphological and physiological adaptation (Hogarth, 2015). The main reason for changes in species composition is reduction due to quantity of fresh water reaching at the mangrove environment (Selvam, V 2003). The presence and luxuriant growth of salt-marsh succulent species such as Suaeda spp. are indicative of an increase in salinity at mangrove site (Kathiresa, K 2000). Indian mangroves showed 46 true mangroves which consists of 42 species and 4 natural hybrids (Ragavan *et al.,* 2016). Based on the classification of mangroves given by (Ghosh *et al.,* 2003), there is 30 species of mangrove associates, 30 species of back mangroves and six species of beach flora (Anon 2015). The trees occurring in mangroves forests of Orissa are of low height having less basal area but higher number of species occur in this area compared to the mangroves of Mexico and Costa Rica (Mishra *et al.,* 2005). In a phytosociological study of mangrove ecosystem of Orissa 16 species from 11 families at Thakurdia site, 20 tree species belonged to 14 families at Dangmala, 24 tree species of 13 families at Bhitarkanika and 17 from 10 families at Kakranasi forest sites were recorded (Mishra *et al.,* 2005). Odisha mangroves cover has increased by 1.0%, represrnting a net gain of 2.55 km^2 and bringing the total area to 259.06 km^2 (FSI, 2023). Bhitarkanika has richest diversity of mangroves in India (Nayak, 2004). The number of mangrove species of Bhitarkanika is varied in opinions and thought to be about 62-67 (Nayak and Bahuguna, 2001), 51 (Pattnaik *et al.,* 2008), 57 (Mandal and Naskar, 2008), 64(Hussain and Badola, 2010). During general floristic study about Bhitarkanika, 168 angiosperm plant species under 131 genera belonging to 66 families have been collected, identified and preserved as herbarium specimens (Pattnaik, *et al.,* 2010). Out of 168angiosperm species, 24 species belong to monocots and rest 144 belongs dicots, 25 plants are classified as true mangroves, 19 species are mangrove associates and 18 mangroves as back mangroves (Pattnaik *et al.,* 2010). The number of true mangrove species of Bhitarkanika National Park is also varies 28 (Hussain and Badola, 2010), 35 (Raghvan *et al.,* 2016). In Bhitarkanika many species having extremely narrow range of distribution having rare and endangered like *Mucunagiganteana, Xylocarpusgranatum, Aglaiacucullata, Merope angulate, Heritierafomes,* and *Cerberaodollam* (Pattnaik, S 2012). *Strychnosnux-vomica* in Kanika Range of Bhitarkanika National Park have documented by (Roychoudhury *et al.,* 2017). In Bhitarkanika, the Mahanadi delta, and Devi estuary, replanting has driven partial returns of key taxa *(Heritierafomes, sonneratiaapetala, Rhizophoramucronata),* enhancing canopy structure and nesting sites (Shyamal, 2023). The study of species diversity in Bhitarkanika has shown varied results species diversity was 0.72, 0.82, 0.75, 0.73 respectively, in Dangmal, Bhitarkanika, Thakurdia and Kakranasi blocks (Mishra *et al.,* 2005). The tree species diversity was highest at (Bhitarkanika) i.e. is 1.24 and least at (Kalibhanjadia) i.e. is 0.99. Whereas concentration of dominance was highest at (Dangmal) i.e. is 0.12 and least at (Gupti) i.e. is 0.08, (Pattnaik S 2012). *Heritierafomes*occupied the highest density at Khola (8.0) followed by Dangmal (7.9) and Bhitarkanika (7.5) as compared to Habalikhati (5.8) and Thakurdia (4.0) (Dash *et al.,* 2007). *Excoeccaiaagallocha* showed higher density values at Gupti (175 plants/ha), Khola (195 plants/ha), Dangamal (475 plants/ha) and Bhitarkanika (260plants/ha) where as *Sonneratiaapetala* showed highest density value at Kalibhanjadia (55 plants/ha) (Pattnaik S 2012). Frequency analysis of the species revealed that *Heritierafomes* represents the highest frequency of 90% at Khola, Dangmal and Bhitarkanika whereas it was 60% at Habalikhati and Thakurdia (Dash *et al.,* 2007). The frequency values of trees were high for *Excoecariaagallocha* at Gupti (35 plants/ha), Khola (25 plants/ha), Dangmal (50 plants/ha), Bhitarkanika (25 plants/ha) and *Sonneratiaapetala* at Kalibhanjadia (20 plants/ha) (Sanjay *et al.,* 2011). The abundance distribution of the tree layers of the mangroves, Excoecariaagallocha dominant at Gupti (5.00), at Khola (7.80), at Dangmal (9.50). at Bhitarkanika(10.40), but at Kalibhanjadia*Sonneratiaapetala* dominant (2.75). The importance Value Index of tree species highest at Bhitarkanika (51.48) as compared to other sites Gupti and Khola. Whereas *Sonneratiaapetala* showed highest value at site-Dangmal (77.87) and *Ceriopsdecandra* at site Kalibhanjadia (49.27) respectively (PattnaikS 2012).

