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Caption: Stripe-backed Weasel *Mustela strigidorsa*. Medium—digital, Software—procreate, Device—iPad + Apple pencil © Dhanush Shetty.



## Population status of *Heritiera fomes* Buch.-Ham., a threatened species from Mahanadi Mangrove Wetland, India

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**Abstract:** *Heritiera fomes* Buch.-Ham. is assessed as an endangered mangrove species by IUCN, and information on population status is lacking. The present study assesses the status of *H. fomes* in Mahanadi Mangrove Wetland on the east coast of India. Three forest blocks were selected and sampled for this study. Among these, the mean girth at breast height (GBH) of *H. fomes* was the highest in Hetamundia (HD) forest block. GBH of *H. fomes* was inversely proportional to the cumulative disturbance index ( $R^2= 0.7244$ ,  $p$  value  $<0.005$ ). The relative density was maximum for *H. fomes* (56%) at Bhitarkharnasi (BK), and for *Excoecaria agallocha* at Hetamundia (HD; 35%) & Kansaridia (KD; 54%), respectively. *Excoecaria agallocha* is a dominant species possibly impacting natural populations of *H. fomes*. Climate change and rising sea levels may also negatively affect the existence of this species. Therefore, appropriate strategies should be taken for conservation of this globally threatened mangrove species prior to its extinction.

**Keywords:** Conservation, disturbance index, diversity indices, East Coast of India, relative density, threatened mangroves.

**Editor:** Anonymity requested.

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**Author contribution:** Study design: NHR, SCS. Fieldwork: SCS, MRM. Data analysis: SCS Writing: SCS, MRM Feedback: NHR, SCS.

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## INTRODUCTION

Mangrove ecosystems are important with respect to their contribution towards biodiversity, carbon storage, ecosystem balance, prevention of soil erosion, economic development, health care and protection against natural calamities (Ellison 2008). Mangrove flora are major reservoirs of biological carbon that contribute significantly towards mitigation of climate change (Mohanta et al. 2020). The social economy in coastal areas is highly dependent on vegetation directly or indirectly through fishing activity, tourism, and medication (Alongi 2008).

Lack of conservation and protection of mangrove habitats in recent decades has resulted in sparse distribution of species and regional extinctions; 35% of mangrove area was lost between 1980–1990 alone worldwide (Valiela et al. 2001). However, an increase in land cover by mangroves has been observed over the last few years in some Indian states, including Maharashtra, Gujrat, Odisha, and Andhra Pradesh (ISFR 2017; Khare & Shah 2019). Odisha has 243 km<sup>2</sup> under mangrove vegetation in the coastal districts of Balasore, Bhadrak, Jagatsinghpur, Kendrapara, and Puri (ISFR 2017).

Information on threatened species is needed for formulation of conservation policies helpful in defining marine protected areas and resource utilization for coastal development (Polidoro et al. 2010). Studies of distribution, ecology, adaptation, and threat assessment are all prerequisites for effective management of resources in general, and threatened species in particular (Lewis et al. 2016; George et al. 2019). Recent global assessment reveals that 16% of total species of mangrove (70) are under threat of extinction.

In India, two species, *Heritiera fomes* Buch.-Ham. (Endangered) and *Sonneratia griffithii* Kurz (Critically Endangered) are under the IUCN category of threatened species (Polidoro et al. 2010). *H. fomes* (Sterculiaceae) is native to India, Bangladesh, Malaysia, Myanmar, and Thailand. In India, it is found only in the Sundarbans in West Bengal, and Bhitarkanika (abundant) and Mahanadi Mangrove Wetland (MMW; rare) in Odisha. *H. fomes* is locally called 'Bada Sundari' in Odisha. It mostly grows towards landward in low saline (5–15 PSU) habitats with fresh water association in upstream estuarine zones and in high intertidal regions. Climate change, sea level rise and salinification of coastal habitats have had adverse effects on sustainability of this species in different habitats. Hence, it can be taken as an indicator of global climate change and sea level rise.

