Analysis of Dietary Preferences of Asian Elephants (*Elephas maximus*) in Rajaji Tiger Reserve, Uttarakhand

Dissertation Submitted in Partial Fulfillment of the Requirement

For the Degree of

Master of Science in Biodiversity & Conservation

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Candidate's Declaration

I, Ayushi Kothari hereby declare that the dissertation entitled, "Analysis of Dietary Preferences of Asian Elephants (*Elephas maximus*) in Rajaji Tiger Reserve, Uttarakhand" is authentic work carried out by me under the supervision of Prof. Rita Singh for the fulfillment of the award of the Degree of Master of Science in Biodiversity & Conservation of Guru Gobind Singh Indraprastha University. The matter embodied in this Dissertation has not been submitted anywhere else for the award of any other Degree/ Diploma.

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Certificate

This is to certify that dissertation entitled "Analysis of Dietary Preferences of Asian Elephants (*Elephas maximus*) in Rajaji Tiger Reserve, Uttarakhand" which is submitted by Ms. Ayushi Kothari, Enrolment Number 00116300319 in partial fulfilment of the requirement for the Degree of Master of Science in Biodiversity & Conservation, Guru Gobind Singh Indraprastha University, Sector 16C, Dwarka, New Delhi is a record of the work carried out by the candidate under my supervision.

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Dissertation Approval Sheet

This is to certify that the dissertation entitled, "Analysis of Dietary Preferences of Asian Elephants (*Elephas maximus*) in Rajaji Tiger Reserve, Uttarakhand" submitted by Ms. Ayushi Kothari, final year student of M.Sc. (Biodiversity & Conservation) Guru Gobind Singh Indraprastha University is approved for the Degree of Master of Science in Biodiversity & Conservation.

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Date:

Place:

Abstract

The main objective of this study is to document the fodder species that are consumed by Elephants (*Elephas maximus*) in Rajaji Tiger Reserve, Uttarakhand throughout the year. Elephants are well adapted to living in a diverse range of habitats by exploiting a wide variety of plant species, however in the study area elephants have been observed feeding on only 50 plant species which are available throughout the year to elephants. Consumption of tree species is the highest followed by grasses and shrubs. Elephants prefer eating fruits and ignore other plants if fruits are present in abundance. Feeding is dependent on migration and water availability. Elephants sometimes spend long time to feed on some particular plant species like Bans/Bamboo *(Dendrocalamus strictus)*, Rohini *(Mallotus phillipinensis)* and Teak *(Tectona grandis)*. Feeding and food preferences are one of the most important factors to study the ecology, habitat management as well as habitat utilization of a mega-herbivore like elephants. Fragmentation of elephant's habitat leads to expansion or shifting of their ranges often in search of alternative food resources resulting in conflict amongst species. It has been proven that anthropogenic climate change is also leading towards the distribution of plant species to higher altitude or towards the pole. The study also highlights how climate change can affect elephants.

TABLE OF CONTENT

List of Figures

List of Tables

1. Introduction……..1-4
2. Review of Literature……5-9
3. Objectives……..10-11
4. Methodology……12-15
   4.1 Study area
   4.2 Methods
5. Results…….16- 28
   5.1 Comparison with previous years studies
6. Discussion……29-33
7. Conclusion…….34

   References……..35-37

List of Figures

Fig1. Population distribution map

Fig2. Tourist map of Rajaji Tiger Reserve

Fig3. Rajaji Tiger Reserve in Uttarakhand map

Fig4. Adult Elephant in Rajaji Tiger Reserve

Fig5. Chart of fodder plant species in Rajaji Tiger Reserve

Fig6. Chart of fodder plant species in Kuldiha wildlife Sanctuary

Fig7. Comparison between Dicot and Monocot species fed upon by elephants in two different geographical zones

List of Tables

Table1 Elephant food species, their common names and part eaten.

Table2 Season-wise Utilization of fodder species by elephants In Rajaji Tiger Reserve

Introduction

Elephants are the largest land mammals on earth today. They are key stone species often referred to as Ecosystem engineers. There are two genera in the order Proboscidea found on our planet today-Asian Elephant (*Elephas maximus* Linn.) which historically has been divided into three subspecies- *Elephas maximus maximus* from Sri Lanka, *Elephas maximus indicus* from India (Asian mainland) and *Elephas maximus sumatranus* from Sumatra. The genetic studies however do not differentiate between Sri Lankan and Asian Mainland Elephants and therefore they should be considered as same species (Fernando et al., 2003). The African Elephant with two subspecies- the savanna (or bush) elephant (*Loxodonta africana*) and the Forest Elephant (*loxodonta cyclotis*). The other two orders *Mammuthus* and *Mammut* disappeared around 10,000 years back (Haynes, 1993). Both African and Asian Elephants considerably differ in physical appearance with Asian elephants being smaller than their African cousin. *Elephas maximus* is the only living species of genus *Elephas* that evolved around Africa 5-6 million years ago and later migrated to Eurasia about 15 million years ago (Haynes, 1993).

Taxonomic Classification of Elephants (Haynes, 1993)

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Proboscidea

Family: Elephantidae

Subtribe: Elephantina

Genus: *Elephas*

Species: *Elephas maximus* (Asian elephant)

Subspecies: *E. m. maximus* (Sri Lankan Asian elephant)
Subspecies: *E. m. indicus* (mainland Asian elephant)
Subspecies: *E. m. sumatranus* (Sumatran Asian elephant)

Subtribe: Loxodontina

Genus: *Loxodonta*

Species: *Loxodonta africana*

Subspecies: *Loxodonta africana africana* (bush or savannah elephant)
Subspecies: *Loxodonta africana cyclotis* (forest elephant)

The natural range of Asian Elephants is confined to Asia (Sukumar, R. 2006). Their average life span in the wild is 60 years. India holds the largest surviving population of Asian elephants, today more 50% of the world's Asian Elephants are thriving in different parts of India (Sukumar, 2006). The state of Uttarakhand has 1346 elephants distributed in its protected areas (Sukumar, 2006). However the population of elephants is declining due to habitat fragmentation, illegal hunting, conversion of forest into agricultural land and human sprawl. Recent development activities have caused a major decline in the flora and terrestrial fauna. Just like many other wild animals, the Asian elephant is under a constant threat due to anthropogenic activities (Leimgruber, 2003).

Asian elephant enjoys the title of 'flagship species' in Rajaji Tiger Reserve (Johnsingh, 1994). Flagship species are those species that serve as an icon or a symbol for defined habitat or an environmental cause (WWF). Elephant viable population can only be maintained in large areas with abundant drinking water, abundant forage and protection from poaching which is all being provided in Rajaji Tiger Reserve (Johnsingh, & Joshua, 1994). Elephants create trails along dense forest land by pushing down trees and facilitate the feeding and movement of other small herbivores. Further they also play an important role in dispersing seeds, nutrient cycling, and have particular impact on plant species through their food requirements. Thus they are referred to as 'ecosystem engineers' (Johnsing, 1994).

Rajaji Tiger Reserve is one of the most successful National Parks established in the year 1983 for the enhancement and long term survival of Asian Elephants. It spreads over an area of 820.42 kilometer square along the North western shivalik landscape which lies in the upper Gangetic plains and lesser Himalayas (Joshi &Singh, 2006). The vegetation is mostly dry deciduous forest dominated by tall grasslands and *Shorea robusta* (sal) trees (Joshi &Singh, 2006). Wildlife in the range includes *Panthera tigris* (tiger), *Panthera pardus* (leopard), *Melursus ursinus* (Sloth bear), *Hyaena hyaena* (Hyaena), *Muntiacus muntjak* (Barking deer), *Axis axis* (Spotted deer), *Cervous unicolor* (Sambhar), *Sus scrofa* (Wild boar), *Ophiophagus hannah* (King cobra) and many

species. The Shivalik landscape is one of the few places in the world where Asian Elephants thrive (Joshi &Singh, 2006).

In the past Gujjar community used to reside inside the park area however they have been rehabilitated now by the state government. Extensive tree lopping, collection of fuel wood, cattle grazing, and grass cutting by this nomadic community has restricted the generation potential of many important fodder plants (Joshi & Singh, 2008), polluted water bodies and further proliferation of weeds. Over a period human population around the park areas has increased and urbanization has led to loss of forest areas to construction and industries (Johnsingh, 1994). A study on elephant demography was conducted between 1996 and 1999 by Williams (2006). At that time, the area was divided into Rajaji National Park and Motichur Sanctuary. An estimated population of 300 elephants was classified in that study. Elephant populations are declining due to unnatural deaths like train and road accidents, electrocution (Singh, 2006, Joshnsingh, 1991). 25 Elephants have been reportedly killed between 1987 and 20018 in Train–elephant Collisions on Haridwar-Dehradun Railway track that passes through Rajaji Tier Reserve (Joshi &Puri, 2019). There is an increasing concern that the area wise population decline of elephants will have an unexpected and dire consequence for long term viability of forest ecosystem.

