RESEARCH ARTICLE

DIVERSITY OF TRUE AND MANGROVE ASSOCIATES OF BHITARKANIKA NATIONAL PARK (ODISHA), INDIA.

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Manuscript Info

Abstract

In the present study, an attempt has been made to distinguish and separated the true mangroves from mangrove associates. The characteristics chosen for true mangrove identification were presence of aerial roots, viviparous or crypto-viviparous embryo development, tidal dispersal of propagules, ability to form pure stands, absence of understory, highly efficient mechanisms for nutrient retention and physiological mechanisms to tolerate salt. The present investigation which was carried out between the periods from September 2014 to July 2016 had recorded a total 29 true mangrove species and 72 associate species from various regions of Bhitarkanika National Park. The recorded true mangroves belong to 11 families and 15 genera and the associates recorded from 39 family and 56 genera. Among the studied true mangrove families, Rhizophoraceae showed maximum richness both at species and generic level with 10 true mangrove species. The present study will solve the confusion about actual number of true mangrove species of Bhitarkanika Wildlife Sanctuary & Mangrove National Park (Odisha), India and will help for conservation of the endemic and diverse flora of this internationally important mangrove wetland.

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Introduction:

Mangroves are diverse group of trees and shrubs that flourish in flooded and saline habitats (Hogarth, 2015) and share a common ability to live in waterlogged saline soils subjected to regular tidal flooding (Kathiresan and Bingham, 2001). The mangrove habit is the complex of physiological adaptations enabling survival and success. The mangroves thrive in such environment where normal flora can’t exist due to their highly specialized morphological and physiological adaptations; most striking adaptations are various forms of aerial root (Hogarth, 2015). Mangroves act as nutrient sinks and protect offshore ecosystems and often referred to as bio-shields or natural sea defense (Roy et al., 2009). Mangroves are quite old, possibly arising just after the first angiosperms, around 114 million years ago (Duke, 1992). The mangrove ecosystems are widely recognized as providers of a wide variety of goods and services to people, including storm abatement, sediment trapping, land accretion, nutrient uptake & transformation and provision of a variety of plant and animal products (Badola and Hussain, 2003).

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However, across the globe, the world’s mangroves are threatened (Arunprasth and Gomarhinayagam, 2014; Rao et al., 2015). The continued decline of the mangrove forests is due to conversion to agriculture, aquaculture, tourism, urban development and overexploitation (Alongi, 2002; Giri et al., 2008; Latiff, 2012). Reduced mangrove 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 (Danielsen et al., 2005; Chaudhuri et al, 2015).

Along the Orissa coast, mangroves are present on the Mahanadi delta & Brahmani- Baitarani delta between 86° 48' - 86° 58' E longitude and 20° 30' - 20° 50' N latitude (Nayak and Bahuguna, 2001). The mangrove area in Odisha is nearly 200 sq.km in extent and its degradation was placed at 20 sq.km over ten years, as percent estimates (Arunprasth and Gomarhinayagam, 2014). The Brahmani-Baitarani delta is enriched with rich mangrove genetic diversity and has been declared as the Bhitarkanika Wild Life Sanctuary (650 sq.km deltaic area of major rivers like Brahmani, Baitarani & the Dhamra, many creeks, mudflats and mangrove forests) in 1975 (Nayak and Bahuguna, 2001; Upadhyay and Mishra, 2008). The Bhitarkanika mangrove vegetation is very thick, difficult to penetrate and legally protected (SAC, 2012).

The ‘true’ or ‘exclusive’ mangroves are those that occur only in mangrove habitat (Santisuk, 1983; Tomlinson, 1986; Duke, 1992 and Giesen et al., 2007) or only rarely elsewhere and the ‘mangrove associates’ or non-exclusive mangroves are those which comprise a large number of species typically occurring on the landward margin of the mangal and often the non-mangal habitats such as rainforest, salt marsh, peat swamp or low land fresh water swamps (Santisuk, 1983 and Hogarth, 2015). According to Tomlinson (1986), the following criteria are required for a species to be designated a “true or strict mangrove”: complete fidelity to the mangrove environment, major role in the structure of the community and has the ability to form pure stands. The exclusive mangroves show the characteristics like aerial roots, viviparous or crypto-viviparous embryo development, tidal dispersal of propagules, absence of understory and growth rings, highly efficient mechanisms for nutrient retention and physiological mechanisms to tolerate salt (Alongi, 2009).

Adaptation to salt tolerance is of three types i.e., 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. Various types of root adaptations of mangroves in the habitat are lenticels (Bruguiera spp.), pneumatophores (Sonneratia spp. & Avicennia spp.), knee roots (Bruguiera spp.), cable roots (Avicennia spp.), and stilt roots (Rhizophora spp.) (Ong and Gong, 2013).

