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Review Article

Mitigation of immediate damages from tropical cyclones on the coastal forest ecosystem: A Case of Wildlife Sanctuaries

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Abstract

The Indian State of Odisha has been the hotspot for extreme weather conditions such as heat waves, cyclones, severe droughts, floods, and extreme cyclones, throughout history. The state is witnessing natural calamities at an alarming frequency challenging sustenance of all sorts. There have been cases of 30 cyclones hitting the state in the last 11 years. Even though the coastline of Odisha constitutes 17% of the eastern coastline of India, it has witnessed damage and destruction of almost 35% of all cyclonic storms which crossed the eastern coast of the Indian subcontinent. Coastal Orrisa has been the battleground for survival from dreadful cyclones in all these cases. Wherever the cyclones make landfall there is a substantive alteration in the dynamics of landscape and wildlife. On the third and fourth of May 2019 cyclone 'Fani' made landfall in Odisha's coastal forest areas comprising Balukhand wildlife sanctuary and caused catastrophic destruction to its landscape and wildlife resources within only a few hours. The sanctuary previously considered to be an important physiological barrier to the nearby agrarian community because of its dense plantation for controlling soil erosion, turned into a barren land with most of the trees severely damaged. Many studies and strategies have been developed to safeguard the interests of man and society during such extreme weather events. However, the formulation of proper strategies for the conservation of biodiversity and wildlife, which could have prevented loss and extreme damage to ecology considerably, has not been done so far. The objectives of this paper are to (1) study the pattern of damage to the existing vegetation, (2) analyze the destruction of wildlife and vegetation, and (3) propose biodiversity management and mitigation measures and increase preparedness for such cyclones in the coming future.

Keywords: Biodiversity, Balukhand Wildlife Sanctuary, Cyclone Fani, Natural disasters, Tropical cyclones

Introduction

Tropical cyclones have proved to be the most catastrophic disasters for tropical ecosystems around the world. Recent researches show that they are becoming remarkably frequent over the north Indian Ocean and with a 17% increase in their intensification rate and a 25% increase in severe cyclone stage in the last 122 years (Singh et al., 2000). Such massive disturbances bring extensive changes in forest composition, dynamics, functional and structural processes (Nandi et al., 2020). The extent of damage and destruction depends upon the profile of the ecosystem, frequency, type and level of severity of the disaster. Consequently, the forest ecosystem gets reshaped multidimensionally in the short and long term (Nandi et al., 2020). Tropical storms come with strong winds, heavy rainfall and high tides that breach everything coming in their way.

The Bay of Bengal imposes substantial geographical vulnerability on the eastern coast of India. Of the 35 deadliest tropical cyclones 26 of them made their way through the Bay of Bengal (Nandi et al., 2020). Odisha, prone to several disasters, has shown higher vulnerability in terms of cyclone landfall as compared to other coastal states of India, with 29% of the total disturbances recorded in Odisha alone, making it the most vulnerable among the coastal states of West Bengal (14%), Andhra Pradesh (13%), and Tamil Nadu (7%). The coastline of Orissa, which constitute 17% of the eastern coast of India, specifically becomes the focal point where nearly 35% of all severe cyclonic storms have made their way (Orissa, 2019b). The state has witnessed 30 cyclones in last 100 years, often challenging the survival of its biodiversity (Downtoearth, 2001).

Cyclone ‘Fani’, an extremely severe tropical cyclone, made landfall on Odisha’s coast around 8.30 AM on 3rd May 2019, wreaking havoc on the coastal stretch between Satapada and Puri. The sustained surface wind speeds were recorded to be 170-180 kmph gusting to as high as 205 kmph during landfall at Balukhand Wildlife Sanctuary, the site of landfall. The cyclone ravaged the wildlife reserve completely within a close span of 6 long hours (Orissa, 2019b). It razed everything to the ground whatever devastatingly came into its way. The combined effect of exposure to natural hazards, the pre-existing vulnerability, and the inability to cope with the impacts of the situation brought catastrophic destruction to the ecosystem of the sanctuary (The Impact of Climate Change on Natural Disasters, 2005).

