

Movement and Ranging Behaviour of Asian elephants *Elephas maximus* in and around the Rajaji National Park, North-West India

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Short Title: Movement and Ranging Behaviour of Asian Elephant in North-West India.

Abstract: The seasonal and annual movements and home ranges of two different recognized elephant herds and bull elephant were assessed by ground based data and direct observations in Chilla forest of the Rajaji National Park and its adjoining protected habitats from May 2005 to June 2007. During summer elephants use the lower slopes of Chilla forest but during monsoon their movement was towards upper areas of Luni, Rawasan and Pulani forest (south-east axis) and towards Shyampur and Chiriapur forests (south axis) and during the winter elephants again return back to plains of Ganges, where they utilize the riparian corridors. Large migration was observed during onset of summer (February-March). Herd's movement was observed within an area of about 80 Km² moving on the average less than 8 kilometers per day whereas bull elephant's movement was observed to be about 390 Km² moving on the average less than 27 kilometers per day. Home range sizes of herds varied between 13 Km² (winter) and 24 Km² (monsoon) and of bulls between 63 Km² (winter) to 177 Km² (monsoon). Annual home ranges of herds were estimated 18 Km² (summer), 24 Km² (winter) and 21 Km² (monsoon) for Chilla herd and 20 Km² (summer), 13 Km² (winter) and 24 Km² (monsoon) for Garhwal herd, whereas bulls home ranges were estimated to be 83 Km² (summer), 63 Km² (winter) and 87 Km² (monsoon) for bull Ist (Ganesh) and 174 Km² (summer), 84 Km² (winter) and 177 Km² (monsoon) for bull IInd (Hitler) respectively. Data from ground based observations confirmed that elephants frequently moved across outside of the Rajaji National Park boundary towards Laldhang forest of Lansdowne forest division and Shyampur and Chiriapur forest of Hardwar forest division. All of these data support the importance of protecting the Rajaji National Park and its adjoining protected habitats as an important elephant range and corridor, linking different protected areas in north-west India. [Nature and Science. 2009;7(2):76-94]. (ISSN: 1545-0740).

Keywords: Asian elephant; movement; ranging behaviour; Rajaji National Park; protected habitats; north-west India.

Introduction

India has between 21,000 and 25,000 Asian elephants (*Elephas maximus*) in the wild and among them Uttarakhand state harbours 1346 elephants distributed within 14 protected areas. India currently has the largest surviving population of the Asian elephant, approximately 50 % of the total world population of the species (Daniel, 1996). A number of wildlife habitats have undergone or are being threatened with fragmentation due to various anthropogenic factors and this has adversely affected the large mammal populations residing in them (Johnsingh et al., 1990). Recently, developmental activities and habitat destruction have caused major decline in the abundance of the terrestrial megafauna. As most of the wild animals are presently categorized under threatened category therefore, there is increasing concern that the area-wise decline of the elephant will have unexpected and grave consequences for the long-term viability of the terrestrial ecosystems.

The Rajaji National Park was established to enhance the long-term survival of the Asian elephant in a sub tropical moist deciduous forest in India. But during the recent past natural continuous forest ranges of India has been broken up into many parts due to agriculture, urbanization, increasing road traffic and development related activities as well as other anthropogenic activities. This situation creates many problems for various organisms living in forests especially for large size mammals like elephant. Genetic isolation, limitation of dispersal, migration and the decline of populations of animals requiring large territories are the most common problems connected with fragmentation of forests and other components of the environment. Shivalik landscape (lesser Himalayan zone) is one of the last few places in the world where elephants exist and offers urgent need for conservation. From conservation point of view Rajaji National Park appears to be India's one of the most successful national park and its management has helped to boost the population of Asian elephant in their natural habitat. Before the Gujjar rehabilitation programme elephants must scarify the feeding grounds in order to feed on the short grasses due to domestic buffaloes being grazed (Joshi and Pande, 2007).

Human settlements in and around the park area have created the shrinking of elephant's natural paths. The human population around the Rajaji National Park alone has doubled during past one decade and rapid urbanization and industrialization has resulting in the loss of many forestlands to townships and to various development related activities. The factors that contribute to the killing of humans by elephants are the presence of people into elephant's habitat to collect firewood and fodder, conflict over water and cultivation of palatable crops near the forest boundary. In between years 1986 to 2004, elephants have killed 47 persons and injured 43 persons in and around the Rajaji National Park area. And in Hardwar forest range, elephants have killed 26 persons and injured 11 persons in between year 1985 to 2001. On the other hand from 1987 to 2004, more than 134 elephants succumbed in the wild to various reasons (train accident, poaching, electrocution, fallen through hillock, disease, bull fight and natural). Human settlements in and around the park area have created the shrinking of elephant's natural paths. The human population around the Rajaji National Park alone has doubled during past one decade and rapid urbanisation and industrialisation has resulting in the loss of many forestlands to townships and to various development related activities (Joshi and Singh, 2007).

Movements in large mammals are considered to be one of the most important ecological factor, which influence the distribution of other small herbivores. Elephants travel long distance as part of their migrational activities and at the same time they stay within different forest habitats those are enriched with water and fodder species. Once elephants of this track were known to perform extensive migration from river Yamuna to Sharda but during the last three decades, elephants are pocketed in small habitats due to escalated rate of developmental activities and fragmentation of large habitats into smaller ones. This has declined the high in-breeding rate among different population of elephants and constrained them to live within smaller habitats. Migration within large mammals also influenced due to water availability as during the dry period elephants required tremendous amount of water and at that time their local movements is quite frequent near to riparian corridors. Thus the home range studies are better options for wildlife management as these highlights the preferred habitats of any animal and the rate of fragmentation of habitat.