Asian Elephants are mega-herbivores, weighing from 2500kgs (females) to 5000kgs or more (males) and can reach a height of up to 908 feet. They can consume 150kg of fodder in one day (Bi et al., 2016). Elephants can affect a variety of process through their food habits, digging and movements. The mostly eat grasses, roots, barks and fruits. Their food requirements are particularly high in dry season and they migrate during dry season due to high energy demand (Joshi & Singh, 2008). Therefore, availability of food resources is a barrier in habitat carrying capacity and also affects the distribution of elephants in the given area. Elephants are generalist feeders and consume a wide number of plant species however there are variations seasonally and regionally depending on the availability of fodder species. They can feed over a large number of plant species in the area but only few species account for most of their total intake.

Elephants are keystone species. They play an important role in maintaining forest ecosystem and biodiversity (Puri & Joshi, 2019). Through their feeding, digging and movement they effect a broad variety of ecological process (Kerley, 2008). They act as habitat modifiers and provide

feeding opportunities to other smaller herbivores. Small herbivores like Deer and Sambhar have been observed following Elephants when they were feeding on some specific plant species which the deer did not have access to (Puri & Joshi, 2019). Elephant feeding and breakage impacts on plants are greater in magnitude than smaller herbivores (Kerley, 2008). In this way they affect the structural component of vegetation. Elephants being mixed feeders consume a wide range of plant parts from browsing to grasses. They have a broad diet (example- 112 plant species in southern India). Elephant herbivory can therefore influence the fate of a considerable number of plant species (Kerley, 2008).

Elephants have a depressed digestive efficiency (Clauss, 2007). This makes them susceptible to toxins and tannins therefore they search for parts of plants that have only small amount of such chemicals (Kerley, 2008). About 50% of the material eaten is passed undigested through the gut. Digestion takes place in capacious hindgut, comprising small intestine and colon (Kerley, 2008).Elephant feeding strategy consist of consuming enormous quantities of low quality food, which passes rapidly through the gastrointestinal tract. Digestive physiology suggests that elephants gain nutrition from quantity rather than quality of food available to them (Fernando, & Leimgruber 2011). Elephants both graze and browse depending on the proportion of plant availability. The areas over which elephants move depend on the availability of plant species and water. This provides information on home-range sizes and elephant movement which is further important for conservation planning.

Since Rajaji Tiger Reserve currently has 352 elephants as per the census of 2020 and there has not been much research in feeding ecology of Asian Elephants, the topic was selected to survey the species on which Asian Elephants feed according to their availability in Rajaji Tiger Reserve. The survey was initially designed to carry out on ground and collect first hand data but due to restrictions imposed by COVID 19 lock down first hand data collection could not be done and published data on the food ecology was collected and analyzed.

Review of Literature

Today, there are an estimated 440,000 elephants left in the world. While African elephants have a vulnerable status as per IUCN, Asian elephant was listed as Endangered by IUCN and appears on Appendix 1 of CITES -Convention on International Trade of Endangered Species of Wild Fauna and Flora. Magnitude of decline of Population of *Elephas maximus* has been far greater than *Loxodonta africana.* Asian elephants have declined due to habitat fragmentation and capture but African elephants have been subjected to hunting (Sukumar, R. 1992). Asiatic elephants have declined considerably over past 60-70 years as per IUCN. There are roughly 40-50 thousand Asian Elephants left in the wild today. There are many reasons as to why the population is declining. Some of them are poaching, unavailability of food and Human-Elephant conflict. Most illegal ivory comes from African elephants. Females are spared but males are killed for their tusks. However, the trade of elephant skin threatens both males and females equally. Loss of habitat is another primary reason for decline in population of *E. maximus* since man has been modifying natural environment in the name of development.

They once covered all the West Asia along the Iranian coast to the Indian subcontinent and ranged eastwards into South-east Asia including the islands of Sumatra, Java, and Borneo and extended north to the Yangtze River in China (Olivier 1978). This range covered over nine million km2 (Sukumar 2003). In the early 1900s, Asian elephant range almost covered about 2.87 million km2 and was composed of several large yet distinct populations throughout Asia. By the early 2000s, the species' geographic range had declined to about 620,000 km2, a 78 percent decline in total area in only one hundred years. Today, the species has disappeared from 95% of its historical range (Sukumar 2006) and are extinct in West Asia, Java, and most of China. Asian elephant populations are now restricted to fragmented habitat islands dispersed across thirteen South and Southeast Asian states. Elephants are distributed unevenly in India, Nepal, Bangladesh, Thailand, Bhutan, Myanmar, China, Kalimantan, Cambodia, Laos, Vietnam, Sri Lanka and Islands of Sumatra (Indonesia). A small population also occurs in Andaman Islands of India.

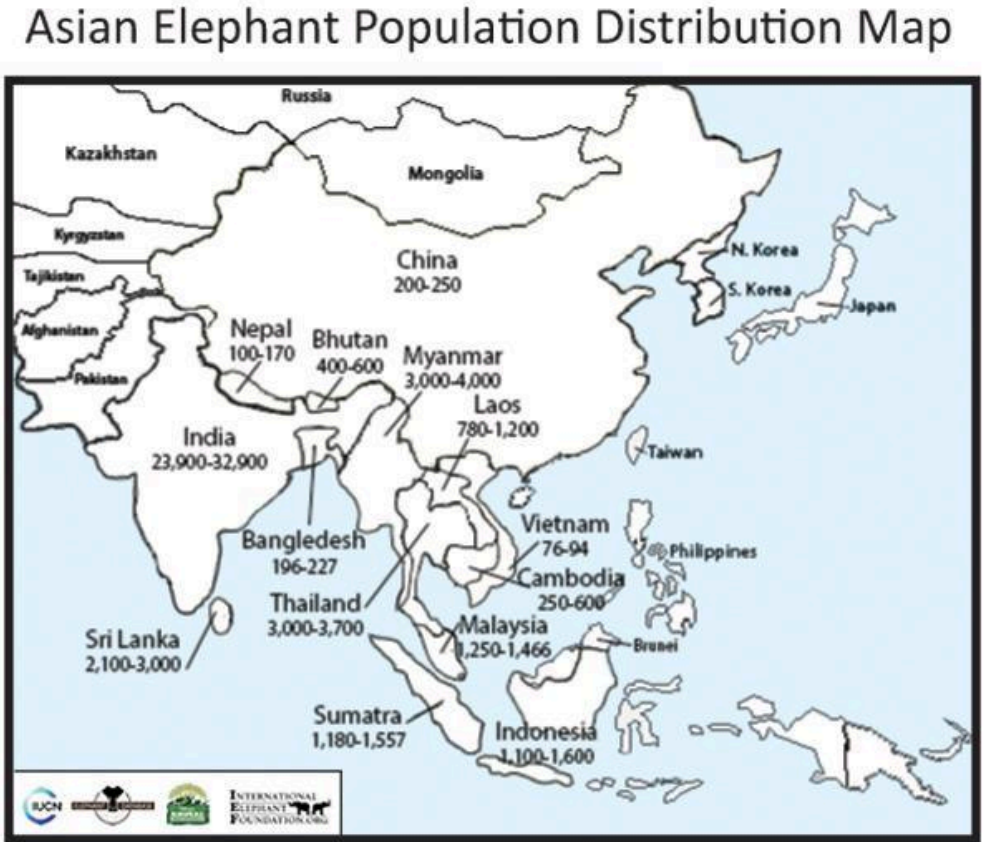

Figure 1. Population distribution map (Source: International elephant foundation)

Retrieved on: 29th April, 2021

Elephants in India- India currently hold the largest surviving population of Asian Elephants approximately 60% of the total world population of the species (Daniel, 1996). Further Uttarakhand harbors 1797 elephants in the state, out of which Corbett and Rajaji Tiger reserve have higher density. The major populations are in southern and north-eastern India, with fewer in the east-central and northwestern regions. Karnataka has the highest population followed by Kerala. In India wild elephants are distributed in 23 states with south and north east accounting for most abundant populations. (Talukdar, & Choudhury (2017)

Many different forest types can be recognized in India. Forest types are directly related with the annual rainfall pattern. National parks and protected areas prevent these original forest covers from degradation and thereby ensure the survival of these mega herbivores. (Eisenberg, 1980)

Elephants have a magnificent and infamous association with man. In a country like India elephants are protected not only due to scientific reasons but also religious believes.

Human-elephant coexistence remains a major conservation and livelihood challenge across the elephant ranges in the world. Even though the elephant has coexisted with humans for millennia, the growth of human populations and extension of agriculture has led to fragmentation of forests bringing humans and elephants into direct conflict. Knowing food preferences of elephants can help us understand one aspect of human elephant conflict i.e as to why elephants prefer wandering off to villages even when they have abundant food in protected areas. Thus food preferences can aid in conservation.

Herbivores influence the growth, survival and reproductive output of plants they consume, by modifying the relative abundance and dynamics of vegetation (Huntly, 1991). This results in the modification of ecosystem processes further passing the effects on other species of insects, birds and mammals. Over browsing by herbivores also reduces plant cover and alters the dynamics of vegetation in the area. This can alter nutrient cycle and carbon cycle. Feeding manners of even smaller herbivores can therefore alter ecosystem. When a large herbivore like elephant is concerned, their feeding and breakage impacts on plants are greater in magnitude than those of smaller herbivores (Kerley, 2006). They can easily affect the structural components of vegetation like canopy trees. This is why elephants are termed as 'megaherbivores' along with other herbivores species whose adult body mass exceeds 1000kgs. Elephants have the ability to greatly impact our ecosystem and learning about their feeding preferences can help us understand them better on an ecological scale (Kerley, 2006).