When it comes to disaster management, including rescue operations, the interest of human societies is largely taken care of due to obvious reasons while priority for the ecosystem is left

aside as another very long-term self-sustained regeneration process. There is a serious knowledge gap and a lack of a mechanism in place for rescue operations and providing medical aid to the injured wildlife. There has been a substantial research gap internationally concerning influence of such disasters on biodiversity particularly regarding the process of recovery, sustainable reconstruction strategies and future precautionary approaches. Destruction due to the landfall of Fani also raises an urgent need to establish a protocol for precautionary measures, a policy framework, and central support system to minimize devastating impacts on biodiversity to a significant extent (Nishida et al., 2017). Close observation of the nature of biodiversity and ecological destruction opens the scope for important learnings in this regard. The objectives of this paper are to (1) study the pattern of damage to the existing vegetation in Balukhand Wildlife Sanctuary in Odisha from tropical cyclones, (2) analyze the destruction of wildlife in relation to vegetation in Balukhand Wildlife Sanctuary, and (3) propose biodiversity management and mitigation measures and to increase preparedness for such cyclone in future.

Materials and methods

Relevant data and information were collected from various sources including books, journals, conference proceedings, newspaper articles, as well as web based and other sources. Emphasis was laid on obtaining information regarding loss of human resources and biodiversity for analyzing the pattern of biodiversity damage due to cyclones. Close observation of the series of events including actions taken before the commencement of the cyclone, just after the disaster and causalities because of the catastrophe has enormous scope of learning to enhance preparedness strategies. Concerns raised by wildlife rescue teams, forest care takers, rehabilitators, and veterinarians during all these periods add substantial details into it which is crucial for biodiversity protection. Advance researches make the strategies even more capable of reducing effects of disaster.

The study area

The study area taken up for this research is Balukhand wildlife sanctuary located on the eastern coast of India along the Bay of Bengal. It covers an area of 1921 hectares and includes an entirely man-made forest sprawling on Chandrabhaga coast, and the Puri-Konark road that used to be one of the finest marine drives in Asia. The ecology of the sanctuary is largely influenced by the sea (Bay of Bengal) (Balukhand Wildlife Sanctuary - Wildlife *Odisha*, 2017). The Balukhanda-Konark tract was declared a sanctuary under the Wildlife Protection Act, 1972 in 1984 with the aim of conserving the coastal ecosystem and biodiversity. Protection of black

bucks (*Macropes excavatus*), found in large numbers, was the original aim behind the creation of this sanctuary (Nandi et al., 2020). It protects 59 villages towards the west side and provides shelter to a large number of animals and birds in the sanctuary (Nandi et al., 2020), (OTV, 2019c).

Results

Fani approached the Balukhand sanctuary with a gushing speed of over 205 Km/h from the southeast and ravaged the seaside parts of sanctuary in a devastating manner. Most of the uprooting and damages were observed towards the shoreline where the soil was loose and sandy. Wildlife temporarily disappears due to such devastating loss of their habitats and forest resources. Torrential downpour wiped out the entire vegetation cover in most parts of the sanctuary (Nandi et al., 2020). The situation for wildlife worsened in an alarming way in the absence of shed, shelter, food and ecosystem services. Existing exotic species of plants like eucalyptus, palm, cashew, suffered maximum destruction as they were neither native to Odisha nor had any resistance to cyclones unlike that of the native trees of costal Odisha (Chandrakar, 2015).

Distribution of pre-existing flora

The plantation started on sandy beaches on the outskirts of Puri towards Konark along the 40 km stretch in 1980. Existing species of trees (Table 1) were all institutionally planted. A few species of mangroves and associates (Table 1) are also seen naturally growing along the Nuanai River, which passes through the sanctuary (*Balukhand Wildlife Sanctuary - Wildlife Odisha*, 2017). The forest has a good composition of medicinal, commercial, and native species which have a varying degree of disaster resistance character. There were different types of grasses, mosses, herbs etc. which supported ecosystem services at large.