Methods

Study Area

Rajaji National Park [29° 15' to 30° 31' North Latitude, 77° 52' to 78° 22' East Longitude] is spread over an area of 820.42 Km² in and around the Shivalik foothills, which lies in the lesser Himalayas and the upper Gangetic plains (Figure 1). Rajaji National Park (RNP) was notified in 1983 by amalgamating three erstwhile wildlife sanctuaries namely, Rajaji, Chilla and Motichur. Spread across Hardwar, Dehradun and Pauri districts of Uttarakhand state, Rajaji National Park has been designated as a reserved area for the "Project Elephant" by the Ministry of Environment and Forests, Government of India with the sole aim of maintaining the viable population of Asian

elephants in their natural habitat. The Shivalik foothills offer the most prominent geomorphic features of this tract. The river Ganges has cut across these hills at Hardwar. The Chilla forest area of the RNP lies in the east of the river Ganges and is attached by the Garhwal Forest Division. The study was conducted in Chilla (District-Pauri) forest range of the RNP. Besides, Laldhang forest range (Lansdowne forest division, LFD), Shyampur and Chiriapur forest ranges (Hardwar forest division, HFD) were also included in this study. The altitude lies between 302-1000 m asl.

This protected area in India's lesser Himalayan region falls under sub tropical moist deciduous forest type with extensive stands of *Shorea robusta* (Sal), *Mallotus phillipinensis* (Rohini), *Acacia catechu* (Khair), *Adina cordifolia* (Haldu), *Terminalia bellirica* (Bahera), *Ficus bengalensis* (Bar) and *Dalbergia sissoo* (Shisham) in its premise besides many other important fodder plant species. This entire belt is natural home of Asian elephants (*Elephas maximus*) besides many other wild animals like *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) and *Ophiophagus hannah* (King cobra).

Data Collection

It is not easy to sight elephants in dense forest habitats due to thickness of the undergrowth and foggy climate especially during the monsoon and winter period. Also there are chances of any casualty. In few of the forest pockets it was difficult to observe directly the elephants in RNP because of dense sub-tropical vegetation and presence of undulating foothills with bushes taller than the animal. Thus the study incorporated both direct as well as indirect methods.

Direct Method

For assessing the movement behaviour of elephant's four forest ranges (Chilla, Shyampur, Chiriapur and Laldhang) of the RNP, HFD and LFD were selected and in-depthly surveyed. All the field observations were made during 2005 to 2007. It was not possible to observe the elephants during monsoon as most of the areas are dominated with tall grasses and dry period was the best time to observe the elephants especially near to water sources. The study area was visited at weekly intervals during which observations on elephants were made along the motorable forest track, present in between different forest habitats. Few other connected rough routes, which link the grassland habitat with motorable road were also used during the course of study. As few forest beats of the study area does not comprises of any road, therefore, study was made on foot. Although some animals were observed up to a maximum distance of 100 meter, most of the observations fell within 50 meter. Besides, all the potential habitats (water dominant areas, cool shaded areas, fodder enriched areas and rough forest routes) were also investigated on foot during early morning, mid-day and evening hours. Cool shaded trees like *Ficus bengalensis*, *Adina cordifolia* and *Ficus glomerata* and dense forest of *Mallotus phillipinensis* and other favourite fodder species were examined mostly during mid day (March-June) hours as elephants generally take rest under these cover. Whereas all the water sources (perennial/annual) were investigated alternatively during evening hours.

As the elephants in RNP have been known to emerge from the forest predominantly during evenings, all sightings of elephants were made between 1500 hours and 1900 hours. Besides, observations were also done during early morning hours (0600 hours to 10 hours). Different forest blocks of concerned forest ranges were selected one after another sequentially and searched for elephants for about 10 – 12 hours (depending upon weather conditions) in a single day search. The observations started at early hours in the morning being the best time to search and observe the elephant in open areas and four hours in the afternoon i.e. before the sunset. The data collected was as part of the animal monitoring activities and the daily record was based on direct sighting of animals, indirect evidences like feeding sign, footprints impression time and fresh dung piles. The direct sighting were noted in duly prepared proforma, recording the Herd composition, age and sex, if observed in Herds and also the place of sighting, time and vegetation type. Besides, villagers of

adjoining areas, Gujjars (where available), staff of forest department, the researchers from various scientific institutions and non-government organizations and other individuals working on this problem, were also interviewed. Field binocular was also used for observing their movement behaviour without disturbing the animal from an adequate and safe distance.

Movement behaviour

Two different Herds and two solitary adult male elephants were selected and alternatively followed in Chilla (RNP), Shyampur and Chiriapur (HFD) and Laldhang (LFD) forests during the early morning hours and evening hours. First Herd consists of 21 individuals and the other one 13 individuals (Table 1). The classification of individuals in the Herds was based on Eisenberg and Lockhart (1972) – namely adult, sub adult, juvenile and calf. Photographs of the herds and bulls were also taken for confirmation upon repeated sightings (Figure 2, 3, 4 & 5). Whenever any marked Herds or solitary males were encountered during early morning circuit, their location was noted along with ongoing activity. An attempt was again made later in the evening hours to relocate the animal that had been observed in the morning. Video camera was also used to cover small footages of Herd composition along with different behaviours of recognized Herds. Whenever herds were encountered, they were observed until they disappeared from sight or until darkness made further observations impossible. As elephant movement was restricted in between Chilla – Motichur and Rajaji – Corbett corridors, therefore, it has made us easy to follow and observe these recognized Herds and bulls those were performed their movements in eastern part of river Ganges.

The movement pattern and the present home range used by identified herds and bull elephants were calculated by plotting sighting locations on a map (1:50,000 scale) (McKay, 1973; Ali et al., 1986; Daniel, 1988; Datye and Bhagwat, 1995). Sometimes, movements of both the herds and bulls were overlapped simultaneously in the same area, and it has helped us to trace their movements sharply.