*H. fomes* is an important traditional medicinal plant,

with reported activity to treat infections and diseases including goiter, skin diseases, gastrointestinal disorders, diabetes, and cancer (Mahmud et al. 2014; Islam et al. 2019). Timbers of the plant have high utility due to their hard and elastic nature. The timbers are used as constructive material for bridges, houses, boats, and hard boards (Ghosh et al. 2004). Locally, the timber is used as fire wood as well. However, the species is disappearing due to absence of fresh water and low seed viability (Kathiresan 2010). There is chance of local extinction of *H. fomes* in India as populations are declining rapidly due to anthropogenic and natural pressures (Kathiresan 2010). In Bangladesh, the species is facing the problem of dieback causing a severe loss of mangroves (Hussain & Acharya 1994). Due to its threat of extinction and lack of data regarding its population structure, it is essential to assess the population status of *H. fomes* for further planning to conserve and manage this species.

## MATERIALS AND METHODS

### Study area

The Mahanadi mangrove wetland is located on the eastern coast of India in Kendrapara district of Odisha, which lies between 20.30–20.53 N and 86.66–86.80 E. The area is covered with dense mangrove forest which extends from Hukitola Bay (North) to Paradip Port (South). The climate of the area is generally tropical monsoon in nature, with about 2,000 mm of rainfall annually. The area faces severe cyclonic storms each year peaking during May–July and October–November. The tidal amplitude ranges as high as 6 m during monsoon and as low as 1.2 m. in dry seasons. The combination of fresh water streams and tidal water in the inter-tidal regions of the Mahanadi river mouth provide luxuriant habitats for mangrove flora. However, there is variation in the salinity level at different seasons, and areas based on the precipitation and distance from sea to river and creeks, respectively. The salinity level of water becomes higher as 11.5 to 19.9 pptv near the sea and becomes lower at interior mangrove regions (landward) as 0.3 to 0.7 pptv (Ravishankar et al. 2004). The wet land is divided into eight forest blocks, i.e., Kansaridia (KD), Bhabar Kharnasi (BK), Bhitarkharnasi (BK), Hukitola, Jambu, Kantilo, Kendrapatia, and Hatamundia. In these forest blocks two important species *Heritiera fomes* and *Sonneratia griffithii* are found which are considered as globally threatened plant species.

