



Functional Role of Elephants in Maintaining Forest Ecosystem and Biodiversity: Lessons from Northwestern Elephant Range in India

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Authors' contributions

This work was carried out in collaboration among all authors. Author RJ designed the study and conducted the field visits. Authors RJ and KP wrote the protocol and managed the analyses of the study. Authors RJ, KP and VY managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This article focuses on the functional role of Asian elephant in maintaining forest ecosystem and biodiversity. Elephant performs different activities in forest which greatly influence ecosystem processes, plant communities and trophic structure of the community. Elephants have cascading effects in altering the vegetation regeneration and providing habitat, water and nutrients to other animals. Besides, elephants also have affirmative effects in controlling illegal poaching, promoting ecotourism and act as an indicator species to know about natural calamities. The information compiled in the present note is based on the literature available and field experience gained in the Rajaji National Park, India. Since elephants play a crucial role in ecological trajectories of ecological communities, developing a rigorous framework to evaluate the qualitative influence made by the elephants in ecosystem would be of paramount importance.

Keywords: Asian elephant; biodiversity; northwestern India; ecotourism, forest ecosystem.

1. INTRODUCTION

It is widely acknowledged that ecological role of wildlife species greatly influences ecosystem, which includes changes in plant communities, ecosystem processes, geomorphology and trophic structure of a community. Even from a tourism perspective alone, presence of wildlife facilitates to boost up the tourism industry. Traditionally, wildlife-habitat relationships, models and databases have focused on how the presence of terrestrial vertebrates is influenced by environmental conditions [1].

Species are an integral component of ecosystems and the value they provide in terms of services should be a standard part of ecosystem assessments [2]. Interactions among species are the backbone of biodiversity, which create the architectural foundation of ecosystems [3]. Ecosystem functions are recognized as important for maintaining ecosystems and biodiversity and are important to maintain the capacity of the region to supply ecosystem services [4]. However, community interactions and ecological roles of species and how organisms change their environments, have been studied rarely [1].

Elephants are one of most iconic and keystone species in forests playing a crucial role in maintaining forest ecosystem and biodiversity (Fig. 1). Several species are associated with elephants to fulfill their routine life requirements. Elephants perform different activities in forests, which assist other wild animals to interact with their ecosystem. Movement of elephants over large landscapes and wide range of habitats also facilitates the territorial animals in interacting with other living communities. The issue of the effects of elephants within ecosystems has emerged strongly since the formulation of the concept of the elephant problem and the concerns that elephants may irrevocably alter the remaining areas, which are available to them [5]. Recently, a study carried out on the effects of elephants on ecosystem and biodiversity pointed out that the modern African elephant emerged about 3 million years ago; therefore, its relationships with other animal and plant species have been an integral part of the co-evolutionary history of the ecosystems and biodiversity of Africa [6]. Studies carried out in some of the African elephant ranges have described 19 relative role of

elephants in ecological processes, which includes browsing, frugivory, seed dispersal, wallow formation, litter production, etc. [6, 7].

Elephants are intelligent and highly social animals and their cognitive ability and capability to respond as per the changing environment makes them less vulnerable and help other wild animals to survive in harsh environmental conditions. It is now widely acknowledged that the elephants are intelligent and learning to adapt to their changing natural environments [8, 9, 10]. A study carried out on the behaviour of elephants in Rajaji National Park pointed out that elephants are learning to adapt themselves to fulfill their requirements, according to the changing environment [11]. Such ability of elephants not only makes them less vulnerable to changing environment but also support other animals in maintaining their existence during severe environmental conditions.

Elephants are known for their large migrations across myriad types of landscapes. Since an adult elephant needs more than 100 kilograms of food every day, which range from grasses to browse, barks, fruits and bulbs, providing a natural connectivity of corridors would ensure their effective participation in restoration of ecological corridors. Connectivity of large migratory corridors also provides the elephant to move across larger landscapes and breed conveniently, ensuring their long-term survival. However, the population of this giant animal remains fragmented and restricted to the foothills dominant areas, mainly because of the conversion of natural habitats to the agricultural fields, industrial areas and human habitations. Asian elephants disperse seeds over several kilometers, although distances are much shorter than those described for African forest elephants, which might reflect a bias towards the study of Asian elephant movements in highly fragmented landscapes [12]. As for other wildlife species, our knowledge about the functional role of elephants in forests is limited and there is a need to document their functions in forest, which strengthen ecological trajectories and communities. This note provides an insight on the role of forest elephants in management of ecosystem and biodiversity.