Table 1. Composition of elephants in Herd Ist (Chilla herd) and Herd IInd (Garhwal herd).

Herd No.	Adult females	Sub-adult females	Juvenile males	Juvenile females	Calves	Total
1	7	5	2	4	3	21
2	5	3	1	1	3	13

Identification of the elephants was important to verify their movement as in the same area there was a possibility that the same Herd was observed in the different forest beats. Therefore, distinctive features, with certain identification marks of individual elephants were noted like; shape of the ears, tusk size and shape, scars and tubercles on the body, tail length, total number of individuals (all ages separately), body mass and nature of Herd or solitary bull.

Indirect Method

In few of the places the indirect count method was followed for checking their number in study area (Dawson and Dekker, 1992; Ramakrishnan et al., 1991; Santiapillai and Suprahman, 1986). This involves path counts and frequency of elephant signs. For conducting the study on elephant's presence, all the observations were made from a vehicle and through adopting the road-strip count method (Hirst, 1969; Santiapillai et al., 2003) to monitor the fluctuations in elephant numbers.

Results

Movement is one of the most important ecological factors that represent the home range as well as habitat utilization of an animal. Both movement and migration depends upon the availability of natural food and water. Changes in season and scarcity of water and natural fodder species force

wild animals to leave a place for few months and reached to new feeding grounds for fulfilling their feeding and breeding requirements. There are seasonal variations in fodder species as RNP area falls under sub-tropical moist deciduous forest vegetation type. Elephants use whole of the park area as their natural habitat but mostly they leave some of the areas having less vegetation cover and water for few months and move towards other ranges richer in fodder species and natural water. Although at that time few of them (mostly solitary bulls) use the same feeding grounds or move frequently in all the forest beats of the park as a general rule of migration of any species.

Movement and Ranging Behaviour of Elephants

Elephant use Chilla forest round the year because of altitude wise variation of rich fodder species. Elephant used to live regularly in lower patches of Chilla forest (Chilla, Mundal, Jhabargarh and Khara forest) during dry period but on the arrival of rainy season elephants migrates towards upper areas (Luni, Pulani, Rawasan and Kasaan forest beats) and that was the time when elephants start their long term migration towards Lansdowne forest division and Hardwar forest division (south-east axis). Again on the onset of winter elephant's movement is towards lower areas (south-east to north-west direction) and at the same time elephants also utilize the adjoining forest of river Ganges, which is spread up to Rishikesh along the river. Besides, many of the Herds and solitary bulls perform their movements in all of the forest beats round the year for their local movements. During the summer elephant's movement was also frequent in the Gohri forest range, which is in the north of the Chilla forest.

Elephants also use the Ghasiram water stream for visiting to river Ganges especially when their movement was frequent in adjoining forest beats, which are major riparian corridors of different tributaries to river Ganges. One bridge over to Ganga canal (Soni shroath) is also utilized during dry period for inter-changing the forest. Some Herds were also observed to use the Shyampur and Chiriapur forest of HFD during rainy season because of availability of Ganga canal water. At the same forest elephants perform their movements towards river Ganges through crossing the Hardwar-Bijnor National Highway. Currently only bull elephants are utilizing this track whereas no Herds were reported during last three years. As per last 6-7 years data, Herds of the elephants were observed in the same area but rapid developmental activities has restricted the frequent movement of elephant's Herd towards river Ganges.

Few of the main reasons affecting local movement of the elephants in rainy season are:

- a) During rainy season the elephants were seen moving towards upper areas of the park. This is because the low lying areas become swampy and unfit for free movement of the elephants.
- b) Another major factor contributing to their upward movement is the abundance of a blood sucking fly locally called as 'daans' in low lying areas which irritates elephants by hovering around their ears and trunk. This fly is commonly found affecting the cattle stock of Gujjars and villagers.
- c) Forest fire is also one a factor to force the elephant's movement to a separate area where fire had not been so extensive. This fire if spread extensively then the movement of such a large animal also restricts to the same area for some time.

The movements of the Rajaji's herds are entirely seasonal and similar seasonality was also observed in the appearance of herds at adjoining protected habitats. Figure 6 and 7 shows the movements of both the Herds (21 and 13 elephants), which constituted part of the population inhabiting the Chilla forest of the RNP from May 2005 to June 2007. During this two year period elephant's movement was observed within an area of about 80 Km² moving on the average less than 08 kilometers per day (Figure 6 & 7). Bull elephant's movement was observed to be more as

compared to herd movement and they ranges about 390 Km² moving on the average less than 27 kilometers per day (Figure 8 & 9).

Herd Movements

During the study period Chilla herd was located on 194 days (summer), 183 days (winter) and 127 days (monsoon) while Garhwal herd was located on 181 days (summer), 162 days (winter) and 114 days (monsoon). The annual home range of Ist herd was observed to be 18 Km² in summer, 24 Km² in winter and 21 Km² in monsoon. Similarly, the range utilization by IInd herd was 20 Km² in summer, 13 Km² in winter and 24 Km² in monsoon respectively. The home ranges of both the recognized herds were almost same throughout the year and they were observed to utilize the same seasonal feeding grounds in both the years. It indicates that both of these herds have had a fixed home range to some extent. Generally herds comprise of baby elephants and their seasonal ranging was also occurred in a fixed manner, therefore, their movements were restricted to particular areas. Longer movements were only observed during the course of migration or when environmental conditions are unfavourable for example forest fire and scarcity of water.