A total 114 species of mangroves and associates were found in the world (Tomlinson, 1986) which includes 54 true mangroves found exclusively only in the mangrove habitats. But, Chapman (1975) described 11 families comprising of 55 species as true mangroves found exclusively in the mangrove swamps. Hogarth (2015) described occurrence of around 70 true mangrove species in 28 genera and belonging to 20 families. Giesen et al. (2007) described 52 species in Southeast Asian countries as true mangrove species which includes 42 trees and shrubs. Mangrove associates are usually not immersed by high tides. They comprise of herbs, ferns, creepers, vines, shrubs, trees and orchids and are mostly found in the landward margin (Giesen et al., 2007). Wang et al. (2010) based on leaf trait and salt content classified the controversial mangrove species like Acrostichum aureum, Acrostichum speciosum, Excoecaria agallocha, Heritiera littoralis as mangrove associates, the species like Acanthus ilicifolius, Acanthus ebracteatus, Xylocarpus granatum, Pemphis acidula as true mangroves. Mangrove region of India constitutes major forests area with rich diversity of flora and fauna but with uneven distribution (Rajendran and Sanjeevi, 2004). The actual true mangrove species of India is a matter of controversy as there exists a difference in the definition of true species and the mangrove associates. Various taxonomists/authors have worked extensively on this topic yet there is no consensus on the agreement of true mangroves versus mangrove associates. Indian mangroves are diverse and variously estimated due to the addition of associate species, 82 species (Mandal and Naskar, 2008), about 125 species, comprising of 39 mangroves and 86 mangrove associates (Kathiresan, 2010). The review of Ragavan et al. (2016) on Indian mangroves showed 46 true mangroves which consists of 42 species and 4 natural hybrids. About 26 true mangrove species and 58 mangrove associates, giving a total of 84 species have been recorded from Sundarbans (Banerjee, 1998), while 24 pure mangroves are reported from Kerala (Mahandas, 2012).

The number of mangrove species of Bhitarkanika is varied in opinions and thought to be about 55 (Banerjee and Rao, 1990), 62-67 (Nayak and Bahuguna, 2001), 51 (Pattanaik et al., 2007), 57 (Mandal and Naskar, 2008), 64
(Hussain and Badola, 2010). The Bhitarkanika NP with such diverse species of mangroves is considered as the third important mangrove habitat among the Indian mangals with respect to mangrove species diversity (SAC, 2012). The number of true mangrove species of Bhitarkanika NP is also varies, 28 (Hussain and Badola, 2010), 35 (Raghvan et al., 2016). The flora of Bhitarkanika is typical of the Sundarbans (Barik and Chowdhury, 2014), and Indo-Malesian type (Banerjee and Rao, 1990).

The present investigation tried to give a detail mangrove species list of Bhitarkanika Wildlife Sanctuary & National Park, separated the true mangroves from associates based on the characteristic features like viviparous and crypto-viviparous seed germination, salt adaptation strategies, ability for tidal dispersal of propagules, root modifications like pneumatophores, stilt roots, buttress and knee roots, horizontal spreading roots & presence of lenticels, whether the species can form pure stand or not and formation of understory or not, etc.

**Study Area:**
The present study was carried out inside the mangrove forests which is a part of Bhitarkanika Wildlife Sanctuary and National Park and situated between 20° 30’ to 20° 47’ N latitude and 86° 39’E to 87° 04’ E longitudes in Kendrapara district of Odisha along the east coast of India. It occupies an area of 672 sq km. Bhitarkanika mangrove ecosystem flourishes in the deltaic region, formed by the rich alluvial deposits of Brahmani, Baitarani & the Dhamra River.

![Map 1: Study sites of Bhitarkanika Wildlife Sanctuary & National Park (Odisha), India.](image)

The river, Brahmani played major role for the establishment of mangrove forests. The river, Brahmani is branched one at Hansina bridge and another at Khola and both enters to Bhitarkanika Wildlife Sanctuary and National Park with different names. Both these river again meet at Gupti and one flows towards Ekakula and meets Bay of Bengal with the name of Pathasala river and Maipura river, the other flows towards Bhitarkanika and Dangmal forest blocks by the name of Bhitarkanika River.
Materials and Methods:--
Intensive field study to different locations within Bhitarkanika National Park was carried out during September-2014 to July-2016. The sites covered for data sampling were Dangmal, Bhitaranka, Ragarapatia, Habelikhati, Ekakula, Mahishamunda, Kalibhanjadiya island, Khola, Gupti, Orasahi, Satabhaya, Bagulidiya, Krishnapriyapur and other riverine sites which come under reserve forests of the Bhitaranka National Park. The present mangrove species and associate flora of each forest sites were recorded, photographed and identified with available literature, Hains (1921-25), Saxena and Brahamam (1994-1996), Santisuk (1983), Tomlinson (1986), Banerjee and Rao (1990), Naskar (2004), Rajendran and Sanjeevi (2004), Selvam et al., (2004), Singh and Odaki (2004), Spalding et al., (2010), Panda et al., (2013), Giesen et al., (2007) and Roy et al., (2009). The identified mangrove species are categorized into true or exclusive and mangrove associate as the characters used by Santisuk (1983), Tomlinson (1986), Hutchings and Saenger (1987), Duke (1992), Spalding et al., (1997), Singh and Odaki (2004), Giesen et al., (2007) and Wang et al., (2010) with consideration of local physiological adaptations of these mangroves.