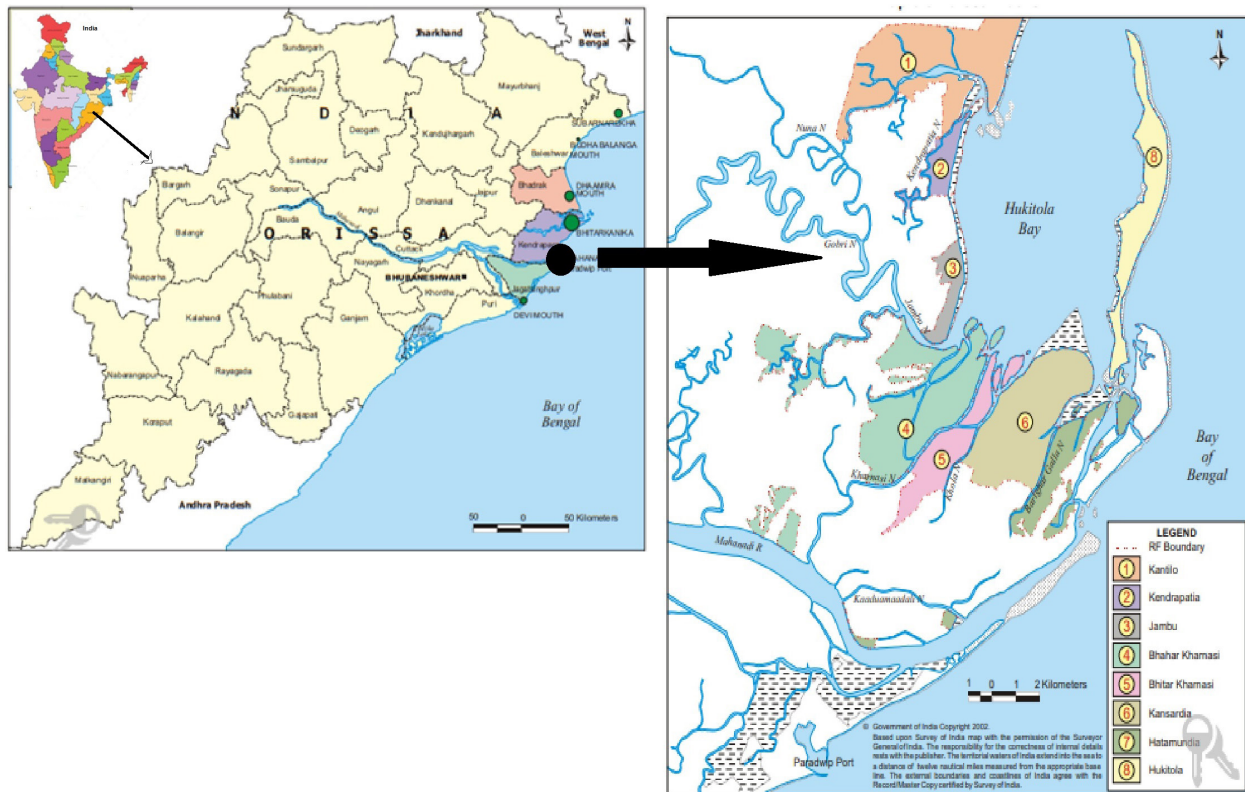


Figure 1. Study area showing forest blocks of Mahanadi Mangrove Wetland (MMW) (Adapted from Atlas of mangrove wetlands of India, part-3, Odisha).

### Data collection

Field surveys were carried out to study the population status of *H. fomes* in MMW from 2013 to 2016. After searching all the forest blocks of MMW, this species was found only in three reserve forests: Bhitarkharnasi (BK), Hetamundia (HD), and Kansaridia (KD). We laid nine quadrats (20 × 20 m) in total, three in each forest block. Woody trees with GBH ≥ 10 cm were considered for the study. The size class wise distribution of plants was estimated considering three levels, i.e., < 10 cm (lower GBH class), 10–20 cm (mid GBH class), and ≥ 20 cm (higher GBH class). Distributions of plants in these classes were compared to understand the future trend of distribution of the species. To study the regeneration status of *H. fomes*, stems < 10 cm girth were counted and recorded under each plot. For studying the stem size class distribution, plants with < 10 cm GBH were treated as *seedlings* and those of ≥ 10 cm GBH as *trees* (Pascal 1988). The global positioning system (GPS-Garmin Oregon-600) was used to record spatial location (latitude, longitude, and altitude) of each quadrat.

The data were analyzed through different diversity indices (Shannon-Weiner index and Simpson's index) and other diversity parameters (Menhinick's species

richness and evenness) following Magurran (2004).

Relative density was also calculated following the formula,

$$\text{Relative Density} = 100 * \left( \frac{\text{Density of one species}}{\text{Density of all species}} \right)$$

where, density was calculated as number of individuals of the species/ha.

Each forest block was observed to determine the type and level of disturbance following Tadwalkar et al. (2012). Observations were based on disease infection, cut stumps, and salinity of tidal water. These three features were measured through four levels, i.e., 0= no impact, 1= low impact, 2= moderate impact, and 3= high impact (Patwardhan et al. 2016). Cut stumps were taken as a sign of active anthropogenic disturbance whereas salinity of tidal water and disease infections were as natural disturbances. The salinity of the water was determined by following standard methodology given by APHA (2005). A cumulative disturbance index (CDI) was estimated for different forest blocks by adding these three scores. The estimated CDI were compared against other diversity parameters and mean GBH values of *H. fomes* in different forest blocks to evaluate the correlation between them.