Figures 6 and 7 shows the movements and areas covered by two herds, the Chilla herd and the Garhwal herd over periods of two year each. As can be seen from both of these figures, each of the herds remained in a particular area for period of 2-3 months, although the Chilla herd did remain primarily in the Chilla region itself for the period extending between February and June. From July to September, these animals were moving fairly regularly and covered an area of approximately 24 Km² throughout this period. In November, they were observed making a long movement into an area where they remained between December to June. It was unfortunately not possible to follow the herd in this area during the monsoon season so; indirect evidences like presence of footprints, feeding signs and presence of dung piles (recognised herds) were followed to compare their movements during this time. The movements of the Garhwal herd (Figure 7) was somewhat similar in that the animals used only small areas of their total range for periods of 1-4 months.

The movement of both the herds in dry season was restricted around the Chilla forest of the RNP mainly due to presence of natural water in some of the forest pockets. Besides, river Ganges is flowing adjoining to this forest, which further ensures the long-term movement of elephants in the adjoining forest areas. At the onset of rains the herds extended their movements to Shyampur and Chiriapur forest (HFD) and Laldhang forests (LFD) area. For a long period of time (4-5 months) Garhwal herd movement was also occasionally observed in Bijnor forest division adjoining to Sigaddi forest beat of Lansdowne forest division. There was considerable difference in the seasonal and annual home range sizes of the herds (Table 2).

Table 2. Annual and Seasonal Home Range Size (km²) of the Herd Ist (Chilla Herd), Herd IInd (Garhwal Herd), Bull Ist (Ganesh) and Bull IInd (Hitler) during 2005-2007.

S. No.	Group / Bull Elephant	Home Range Size (Km ²)				Number of Locations of Sightings			
		Summer	Winter	Monsoon	Annual	Summer	Winter	Monsoon	Annual
1.	Herd Ist (Chilla Group)	18	24	21	63	194	183	127	504
2.	Herd IInd (Garhwal Group)	20	13	24	57	181	162	114	457
3.	Bull Ist (Ganesh)	83	63	87	233	147	123	97	367
4.	Bull IInd (Hitler)	174	84	177	435	129	113	89	331

Bull Movements

The movement of the first bull elephant (Ganesh) in dry season was restricted around the Chilla forest of the RNP and its adjoining areas whereas the movement of second bull (Hitler) was not confined to any particular area. As both the bulls are sharp crop raiders, therefore, the movement of both the bulls was regularly observed in Shyampur forest of the Hardwar forest division. First bull elephant was located on 147 days (summer), 123 days (winter) and 97 days (monsoon) and the second bull 129 days (summer), 113 days (winter) and 89 days (monsoon). The annual home range of second bull (Hitler) was approximately two times larger than the first bull (Ganesh). The summer home range of the first bull was 83 Km² while the second bull was 174 Km². Similarly, the winter and monsoon home range of first bull was 63 Km² and 87 Km² while that of second bull was observed to be 84 Km² (winter) and 177 Km² (monsoon) (Table 2).

Bulls always range over a longer area as part of their habit. In RNP and its adjoining areas bull were sharply observed to raid crops in out skirts of protected areas as compared to Herds. During the musth period the movements of bull elephants were enhanced and they traveled long distances. The first bull (Ganesh) was more than 45 years old whereas the second bull was aged between 35-40 years. Our long course of study on the behaviour of elephants in this region indicated that the second recognized bull (Hitler) was very aggressive and as per our earlier observations it has killed about eight persons in the same area during the last two years. The summer and monsoon home range size of the second bull (Hitler) was comparatively larger, whereas the home range size of the first bull (Ganesh) showed a definite movement pattern with a greater monsoon home range size. The home range of both the bulls was more overlapped with herd's movements during summer.

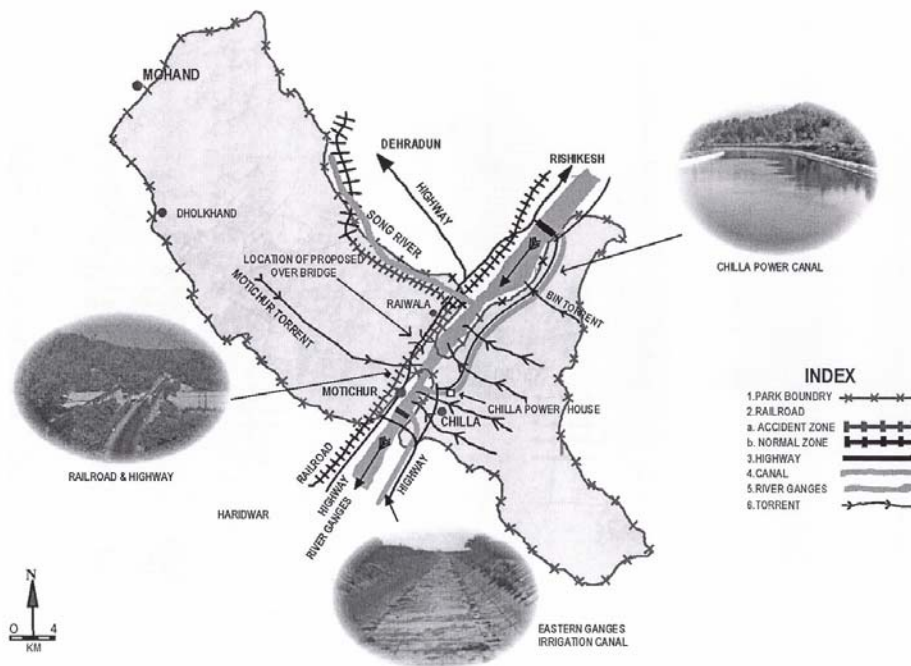


Figure 1. Map of the Study Area (RNP).



Figure 2. Chilla Herd (Herd Ist) at Luni river of the Rajaji National Park.



Figure 3. Garhwal Herd (Herd IInd) at Siggadi Forest of Lansdowne forest division.