The species of contention for present classified true or associate mangroves were also justified by comparing the literature explained by different workers. A check list of mangrove species and their associates has been prepared for Bhitaranka mangrove National Park.

Results and Discussion:--
Present study recorded a total of 29 true mangrove species (Table 1 and Plate 1) and 72 mangrove associates from different reserve mangrove forest sites of the Bhitaranka National Park (Table 2 and Plate 2). The classified true mangroves have adaptation mechanisms to resist the physiologically dry surrounding environment and they generally form pure stands in Bhitarkanika National Park.

True or exclusive Mangroves:--
The recorded true mangroves belong to a total of 11 angiosperm family and 15 genera (Table 1 and Fig. 1). Highest number of true mangrove species were recorded from the family Rhizophoraceae i.e., 10 species. The family Meliaceae, Avicenniaceae and Sonneratiaceae were found to have 3 true mangrove species each. Another three family Acanthaceae, Areaceae, Sterculiaceae were found to have 2 true mangrove species each. Single species of true mangrove were recorded from four families, i.e., Combretaceae, Euphorbiaceae, Plumbaginaceae and Myricaceae. The study also noted that the species A. ilicifolius L., A. officinalis L., A. marina (Forsk.) Vierh., E. gallocha L., H. fomes Buch-Ham., H. littoralis dryand ex Ait., P. paludosa Roxb., R. mucronata Lamk., C. decandra (Griff.) Ding Hau, K. candel (L) Druce, S. petala Buch.-Ham., X. granatum Koenig. as the frequently occurring true mangrove species of Bhitaranka National Park. Other species showed site specific restricted distribution and rare type of occurrences. The species like R. apiculata Blume is restricted to Khola and Habelikhati, B. sexangula (Lour.) Poir. and B. gynorrhiza (L.) Lam. were recorded from forest blocks of Dangmal, Bhitaranka, Khola and Krishnapriyapur sites, C. tagal (Perr.) C.B. Robinson was recorded from Ranahansua and Habelikhati reserve forests. The species like, R. stylosa Griff., A. corniculatum (L.) Blanco, A. alba Blume were recorded as the riverine mangroves of Maipura river and its branch Angari at Satabhaya. The mangrove species, L. racemosa Willd. and A. rotundifolia Roxb. were only recorded from Kalibhanjadiya island, Habelikhati and Ekakula reserve forest sites which are situated close to Bay of Bengal. A. bracteatus Vahl. is of rare occurrence and recorded only from Ragarapatia and Khola reserve forests. X. mekongensis Pierre and X. moluccensis (Lamk.) Roem., mostly confined to Dangmal and Bhitaranka forest blocks. S. alba J Smith was found at Ekakula and S. caseolaris (L.) Engler was recorded to occur at Khola jetty and as a riverine mangrove of Bhitaranka and Maipura river. The recorded exclusive and true mangrove species were of three growth forms in habit (i.e., tree, shrub and herb). Out of 29 true species, 26 were trees, 2 species were herbs, (A. ilicifolius L., and A. bracteatus Vahl.) and one species (P. paludosa Roxb.) was recorded as shrub (Fig. 3). All the present listed true mangrove species showed their prominent morphological and physiological adaptations like presence of one or more type of aerial roots, ability to resist long term saline water inundation, all form pure stands and lack understory vegetation, most of them have viviparous or crypto-viviparous embryo development and the species of family Rhizophoraceae with long distance seed or propagule dispersal abilities.

Associate mangroves:--
The mangrove associate flora study listed a total of 72 plant species which belongs to 39 families and 56 genera (Table 2 and Fig. 2). Highest number of species recorded from the families Fabaceae & Asclepiadaceae, i.e., 8 species each. The second highest numbers of mangrove associate species, (i.e., 5) were recorded from the family
Poaceae. Five families were found to bear 3 associate species each, i.e., Caesalpinioideae, Salvadoraceae, Pandanaceae, Malvaceae and Chenopodiaceae. Another five families were found to bear 2 associate species each and these families were Pteridaceae, Verbenaceae, Amarylidaeae, Convolvulaceae and Aizoaceae. A total of 26 families were found to have one species each and these families were Acanthaceae, Meliaceae, Aposeanaceae, Bignoniaceae, Cyperaceae, Flagellariaceae, Colchicaceae, Boraginaceae, Rubiaceae, Anacardiaceae, Asteraceae, Rutaceae, Lythraceae, Celastraceae, Goodeniaceae, Solanaceae, Blechnaceae, Tamaricaceae, Combretaceae, Loranthaceae, Araceae, Ebenaceae Opuntiaceae, Tiliaceae, Legumininae and Euphorbiaceae (Table 2 and Fig. 3). The growth habit study of the recorded associate species resulted, Herb (20 spp.), Shrub (16 spp.), Tree (14 spp.), Climber (17 spp.), Fern (3 spp.), Creeper (2 spp.) (Fig. 4). All the recorded mangrove associates lack the adaptation characters to be a true mangrove and depend on true mangrove species for their own existence on this mangrove wetland. The comparison of growth habit of the recorded mangrove associates showed 58 species as non tree plants and generally found understory or hanging on the surface of true mangrove species.