Large size herbivore species like elephants were general features of ecosystem worldwide until humans started transforming land 50,000 and 12,000 years ago and started hunting these mega herbivores. It is said that the elimination of elephants and other herbivores led to the demise of many other large mammalian species. Consequently species diversity reduced outside of Africa and tropical Asia due to habitat changes. (Owen-Smith, 1987, 1989) Therefore the emphasis of elephants on Biodiversity is both positive and negative. However, the consequences to Biodiversity should not be judged only on species level but also in terms of changes of habitat composition and functional processes (Noss, 1990).

Elephants display a variety of feeding behaviors. They have been known as vigorous and wasteful feeders. They can consume forage by directly biting from mouth although this doesn't occur frequently. Alternatively, the forage is plucked by either breaking off the plant or uprooting the entire plant with the trunk and passed to the mouth where it is ingested through a single or multiple bites, or material is stripped off a branch with the trunk and passed to the mouth. While they can strip off the bark discarding the interior wood, at certain times they discard leaves before consuming the bark, or they eat leaves of same species. - Elephants spend 12-19 hours per day in feeding. Even though they are generalist feeders, they can be very specific about which part of plant they eat (Mohapatra et al., 2013).

In Rajaji Tiger Reserve, Elephants can be seen feeding on Rohini (*Mallotus phillipinensi),*khair *(Acacia catechu),*Dhauri *(Lagerstroemia parviflora),* Chamror *(Ehretia laevis),* shisham *(Dalbergia sissoo),* Sagaun/ Teak *(Tectona grandis),*Ber *(Zizyphus Mauritiana),* bel (*Aegle marmelos) and* bargad *(Ficus bengalensis*). Elephants also utilize various grasses and shrubs as their food, which mainly included *Dendrocalamus strictus, Helicteres isora, Saccharum munja, Saccharum spontaneum, Cynodon dactylon, Desmostachya bipinnata and Neyraudia arundinacea*. Elephants sometimes spent long time to feed on some particular plant species like Bamboo, Rohini and Teak. Eastern populations of elephants In Rajaji were observed feeding extremely on Teak and sagaun, whereas currently south-western populations of elephants were not utilizing these species as their food (Joshi &Singh, 2008).

The distribution of Asian elephants is largely influenced by availability of natural fodder and water. In recent times, the conversion of forests to agricultural lands have reduced the areas of elephant habitat and in turn resulted in reduced accessibility of naturally available food and water (Sukumar, 2006). This is why elephants are migrating to areas outside their natural habitat and look for alternate food sources further resulting in man-elephant conflict.

Anthropogenic climate change is impacting biodiversity and species (Martínez‐Freiría, 2016). Climate change is a major issue in global biodiversity and conservation besides habitat fragmentation. Long term human induced factors have resulted in local extinctions and also in reduction of distributional ranges of species (Martínez-Freiría, et al., 2016). Understanding of how climate change interacts with other underlying anthropogenic factors is crucial for

understanding of their impacts on biodiversity patterns and predicting the fate of species in advance and further design effective conservation strategies (Martínez- Freiría et al., 2016).

Climate change leads to redistribution of species both directly through temperature change and indirectly through modification of habitats and feedback loops. Higher temperature variability will lead to elephant mortality ((Mumby, 2013). Climate change is also going to redistribute plant species to higher altitude or towards pole affecting ecosystem functioning (Kanagaraj, 2019). Anthropogenic threats to Asian elephants are aggravated under climate change. The future projections under climate and land use study predict a heavy loss of potential elephant habitat in low altitude human dominated regions.

Biology- Their size is up to 6.6 to 9.8 feet. And they weigh from 2.25 (2500kgs) to 5.5 (5000kgs) tons. Elephants are highly intelligent and have superior cognitive abilities (Sukumar, 2006). Their social unit consists of adult cow (female elephant) and her offspring. Previous studies on Asian elephants have confirmed the existence of social units comprising of mother and dependent off-springs and family groups comprising of two or more mothers and off-springs (Vidya, & Sukumar, 2005). Elephant society is matriarchal, starting from mother-calf units to larger joint family units (several adult cows, 'kin' or bond group) (Sukumar, 2006). A new born child is 90 cm in height and a mass of about 100kgs. The elephant is a hind-gut fermenter. Plant cellulose is digested in large intestine (caecum) and colon with the help of symbiotic microbes. Only 40-50% of the forage is digested rest is passed as such. It has been hypothesized that elephants are less readily able to handle plant secondary chemicals like resins and tannins which are concentrated in leaves than other ruminants because of their simple digestive system (Kerley, 2008). This is why elephants utilize bark and soft twigs after removing the leaves from them and the leafy portion remains on ground which may serve as a food source for ungulates (Puri &Joshi, 2019).

Elephants have low metabolic rate per unit of their body mass because of their large size. This enables them to obtain adequate nutrition from a low nutrient content plant material. The large quantities of dung generated further helps in nutrient cycling and also facilitate dispersal of seeds. Dung piles of elephants create microhabitat in forests providing food source and habitat to fungi, beetles, ants, termites, spiders, centipedes, crickets and other insects (Puri, 2019).

Objectives

Elephants are well adapted to live in their habitats by exploiting a variety of species of plants. (Baskaran 2010) Protected areas not only aid in conservation of these mega herbivores but also provide them with their feeding grounds and water availability further preventing them to wander off nearby villages in search of food. Thus, protected areas help in the prevention of Human-wildlife conflict as well.

Today this giant Proboscidian is restricted to only few of the protected areas (Joshi, & Singh, 2008). Rapid development activities have led to the loss of their natural habitats due to which their population is falling rapidly. This situations calls out for some action oriented research studies that will help in greater understanding of the nature of elephants by setting up some ground facts and further aid in protecting the biodiversity of Asian Elephants.

Elephants are keystone species many scientists have hypothesized as they maintain the structure of open woodlands by destroying trees and allow the growth of grasses to sustain themselves and other herbivores community (Fernando, & Leimgruber 2011) in this way they play an important role in maintain ecosystem's biodiversity. This hypothesis has been amplified in recent years through extensive research work by scientists. However, most of these studies have been done on African Elephants. Even though Asian elephants are also considered as key stone species, comparative studies and evaluation of its effects on ecosystem are largely non-existent (Fernando, & Leimgruber 2011). Because of the lack of scientific studies on Asian Elephants, observations made on African elephants are generalized even when these generalizations hold no guarantees.

It is a common presumption that elephant herbivory is a mechanism that builds plant communities (Mapaure & Campbell, 2002; Conybeare, 2004). Thus it is important to have an understanding of elephant diet, and particularly their dietary preferences, in order to predict its impact on plant communities and vice versa

Objectives:

1. To study food preferences of Asian Elephants in general.
2. To list out the species of plants that elephants consume and which species contribute to the greatest proportion of the elephant's diet in Rajai Tiger Reserve, Uttarakhand.
3. To find out whether climate change will impact Elephants and their food habits.

Methodology

Study area- Rajaji National Park & Tiger reserve is located in shivalik foothills of Uttarakhand spreads over an area of 820.42sq km, which is lesser Himalayas and the upper Gangetic Plains. It was declared a national park in 1983 by joining of three sanctuaries- Rajaji sanctuary, Motichur sanctuary and Chilla Sanctuary. Combining all the three sanctuaries, it is spread to Pauri Garhwal, Dehradun and Saharanpur Districts of Uttrakhand. While Motichur and Rajaji Sanctuary are continuous, Chilla sanctuary is separated from them to the South-east by Ganges river and Chilla river A railway line passed through Kansaro, Motichur and Haridwar ranges of Rajaji National park. The protected area represents several distinct zones and forest types like Riverine forest, Broad leaf mixed forest, chirpine forest, scrubland and grassy pasture land. Rajaji harbors one of the most diverse ranges of wildlife habitat.

More than 23 species of mammals and 315 species species of Avifauna are found in the park, including highly endangered Asian elephant and tiger. Beside tiger, leopard, Himalayan Black bear, sloth bear, civet, Marten, Jackel, Hyena etc. It is estimated that there are more than 350 Asian elephants in the park. Three species of deer- Sambhar, Spotted deer(cheetal) and Barking deer(kakar) and animals like wild boar, Neel Gai, Langoor etc are also found. The park also teems with Reptilian species like lizards, snakes and tortoise. It's location in a transition zone between temperate western Himalaya and central Himalaya enhances the species diversity. It is the first National park in the state to run the two most prestigious wildlife conservation projects- The Project Elephant and The project Tiger.

Rajaji National Park has been designated as a reserve area for the "Project Elephant" launched by the Ministry of Environment and Forests, Government of India in 1992 as a centrally sponsored team with the sole aim of maintaining a viable population of Asian elephants in their natural habitat. The Shivalik landscape in northwestern India supports approximately 1246 elephants in its limited area. However, this population has been declining over the past decade; more than 134 elephants succumbed in the wild from 1987 to 2004 due to various reasons.