Figure 4. Bull Ist (Ganesh) at Chilla Forest of the Rajaji National Park.



Figure 5. Bull IInd (Hitler) at Mundal Valley of the Rajaji National Park.

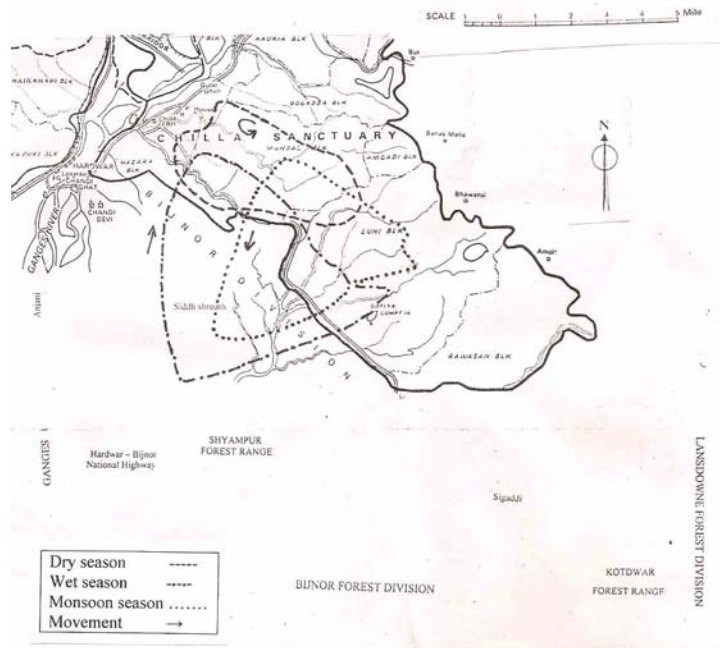


Figure 6. Seasonal Home Range of Ist Herd (Chilla Herd) in and adjoining to Chilla Forest of the Rajaji National Park.

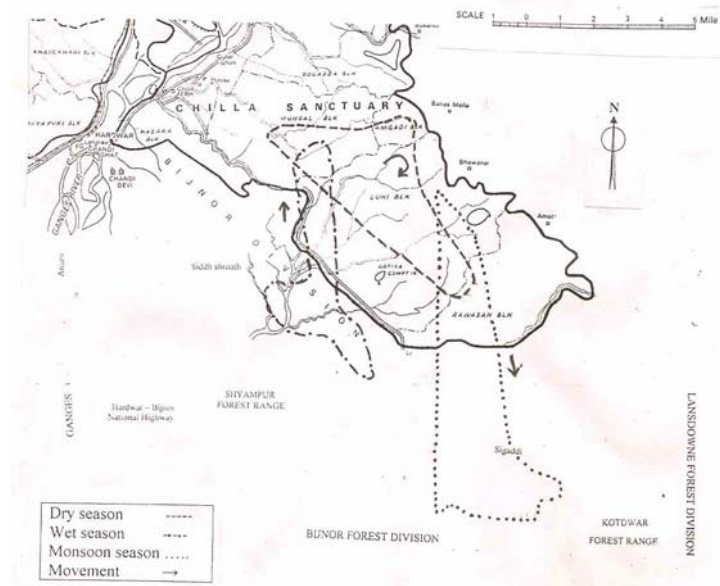


Figure 7. Seasonal Home Range of IInd Herd (Garhwal Herd) in and adjoining to Chilla Forest of the Rajaji National Park.

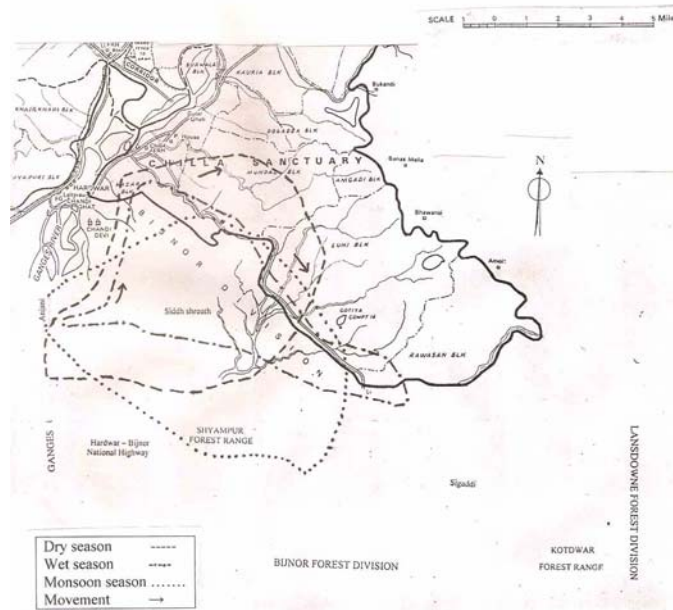


Figure 8. Seasonal Home Range of Ist Bull (Ganesh) in and adjoining to Chilla Forest of the Rajaji National Park.