Besides associate mangrove flora, Bhitarkanika Wildlife Sanctuary and National Park was found to host many non-mangroves of purely terrestrial angiosperms and cryptogams but present study excludes listing of them.

Species of Contention:-
A total of 17 mangrove species were found to be in a position of controversy and various opinions exists whether they are true or mangrove associates (Table 3).

The mangrove species like, Acanthus ebracteatus Vahl., Nypa fruticans (Thumb.) Wurmb., Heritiera littoralis Dryand ex Ait., Kandelia candel (L) Druce, Phoenix paludosa Roxb., Xylocarpus moluccensis (Lam.) Roem., are presently classified as true mangroves due to their physiological and morphological adaptations and mostly supported the work of Santisuk (1983) and Singh and Odaki (2004). Other species, Acanthus volubilis Wall., Acrostichum aureum L., Acrostichum speciosum Willdenow, Aglaia cucullata (Roxb.) Pellegrin, Brownlowia tersa (L.) Kostern, Cerbera odollam Gaertn., Cynometra iripa Kostel, Dalbergia spinosa Roxb., Dolichandrone spathacea K.Schu., Excoecaria indica (Willd.) Mull. and Suaeda maritima L. (Dumort) are classified as mangrove associates due to the lack of adaptation modifications, poor capability of toleration to long term saline water inundation and most of them found as the understory vegetation.

Latiff (2012) included the mangrove species like Nypa fruticans (Thunb.) Wurmb., Intsia bijuga (Colebr.) Kuntz. and Heritiera littoralis Dryand ex Ait. as non exclusive mangroves. Wang et al., (2010) classified the species like E.agallocha L. and H.litoralis Dryand ex Ait. as mangrove associate although they have wide range of salinity tolerance and both physiological and morphological adaptation modifications. Similarly, the species Pemphis acidula Forst. is described as true mangrove by different workers (Table 3) but our present classification included it into mangrove associate due to lack of adaptation modifications, like aerial roots, viviparous or crypto viviparous seed development and salt resisting abilities etc. Pemphis acidula Forst is an understory mangrove with succulent leaves and the species need freshwater input. The species, Acanthus volubilis Wall. being having viviparous embryo development, classified as mangrove associate due to absence of required characters to be a true mangrove and the important one, this species is a climber and grow on the surface of other true mangrove species (i.e., most frequently on E.agallocha L.) and lack forming pure stands.

The previously recorded species Heritiera kanikensis (Majumdar and Banerjee, 1985) and Sonneratia griffithii Kurz., Cynometra ramiflora L. (Selvam, et al., 2004; Upadhyay, 2008) were not recorded during our present study. The mangrove species Excoecaria indica (Willd.) Mull. Arg. is commonly known as Sapium indicum Willd. in Bhitarkanika NP. But our present classification explained it as E.indica (Willd.) Mull. Arg. due to the presence of characters like spiny stem and trunk, leaf morphology etc. and the name is globally used. H.fomes Buch-Ham. is a globally threatened species of extinction but this is one of the dominating species of Bhitarkanika NP. Another species, Brownlowia tersa (L) Kostern. which is in the category of near threatened (Kathiresan, 2010) is abundantly found at the sites like Ragrapatia and river banks close to Dangmal, Bhitarkanika and Mahisamunda reserve forests of Bhitarkanika NP.

The recorded flowering period of each mangrove species favors the work done by (Upadhyay and Mishra, 2010) with small variation. The phenological study of mangrove species showed most of the mangrove species go flowering during winter or late winter but before start of monsoon rain due imposed stress of nutrient scarcity and high water and soil salinity.
Many mangrove species of Bhitarkanika are endemic and not found elsewhere in India. The species like *C. iripa* Kostel, *I. bijuba* (Colebr.), *Dolicandron spathecia* (L.f.) K.Schum., *A. volubilis* Wall., *A. ebracteatus* Vahl. etc. are endemic to Bhitarkanika NP and only found in some part of Sundarbans and Andaman mangrove ecosystem (Rajendran and Sanjeevi, 2004; Raghvan *et al*., 2014). *E. indica* (Willd.) Mull. Arg. is only found close to Khola creek in Bhitarkanika NP and not elsewhere in India. The global trend of *E. indica* (Willd.) Mull. Arg. is decreasing. The mangrove plant, *N. fruticans* (Thumb.) Wurmb, was extinct from Bhitarkanika NP but it has been reintroduced to the site from Sundarban to maintain the diversity of the ecosystem (Panda *et al*., 2013). Many associate flora are also endemic to this site and not found elsewhere in India. The number of true mangroves and dominating mangrove species of Bhitarkanika and Sundarban is of similar (Selvom, 2003). The present recorded mangrove diversity of Bhitarkanika ecosystem shows it is one among the most diversified mangrove ecosystems of world (Kathiresan and Rajendran, 2005) and if the mangrove associate flora is taken into consideration, then Bhitarkanika mangrove ecosystem will be the most species diversified ecosystem of India.