Table 1. List of existing flora (Pre Fani)

S. No.	Flora Category	Scientific name
1	Trees	Casuarina equisetifolia, Eucalyptus globulus, Acacia auriculiformis and Anacardium occidentale, Azadirachta indica, Tamarindus indica, Millettia pinnata, Albizia lebbeck, Bombax ceiba etc.
2	Shrubs and herbs	Rothia indica, Ipomoea pes-caprae, Spinifex hirsutus, Polycarpaea corymbosa, Opuntia stricta, Abutilon indicum etc
3	Mangroves and associates	Acanthus ilicifolius, Porteresia coarctata, Avicennia albaetc.

Sources: (Balukhand Wildlife Sanctuary - Wildlife Odisha, 2017; DNA, 2019; Nandi et al., 2020)

Extent of damage to flora

The flora and fauna in forests suffer tremendous loss form extreme cyclonic events. Although the

quantum of damage to flora resources in the Balukhand sanctuary due to cyclone Fani could not be properly analyzed and documented so far, information provided by forest guards has revealed that more than 80 lakhs trees were destroyed by the storm (OTV, 2019c). Field verification reports further revealed that Fani caused widespread sand deposition, trunk snapping, uprooting, stem loss, debranching, foliage removal, forest floor flooding, as well as washout of plant saplings, forest litter and seedlings at most of the locations (Nandi et al., 2020). Subsequently, it substantially destroyed ecosystem services rendering it incapable of supporting its life and functions.

Analysis of satellite images reveals severe damage to more than 90% of the forest landscape. Except for the main trunks of a few small and medium-height *Casuarina equisetifolia*, and bushes of *Opuntia stricta*, which were found rooted to the ground after the cyclone was over, the rest were washed away with sea water which reduced the capacity of the forest to regenerate on its own. Tree density got reduced immensely after the great loss and now the forest floor was open for harsh light to enter, which was enough to trigger deforestation. Non-native trees like Eucalyptus globulous, specifically taller and thinner, got completely wiped out as they are not suitable for plantation in such geographical locations (Nandi et al., 2020). Many plants of medical and commercial importance were also destroyed and lost forever (Sandeep, 2019). However native ones like some of the mangrove species underwent the least damage due to better resilience towards cyclone disturbances (Nandi et al., 2020). Tree debris drying on the forest and other storage areas put leftover reserves and the adjoining villages at additional risk of fire (Orissa, 2019a).

Distribution of pre-existing wildlife

Balukhand sanctuary is used to house various categories of fauna (Table 2) in large numbers. Meadows have been created inside the forest to provide them with sufficient food (*Balukhand Wildlife* Sanctuary - Wildlife Odisha, 2017). The sea shores of the sanctuary, where the endangered Olive Ridley Sea Turtles (Lepidochelys olivacea) nest their eggs, are the hotspots for tourists (Balukhand Wildlife Sanctuary - Wildlife Odisha, 2017). Despite being a wildlife sanctuary, the forest is often exploited and accessed for illegal small-scale logging, dumping of municipal wastes, beach hiking, road construction, wood pilferage etc. by the nearby community (Nandi et al., 2020).

Impact on wildlife

Long-term loss of habitat and biodiversity leads to an ecological imbalance within the

sanctuaries. Strong tropical cyclones such as Fani destroy both forest productivity as well as their capacity to regenerate themselves leaving long-term stress on wildlife survival (Nandi et al., 2020). Destruction of forests creates havoc and causes destruction of food chain, which further leads to starvation and the death of species (Sarangi, 2019). Forest infrastructure, which supports wildlife, monitoring, rescue and wildlife protection gets severely damaged and disturbed (OTV, 2019a, TV, 2019).