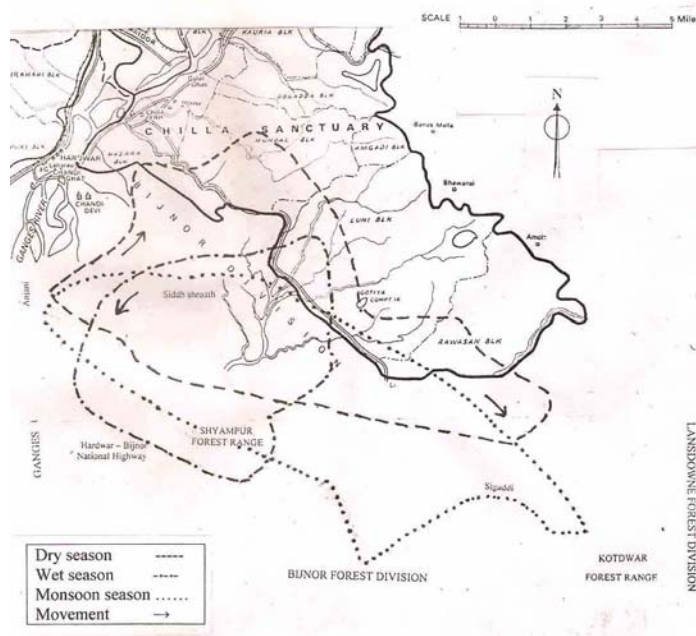


Figure 9. Seasonal Home Range of IInd Bull (Hitler) in and adjoining to Chilla Forest of the Rajaji National Park.



Figure 10. Recording the Geo-Positioning of Ganesh during his walk at Shyampur forest.



Figure 11. Observing the Associational Behaviour of Ganesh (facing behind).

Discussion

During the recent past extensive work has been carried out on the movement pattern and habitat utilization of Asian elephants (Singh, 1969; McKay, 1973; Ali et al., 1986; Santiapillai and Suprahman, 1986; Easa, 1988; Daniel, 1988; Sukumar, 1989; Datye and Bhagwat, 1995; Williams and Johnsingh, 1996; Williams, 2002; Joshi, 2002; Joshi and Singh, 2007) but enhancing rate of developmental and anthropogenic activities forced elephants to change their traditional routes and therefore, regular documentation of movement activities is highly required to know the exact population persistence of species. Besides, wildlife biologists have also explored new conservation tools regarding to long term survival of various endangered wild species but currently there is a need to obtain more and more biological information about wild species to enhance the status of their habitat and population in forest habitats.

Seasonality of Movements

Some herds, especially those in the eastern and western regions of Corbett Tiger Reserve, showed distinct seasonal movements. Others, such as the elephants in the Kalagarh region show little seasonal movement (Singh, 1969). Movement pattern of elephants in the study area indicated that elephants alternatively utilize the Chilla forest (RNP), Shyampur and Chiripur forest (HFD) and Laldhang forest (LFD). During the summer, elephant's movement was more in the Chilla forest and at the onset of monsoon they migrate towards Laldhang and Shyampur forest. And at that time their movement was more common near the foothills dominant areas as all the small ponds were fulfilled with water during the said period. At the onset of winter they again migrated towards lower slopes and their movement was more observed in grassland dominated areas. During the winter elephant's movement activities generally enhance and they travel more distances up to the onset of summer. Few of the bull elephants and occasionally Herds use whole of the forest for their movements.

Overlapping of the home ranges of Herd Ist and IInd and bull Ist and IInd was more observed during summer season, which was also the time for mating in elephants. Mixing of the adult bulls, selection of prospective partner to mate, smelling of genital organ and discharge of urine were few of the major features of mating behaviour in elephants. Breeding season in Rajaji National Park was noted to be extending maximum from May to November, which through embraces the hot, rainy and beginning of cold seasons but largely the warm period (Joshi, 2008). Water and fodder are one of the important factors, which influence the distribution of elephants. Besides, forest fire also influences the range utilization in elephants. But, fodder species presence did not restrict the movement of elephants in study area as all the forest zones are enriched with huge amount of food plant species, which the elephants like.

Elephant's diet in Rajaji mainly consisted of 50 plant species, which are available to them alternately round the year. Alteration between a predominantly browse diet throughout the year with a grass diet during the early dry season was related to the seasonally changing mineral content of grasses. Consumption of tree species (74%) was highest as compared to grasses (14%) and shrubs (8%) but their diet was mainly dependent on availability of seasonal food round the year and on their migration (Joshi and Singh, 2008b). The seasonal movement of the Chilla herd (Herd Ist) and Garhwal herd (Herd IInd), which took place during 2006-2007 (summer, winter and monsoon) was almost similar to that of 2005-2006 but a slight change was observed in the movement of Herd Ist during their migration towards Chilla area in the beginning of winter. During 2007 heavy flood was observed in annual water streams of Chilla forest (Mundal, Ghasiram and Hazara) and due to this different grassland has got destructed. A large extent of the Chilla forest was affected from the impact of heavy floods during July, August and September, 2007. On one hand floods has affected the migrational pattern of elephants and on the other hand disrupts the natural regeneration potential of several grass species those grow especially in between dry river beds (Joshi and Singh, 2008a).

Riparian wildlife corridors (annual water stream beds) inside the RNP generally comprises of several fodder grass species like *Saccharum munja*, *Saccharum spontaneum*, *Desmostachya bipinnata* and *Cynodon dactylon*. All of these species are the favourite food item for elephants. Besides, few tree species those grow generally nearer to the Gangetic plains like *Acacia catechu*, *Dalbergia sissoo*, *Bauhinia variegata*, *Albizzia lebbek*, *Ehretia laevis* and *Lagerstroemia parviflora* were also damaged due to heavy floods. Mundal valley consists of larger feeding grounds (grasslands) but this environmental event has destroyed whole of the area. Water flow has also caused damage to some extent in higher slopes of the protected area. Grass species which grow in profusion in higher altitude area like *Neyraudia arundinacea* were severely affected due to floods (Joshi and Singh, 2008a).

The movement of the Chilla herd was nearer to the *Haplophragma adenophylla* (Kut Sagaun), *Tectona grandis* (Sagaun) and *Mallotus philippinensis* (Rohini) species during 2006 whereas next year their movement was not observed nearer to *Haplophragma adenophylla* and *Tectona grandis* forests as these species were infected by termites during 2007 in some parts of Chilla forest beat. As bull elephants were observed to be sharp cop raiders, therefore, they perform extensive movements nearer to human habitation areas besides, their movements is also influenced by musth phenomenon and to search prospective group and female. Some time their movements were also observed in National Highways passing in between the protected habitats while moving towards adjoining village to feed on cultivated crops (Figure 10 & 11).