Fig. 1. Effects of elephant on ecosystem

2. ELEPHANTS AS SEED DISPERSERS AND HABITAT PROVIDERS

Elephants are one of the imperative species, who disperse the seeds of trees; even some species rely entirely on elephants for seed dispersal. The digestive efficiency of a large herbivore is relatively low, elephants absorb only 50 percent or less of the nutrients from the food which they consume [13,14]. Similarly, in the African elephants, the digestive efficiency is quite low, with less than half of the ingested food being assimilated and the remainder passed out as faeces [6]. Elephant play an important role in dispersal of seeds of large trees like black cutch (*Senegalia catechu*), bhimal (*Grewia optiva*), Indian jujube (*Ziziphus mauritiana*), orchid tree (*Bauhinia variegata*), Indian rosewood (*Dalbergia sissoo*), black plum (*Shyzzgium cumini*), wood apple (*Aegle marmelos*), kamala tree (*Mallotus philippensis*), cluster fig tree (*Ficus racemosa*), etc., as some portion of ingested food is released as faeces.

Since a mature elephant consumes more than 100 kilograms of food every day, the large volume of forage intake by the elephants allow them to disperse large numbers of seeds. Elephants aid in the dispersal and subsequent germination of seeds, by their fruit-eating habits; the passage through the elephant gut helps break the dormancy of seeds and speeds up

their germination [13]. Mortality of seeds during passage through the digestive tract was significantly lower in elephant compared to a model ruminant [15]. Some megafaunal-syndrome plants have developed large seeds protected with a thick testa that benefit from going through elephant guts in that gastric acids scarify the seeds and break dormancy, thus stimulating germination [16]. Failures of seed dispersal are currently the most obvious impacts of animal losses, and restoration of seed dispersal services is potentially one of the most effective ways of enhancing forest recovery after logging and increasing resilience to climate change [17].

Dung piles of elephant play an important role in creating micro-habitat in forests. Elephant dung provides an ideal food source and habitat to fungi, beetles, termites, ants, centipedes, crickets, spiders, etc. Butterflies also use to suck nutrients from the dung. Several species of birds like peacock, parakeet, jungle fowl, pigeon and jungle babbler also use elephant dung to feed on tiny seeds, as these are rich in nutrients. Studies carried out in African elephant ranges reveal that dung beetles use elephant dung to protect their larvae, which later provides the honey badgers with a rich food sources as they will then dig up the dung beetle balls and feed off the plump grubs inside [18]. All such functions performed by the elephant dung rejuvenate entire habitats.

3. ELEPHANTS AS HABITAT MODIFIERS AND FEEDING OPPORTUNITIES PROVIDERS

Terrestrial mammals regularly use trails inside the forests, which generally prepared by the elephants (Fig. 2). Interestingly, other wild animals use these trails during their routine activities. The elephants always use some fixed paths to move inside the forest. However, during their migration in monsoon, such trails are damaged. Besides, elephants establish a gap in vegetation while feeding on the vegetation; such gaps facilitate vegetation regeneration and in creating small rough routes for other animals. As the dung of elephant consist seeds and nutrients, the movement of elephants across the open and degraded forests helps in regeneration of vegetation, which in turns alters the wilderness of the ecosystem.

In order to feed on some of the roots of succulent species of grasses like kans grass (*Saccharum spontaneum*) and munja grass (*Saccharum munja*), elephant dig out the grass tussocks (Fig. 3). They clean grass tussocks to dislodge soil with the help of their forefeet. During the process of uprooting the grass species, elephants create small holes in grasslands. When elephants feed upon the soft roots and move away, some of the animals like wild boar, hare and porcupine feed on the remains. Small holes established during the process are sometimes utilized by the rodents as well.

Elephants produce several effects on the habitat, which may affect other animals as well. Sometimes, spotted deer (*Axis axis*), barking deer (*Muntiacus muntjak*) and sambar (*Rusa unicolor*) used to follow elephants when they were feeding on some specific plant species, which the deer could not access at their own. Elephants often break the twigs of the trees like Indian banyan (*Ficus bangalensis*), Indian fig tree (*Ficus racemosa*), cotton tree (*Bombax ceiba*), silver grey wood (*Terminalia elliptica*), Java plum (*Syzygium cumini*), orchid tree (*Bauhinia variegata*), Indian jujube (*Zizyphus mauritiana*) and Indian gooseberry (*Phyllanthus emblica*) to feed on soft twigs, removing the leafy portion, which is consumed by ungulates. Elephants utilize only the bark and soft twigs after removing the leaves from them and the leafy portion remains as such on the ground. Ungulates consume the thrown leaves as fodder, once the elephants move away from there. Even relatively small herbivores can have profound effects in

shaping ecosystem structure, particularly when they occur at high densities [6].