**Conclusion:**
Our present work classified two groups of mangroves (i.e., true or associate mangroves) based on individual species adaptation and not divided the exclusive or true mangroves further into ‘major’ and ‘minor’ as done by Tomlinson (1986). Mangroves have great ecological role and provides resource to the coastal livelihoods of Odisha. The past conditions favored the luxuriant growth of *E. agallocha* L. and *H. fomes* Buch-Ham. inside Bhitarkanika National Park but both are low saline tolerating species. The study noted many mangroves of Bhitarkanika National Park had site specific distribution. The sites with more freshwater inputs and water inundation, housed more number of species than the site with less fresh water input. But still there are some areas (i.e., Habelikhati, Ekakula) where many riverine mangroves (i.e., *Rhizophora* spp.) were found towards land in number of patches. The global climate change induced sea level rise may become a critical factor (Gilman, *et al*., 2008) for the present existing dominating species of Bhitarkanika mangrove reserve forests and for change in mangrove habitat (Selvom, 2003; SAC, 2012 and Rao, *et al*., 2015). The study of Upadhyaya and Mishra (2008), showed that more than 80% of death and damages of mangrove trees have been due to anthropogenic (human induced) disturbances. The mangroves and associates are likely to become vulnerable in near future due to both man-made and natural threats (Kathiresan, 2010). The Coastal Vulnerability Index (CVI) study also showed that some part in coastal area of Kendrapara district (close to Dhamara mouth) has high risk of vulnerable to coastal change (Kumar, *et al*., 2010). Many species of this wetland is under pressure of extinction (Panda *et al*., 2013) and must be conserved before the genetic erosion. Many mangrove species in Bhitarkanika were found as rare of occurrence (i.e., *C. tagel* (Per.) Rob., *B. parviflora* Wt. & Arn., *B. gymnorrhiza* (L.) Lamk, *R. stylosa* Griff., *A. ebracteatus* Vahl., *A. volubilis* Wall., *E. indica* (Willd.) Mull. Arg., *I. bijuga* (Colebr.) Kuntz, *Tylophora* spp. and *Sarcobolobus* spp.) and these species should be given priority for conservation.

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Table 1: List of recorded true mangrove species of Bhitarkanika mangrove forest and their phenology (Odisha), India.