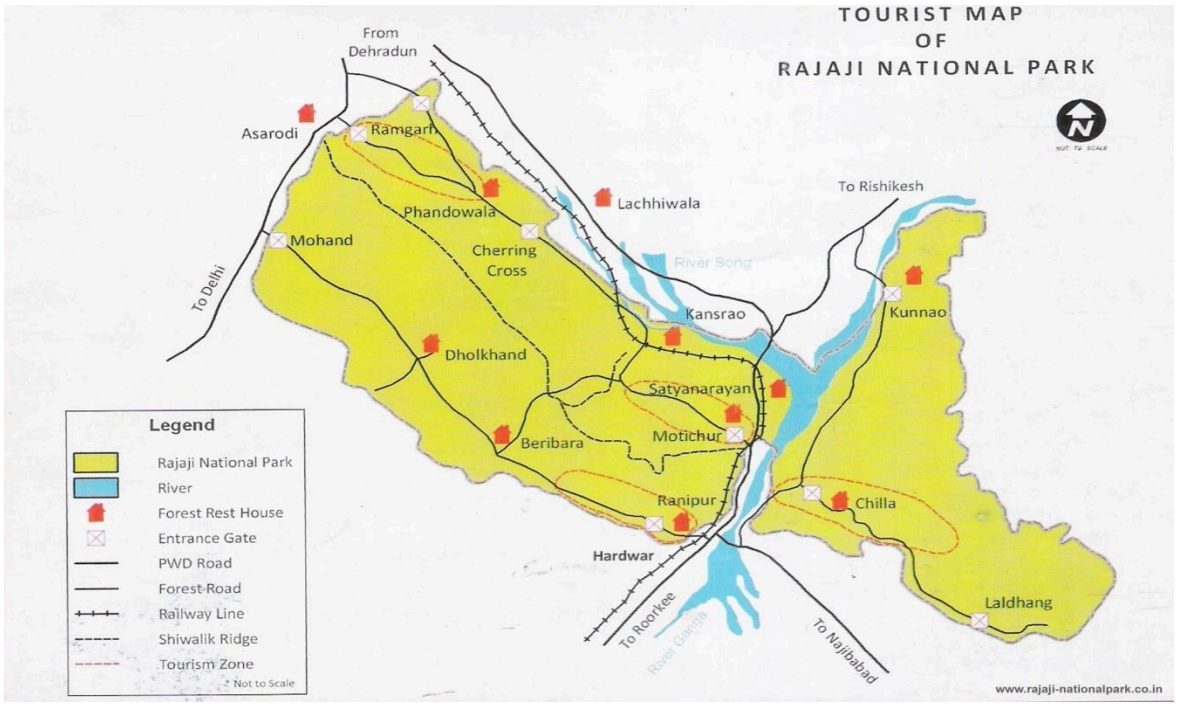

Figure 2. (Image courtesy: Rajaji National Park website)

Retrieved on: 1st june 2021

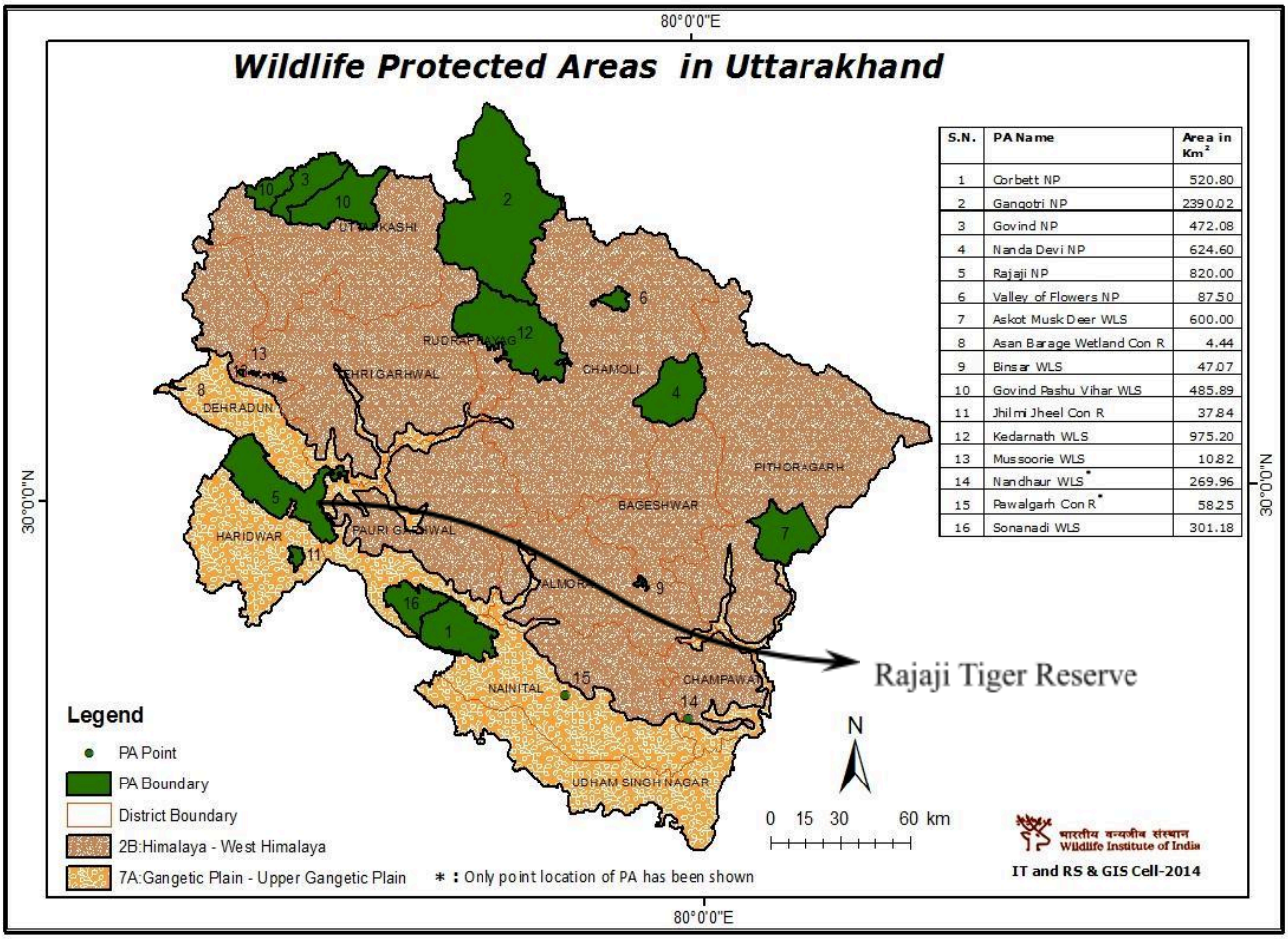

Figure 3: Rajaji Tiger Reserve in Uttarakhand map

Image Courtesy : ENVIS centre on Wildlife and Protected Areas

Retrieved on: 2nd June 2021

Methods

1. Collection of published literature- All the qualitative and quantitative data has been gathered from various search engines like- Google Scholar, Research gate, science direct, and springer Nature etc.
2. Review of data collected and Analysis
3. Following key words were used- Feeding, Asian Elephant, Ecology, Diet, *Elephas maximus*, Feeding behavior, Climate change, Vegetation.

Results

Feeding and food preferences are one of the most important factors to study the ecology, habitat management as well as habitat utilization of a mega-herbivore like elephants. Natural food and water availability define the movement and migration of elephants. All the previous research done in the study area shows than wild Elephant species consumes a variety of plant species. However recent studies have mentioned that their diet mainly consists of 50 species which are found in and around the study area. Changes in season, scarcity of water and unavailability of natural fodder species force animals to leave their feeding grounds for few months and search for new grounds that can fulfill their needs for survival. Rajaji Tiger Reserve area falls under subtropical moist deciduous forest vegetation type and therefore there are seasonal variations in food species available. The whole park is natural habitat of elephants but during the year they move for few months leaving areas with less vegetation and water towards areas which are richer in natural water and fodder. During this time, few solitary bulls can also be seen using same feeding grounds, moving around the forest beats just like migration.

Asian Elephants can consume almost 150kg of biomass per day (Mahopatra, 2012). Especially during dry season and due to high energy demands they tend to migrate. Therefore, availability of food resources is a major contributing factor of the habitat carrying capacity and also affects the population distribution of Asian elephants in the given area. Elephants do not discriminate over the selection of food plants and may feed over a hundred plant species in an area therefore they are generalist feeders. However, plants from some botanical families may account for their total intake of which 56%-74% accounts for tree species in majority of the total forage species. This can be seen during dry season when green herbaceous fodder with high palatability and high nutrient concentration dries up (Sukumar,1990). In parts of Northern India including Uttarakhand, evergreen Kamala tree/Rohini *(Mallotus philippinensis)* constitutes an important part of Asian Elephant diet especially during dry season. (Pradhan & Wegge, 2007). In fact, these trees represent 42% of elephant diet tracks (Pradhan 2008). Therefore, distribution of Kamala tree can be a good indicator of Asian elephant's presence during the dry season. The most chosen food item in the study area is Bamboo *(Dendrocalamus strictus)* and Rohini *(Mallotus philippinensis)* but elephants use different food resources round the year as per their availability.