PHYSICO CHEMICAL PARAMETERSTUDY

India covers 4921 sq.km (0.15%) of its total land area with mangroves, accounting for 3% of the world's total and 8% of Asia (FSI 2017). The physicochemical parameters of water such as pH, EC, differed significantly in estuarine, mangrove and bay sectors (Chauhan & Ramanathan, 2008). The lower value of pH was quite low during monsoon period, which may be due to the influence of freshwater influx and decomposition of organic matter carried out by the flood water into the riverine system (Raju *et al.,* 2000). The high conductivity in the month of November may be due to high organic residue in the water body. The analysis of various physic-chemical parameters of pond, tube well, nala and river water were studied. The pH values of Nala water of four sites namely, Dangmal, Bhitarkanika, Khola, Gupti and Dhamara river (Near Kalibhanjadia) ranged between 6.5 least at Dangmal to heights 7.6 at Khola. The ph values of pond and tube well water at Dangamal were highest i.e. 8.34 and 8.27 respectively (Pattnaik., S 2012). The electrical conductivity high variation in water samples collected from different sites which shows least at Khola (1.09Ms/cm) and highest (9.91Ms/cm). Calcium – Magnesium content was highest as (18.68 meq/L) in Kalibhanjadia pond (14.02 meq/L) at Dangmal tube well water and (37.66 meq/L) at Bhitarkanikanala water. On the other hand, less amount of Calcium – Magnesium was found in all the water (pond 8.22 meq/L), tube well (3.36 meq/L), Nala water (4.0 meq/L)) samples of khola. The nitrate – nitrogen content was highest in pond water of Gupti (2.18 mg/L) and lowest in tube well water of khola (0.68 mg/L). Similarly phosphorous content was at its peak in pond water of Bhitarkanika (2.84 mg/L) and declined level in tube well water of Kalibhanjadia (0.51 mg/l) as observed (Pattnaik S 2012). Among all the water samples studied at different sites, sodium content was highest in nala water of Dangamal (70.0 meq/L) and significantly low in tubewell water of Gupti i.e. (6.11 meq/L). The sodium Absorption Ratio (SAR) was highest in nala water of Dangamal (27.95 Na meq/L) and lowest in tube well water of Gupti (3.47 Na meq/L). The pH values of soil samples of five different study sites (Gupti, Khola, Dangmal, Bhitarkanika and Kalibhanjadia) were slightly acidic ranging between 6.11 at Khola to 6.60 at Kalibhanjadia and the conductivity values varied from 1.05 mS/cm at Gupti to 2.14 at Khola. The availability of both phosphorous and nitrate-nitrogen were high in Bhitarkanika (79.01kg/ha), (6.62 kg/ha). However, significantly less amount of phosphorous and nitrate – nitrogen was found Gupti (10.79 kg/ha) and Kalibhanadia (3.58 kg/ha) respectively. Potassium contents was high in Kalibhanjadia soil (126.05 mg/kg dry soil) whereas it was minimum in Dangmal (80.21 mg/kg dry soil) (Pattnaik S 2012). The organic carbon content was reported moderately high and varied from site to site. Maxium values of organic carbon were observed in Khola (0.21 mg/gm dry soil) and minimum in Kalibhanjadia (0.09 mg/gm dry soil).The total exchangeable acidity content of the soil at different sites was moderate and varied from 0.31 meq/100gms to 0.37 meq/100gms. The water holding capacity was high varying from 200% in Dangamal to 90% in Bhitarkanika. It was observed to be high in khola (118.49%) and least at Dangmal(18.06%) (Pattnaik S 2012).

SOCIO-ECONOMIC STUDIES

Mangrove forests are extremely important coastal resources, which are vital to our socio-economic development. A vast majority of human population lives in coastal area, and most communities depend on local resources for their livelihood. The mangroves are sources of highly valued commercial products and fishery resources and also sites for developing a burgeoning eco-tourism (Kathiresan and Bingham 2001). The mangrove and associated forests help meet subsistence requirements for timber, fuel wood, tannin, honey, fodder and thatch and provide livelihood opportunities for local people (Badola and Hussain 2003). Over 60% of Bhitarkanika households rely on restored mangroves for fuel wood, honey, and fish, while flood buffering and nutrient cycling secure downstream water quality (Srikanthan *et al.,* 2024). Indigenous medicines are prepared from *Bruguieragymnorrhiza* (for control diarrhea and blood pressure), *RhizophoraMucronata* (angina), *Acanthus illicifolius* for asthma, rheumatism, *Lumnitzeraracemosa* for herpes and itches, *Cynometraramiflora* and *Excoecariaagallocha* for Leprosy. Further, these plants are also used to treat various other disorders like headache, abdominal troubles and skin diseases etc. (Upadhaya 2002).