Fig. 2. Two cow elephants along with one baby climbing up in a hillock through a narrow passage. Such movements of elephants are helpful in maintaining forest trails



Fig. 3. Bull elephant is dusting-off mud from *Saccharum spontaneum* (a grass species) to feed upon its roots

4. ELEPHANTS AS WATER PROVIDERS

Elephants can sense the underground water sources. They dig holes in potential dry riverbeds using their forefeet and trunk, especially during summer to drink fresh water, since by nature, elephants do not prefer to drink dirty water (Fig. 4). These small water points are later utilized by the small animals like spotted deer, sambar, small Indian mongoose, Asiatic jackal, small Indian civet, wild boar, etc. Besides some birds including peacock, parakeet, pigeon and jungle fowl also utilize such water sources to drink and bath. Such behaviours of elephants facilitate in establishing associations with other animals, especially during harsh conditions. A

study carried out on the ecology of Asian elephants in Sri Lanka revealed that elephants do have associations with other wild animals, which benefits them and the other animals in various ways like feeding and drinking [19].

Similar behaviours of elephants have also been recorded from most of the African elephant ranges, wherein elephants were found using their tusks to dig water [20]. This not only allows the elephants to survive in dry environment, especially when droughts strike, but also provides water for other animals that share harsh habitats. The desert elephants in Africa travel miles in search of water and remember the underground water spots from which they can draw out the water; the water spots remains open for other animals to drink [18]. It is also a fact that some of the communities follow elephants for many miles in Kenya, as the elephants lead them to water sources.



Fig. 4. Indigenous knowledge: Elephants dig out the water from a dry river bed at Rajaji Tiger Reserve. Footprints of elephants and dung piles are clearly visible



Fig. 5. Water pool created by the elephants at Chilla forest in Rajaji Tiger Reserve

In forest, elephants use several fixed spots for rest. Such spots sometime turn in to a small open patch (Fig. 5). During monsoon and winter, rain water gets deposited in these patches, which later act as a water spot for animals. Some of these patches act as wallowing and drinking points for animals. In such a way elephants are able to create small ponds and wetlands and provide opportunity to ungulates to use these water pools. During monsoon, various species of reptiles and amphibians also use these pools as their habitat. All these functions perform by the elephant can influence the distribution of animals as well, which may affect the population dynamics of wildlife.

5. ELEPHANTS AS ECOTOURISM PROMOTERS

In India, wildlife tourism is increasing mainly because of the presence of rare species in forests like Bengal tigers, Asian elephants, Asian one horned rhinoceros, Asiatic lions, Nilgiri thar and marten and red panda. Further presence of bird species and arrival of winter migratory birds attracts the tourists to stay connected with protected areas of the country. Unique landscapes and frequent sighting of wild animals form major tourist attraction during wildlife expedition. Recent statistics reveal that wildlife safaris in Indian forests account for one third of tourism sector. Elephant in Indian forests is a magnificent species which plays a vibrant role in increasing tourist footfall. India currently has 29 Elephant Reserves, which are natural home to Asian elephants.

The world famous Corbett Tiger Reserve is famous for its healthy population of Bengal tigers. Every year tourists from the world visit the reserve to see the tigers in their natural habitat. Similarly, Rajaji Tiger Reserve is known for its population of free ranging Asian elephants. Rajaji Tiger Reserve also consists of a healthy elephant sex ratio. Every year lacks of both national and international tourists visit the reserve to see the elephants in their natural habitat. Recent statistics reveal that during the years 2015-2016, nearly 45,590 tourists visited the reserve, and a revenue of Rs. 1,02,02,739/- was received. Therefore, learning the experience of ecotourists and sharing the functional role of elephants in keeping the ecosystem vibrant and maintaining biodiversity would contribute to our objectives of the Indian Wildlife (Protection) Act 1972.