Shorea (Sal) mixed vegetation types holds a higher density in food.(Williams, Johnsingh, Krausman, & Qureshi, 2008)

Elephants are generally active before dawn and start their morning routine in the vicinity of the area where they spent night. During the day they retire under shade however during wet season they spend their time feeding. Summer evenings are for drinking and bathing. Feeding is during early hours of the morning and late hours of the afternoon. In winters feeding activity is constant but maximum during evening hours. More time is spent in resting during mid-day in summers because elephants cannot tolerate high temperatures and direct sun light. During summers they have to travel more due to lack of fodder species and shortage of water however in winters and monsoon, fodder and water are in abundance in park areas.

A total of 50 pant species have been recorded that are favorite fodder species of elephants (Table 1.) the list has been compiled from various research papers and previous studies done on Asian Elephants in Rajaji Tiger Reserve. The list includes the name of plant species, their vernacular name and the parts consumed by elephants. At the same time, month wise utilization of fodder species is also mentioned in Table 2.

Elephants utilize both leaves and twigs of few plant species like Shisham (*Dalbergia sissoo*), Khair (*Acacia catechu*), Semale (*Bombax ceiba*), Bel (*Aegle marmelos*), Bargad (*Ficus bengalensis*) and Sandaan (*Ougeinia oojeinensis*), they ate different parts of the plant according to various seasons. Elephants prefer feeding on the bark and twigs of teak (*Tectona grandis*) during the onset of summers however they prefer eating the bark of Semal tree during very hot season. Elephants like eating fruits, they often uproot the whole plant with the help of their trunk and sometimes foot. Grass species like *Saccharum munja* and *Saccharum spontaneum* are preferred though they are not available throughout the year in park area.

Elephants are wasteful feeders; they push over trees so that they can have access to higher branches which are out of range. It is generally assumed that the non-eaten vegetation forms the secondary food source to other herbivores (Joshi, R., & Singh, R. 2008). Sometimes Spotted deer (Axis axis), Barking deer (Muntiacus muntjak) and Sambhar (Rusa unicolor) have been observed following elephants when they were feeding on specific plant species that the deer could not access on its own (Puri et al., 2019). Elephants after feeding on soft twigs remove the leafy

portion which is consumed by ungulates. 12–18 hours a day is spent on feeding during of which they can consume up to 10% of their body mass as fresh-mass fodder (Vancuylenberg, 1977; Sukumar, 1989).

Table 1: Elephant food species, their common name and parts eaten (Joshi&Singh, 2008)

S. no	**Name of the plant species**	**Common name/vernacular name**	**Species**	**Parts eaten**
1.	*Acacia catechu*	Khair	tree	Leaves, twigs, bark
2.	*Acacia arabica*	Babool	tree	Leaves, twigs, bark
3.	*Aegle marmelos*	Bel	tree	Leaves, twigs, fruits
4.	*Albizzia lebbek*	Kala siris	tree	Leaves and twigs
5.	*Albizzia procera*	Safed siris	tree	Leaves and twigs
6.	*Bauhinia variegate*	kachnar	tree	Leaves, twigs, bark
7.	*Bauhinia vahlii*	Maljhan	climber	Leaves and twigs
8.	*Bauhinia malabarica*	Khatua/amli	tree	Leaves and twigs
9.	*Bombax ceiba*	Semale	tree	Bark
10.	*Bridelia retusa*	Ekdana	Tree	twigs
11.	*Cordia obliqua*	Lassora	tree	twigs
12.	*Cynodon dactylon*	Doob grass	Grass	Leaves and roots

13.	*Dalbergia sissoo*	Shisham	tree	Leaves, twigs and bark
14.	*Dendrocalamus strictus*	Bamboo/Bans	shrub	Leaves and twigs
15.	*Desmostachya bipinnata*	Dav/Khush	Grass	Leaves and roots
16.	*Ehretia laevis*	Chamror	tree	Leaves and twigs
17.	*Embelica officinalis*	Amla	tree	Leaves and twigs
18.	*Eulaliopsis binata*	Bhabhar grass	grass	Leaves and roots
19.	*Ficus bengalensis*	Bargad	Tree	Leaves, twigs and bark
20.	*Ficus glomerata*	Gular	tree	Leaves, twigs, bark, fruit
21.	*Ficus religiosa*	Peepal	tree	Leaves and twigs
22.	*Ficus rumphii,*	Pilkhan	tree	Leaves and twigs
23.	*Ficus infectoria*	khabar	Tree	Leaves and twigs
24.	*Flacourtia indica*	kandai	tree	Twigs and bark
25.	*Garuga pinnata*	Kharpat	tree	Leaves and twigs
26.	*Grewia oppositifolia*	Bhimal	tree	Leaves, twigs
27.	*Grewia elastica*	Dhaman	tree	Twigs
28.	*Helicteres isora*	Kapasi	Shrub	Leaves and twigs
29.	*Holarrhena antidysenterica*	Kura	tree	Twigs
30.	*Holophramitis*	Kut sagaun	tree	Leaves, twigs and bark
31.	*Kydia calycina*	Pula	Tree	Twigs

32.	*Lagerstroemia parviflora*	Dhauri	Tree	Leaves, twigs
33.	*Lannea coromandelica*	Jhinghan	tree	Leaves, twigs
34.	*Mallotus philippinensis*	Rohini/Kamala	Tree	Twigs
35.	*Mitragyna parvifolia*	Phaldu/Kaem	tree	Bark
36.	*Neyraudia arundinacea*	Bichhloo	Grass	Leaves and roots
37.	*Ougeinia oojeinensis*	Saandan	Tree	Leaves and twigs
38.	*Pithecellobium dulce*	Jangal Jalebi	Tree	Leaves and twigs
39.	*Randia dumetorium*	Mainphal	Tree	Twigs
40.	*Saccharum munja*	Phoos/Sarkanda	Grass	Leaves and roots
41.	*Saccharum spontaneum*	Kans	Grass	Leaves, roots
42.	*Schleichera oleosa*	Kusum	Tree	Leaves, twigs
43.	*Shorea robusta*	Sal	Tree	Bark
44.	*Syzygium cumini*	Jamun	Tree	Leaves, twigs and Bark
45.	*Terminalia tomentosa*	Sain	Tree	bark
46.	*Tectona grandis*	Sagaun/teak	Tree	Twigs, bark
47.	*Tinospora malabarica*	Giloe/Gurch	Climber	Leaves and twigs
48.	*Thysanolaena agrostis*	Hathi ghas/Pirlu	Grass	Leaves and roots
49.	*Zizyphus mauritiana*	Ber/Beri	Shrub	Leaves and twigs
50.	*Zizyphus xylophyra*	Bhander	Shrub	Leaves and twigs

It has been observed that during 12 hours of the day, feeding during the winters is highest (11.1 hours) followed by feeding during the summers (10.5 hrs) and monsoon (9.1 hrs). Movement is 1.4hrs in winters, 1.5hrs in summers and 1.3hrs in monsoon. Resting activity is largely dependent on seasons (These observations are taken from previous studies done on Asian elephants and data may vary from time to time).

Table 2: Season-wise Utilization of fodder species by elephants In Rajaji Tiger Reserve

S.no	**Name of the Species**	**Common Name/vernacular name**	**Seasonal Utilization**		
			Summers	**Rainy**	**Winters**
1.	*Acacia catechu*	Khair	Mar, April, May	Jul.	Nov., Dec., Feb.,
2.	*Acacia arabica*	Babool	-	Sep.	Oct.
3.	*Aegle marmelos*	Bel	Mar., Apr., May, June	Sep.	Oct, Feb.
4.	*Albizzia lebbek*	Kala siris	Mar. Apr., May	Sep.	Oct., Feb.
5.	*Albizzia procera*	Safed siris	Mar., Apr.	-	Feb.
6.	*Bauhinia variegate*	kachnar	Mar., Apr., May	-	Feb.
7.	*Bauhinia vahlii*	Maljhan	Mar., Apr. May	-	Dec., Jan.
8.	*Bauhinia malabarica*	Khatua/amli	Mar., Apr.	Aug., Sep.	Feb.
9.	*Bombax ceiba*	Semal	Mar., Apr., May, Jun.	Sep.	Oct.