Table 2. List of existing fauna (Pre Fani) (Nandi et al., 2020, BALUKHAND Wildlife Sanctuary - Wildlife Odisha, 2017, DNA, 2019)

Orders	Scientific names
Mammals	*Antilope cervicapra, Axis axis, Semnopithecus entellus, Funambulus palmarum, Rusa unicolor, Melursus ursinus, Canis aureus, Panthera pardus, Macaca silenus, Muntiacus, Ratufa indica, Manis crassicaudata, Tragulidae, Tetracerus quadricornis, Erethizon dorsatum* etc.
Reptiles	Serpentes, Pythonidae, Gavialis gangeticus, Varanus, Chamaeleonidae etc.
Birds	*Haliaeetus leucogaster, Haliastur indus, Milvus migrans, Columbidae, Ardea alba, Ardeidae, Sterna aurantia, Larus argentatus, Dicruridae, Centropus sinensis, Athene brama, Microcarbo niger, Bubulcus ibis,* etc.

Extremely dense foliage in the forest of Balukhand Wildlife Sanctuary used to provide shade and shelter to a large number of creatures but ravaged by Fani, the forest and its floor has been exposed to harsher sunlight, which otherwise would have provided a pleasing shelter to many species (News, 2019). Approximately 4000 deer were found missing right after the cyclone and returned to the sanctuary a few days later (OTV, 2019c), (News, 2019). In many cases, animals jumped into water bodies and lost their life (Ghosh, 2020). The uprooting of large trees displaced the colonies of nesting birds. Many chicks and birds were either found dead or severely injured (WTI, 2019). Due to the loss of habitat and food chain some species escaped the sanctuary towards human shelters in search of food, which resulted in animal-human conflicts leading to further damage to wildlife (Barik, 2019, Sarangi, 2019, Sengar, 2019).

Impact of Human influence and intervention

A review of the situation in the aftermath of cyclone Fani has also exposed a serious knowledge gap and lack of a proper mechanism for rescue operations to provide medical aid to injured biodiversity. Due to a lack of experience and guidance, a considerable number of injured species could not be removed and recovered which put a question mark on the preparedness of the team of veterinary and trained caretakers in the aftermath of such events (Ghosh, 2020). Subsequent causalities caused by cyclone Fani highlighted serious shortcomings in administrative, academic and social systems that could have continuously monitored local biodiversity and ecosystem to provide the required information for rescue and restoration field works (Nishida et al., 2017).

This ecologically fragile area due to increased human intervention like tourism, weekend walks, road construction, wood pilferage, and illegal solid waste dumping, showed the least resistant to destruction by Fani and hence required prohibition of such activities to restore the ecology of the forest. It was also observed that exploitation and anthropogenic activities intensified the extent of damage to ecology to such a massive scale (Nandi et al., 2020).

Discussion

The type and extent of damages sustained by the flora and fauna of Balukhand Wildlife Sanctuary necessitate measures to be initiated towards biodiversity management and mitigation of impacts of such cyclonic events along with those that improve preparedness towards better safety and survival possibilities in future.

Restoration measures for flora

Unpremeditated plantations and uncontrolled exploitation of fragile coastal resources had made this region severely vulnerable to environmental hazards. Emergency response and other management plans should be considered from short, medium as well as long-term perspectives and action-plans (Nandi et al., 2020).

Immediate actions

The degree of damage depends upon the severity of the disaster. The nature of damages should be analyzed at the grass root level and their remedies should be executed in response to the documented damages. Biodiversity damages of urgent nature need to be dealt at an urgent basis (Nandi et al., 2020). Less damaged and uprooted trees should be replaced and restored (Sandeep, 2019). Survey mapping and GIS data should be analyzed to demarcate the extent of damages to the forest range so that it can help formulate replantation strategies(Government of Orissa, n.d.).

Medium-term actions

A GIS database should be prepared consisting of a list of species of different plants for monitoring and documentation purposes (Government of Orissa, n.d.). Records should be maintained to identify endangered plant species that have a high likelihood of going extinct in near future. A complete directory of existing species of flora should be created and rare, threatened and endangered species must be identified, their seeds should be collected and stored in designated seed banks so that they could be recovered after incidences of severe loss to the forest. Seeds, pollen, DNA, and tissue cultures should be preserved in various repositories to recover the loss of plants in an extreme situation (Chandrakar, 2015).