6. ELEPHANTS AS INDICATOR SPECIES

For centuries it has been considered that animals have a sixth sense, as they have some senses more developed than those of human beings. It is said that animals can sense changes in environment and are capable of sensing and predicting natural calamities before occurrence. Human beings are able to hear sounds that are in the range of 20 hertz to 20,000 kilohertz, and cannot detect any sound beyond this range. However, some animals transcend this range and can sense these sounds. Various wildlife experts pointed out that animals have intense hearing abilities which make them capable of feeling the earth's vibration before the human beings. A catastrophic tsunami hit the Northern Sumatra islands on 26 December 2004. Statistical data revealed that more than 150,000 people in a dozen of countries were killed by tsunami. Interestingly, only a few animal deaths were recorded during the period. According to a report strange behaviour of animals was observed and nearly an hour before the tsunami hit, people at Yala National Park observed three elephants running away from the Patanangala beach [21].

O'Connell-Rodwell, a renowned wildlife expert in the Stanford University, has given a detailed insight on elephant communication, which reveal that elephants communicate over long distances using low-pitched sounds that are barely audible to human beings [22]. Nearly two decades ago, her studies indicated new direction by proposing that low-frequency calls also generate powerful vibrations in the ground-seismic signals that elephants can feel, and even interpret, via their sensitive trunks and feet. Earlier it was known that seismic communication is common in small animals, including spiders, scorpions, insects and a few vertebrate species, such as white-lipped frogs, kangaroo rats and golden moles. However, O'Connell-Rodwell for the first time suggested that large land animals are capable of sending and receiving vibrational messages. During the tsunami, she recorded that trained elephants in Thailand were agitated and fled to higher ground before the devastating wave struck, thus saving their own lives and those of the tourists, riding on their backs [23].

A study carried out on the tornadic storm avoidance behaviour in breeding songbird indicated that close observations of the behaviour of certain species of animals in the time period before natural disasters such as

tornadoes, earthquakes and storms, could help with disaster mitigation planning and evacuation procedures [24]. Although there are no tangible scientific evidences, which may validate this theory about animal's power of detecting natural disasters before they actually occur, there are significant anecdotal evidences from which reasonable explanations can be concluded. This aspect, however, needs to be studied in Indian elephant ranges.

Currently, most of the elephant ranges are suffering from the consequences of human-wildlife conflict. Today, Asian elephant is listed under Schedule I of the Indian Wildlife (Protection) Act 1972, Guidelines of the CITES and as Endangered in IUCN Red List of Threatened Species. As per the recent records, over 1,000 people have been killed since the year 2014 by the elephants in India. Unfortunately, about 650 elephants also died for various reasons since the year 2009-10, which include natural and accidental deaths. Large-scale habitat loss, developmental activities and human encroachment into the deeper forest regime have escalated the instances of man-elephant conflict in the country, which also leads to the unnatural deaths of elephants. In order to provide financial and technical support to wildlife management efforts by the Indian States in respect of their free ranging populations of wild Asian elephants, the Ministry of Environment, Forest and Climate Change, Government of India launched 'Project Elephant' in 1992. The project aims at ensuring long-term survival of viable populations of elephants in their natural habitats by protecting the elephants, their habitats and migration corridors.

7. CONCLUSION

Elephants play a major role in restructuring forest ecosystem and biodiversity. This aspect has so far been poorly studied and needs attention, which would fill gaps in our database as well. Elephants have cascading effects in altering the vegetation regeneration in forests, providing habitat, water and nutrients to other animals. Besides, elephants also have an optimistic effect in promoting ecotourism and indicating about natural calamities. In most of the protected areas, people live near elephant habitats and are dependent upon forest resources. It is true that human encroachment into the forest and elephant movement across the agriculture fields has established a conflict over resources and brings this giant animal at risk. However, it is also

a fact that in forests where such a mega-herbivore and other wild animals like tigers, leopards and bears reside, people feel threatened and do not enter the forest frequently. The fear of causality restricts the local people even the unauthorized people from entering the elephant areas, which also control illegal poaching.

The loss of elephants will have severe negative consequences for the ecological trajectories of some plant species and whole ecological communities [16]. Protected area managers of different elephant ranges along with the frontline wildlife staff may develop a rigorous framework to evaluate the qualitative influence of elephants and other wildlife on their immediate ecosystems. This would not only help in designing a concrete plan of action/roadmap for landscape management but also in conducting an empirical study on its natural history. In most of the elephant ranges, the frequent movement of elephants has restricted to smaller pockets mainly because of habitat fragmentation and disconnectivity of large migratory corridors. This has also affected the activities of this mega-herbivore in larger landscapes. Since elephants play an important role in managing the entire ecosystem functions, restoration of large fragmented forest stretches and corridors for elephant migration and habitat management are of paramount importance. Moreover, local community and stakeholder's participation in conservation initiatives and habitat monitoring would be an effective management and conservation strategy.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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