## RESULTS AND DISCUSSION

Among eight studied forest blocks, *H. fomes* was found only in three: Bhitarkharnasi (BK), Hetamundia (HD), and Kansaridia (KD) reserve forests. These forest blocks comparatively represented with low salinity conditions due to absence of continuous tidal water. The cumulative species richness of all the studied plots was 10, including a single herb species named *Acanthus ilicifolius* L. The other woody species were *H. fomes*, *Excoecaria agallocha* L., *Cynometra iripa* Kostel., *Xylocarpus granatum* J.Koenig., *Avicennia officinalis* L., *Phoenix palludosa* Roxb., *Ceriops tagal* (Perr.) C.B.Rob., *Pongamia pinnata* (L.) Pierre, and *Rhizophora apiculata* Blume. *H. fomes* was found to occur at an altitude of 6–25 m. The detailed ecological information of sampling sites is given in Table 1. The Shannon diversity index varied among the three forest blocks as HD having the highest diversity index ( $1.32 \pm 0.18$ ) followed by KD ( $1.26 \pm 0.01$ ) and BK ( $1.16 \pm 0.20$ ) (Table 2). The overall Shannon diversity index was  $1.25 \pm 0.15$ . Simpson's Index was highest at HD ( $0.70 \pm 0.04$ ) followed by KD ( $0.64 \pm 0.01$ ) and BK ( $0.60 \pm 0.09$ ). Here, the HD seems to have better diversity than BK but closer to the KD. The visible variation in the diversity indices values is may be due to the differences in potential threat effects or soil nutrient status or both. However, the lower diversity indices of mangrove forest compared to other tropical forests ecosystem is quite common due to lower species richness (Gevana & Pampolina 2009; Stanley & Lewis 2009; Joshi & Ghose 2014).

The total number of individuals of *H. fomes* recorded in nine plots (0.36 ha) of three forest blocks was 482, including 398 trees and 84 regenerating individuals (Seedlings). BK possessed 231 individuals followed by

HD (133) and KD (118). The values of tree number in the region is quite satisfactory but number of seedlings was very low, indicated towards reduction of population size in future because the number of juveniles must exceed the number of trees to ensure population expansion (Upadhyay & Mishra 2014). Similarly, for a stable population size these numbers should be equal or nearly equal to satisfy one to one replacement condition (Upadhyay & Mishra 2014). But the cumulative result of these nine studied plots put the ratio near 5 : 1 (Tree : Seedlings), which indicates poor regeneration status of the species in the area and urgent need for conservation.

The distribution of GBH class revealed that in BK, 25 individuals had stems less than 10 cm GBH (seedlings), 78 had stems between 10–20 cm, and 128 had stems greater than 20 cm (mature trees), indicating a healthy population structure with good representation of individuals of all size classes. In HD, stems less than 10 cm GBH (seedlings) was 39 individuals followed by stems between 10–20 cm at 78 individuals and stems greater than 20 cm (mature trees) at 16 individuals. In KD, stems less than 10 cm GBH (seedlings) was 20 individuals followed by stems between 10–20 cm at 64 individuals and stems greater than 20 cm (mature trees) at 34 individuals (Figure 2). Among these three forest blocks, there was a visible difference among of matured tree numbers. BK was bearing the highest number whereas it was lowest in HD, indicating the difference in the level of potential threat among two blocks. The reason evaluated for less number of mature trees in HD was the more anthropogenic activities in the region (Highest CDI, Table 1). KD showed less number of seedlings than other forest blocks indicating poor regeneration status of *H. fomes* in this block. It may be due to more salinity ( $6.8 \pm 1.2$  pptv) and disease infection. The lowest salinity level ( $4.7 \pm 1.5$

**Table 1. Ecological information of study sites.**

Forest block/ Plot no.	Latitude (degree, minute)	Longitude (degree minute)	Altitude (meter)	Density (ha <sup>-1</sup> )	Mean GBH	CDI
BK-1	20.393	86.719	21	2475	19.49	4
BK-2	20.364	86.719	25	1200	31.02	3
BK-3	20.371	86.726	23	2100	22.96	4
HD-1	20.352	86.767	13	1000	14.55	6
HD-2	20.355	86.768	9	1275	10.45	7
HD-3	20.35	86.765	6	1050	16.26	5
KD-1	20.368	86.763	17	1040	18.90	5
KD-2	20.369	86.719	16	925	15.40	6
KD-3	20.37	86.719	15	975	15.79	4

BK—Bhitarkharnasi | HD—Hetamundia | KD—Kansaridia (1, 2, 3 represents sampling plots).



Table 2. Diversity indices in three forest blocks.