Long term measures

Plantation and ecosystem regeneration activities should be looked after and supported on a long term basis because lost vegetation takes years to regenerate its vitality (Nandi et al., 2020). Post-cyclone forest management provides a unique opportunity to build a sustainable and resilient ecosystem in a wildlife sanctuary (Orissa, 2019a). Ecological restoration strategies should be adopted as an alternative to regenerating the forest ecosystem through strategic plantation (Nandi et al., 2020).

Plantation of native grasses like Porteresia coarctata should be done in non-vegetated gaps which could support regeneration of lost vegetation cover. Rather than species that are exotic or of commercial benefits, plantation of deep-rooted native species like Alstonia scholaris, Millettia pinnata, Lantana camara, Cocos nucifera, Mimusops elengi, and Ceriops decandra etc. should be promoted, which exhibit higher resilience in tropical storms (Orissa, 2019a), (Nandi et al., 2020). Fragile species like Eucalyptus globulus should be strictly prohibited in post-cyclone plantation as their lower resilience to tropical storms poses risk of damage to the local ecosystem (Nandi et al., 2020). Coastal dunes play an important role by acting as the first line of defense against storm/tidal surges. Mixed native species plantation strategy should be adopted to recreate diversified ecosystem and species like Azadirachta indica, Millettia pinnata, Butea monosperma etc. should be planted to withstand high wind speed (Orissa, 2019a). Native herb species like Ipomoea Pes-caprae, Cyperus arenarius, Spinifex hirsutus, and Acanthus ilicifolius should be planted followed by shrub species like Pandanus tectorius which can support dune and bank stabilization (Nandi et al., 2020).

Miyawaki method of plantation can be adopted to grow dense wild forest comprising local species to restore the indigenous ecosystems in the aftermath such disasters (Schirone et al., 2011). This technique ensures 10 times the normal speed and 30 times the normal density of plant growth. Forests towards the coastal borderline should be planted only with native, disaster-resistant species in a very dense pattern which can act as the first line of resistance for any cyclone as they are the most exposed to disasters.

Strategies to safeguard wildlife resources

In the aftermath of such an extremely devastating natural disasters human communities rush to support each other while wildlife is left to its fate. Human beings have a moral responsibility to look after those innocent creatures. Every possible action must be taken to safeguard the interest in biodiversity conservation before and after cyclones.

Pre- and post-cyclone immediate preparedness

A control room should be established that can monitor and guide all events on a 24X7 basis for rescue operations or other needs for all sorts of wildlife and biodiversity. Alerts and investigations from the disaster monitoring and control room should be channelized properly to the investigating team for rescuing wildlife. All concerned departments and units should work in coordination (Orissa, 2019b). Existing zoos in the nearby areas must be geared up with necessary aids to support wildlife in such circumstances (SEOC, 2019). Vulnerable and endangered species can be tracked and shifted to a safe location till the cyclone recedes. A team of veterinary doctors should be availed from the region after the event has been forecasted so that healthcare facilities can be provided on an urgent basis (OTV, 2019a). Necessary medicines, equipment and kits should be availed in a rescue operation (Orissa, 2019b).

Communities residing nearby should be sensitized not to harm wildlife but rather to inform if any wild animal is found outside the sanctuary and provide them shelter and security if possible until they are rescued (DNA, 2019; Orissa, 2019b; Sengar, 2019). Disaster management teams, media, FM channels etc. should conduct awareness programs about protection of wildlife instead of harming them, giving them safe shelter and informing the concerned NGO/Organization (Sengar, 2019; Orissa, 2019a; DNA, 2019). Animal and human conflicts should be checked by deploying special squads in vulnerable areas to rescue and protect wild animals (WTI, 2019), (Orissa, 2019b).

Patrolling paths and other roads should be cleared on priority so that patrolling and inspection is carried out smoothly. Drone cameras should be availed to assess damages and investigate rescue operations roads are blocked for the movement of vehicles (WTI, 2019; OTV, 2019b; OTV, 2019b). Cyclone-proof power supply should be installed so that rescue operations could be continued without any obstructions (Patra et al., 2013). All sorts of dead biotic components find their way into the adjoining water bodies which makes them highly polluted and unsuitable for consumption on which all species depend for drinking water. So, clearing debris from water bodies should be of utmost priority to prevent a subsequent disaster in form of diseases among the sanctuary's wildlife. Arrangements should be made for quick identification and removal of carcasses to prevent the spreading of diseases among the wildlife of the sanctuary (Orissa, 2019b).