| Sl No | True mangrove species                        | Family          | Flowering period | Adaptation                      | Seed development | IUCN status | Habit |
|-------|-----------------------------------------------|------------------|------------------|---------------------------------|------------------|-------------|-------|
| 1     | Aegiceras corniculatum (L.) Blanco             | Myrcinaceae      | April            | Cable roots                     | CV               | LC          | Tree  |
| 2     | Aegialitis rotondifolia Roxb.                 | Plumbaginaceae   | March            | Peg like roots                  | CV               | NT          | Tree  |
| 3     | Acanthus ilicifolius L.                       | Acanthaceae      | April            | Cable & Stilt roots             | CV               | LC          | Herb  |
| 4     | Acanthus ebracteatus Vahl.                    | Acanthaceae      | March            | Cable & Stilt roots             | CV               | LC          | Herb  |
| 5     | Avicennia alba Blume                          | Avicenniaceae    | May              | Knee root & Pneumatophores      | CV               | LC          | Tree  |
| 6     | Avicennia marina (Forsk.) Veierh              | Avicenniaceae    | April/May        | Pneumatophores                  | CV               | LC          | Tree  |
| 7     | Avicennia officinalis L.                      | Avicenniaceae    | April            | Pneumatophores                  | CV               | LC          | Tree  |
| 8     | Bruguiera cylindrica (L.) Blume               | Rhizophoraceae   | January          | Buttress, Knee & Stilt roots    | V                | LC          | Tree  |
| 9     | Bruguiera gymnorhiza (L.) Lamk.               | Rhizophoraceae   | February         | Buttress, Knee & Stilt roots    | V                | LC          | Tree  |
| 10    | Bruguiera parviflora Wt. & Arn.               | Rhizophoraceae   | August           | Stilt & Knee roots              | V                | LC          | Tree  |
| 11    | Bruguiera sexangula (Lour.) Poir              | Rhizophoraceae   | March            | Stilt & Knee roots              | V                | LC          | Tree  |
| 12    | Ceriops decandra (Griff.) Ding Hou            | Rhizophoraceae   | November         | Buttress, Knee & Stilt roots    | V                | NT          | Tree  |
| 13    | Ceriops tagal (Per.) Rob.                     | Rhizophoraceae   | May/June         | Buttress, Knee & Stilt roots    | V                | LC          | Tree  |
| 14    | Excoecaria agallocha L.                       | Euphorbiaceae    | April            | Spreading horizontal root       | NV               | LC          | Tree  |
| 15    | Heritiera littoralis Dryand ex Ait            | Sterculiaceae    | April            | Peg & Buttress root             | NV               | LC          | Tree  |
| 16    | Heritiera fomes Buch.-Ham.                    | Sterculiaceae    | September        | Peg & Buttress root             | NV               | EN          | Tree  |
| 17    | Kandelia candel (L.) Druce                    | Rhizophoraceae   | November         | Stilt roots                     | V                | LC          | Tree  |
| 18    | Lumnitzera racemosa Willd.                    | Combretaceae     | December         | Knee & Stilt roots              | NV               | LC          | Tree  |
| 19    | Nypa fruticans (Thumb.) Wurmb.                | Arecales         | -----------------| No aerial roots                 | No aerial roots  | V            | LC    | Tree  |
| 20    | Phoenix paludosa Roxb.                        | Arecales         | December         | Pneumatophores                  | V                | NT          | Shrub |
| 21    | Rhizophora apiculata Blume                    | Rhizophoraceae   | November         | Prop & stilt roots              | V                | LC          | Tree  |
| 22    | Rhizophora mucronata Lamk.                    | Rhizophoraceae   | September        | Prop & stilt roots              | V                | LC          | Tree  |
| 23    | Rhizophora stylosa Griff.                     | Rhizophoraceae   | September        | Prop & stilt roots              | V                | LC          | Tree  |
| 24    | Sonneratia alba J. Smith                     | Sonneratiaceae   | March            | Pneumatophores                  | NV               | LC          | Tree  |
| 25    | Sonneratia apetala Buch. – Ham.               | Sonneratiaceae   | February         | Pneumatophores                  | NV               | LC          | Tree  |
| 26    | Sonneratia caseolaris (L.) Engler             | Sonneratiaceae   | December         | Pneumatophores                  | NV               | LC          | Tree  |
| 27    | Xylocarpus granatum Koenig                   | Meliaceae        | November         | Buttress                        | NV               | LC          | Tree  |
| 28    | Xylocarpus mekongensis Pierre                 | Meliaceae        | November         | Plank root                      | NV               | LC          | Tree  |
| 29    | Xylocarpus moluccensis (Lamk.) Roem.          | Meliaceae        | November         | Buttress & Pneumatophores       | NV               | LC          | Tree  |
| Sl. No. | Mangrove associates | Family         | Flowering period | Habit      |
|---------|---------------------|----------------|------------------|------------|
| 1       | Acanthus volubilis Wall. | Acanthaceae   | April            | Climber   |
| 2       | Acrostichum aureum L.  | Pteridaceae    | .................. | Fern       |
| 3       | Acrostichum speciosum Wild | Pteridaceae   | .................. | Fern       |
| 4       | Aeluropus lagopoides (L.) Trin. | Poaceae      | December         | Herb (Grass) |
| 5       | Aglaia cucullata (Roxb.) Pellegrin | Meliaceae | March            | Tree       |
| 6       | Allococcus serratus (Roxb.) Kurz | Verbenaceae | December          | Shrub     |
| 7       | Azima tetracantha Lam.  | Salvadoraceae  | October          | Shrub     |
| 8       | Brownlowia tersa (L.) Kostern. | Tiliaceae | May              | Shrub     |
| 9       | Caesalpinia bundoc (L.) Roxb. | Caesalpiniaceae | January         | shrub     |
| 10      | Caesalpinia crista L.  | Caesalpiniaceae | March        | Shrub     |
| 11      | Canavalia maritime (Aubl.) Thouars | Fabaceae | December         | Climber   |
| 12      | Cerbera odollam Gaertn  | Apocenaceae    | Year             | Tree       |
| 13      | Clerodendron inerme (L.) Gaertn | Verbenaceae | April           | Shrub     |
| 14      | Crinum asiaticum L.    | Amarylidaceae  | December         | Herb      |
| 15      | Crinum defixum Ker Gawl. | Amarylidaceae | December         | Herb      |
| 16      | Cryptocoryne ciliata (Roxb.) Fisch. ex Wydler | Araceae | July            | Herb      |
| 17      | Cynometra iripa Kostel  | Caesalpiniaceae | November      | Shrub     |
| 18      | Dalbergia candenatensis (Dennst.) Prain | Fabaceae | May             | Shrub     |
| 19      | Dalbergia spinosa Roxb. | Fabaceae | October          | Shrub     |
| 20      | Derris heterophylla (Willd.) K. Heyne | Fabaceae | April           | Climber   |
| 21      | Derris scandens (Roxb.) Benth. | Fabaceae | April           | Climber   |
| 22      | Derris trifolia Lour.  | Fabaceae       | February         | Climber   |
| 23      | Dendrophthoe falcate (L.f.) Etting. | Loranthaceae | August          | Tree      |
| 24      | Diospyros melanoloxyn Roxb. | Ebenaceae | November         | Tree      |
| 25      | Dolichocarpus spathaceae (L.f.) K.Schum. | Bignoniaceae | January        | Tree      |
| 26      | Excoecaria indica (Willd.) Mull. Arg. | Euphorbiaceae | March          | Tree      |
| 27      | Fimbristylis ferruginea (L.) Vahl | Cyperaceae | August           | Herb      |
| 28      | Flagilaria indica L.  | Flagillariaceae | September     | Climber   |
| 29      | Finlaysonia obovata Wall. | Asclepiadaceae | November       | Climber   |
| 30      | Gloriosa superba L.    | Colchicaceae   | October           | Climber   |
| 31      | Heliotropium curassavicum L. | Boraginaceae | March          | Herb      |
| 32      | Hibiscus tiliaceus L.  | Malvaceae      | November         | Tree      |
| 33      | Hoya parasitica (Roxb.) Wall | Asclepiadaceae | August          | Climber   |
| 34      | Hydrophyllax maritime L.f. | Rubiaceae | February         | Herb      |
| 35      | Intsia bijuba (Colebr.) Kuntz. | Caesalpiniaceae | March        | Tree      |
| 36      | Ipomoea pes-caprae (L.) R. Br. | Convolvulaceae | February       | Creeper   |
| 37      | Ipomoea tuba (Sch.) G. Don | Convolvulaceae | January/February | Creeper   |
| 38      | Lannea coramandellia (Houtt.) Merr | Anacardiaceae | March            | Tree       |
| 39      | Launea sarmentosa (Willd.) Schultz-Bip. | Asteraceae | April           | Herb      |
| 40      | Macuna gigantean (Willd.) DC. | Fabaceae | September       | Climber   |
| 41      | Merope angulata (Willd.) Swingle | Rutaceae | May             | Shrub     |
| 42      | Myriostachya wightiana (Nees ex Steud) Hook. F | Poaceae | February         | Herb (Grass) |
| 43      | Opuntia dillenii (Ker-Gawl.) Haw. | Opuntiaceae | April           | Herb (Succulent) |
| 44      | Pandanus fascicularis Lam. | Pandanaceae   | April            | Shrub     |
| 45      | Pandanus foetidus Roxb. | Pandanaceae   | February         | Shrub     |
| 46      | Pandanus odorotissms L.f. | Pandanaceae   | February         | Shrub     |
| 47      | Peplis acidula Forst.   | Lythraceae    | April            | Shrub     |
Table 3: The mangrove species of controversy in position (Justification by comparing the work of various authors and present classified mangrove type)