Diversity index	Bhitarkharnasi (BK)	Hetamundia (HD)	Kansaridia (KD)	Overall
Shannon-Weiner	1.16±0.20	1.32±0.18	1.26±0.01	1.25±0.15
Simpson	0.60±0.09	0.70±0.04	0.64±0.01	0.65 ±0.06
Evenness	0.61±0.08	0.72±0.09	0.58±0.01	0.64±0.09
Menhinick	0.45±0.03	0.43±0.10	0.51±0.01	0.46±0.06

Note: mean ± standard deviation are presented.

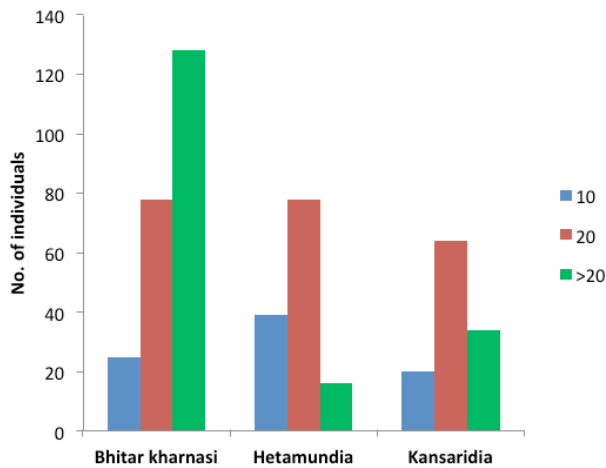


Figure 2. Distribution of no. of individual trees in different GBH classes (in cm).

pptv) and moderate anthropogenic disturbance in BK supposed to support highest tree density and seedling density among blocks. Different parameters like viable seed number, germination, establishment, and growth are the indicators of regeneration of plant community and also structurally reforms the community based on the age group distribution to the habitat (Cunningham 2001). The relative density was highest for *H. fomes* (56%) at Bhitarkharnasi and *Excoecaria agallocha* at HD (35%) and KD (54%), respectively (Figure 3). This indicates that *Excoecaria agallocha* is invading and dominating in a very fast rate due to its more ecological adaptations to the existing environmental conditions.

The mean CDI for the three forest blocks were: 3.36 (BK), 6 (HD), and 5 (KD). In the analysis, the CDI was found to be negatively correlated with mean GBH of each plot ( $R^2 = 0.7244$ ,  $p$  value  $< 0.005$ ) (Figure 4). However, there was a clear indication cumulative disturbances in the distribution of higher GBH class individuals in HD. Similarly, the lowest mean CDI value in BK supported the maximum distribution of trees with higher GBH class. The CDI value did not show any significant correlation with other variables like density and altitude. However, it was found that CDI value was highest in the forest