As per the observations of a previous study on radio-telemetry of elephants in Chilla forest, the annual home range of bull and the cow was observed to be 200 Km² and 34 Km² (Joshua and Johnsingh, 1995). Elephant's home ranges were estimated to range from 188 Km² to > 400 Km² but no differences were found between male and female home ranges (Williams, 2002).

In Kuppam, Palamaner, Gudiyattam, Panganur and Bangarupalayam (south India) elephant's home range was estimated to 409 Km². Similarly, a study in south India estimated the home range of elephant's herds to be 105 Km² and 115 Km² (Sukumar, 1989). Home range size of two different Herds was estimated to be 34.7 Km² (dry season) and 87.2 Km² (wet season) and 81.3 Km² (dry) and 46.1 Km² (wet) in Parambikulam Wildlife Sanctuary, south India (Easa, 1988). Movement of elephants in Dudhwa National Park has been also seasonal and erratic. Animals of the western Nepal population range south along the Karnail river from the reserve to a patch of riverine forest across the border along India (Javed, 1996). The home range estimated to be 258.6, 3343.1 and 4348.9 Km² for three different bulls in Dalma Wildlife Sanctuary and Chhotanagpur Plateau (central India). Study also highlighted that home ranges expanded to be maximum in winter and shrunk to minimum in summer (Datye and Bhagwat, 1995).

The same populations of elephants used to perform their movements in Gohri, Chilla, Laldhang, Kotdwar, Shyampur, Chiriapur and Sonanadi forest whereas Herd movement was almost restricted towards Corbett National Park area as both of the forest zones are disconnected mainly due to huge amount of anthropogenic and developmental activities. It was also observed during the study period that Chilla forest was the favourite place for elephants during summer and large number of elephants stayed in this forest and among them some herds represent their seasonal traditional movements adjoining to river Ganges. In few of the places, elephants utilize the same feeding grounds round the year (recognised Herds).

Elephants inter-change the forests of Rajaji and Corbett National Park as their part of traditional migration. But presently in few of the areas their traditional feeding grounds and corridors are denied to them, which have causes man–elephant conflict. The long-term effects will include genetic isolation, habitat fragmentation within the same forest and enhancement in the human–elephant conflict in adjoining areas. Genetic isolation of elephant populations may also increase the chances of replacement of interbreeding to intrabreeding, and thereby reduce the population persistence even for wide ranging wildlife species (Joshi and Singh, 2008a).

Same situation is with other corridors present adjacent to the RNP area. Kotdwar – Lansdowne road runs parallel to the river Kho and crosses the Rajaji-Corbett corridor, the major movement

track of northwestern elephant population between the Yamuna and river Sharda. This road serves as the major transport link between Pauri town and Kotdwar area. The presence of traffic on the road, construction of steep retaining walls by the side of road and the presence of human population along the entire corridor area have almost restricted the migration of elephants using this corridor (Johnsingh and Williams, 1999). The motor roads, which are adjacent to the forests like Hardwar-Dehradun National Highway and BHEL roads have heavy traffic pressure. As per a preliminary study, the average number of vehicles passing on Dehradun-Hardwar road per day is 7,929 and all the wild animals, including elephants, are not in a position to cross this track at any time due to the presence of heavy traffic (Singh and Sharma, 2001).

A large mammal like the elephant could be expected to move more considerable distances even with a short period and families of a clan seemed broadly coordinated in their seasonal movements (Sukumar, 1989). In the dry months (January to April), when no rainfalls occur, the Herds seek the neighbourhood of streams and shady forests. From the month of July, after the first shower, they start roaming and feed on the fresh grass. This grass in hill tracts become long and course by July and August, the elephants then shows their upward movements. The reason for the elephants and other animal's migration is the high lands, continuous and uninterrupted hilly terrain for grazing, assured food, ideal breeding ground and thick population (Sinha, 1981).

During the last 5-6 years, state Government has constructed about six flyovers in Hardwar – Bijnor National Highway. As a result of anthropogenic activities about 18 kilometers forest stretch existing on both the sides of highway has got disturbed. Besides, agricultural expansion near river Ganges has lead to the loss of forest wealth, which has also hindered the traditional movement of elephants. This forest stretch is one of the major corridor for elephant movement and presently has got disturbed mainly due to habitat loss around the national highway. Sometimes few of the male elephants associate to enter the forest near to river Ganges through this route. Elephants cross the national highway in the evening hours and return back to the forest area during early morning hours.

Besides, elephants also utilize the Gaziwali bridge, Shyampurwali bridge and Pili bridge situated peripheral to the canal road over to Ganga canal for their movements towards western direction and to feed on the cultivated crops in nearby villages. During the study period all the villages suffering from crop raiding have been investigated. The affected villages are Jagjeetpur, Mishrpur, Panjneri, Ajeetpur and Jaipota in the western side of the conservation area and all these villages are situated peripheral to river Ganges. Villages Kangri, Ghaziwali, Shyampur, Sajanpura, Pili and Rasiabad are located peripheral to forest area and national highway whereas villages Gaidikhata, Lahadpur, Chiriapur, Vasuchandpur and Naurangabad are also situated adjacent to the forest area and national highway on south western direction of the conservation area.

The villages along the river Ganges are situated on land that was once part of the elephant's home range. Therefore, the increasing elephant – man conflict is unfortunate but inevitable. The electric fence erected along with these villages and river Ganges has presently got damaged due to lack of proper maintenance. It was observed that elephants are utilizing their traditional feeding grounds in few of the areas, which are presently denied to them and are replaced by human settlements.