10.	*Bridelia retusa*	Ekdana	-	-	Nov.
11.	*Cordia obliqua*	Lassora	May.	-	-
12.	*Cynodon dactylon*	Doob grass	Mar., Apr.	-	Jan., Feb.
13.	*Dalbergia sissoo*	Shisham	Mar., Apr., May, Jun.	Jul., Sep.	Oct.
14.	*Dendrocalamus strictus*	Bamboo/Bans	Mar.	Jul., Aug., Sep.	Oct., Dec.
15.	*Desmostachya bipinnata*	Dav/Khush	Mar., Apr., May.	Aug., Sep.	Oct., Dec.
16.	*Ehretia laevis*	Chamror	Mar., Apr.	-	Dec., Jan., Feb.
17.	*Embelica officinalis*	Amla	Apr., May	-	Feb., Mar.
18.	*Eulaliopsis binata*	Bhabhar grass	Mar.	Aug., Sep.	Oct., Nov.
19.	*Ficus bengalensis*	Bargad	Mar., Apr., May, Jun,	Jul., Aug., Sep.	Feb.
20.	*Ficus glomerata*	Gular	Mar., Apr., May	-	Oct.
21.	*Ficus religiosa*	Peepal	Mar., Apr., May, Jun.	Jul.	Nov.,Dec.
22.	*Ficus rumphii,*	Pilkhan	Mar., Apr.	-	Dec.
23.	*Ficus infectoria*	khabar	Mar., jun.	Jul., Aug.	Dec., Feb
24.	*Flacourtia indica*	kandai	Apr., May, Jun.	-	-
25.	*Garuga pinnata*	Kharpat	Mar.,	Aug., Sep.	Nov., Dec., Feb
26.	*Grewia oppositifolia*	Bhimal	Mar.	-	Nov., Jan., Feb.

27.	*Grewia elastica*	Dhaman	-	-	Nov., Jan., Feb.
28.	*Helicteres isora*	Kapasi	May, Jun.	Jul., Aug., Sep	Oct.,
29.	*Holarrhena antidysenterica*	Kura	Mar.	-	Feb.
30.	*Holophramitis*	Kut sagaun	Mar., Apr., May		Jan., Feb.
31.	*Kydia calycina*	Pula	Mar., Ar., May, Jun.	-	-
32.	*Lagerstroemia parviflora*	Dhauri	Mar., Apr., May, Jun.	Jul.	-
33.	*Lannea coromandelica*	Jhinghan	Mar., Apr.	Aug., Sep	Oct., Nov., Feb
34.	*Mallotus philippinensis*	Rohini/Kamala	Mar., Apr., May, Jun	Jul.	Jan., Feb.
35.	*Mitragyna parvifolia*	Phaldu/Kaem	Mar.	-	Feb.
36.	*Neyraudia arundinacea*	Bichhloo	-	Jul., Aug., Sep.	Oct.
37.	*Ougeinia oojeinensis*	Saandan	-	Aug., Sep.	Oct., Nov., Dec., Jan., Feb.
38.	*Pithecellobium dulce*	Jangal Jalebi	-	-	Nov., Jan., Feb.
39.	*Randia dumetorium*	Mainphal	May	-	Dec., Jan.

40.	*Saccharum munja*	Phoos/Sarkanda	Mar.	-	Oct., Nov., Dec., Jan., Feb.
41.	*Saccharum spontaneum*	Kans	Mar., Apr.	-	Dec., Jan., Feb
42.	*Schleichera oleosa*	Kusum	Mar.	Jul., Sep.	Oct., Feb.
43.	*Shorea robusta*	Sal	Mar.	Aug.	Dec., Jan., Feb.
44.	*Syzygium cumini*	Jamun	May, Jun.	Jul.	Jan., Feb.
45.	*Terminalia tomentosa*	Sain	Mar.	Aug.	-
46.	*Tectona grandis*	Sagaun/teak	Mar., Apr.	-	Jan., Feb
47.	*Tinospora malabarica*	Giloe/Gurch	Mar., Apr., May, Jun.	-	Oct., Nov., Dec.
48.	*Thysanolaena agrostis*	Hathi ghas/Pirlu	Mar.	-	Nov., Dec., Jan., Feb.
49.	*Zizyphus mauritiana*	Ber/Beri	-	-	Oct., Nov., Dec., Jan., Feb.
50.	*Zizyphus xylophyra*	Bhander	-	-	Nov., Dec., Jan., Feb

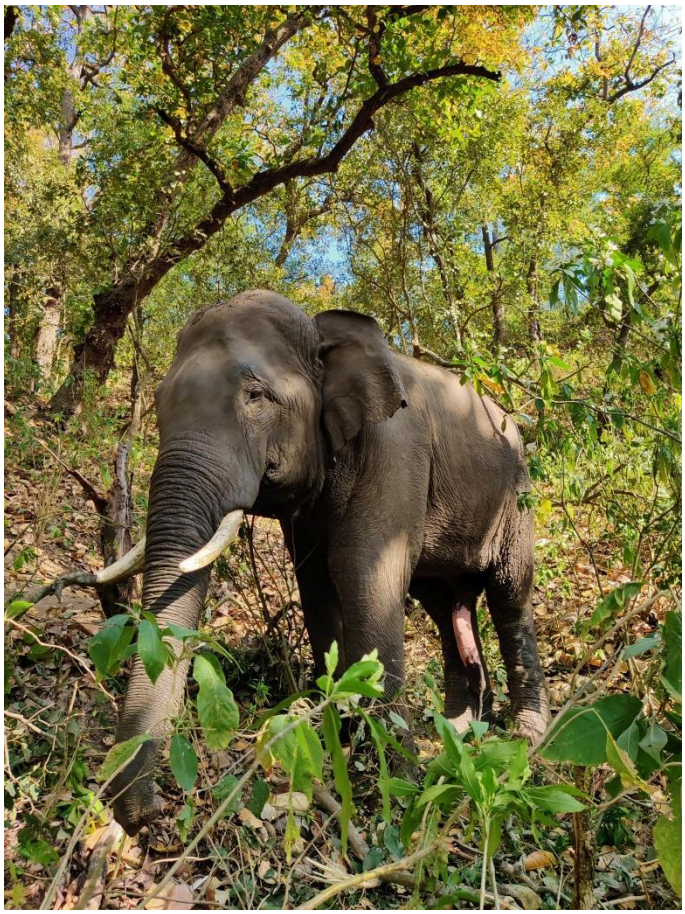

Figure 4. Adult elephant in Rajaji Tiger Reserve

Photo by- Ayushi Kothari

Comparison with previous years studies- Previous research done on Elephant feeding ecology shows that elephants can feed on a variety of plant species depending on their habitats. Research on Feeding ecology of *Elephas maximus* in Niligiri Biosphere Reserve in Southern India shows that overall 83 plant species are eaten by elephants (Baskaran, Balasubramanian, Swaminathan, & Desai, (2010). Out of the 83 species, 59 were browse species (trees, shrubs, herbs, bamboos) and the rest 24 were grass species. Amongst those 24 grass species, 6 species (*Themeda cymbaria, Heteropogon contortus, Themeda triandra, Bothriochloa sp., Aristida adscensionis,* and *Cymbopogon flexuosus*) constituted more than 75% of the total diet.

Another study of Southern India recorded that atleast 112 plant species are eaten in wild by Asian elephants. A study of Kulhida Wildlife sanctuary, Odisha showed that total 71

plant species (Dicot 61, Monocot-10) form elephant diet. Out of these 44% of total plant species were non-trees- shrubs, herbs, climbers, grass (Mohapatra, Patra, & Paramanik, 2013). 56% were trees, Shrubs were 20% Herbs 14% and Climbers were 10%.

Studies carried out within Rajaji Tiger Reserve in 2002, recorded a total of 30 species which were fed upon by elephants (Williams, 2002). Another study by Khan in 2004 revealed that elephant's browse component comprised of 38 species out of which percentage of tree species were highest. Rohini (*Mallotus philippensis*), Bel (*Aegle marmelos*), Khatua (*Bauhinia malabarica*) and Padhal/podal (*Stereospermum* suaveolens) were the preferred food species of elephants. Recent studies have however reveled 50 plant species fed upon by elephants and the most preferred food item is *Dendrocalamus strictus* (Bamboo) and *Mallotus philippinensis* (Rohini) but elephants used different food resources round the year as per their availability (Joshi &Singh, 2006). Out of these 50 plant species, 41 are Monocot and 9 are dicot. Study done by Joshi and Singh does not mention the use of Padhal as food source by Elephants.

The study area enumerates 50 species that comprises the diet of wild elephants. There are 262 species of plants found in Rajaji Tiger Reserve. The total recorded plant species (50) diet of elephants comprises of 74% species of tree, 14% grass species, 8% shrub species, and 4% climber species.