| Sl. No. | Mangrove species               | True Mangrove                                                                 | Mangrove Associate                      | Present Classification |
|---------|--------------------------------|--------------------------------------------------------------------------------|------------------------------------------|------------------------|
| 1       | *Acanthus ebracteatus* Vahl.    | Santisuk (1983), Singh & Odaki (2004), Kathiresan & Rajendran (2005), Giesen et al. (2007), Balachandran et al. (2009), Polidoro et al. (2010), Wang et al. (2010) | Tomlinson (1986), Spalding et al. (2010) | True mangroves         |
| 2       | *Acanthus volubilis* Wall.      | Naskar (2004), Ravishankar et al. (2004), Singh & Odaki (2004), Giesen et al. (2007), Polidoro et al. (2010) | Tomlinson (1986), Naskar (2004) | Mangrove Associate      |
| 3       | *Acrostichum aureum* L.         | Tomlinson (1986), Ravishankar et al. (2004), Selvam et al. (2004), Kathiresan & Rajendran (2005), Giesen et al. (2007), Polidoro et al. (2010), Sakhthe (2014), Donoso (2016), Wang et al. (2010) | Santisuk (1983), Naskar (2004), Singh & Odaki (2004), Spalding et al. (2010) | Mangrove Associate      |
| 4       | *Acrostichum speciosum* Wildenow | Tomlinson (1986), Kathiresan & Rajendran (2005), Giesen et al. (2007), Polidoro et al. (2010), Donoso (2016), Wang et al. (2010) | Santisuk (1983), Singh & Odaki (2004), Naskar (2004), Spalding et al. (2010) | Mangrove Associate      |
| 5       | *Aglaya cucullata* (Roxb.) Pellegrin | Naskar (2004), Ravishankar et al. (2004), Selvam et al. (2004) | Santisuk (1983), Spalding et al. (2010) | Mangrove Associate      |
| Number | Species                                             | Authors References                                                                 | Status              |
|--------|-----------------------------------------------------|------------------------------------------------------------------------------------|---------------------|
| 6      | *Brownlowia tersa* (L.) Kostern.                    | Naskar (2004), Selvam et al. (2004), Giesen et al. (2007), Polidoro et al. (2010), Donoso (2016) | Santisuk (1983), Ravishankar et al. (2004), Singh & Odaki (2004) | Mangrove Associate |
| 7      | *Cerbera odollam* Gaertn.                           | Ravishankar et al. (2004)                                                          | Santisuk (1983)     | Mangrove Associate |
| 8      | *Cynometra iripa* Kostel                            | Selvam et al. (2004), Singh & Odaki (2004), Kathiresan & Rajendran (2005), Polidoro et al. (2010) | Santisuk (1983), Naskar (2004), Spalding et al. (2010) | Mangrove Associate |
| 9      | *Dalbergia spinosa* Rxb.                            | Balachandran et al. (2009)                                                         | Naskar (2004), Rao (2015) | Mangrove Associate |
| 10     | *Dolichandrone spathacea* (L. f.) K.Schum.          | Tomlinson (1986), Ravishankar et al. (2004), Kathiresan & Rajendran (2005), Polidoro et al. (2010) | Santisuk (1983), Naskar (2004), Singh & Odaki (2004), Spalding et al. (2010), Wang et al. (2010) | Mangrove Associate |
| 11     | *Excoecaria indica* (Willd.) Mull.                  | Kathiresan & Rajendran (2005), Polidoro et al (2010)                               | Santisuk (1983), Spalding et al. (2010) | Mangrove Associate |
| 12     | *Heritiera littoralis* Dryand ex Ait.               | Sakthive (2014), Singh & Odaki (2004), Polidoro et al (2010), Tomlinson (1986) Ravishankar et al. (2004), Kathiresan & Rajendran (2005) | Santisuk (1983), Spalding et al. (2010), Wang et al. (2010) | True mangroves |
| 13     | *Kandelia candel* (L) Druce                         | Naskar (2004), Ravishankar et al. (2004), Selvam et al. (2004), Singh &Odaki (2004), Kathiresan & Rajendran (2005), Giesen et al. (2007), Polidoro et al. (2010), Spalding et al. (2010), Bark & Chowdhury (2014) | Santisuk (1983) | True mangroves |
| 14     | *Nypa fruticans* (Thumb.) Wurmb.                    | Santisuk (1983), Selvam et al. (2004), Singh & Odaki (2004), Kathiresan & Rajendran (2005), Giesen et al. (2007), Polidoro et al. (2010), Bark & Chowdhury (2014), Donoso (2016) | Spalding et al. (2010) | True mangroves |
| 15     | *Pemphis acidula* J.R.Forst. and G.Forst           | Tomlinson (1986), Selvam et al. (2004), Kathiresan & Rajendran (2005), Giesen et al. (2007), Polidoro et al. (2010), Wang et al. (2010) | Santisuk (1983), Singh & Odaki (2004), Spalding et al. (2010) | Mangrove Associate |
| 16     | *Phoenix paludosa* Roxb.                            | Santisuk (1983), Singh & Odaki (2004), Polidoro et al (2010), Bark & Chowdhury (2014), Donoso (2016) | Ravishankar et al. (2004) | True mangroves |
| 17     | *Suaeda maritima* L. (Dumort)                       | Santisuk (1983)                                                                    | Untawale (1986), Naskar (2004), Ravishankar et al. (2004), Sakthive (2014), Rao (2015), Balachandran et al. (2009) | Mangrove Associate |
Fig 1: Family wise recorded number true mangroves of Bhitarkanika mangrove National Park