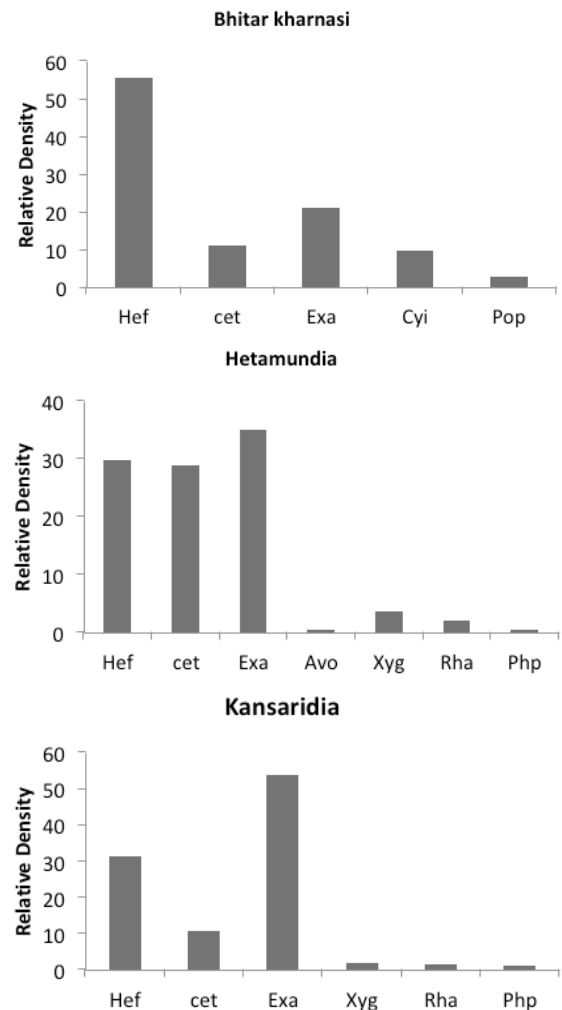


Figure 3. Relative density of *H. fomes* and its associated species. Hef—*H. fomes* | Exa—*Excoecaria agallocha* | Cyi—*Cynometra iripa* | Xyg—*Xylocarpus granatum* | Avo—*Avicennia officinalis* | Php—*Phoenix palludosa* | Cet—*Ceriops tagal* | Pop—*Pongamia pinnata* | Rha—*Rhizophora apiculata*.

block at lower altitude and similarly it was less in higher altitude. This was clearly showing the tidal effect on habitat modification and distribution of flora. The density among study plots showed high variability, ranging from 925 to 2,475 individuals/hectare. Variation was also observed among plots within forest blocks,



Image 1. *H. fomes* infected with gall cankers. © Sudam Charan Sahu.

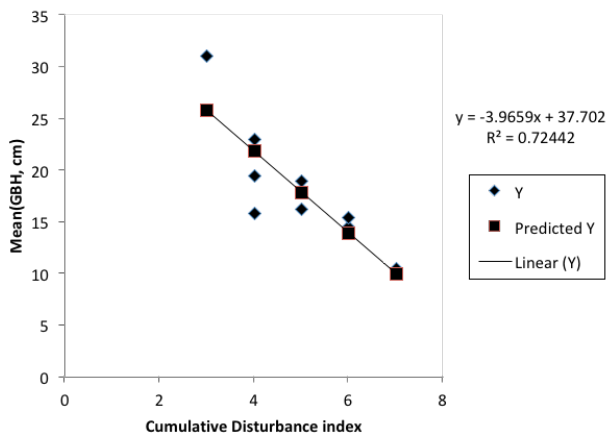


Figure 4. Cumulative disturbance index versus mean GBH.

being highest in BK and lowest in KD. These variations are common due to uneven distribution of plants due to tidal effects and variations in soil nutrient status (Xin et al. 2013). The role of human disturbances cannot also not be ignored.

### Threats

*H. fomes* grows well in low salinity condition about 2–5 PSU (Mitra et al. 2004; Ravishankar et al. 2004). Growth of mangroves is impacted by salinity level (Mitra et al. 2004). The higher salinity level in water affects the concentration of chlorophyll pigments a and b in leaves that decreases chances of sustainability of low salt tolerant plants in those regions (Clough 1985). Hence, salinity level can be a cause for stunted and rare distribution of flora or even to their regional extinction. In our study, lowest mean GBH was found in HD forest block indicating highest Cumulative Disturbance Index

(CDI) due to high salinity ( $5.4 \pm 1.3$  pptv) and disease infection. In Bangladesh Sundarban, about 20% of the entire forests have been affected due to top dying disease in *H. fomes* (Kathiresan 2010). Natural conditions like excessive flooding, increased soil salinity, sedimentation, imbalance in soil nutrients, and cyclone induced threats are the known factors for the disease. In the present study we observed some *H. fomes* trees were infected with gall cankers (Image 1).

Biological invasion is a major threat to biodiversity (Biswas 2003; IUCN 2003). In the present study no known invasive species was reported, but the domination of some true mangrove species and their associates was observed which might be giving inter-specific competition to *H. fomes* in different aspects. These species of MMW might have impacts on the natural population of *H. fomes* in competing for light and nutrients to suppress natural regeneration and cause physical damage. We recorded seven such species belonging to seven families and seven genera. Out of seven species, *Excoecaria agallocha* L., *Acanthus ilicifolius* L., and *Ceriops decandra* (Griff.) W.Theob. are pre-dominating the study area. The distribution of *E. agallocha* and *C. decandra* in the region may also have negative impact over the *H. fomes*. It is because a previous study at Sundarban mangrove reported a negative association between *H. fomes* with *E. agallocha* and *C. decandra* (Ellison et al. 2000). Further, we assumed that the future environmental conditions may support extensive growth of *Excoecaria agallocha* in the region because the species is highly salt tolerant, faster growing, and have high ability to colonize in degraded habitats (Harun-or-Rashid et al. 2009). The other important species were *Derris trifoliata* Lour., *Clerodendru minerme* (L.) Gaertn., *Eichhornia crassipes*





(Mart.) Solms, and *Saccharum spontaneum* L. Although, the relationship *H. fomes* with these species is not clear but there must be a negative interaction in them that supposed to affect the regeneration of the species due to inter specific competitions. Hence, the nature of relationship between *H. fomes* and other invasive species is the part of future research.