Uprooting of large trees displaces colonies of nesting birds. Young species are especially vulnerable and incapable to protect themselves, hence they must be rescued immediately after the event as much as possible (Orissa, 2019b). Temporary holdings should be created where

rescued chicks and injured birds can be nursed and rehabilitated by trained caretakers (WTI, 2019). Small sheds should be prepared for animals. Food and water should be provided (Orissa, 2019b; OTV, 2019a; Orissa, 2019b). Food can also be dropped with the help of robotic drones in and inaccessible areas. Operation of the stabilization, feeding, rehabilitating and rescuing and monitoring should be continued until wildlife returns to its normal condition (WTI, 2019). Replantation should be initiated considering the extent of damage so that productivity can be restored and food chain can be regenerated as quickly as possible for wildlife (Trees for Cyclone-Affected Area, n.d.).

Long term action plan

Record of existing wildlife should be maintained, and the following types of species should be identified.

a. Category of endangered species which have high chances of going extinct in coming future (Chandrakar, 2015).

b. Category of vulnerable species whose population is decreasing considerably and are going to be declared as endangered species in near future (Chandrakar, 2015).

c. Some rare species that have very low population due to limited geographical range or very low population densities (Chandrakar, 2015).

d. Partially known category of species that probably belong to one of the conservation categories but are not sufficiently known to be assigned under certain specific category (Chandrakar, 2015).

Endangered species must be identified and monitored on regular basis. Radio-telemetry and GPS systems should be used in wildlife conservation, which will be useful in tracking their real time location after a cyclone (Habib et al., 2014). Genes/germplasm/semen of endangered and soon to be endangered species should be protected and conserved through proper channel. Research and development programs should be connected with wildlife protection and conservation so that further development could be made (Chandrakar, 2015).

Immediate actions must be taken to replant the trees and revive the whole ecosystem so that wild life habitats can be restored at the earliest (WTI, 2019),(Trees for Cyclone-Affected Area, n.d.). Traditional knowledge system and conservation skills must be supported and adopted as per local environment, which will also ensure cost effectiveness (Chandrakar, 2015). Biodiversity conservation program should be adapted by creating a network of protected areas such as national parks, biosphere reserves, gene banks etc. Access to different nature reserves must be ensured during such events of long- and short-term migration of animals, if needed (Chandrakar,

2015). Active participation of local people towards conservation and protection of biodiversity should be ensured by creating local committees to support wildlife rescue and rehabilitation to a large extent (Government of Orissa, n.d.). Public participation, training and preparedness must be ensured as much as possible (Sengar, 2019). Also, intensive, and regular training much be provided to employees, staff, and workers of sanctuaries towards the rescue and rehabilitation of wildlife.

Conclusion

The authors conclude that extreme weather events shall continue to occur in future, with increasing frequency and intensity as a result of the substantial impacts of climate change on the environment globally. Vulnerability is likely to increase as climate change is accelerating and such disasters are going to be even more unpredictable and frequent. It has also been proved that tropical cyclones can cause severe disasters to the forest landscapes which have an overwhelming impact on their existence and survival. The extent of damage depends upon the severity of the cyclone, yet preparedness can avert the damage to wildlife to a large extent. Rehabilitation and ecosystem regeneration can restore the biodiversity of the affected biome. This study explored possible strategies and mitigation measures for the restoration of biodiversity both as preparatory measures as well as in the aftermath of tropical cyclones as immediate actions, medium-term and long-term measures. Human beings, an important component of the global ecosystem, have the moral responsibility to be sensitive towards the devastation of the ecosystem due to weather events of such extreme nature. Plants and animals should be treated with the same compassion that is exhibited towards fellow human beings when needed.

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