THRATS

The major threats is the conversion of mangrove forests in other land use types and categories, such as aquaculture, coastal development, construction of channels, agriculture, urbanization, coastal landfills, and deterioration due to indirect effects of pollution (Alongi., 2002). The impact of natural threats on mangroves forest which includes sea level rise, tropical storm, insects, lighting, and tsunami affected (Giri *et al.,* 2008). Reduced mangroves area and health will increase the threat to human safety and shoreline development from coastal hazards such as erosion, flooding, storm waves and surges, and tsunami (Chaudhury *et al.,* 2015). Elevated levels of pollutants (industrial and residential waste) can harm mangrove vegetation and negatively impact the health and existence of various plants and animals, including fish and other marine species (Banerjee *et al.,* 2019). According to the Government of India report published in 1987, India lost 40% of its mangrove area during the last century. Mangroves have not received proper attention and there is an overall decline in quality and quantity of mangrove cover in Orissa mainly due to shoreline changes, settlements, sediment load and conversion for agriculture and aquaculture (Upadhyay *et al.,* 2002). Habitat destruction one of the primary problems faced by the Bhitarkanika mangrove forest is deforestation due to various human activities, illegal logging, for agriculture and aquaculture, and infrastructure development leading to a loss of biodiversity and degradation of the ecosystem (Oppelt*etal.,*2013). The species like C.iripaKostel, I.bijuba (Colebr), Dolicandronspathecia (L.F) K.Schum., A.volubilis Wall., A. ebracteatusVahl.etc. are endemic to Bhitarkanika National Park and only found in some part of Sundarbans and Andaman Mangoveecosystem (Raghvan *et al.,* 2014). The mangrove plant, N.fruticans, was extinct from Bhitarkanika National Park but it has been reintroduced to the site from Sundarban to maintain the diversity of the ecosystem (Panda *et al.,* 2013). In Bhitarkanika and the Mahanadi Delta, shrimp aquaculture, port expansion, and agricultural encroachment drive mangrove loss, (Dhyani *et al.,* 2023). Climate change that represent a danger to the Bhitarkanika mangrove forests are the rising sea levels and upsurge in the occurrence of extreme weather phenomena (Kandasamy *et al.,* 2017). Limited awareness about the importance of mangroves and sustainable resource management practices among the local communities can contribute to the problems faced by the Bhitarkanika mangrove forest (Badola *et al.,*2012).

CONSERVATION

Mangrove conservation, such as eco-tourism, can help reduce dependency on destructive activities (Rajak *et al.,* 2023). The mangroves play a significant role in protecting the hinterland against cyclones and the ingress of seawater during tidal surge. Mangroves stabilize coastal landmass against sea erosion. Mangroves forests act a buffer against any natural disaster. In accordance with the Ramsar Convention, the Bhitarkanika mangrove is also nominated as a Ramsar Site, a globally recognized wetland. This designation is based on the significance of the Bhitarkanika mangroves as a habitat for migratory birds and the conservation of biodiversity (Ramsar Conservation 2002). Some key strategies that can help to preserve and restore these critical resources. Enforce and strengthen existing laws and regulation on mangrove protection and conservation (Rajak *et al.,* 2023). Manage protected areas within the Bhitarkanika mangrove forests, such as wildlife sanctuary (Rajak *et al.,* 2023). Implement mangrove restoration programs to rehabilitate degraded areas within the Bhitarkanika mangrove forest. (Kathiresan, 2018). Engage local communities in conservation efforts and promote their active participation in sustainable resource management practices (Kathiresan, 2018). The Mangrove forest of Bhitarkanika National Park is under severe biotic and natural pressure. This is largely due to reclamation of the mangrove forests for paddy cultivation, prawn culture, forest clearing for human settlement and cover exploitation of economically important mangrove taxa to meet the ever increasing human needs. Thus, it is high time to conserve the existing mangrove forests and take up large scale vegetation programmes for long term survival of the special and unique ecosystem. Though late, still there is time to set priority for conservation and protection of the existing mangrove ecosystem, which have profound ecological and economic importance for state of Odisha in particular and the country in general.

CONCLUSION

Mangrove ecosystems are threatened globally due to various anthropogenic activities and global climate change. Damage to mangroves affects the sediment budget and promotes the coastal erosion. Moreover, the ecological and socioeconomic values offered by the mangroves are innumerable, immeasurable and incomparable. So conserving the mangroves should be a priority in any nation's conservation programs. Thus, the comprehensive information on diversity in Bhitarkanika Mangroves provided here will help in the long term monitoring the mangrove species and formulating species specific conservation strategies.

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