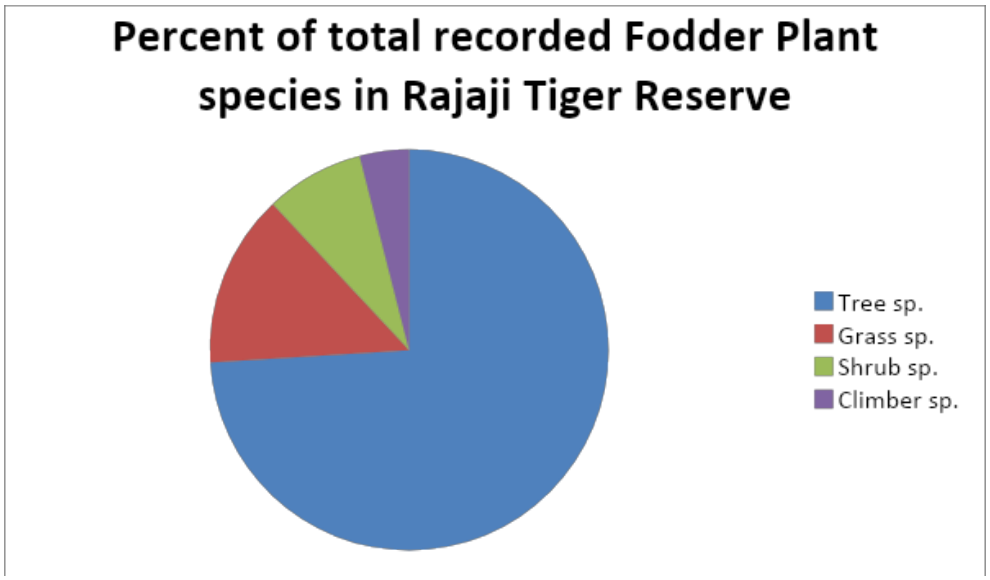

Figure 5: Chart of Fodder plant species

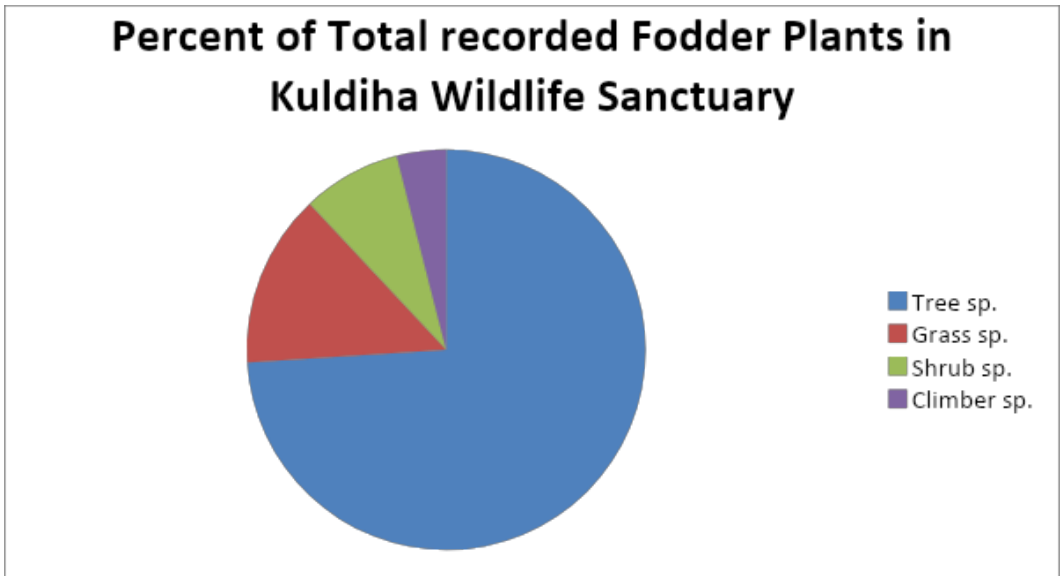

Figure 6: chart of fodder plant species in Kuldiha wildlife Sanctuary

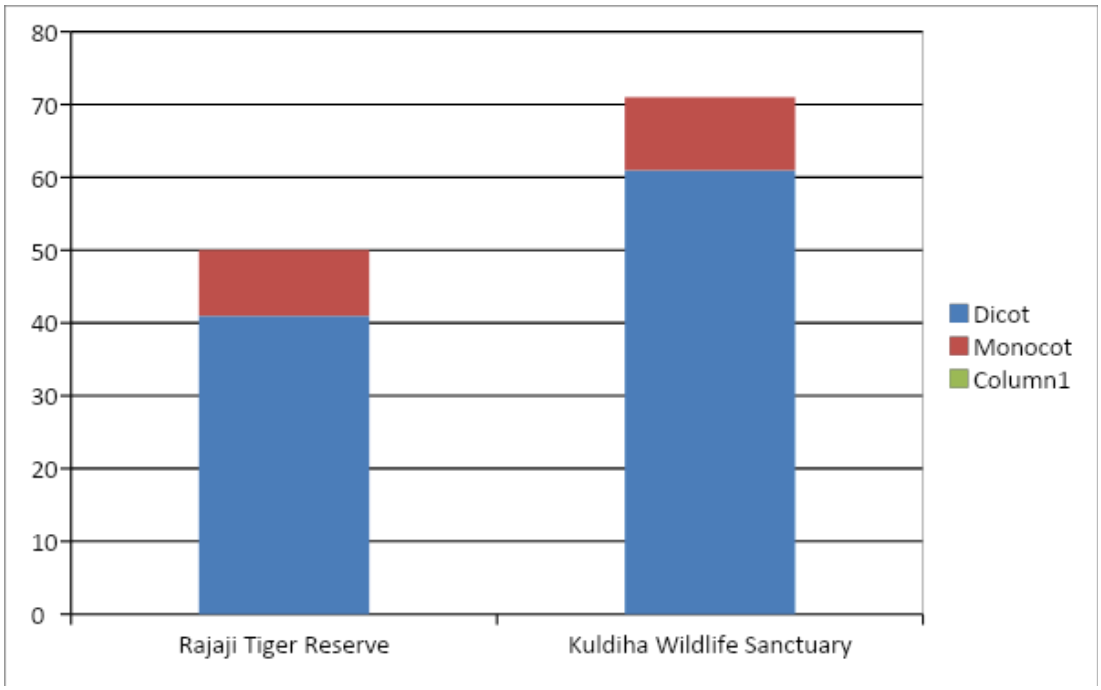

Figure 7: Comparison between Dicot and Monocot species fed upon by elephants in two different geographical zones

A cause Asian
El herefore it is
expected that they utilize varied habitat types.(Khan, 2004)

Previous study has revealed that low intake of grasses in diet is due to less availability of grass (Khan, 2004). Sukumar in 1985 illustrated that proportion of grass in diet will be high in a grass dominated habitat and least in browse dominated habitat. In the study, grass constitutes 14 % of elephant diet. Such low percentage of grass in elephant diet is mainly due to the distribution of grasses. As such no grasslands exist in the Rajaji (Khan, 2004). The nutritional requirements of elephants in Rajaji are thus met by the browse, which is quite easily available (Khan, 2004).

Food preferences of Elephants have undergone slight change. We can see that Rohini (*Mallotus philippensis*), Bel (*Aegle marmelos*), Khatua (*Bauhinia malabarica*), Bamboo (*Dendrocalamus strictus*) are mainly preferred food of elephants in Rajaji Tiger Reserve. Bark of teak is consumed both in Southern and Northern India however before 2002 elephants were not reported

to feed on these species (Joshi &Singh, 2008). In an unsual behavior, elephants were reported feeding on *Eucalyptusobliqua* (eucalyptus) in the year 2007 (Joshi and Singh, 2008). But in Southern India Elephants for the first time were reported using the bark of the eucalyptus tree in 1990's (Sukumar, 1994). In a study conducted by Khan in 2004, he observed that elephants don't feed on Sal in Rajaji however they have been observed feeding on Sal in eastern side of the park by Joshi and Singh in 2008.

Discussion

The Asian Elephant is distributed throughout its range in many types of habitats spanning across 13 countries. This distribution is widely influenced by the availability of its natural food (Koirala et al., 2016). Grasses comprise of Majority of diet during the wet season however in the dry season, the diet is dominated by browse especially in the tropical region. In recent times, conversion of forests to agricultural lands and human settlements (Sukumar, 2006) has reduced the area of elephant habitat which in turn has resulted in reduced accessibility of naturally available food and water. In addition to this there are increasing seasonal forest fires (Koirala et al., 2016). This is the reason why elephants are being forced to migrate to areas outside their natural habitat and look for alternate food sources resulting in Human-Wildlife Conflict. Elephants might move to a patch for a particular food species. Their movement patterns are also associated with specific nutrient needs, for example due to high amount of water they consume, their demand for sodium increases, consequently their movement is influenced by spatial and temporal distribution of food with high salt content. Habitat fragmentation of elephant habitat leads to expansion or shifting of their ranges often in search of alternative food resources resulting in conflict amongst species.

Asian Elephants being an endangered species occupies only a small fraction of their historical range (Sukumar, 2006). India and Nepal harbor the bulk, more than 60% of the total population of wild Asian Elephants. The species also survives in human dominated habitats with human density varying from 149 to 292 people per km^2 however due to continuous conversion of its habitat to agriculture or urbanization, elephant populations are now becoming small and usually restricted to protected areas (Kanagaraj et al., 2019).

Climate change causes redistribution of species both directly and indirectly. Directly through temperature and water availability, indirectly through habitat modification and feedback loops between climate and vegetation, agricultural practices and land use.

The effect of climate change and its intensity varies spatially and depends upon the location (IPCC). Climate change is going to bring delay in onset of monsoons, increase the occurrence of monsoon break periods, and by the end of 21^{st} century reduce the summer precipitation. These changes over a period of time can lead to enhanced drought

(Kanagaraj et al., 2019). Warming due to temperature changes will lead towards the distribution of Elephant species to higher altitude or towards the pole (Kanagaraj et al., 2019). Higher temperature and variability in temperatures can also lead to increased elephant mortality (Mumby et al., (2013).