Fig 2: Family wise recorded number of mangrove associate species of Bhitarkanika mangrove NP (Odisha), India

Fig 3: Number of true mangroves in each habit form

Fig 4: Number of mangrove associates in each habit form
Plate 1: The true mangrove flora of Bhitarkanika National Park (Odisha), India

Note: 1: Fruit of *Avicennia alba* 2: Pneumatophore of *Avicennia marina* 3: Fruit of *Avicennia officinalis*
4: Flower of *Bruguiera cylindrical* 5: Flower bud of *Bruguiera gymnorhiza* 6: Propagules of *Bruguiera sexangula* 9: Propagules of *Ceriops tagal* 10: Spreading horizontal roots of *Excoecaria agallocha* 11: Fruit of *Heritiera littoralis* 12: Buttress root of *Heritiera fomes* 13: Propagules of *Kandelia candel* 14: Flower and seed of *Lumnitzera racemosa* 15: *Nypa fruticans* 16: Fruiting branch of *Phoenix paludosa* 17: *Rhizophora mucronata* with stilt root 18: *Rhizophora stylosa* 19: Stilt root of *Rhizophora apiculata* 20: *Sonneratia alba* 21: Pneumatophores of *Sonneratia apetala* 22: Fruit of *Sonneratia caseolaris* 23: Inflorescence of *Xylocarpus granatum* 24: Fruit of *Xylocarpus granatum* 25: *Xylocarpus mekongensis* 26: Flower of *Aegiceras corniculatum* 27: Fruit of *Aegiceras corniculatum* 28: *Aegialitis rotundifolia* 29: Inflorescence of *Acanthus ilicifolius* 30: Fruit of *Acanthus ilicifolius*
Plate 1: Some mangrove associate flora of Bhitarkanika National Park (Odisha), India

Note: 1: Acanthus volubilis 2 & 3: Excoecaria indica 4: Suaeda monoica 5: Suaeda nudiflora 6: Suaeda maritima 7: Cynometra iripa 8: Dolicandrone spathacia 9: Aglaia cucullata 10: Cerbera odollam 11: Tylophora indica 12: Intsia bijuga 13: Acrostichum speciosum 14: Acrostichum aureum 15: Finlaysonia obovata 16: Flagillaria indica 17: Porteresia coarctata 18: Macuna gigantea 19: Derris scandens 20: Pongamia pinnata 21: Derris candenatensis 22: Opuntia dilleni 23: Stenochlaena palustre 24: Salvadoria parsica 25: Ipomoea pes-caprae 26: Cesaalpinia crista 27: Sesuvium portulacastrum 28: Tamarix tropii 29: Thespisia populnea 30: Cryptocoryne ciliata 31: Hibiscus tiliaceus 32: Canavalia maritima 33: Clerodendrom inerme 34: Fimbriostylis ferruginea 35: Diospyros melanoxyylon 36: Allophylus serratus

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