The unscientific utilization and management of resources is a major threat to biodiversity. Globally, there is not been a single policy that ensures sustainable use and conservation of mangrove resources (Romanach et al. 2018). Repeated logging and unscientific exploitation of plant species force distributions to be sparse. However, the present condition in the study areas are much organized and restricted for logging and other activities due to active involvement of forest department. But extensive logging of large trees for construction and firewood in these areas was quite frequent in the past. The interaction with local people revealed that the information about the threat status of the species was completely unknown by the local communities. There was complete absence of awareness programs regarding environmental education and threatened species in the area among tribes. This was the one among the valid reasons for disperse distribution of the species.

The study site is located in the eastern coast of India where tropical cyclonic storms are very common, specifically the coast of Odisha state. Disastrous tsunamis with high tidal force and above 150 km/hr wind speed severely affect coastal mangrove vegetation almost each year. Recent examples of such natural calamities are cyclone Phailin (2013), cyclone Hudhud (2014), and cyclone Fani (2019). The disastrous effect of the super cyclone in 1999 to the coastal areas of Odisha is well known. Apart from immediate damage, post-cyclonic changes in habitat create issues such as increased infections and temperature reduction (Shengyan et al. 2019). Thus it is a major challenge for forest managers to protect mangrove diversity and effectively implement conservation strategies. In these conditions, the regeneration and sustainability of *H. fomes* is highly affected due increase in habitat salinity levels and disease after cyclones.

### Conservation measures

Effective conservation measures are essential for the sustainability of *H. fomes* in the region. This can be achieved by supply of fresh water to high salinity areas, for better growth and regeneration. Preparation of specialized habitats and plantation areas with optimal salinity condition for *H. fomes* may aid conservation in

the area. Further, plantation areas could be established at a safe distance from the sea so that required amounts of fresh and saline water can be channeled, and arrival of high tidal water during cyclones and other natural calamities prevented. The present policies of plantation of mangrove flora are quite successful in the area, but the active and effective participation of local people is lacking. Here, it can be suggested that the population strength of *H. fomes* in the area can be achieved through active participation of local people and taking the species at high priority.

*H. fomes* has been reported to be infected by different pests and diseases that directly affect regeneration. Hence, effective research to the problem is required to overcome this issue in an eco-friendly way. Use of artificial pesticides may be an option, but use of bio pesticides will be better for healthy ecosystem development. Germination of this species is low, and seedlings are few. Further study of germination and seed viability of this species in different environmental conditions is required.

Inter-specific competition is common in natural ecosystems, and it is a major determinant of population structures. Further study is needed to observe the impact of *Excoecaria agallocha* and other species on the life cycle of *H. fomes*. The awareness programs regarding importance of biodiversity and sustainable utilization of the resources to be conducted in regular intervals in the coastal areas. Government and local community should involve in plantation of *H. fomes* in suitable areas where the salinity level is low and sufficient supply of fresh water is available. Tree cutting should be completely avoided providing alternative livelihood for the local communities. The Coconut plantation, oil extraction, tourism promotion, and small scale industry development can be seen as alternatives for livelihood development for the associate communities. Further, climate change and sea level rise may negatively affect existence of this species (increase in salinity level) and appropriate adaption strategies may be taken for conservation of the globally threatened mangrove species *H. fomes* prior to its extinction in the region.

In summary, well-organized and coordinated efforts of researchers, forest managers, and administrators are needed to achieve the goal of *H. fomes* conservation. Fruitful investment of funds, effective implication of policies, continuous supervision, and evaluation are key to effective conservation strategies.

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