It is assumed that temperature is a principal factor in determining the species distribution. However, the distribution of plant species is determined by actual evapotranspiration and water deficiency (Crimmins, 2011). Ultimately, climate driven geographical redistribution of plant species can affect ecosystem functioning, human well-being and alter the dynamics of climate system.

Research has been done previously on impact of climate change in the distribution of elephant species. The study of climate change impact over a particular species can only be done over a period of time. To advance our understanding of climate change impact on species and also evaluate any potential impacts, studies have been done to identify and use relevant bioclimatic variables (Li, 2019). These are also called as environmental variables (Kanagaraj et al.,2019).

Studies have shown that elephant prefer habitat that have higher active vegetation. It also indicates that elephants actively avoid areas like desert or seasonal drought prone areas. Various models that study the future impact of climate change and land use change have predicted a heavy loss of potential elephant habitat in low altitude human dominated regions (Kanagaraj et al.,2019). Anthropogenic threats to Asian elephants are aggravated under climate change (Wenwen, 2019). Climate change impacts natural forest ecosystem which can lead to shortage of natural food for elephants forcing them to farmlands further leading to conflict situations.

Greenhouse gases are continuously rising and thereby temperatures are increasing leading to high intensity summer monsoons in India. The effect of climate change and increasing temperatures can be clearly felt. Higher temperatures will lead to increase in evaporative demand and water availability. This can lead to shift in species ranges towards higher altitude. However, this range shift is going to be along the water availability gradient. Actual Evapotranspiration (AET) is an important factor in net primary productivity of terrestrial ecosystems. It measures both water availability and energy- factors responsible to enhance photosynthetic rates. Forage and water are crucial for elephants to survive

(Sukumar, 2006). For past several decades there has been a change in the patterns of monsoonal rainfalls, with breaks during wet spells and prolonged dry periods leading to seasonal droughts. Prolonged dry seasons have been seen to cause drought related mortalities in African elephants too. Water availability and vegetation dynamics are influenced by seasonally driven rainfall and elephants being a megaherbivore respond to those changes in their habitat, especially in dry seasons by moving to more suitable sites (Birkett, 2012; Bohrer et al., 2014). Studies have suggested that magnitude of evaporative demand is going to increase in future leading to shift of elephant habitat towards North and habitat loss will be accelerated in lower altitudes (Kanagaraj et al., 2019).

Mammals in general can serve as an indicator of climate change impact on distribution of species due to the wide range of ecological niches they occupy. Changes in annual precipitation and temperature could reduce suitable habitats for mammals like elephants and therefore increase their extinction risk.

Rajai Tiger Reserve is a moist deciduous type of forest. Hence, elephants are provided with necessary nutrients throughout the year by seasonal food resources. Elephants are very much attracted to fruits and consume seasonally available fruits. During the availability of fruits they don't pay much attention to other food species.

Elephants remove the leafy portion of soft twigs, and rip off the bark from woody plants for the purpose of feeding. Tree barks are rich in Calcium and therefore they are essential for the growth of skeleton and tusks in male (Joshi, & Singh 2008). Though a diet of only grass can give sufficient calcium, however how much of it is available physiologically is not much known. In wild, a mature elephant can spend as much as 18 hours on feeding and consume 280 kgs of food. Captive elephants however have been observed having better health and grow faster than wild elephants. This is because in wild the food consumed is high in fiber but low in nutrients (John & Subramanian, 1991). The present study has shown that tree species are a major food source for elephants in RNP. The diet is also dependent on migration and movement related activities. Some species of plants that are widely distributed are utilized throughout the year. Species that are distributed altitude wise are utilized during migration or seasonal movement. For example- Grasses like *Saccharum munja* and *Saccharum spontaneum* are fed on when the movement is

towards lower areas. When the movement is towards upper slopes of National park then grasses like *Neyraudia arundinacea* are utilized.

Rohini is one plant that is commonly eaten from the onset of summers, especially during dry season. Kamala or Rohini tree is also an indicator of the distribution of Asian elephants in northwestern India during dry seasons (Bi et al.,2016). Elephants feed on *Dendrocalamus strictus* from July to December and especially fond of Ficus species in most of the months in the year (Joshi & Singh, 2008). Elephants feed extensively during the months of March to May when they are moving around in search of water. Presence of wild elephants can be determined by availability of fresh water too.

The diet of elephants is influenced by various anatomical and physiological characteristics of animal as well as structural and chemical constituents of plants (Owen-Smith 1982). Palatability of food item is a major factor contributing to the decision of consumption or rejection of food by mega herbivore like elephant. Elephants are also known to be prone to sodium deficiency and therefore prefer water and soil rich in sodium, however most of the wild plants are known to have low sodium content.

Crop raiding is common in the adjoining areas of Rajaji National Park. Villages are situated around various forest ranges and grow many crash crops. Elephants leave the forest to feed in nearby villages often during the night. Studies have shown that movement pattern visible today is as close to a natural situation as possible in spite of habitat changes by humans. Few studies in Southern India have also highlighted that elephants are following the same movement strategy as they used to a hundred years back. Scarcity of water is another main reason that leads them outside the protected area. Movement of Elephant outside protected area is more common between November to February. Raiding group sizes changes as per seasons. Elephants are capable of withstanding a great deal of environmental stress and are likely to remain confined to their home range even if the habitat suffers some degree of transformation. However when the natural food within their home range is not adequate they tend to make up the deficit in their dietary requirements by eating crops (Balasubramanian et al. 1995; Madhusudan 2003) which leads to human-elephant conflict situations. Occasionally elephants are moving outside the park area. Stray behavior of elephants is becoming more common from few years as compared previously as elephants are feeding on cultivated

crops. This may be attributed due to increase in fragmentation and change in land use pattern.

Gujjar community is a group of nomadic pastoralists that used to live inside Rajaji Tiger Reserve, however under Gujjar rehabilitation programs they have been shifted to other areas Traditional practice of tree lopping by Gujjars have not only the natural regeneration of various species but also exposes the ground leading to weed infestation. Their cattle also compete against the wild animals for grazing and water requirements (Joshi & Singh, 2009). However after their rehabilitation, regeneration process of forest ecosystem has strengthened as lopping and grazing of cattle stopped.

75% of the park area is 'moist deciduous forest' (Champion & Seth 1968) with subtypes of Moist sivalik sal (Shorea robusta), moist bhabhar dun sal, and dry sivalik sal (Singh & Sharma, 2001). The rest of the forest is mixed type. The roads adjacent to forest: Hairdwar- Dehradun national, etc are covered by heavy traffic during peak hours of the day. The average vehicle passing through this highway is 7,929 with almost 1,972 heavy commercial vehicles; 3,957 passenger cars, and 2,000 motor bikes. Also, railway line haridwar-Rishikesh is situated inside the park through a 23km stretch out of which 18km is between kansaro and motichur range and highly accident prone area. The railway line is almost 100 years old and with time has become very busy. The migration of elephants has been almost restricted due to presence of traffic, roads, railway lines and human population surrounding the park areas (Joshi & Singh, 2008). This presents a major challenge for elephant conservation and management.

The study has shown that tree species form a major part of elephant diet which is directly dependent on migration and movement. In Rajaji Tiger reserve, some species are present throughout the year and some are distributed altitude wise, while some are utilized during seasonal movement. Ritesh Joshi concluded that in Rajaji only few populations of elephants were observed feeding on teak and Sagaun whereas in other areas elephants are not utilizing either of these species as food. Basis of selection of fodder species by elephants is still not understood. Prolonged observation on fodder species and biochemical studies of the plant parts may yield some result on their choice of food.

Conclusions

The feeding habit of elephants shows variation with respect to season, regions, natural water availability and movement patterns. Even though the study has shown that 50 plant species are consumed by elephants, it has also been suggested that elephants in same forest use separate fodder species. Much less work has been done previously on feeding ecology of *Elephas maximus* in Rajaji Tiger Reserve. Therefore to understand this better, more information is required on feeding habits so that elephant management and conservation becomes easier.

Being generalist feeders, the home range of elephants has a wide variation (Koirala, 2016). Appropriate land planning by preventing fragmentation and creation of incentives for the continued protection of forest patches is the first step towards conservation of wild elephants. The protected area provides an abundant food for wild elephants. The problem however lies in the expansion of subsistence agriculture, development projects (roads, highways, dams, railways) leading to loss and fragmentation of habitat. We can see that RajajiTiger Reserve is a rich natural habitat for Asian Elephants but the area was under a constant biotic pressure. The growing human population along with declining space for elephants and humans is resulting in conflict. From the point of view of conservation, every aspect has to be taken in mind before making strategies for elephant management. We know the species which elephants feed on throughout the season in Rajaji Tiger Reserve even though substantial changes in the data may take place in the future due to anthropogenic activities and climate change. Rajaji Tiger Reserve is one of the rare natural habitats of Asian Elephants in diverse and productive lesser Himalayan ecosystem. Therefore, we need extreme management and conservation practices for the long term survival of Asian Elephants.

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