The present study reveals that elephants utilizes whole of the park area for their movement, but mostly they leave some of the areas for few months, as part of their seasonal migrational activities. The local movement and long term migration of elephants within the RNP shows a definite range use pattern. After the isolation of Chilla forest and Motichur forests the elephants population of the RNP has divided into two parts. Presently, elephants of Chilla and adjoining areas in the eastern part of river Ganges show the better migration between the Chilla area and Kotdwar (LFD) whereas the elephant populations of Hardwar, Motichur, Kansrao and Dholkhand has been isolated. Again due to large scale developmental activities inside the Dogadda forest area has caused the hindrance in their corridor area. Slowly seasonal movements and migratory routes have also undergone to minor changes. Elephants in North Bengal are pocketed but these pockets have

increased in number and also changed their locations with the passage of time. Elephants are trying to adopt themselves to the changing environment by changing their ranges, moving on to new areas and by adopting new routes (Barua and Bist, 1996).

The reasons for migration of elephants can be annual fire, drought, non-availability of fodder, paucity of drinking water and absence of cool green shades in their respective areas (Ramachandran, 1990). In Chilla, the elephants, which were deep in the hilly terrain of north in the rainy season, gradually start moving towards the south due to scarcity of water winter season in the hilly areas. The study further reveals that the animals are directly affected by water availability and availability of fodder species inside the park area. Presence of river Ganges in Chilla area further ensures the migration of animals at the onset of summer. Most of the seasonal migratory routes through which elephants performed their long-term migration have been shrunk presently as the result of which elephants of Rajaji are restricted to move only in internal ecological units, whereas bull elephants occasionally were observed to move within such long corridors like Chilla - Motichur and Khara – Anjani (Joshi and Singh, 2007).

India's elephant populations are currently threatened by habitat deterioration, developmental activities, anthropogenic pressure inside the deeper forest regime and unregulated exploitation of natural resources. Effective human-elephant conflict mitigation cannot take place in the long-term without the involvement and true support of the local communities. Similarly, rural livelihoods depend on a flow of natural resource benefits, many of which cannot be sustained without active protective measures. To build these partnerships requires greater understanding about working with local communities in designing programs to realize joint benefits. It also requires effective community empowerment to allow the communities to plan for wildlife management and conservation.

The Rajaji National Park, Lansdowne and Hardwar forest divisions are important biological areas and have great potential for wildlife and its conservation. One line of evidence is that the Rajaji National Park harbours important populations of species on the IUCN Red list, the Asian elephant. In recent years, human activities have expanded in the boundaries of the protected areas and as a result most of the wildlife corridors have been shrinking rapidly and elephant's long-term migration became restricted, which can influence their population persistence.

Recommendations

- 1) As pointed out from the present investigation that the same herds were utilizing the Chilla (RNP), Shyampur and Chiriapur (HFD) and Laldhang (LFD) forest alternatively round the year and their movements are entirely seasonal, therefore, proper census should be carried out, which will provide us the exact population composition database of elephants of this entire forest stretch.
- 2) During the course of elephant movement nearer to the national highways (Hardwar – Dehradun and Hardwar - Bijnor), traffic should be stopped at a safe distance. At the same time people are not allowed to deter the elephants.
- 3) In Chilla forest elephants interchange the forest through a small bridge over to Ganga canal commonly known as Soni shroth. The bridge should be widened to some extent so that elephants may cross easily.
- 4) Ghasiram shroth is a traditional corridor in Chilla area and elephants utilize this track especially during dry months. During that period traffic of the Chilla – Rishikesh road should be stopped in evening hours. Similarly, heavy traffic should not allowed in Laldhang – Kotdwar forest road.
- 5) Dudhia forest beat (island) and the islands situated in between river Ganges should be restored from any anthropogenic disturbances.
- 6) Grazing may be banned at least from the crucial areas of the corridors.
- 7) Habitat restoration may be planned to enhance forest cover in degraded areas. Besides, plantation of fodder plant species is also required.

- 8) Artificial water holes must be created, spread within the park area at short distance. For solving the problem water uplifting pumps will be used to uplift the well water during day hours, which will help during dry periods. Waterholes can also be connected with Ganga canal and management related practices should be carried out regularly.
- 9) Relocation of villages and Gujjar deras (shelters) those are in the corridor area.
- 10) It was observed during the study period that the population of elephants of Gohri, Chilla, Shyampur, Chiriapur and Laldhang forests are same and their movements in these forest zones are entirely seasonal. Therefore, proper monitoring of elephant's populations is required and few research studies are also required, which will help us in documenting the appropriate management plan.
- 11) Besides, managed tourist activities, minimizing the forest fires effect and proper thinning of trees under high-tension lines, which pass through the protected habitats are highly recommended.

Acknowledgements

We are thankful to the Science and Engineering Research Council, Department of Science and Technology, Government of India for providing financial support and thanks are due to Late Dr. R. C. Srivastava, Scientist 'G' & Advisor – SAC (PM of India) and Dr. Jagdish Chander, Scientist 'F', DST, for their cooperation and valuable suggestions. Director and Dr. R. K. Maikhuri, (Scientist Incharge, Garhwal Unit) of G. B. Pant Institute of Himalayan Environment and Development, Kosi – Katarmal, Almora are acknowledged for providing facilities, encouragement and suggestions. Shri Srikant Chandola, Additional Principal Chief Conservator of Forests (Wildlife), Government of Uttarakhand, Shri G. S. Pande, Former Director, Rajaji National Park and Shri S. S. Rasaily, Director, Rajaji National Park are acknowledged for giving the permission to carry out the research work in the said area. Thanks are to Mr. Raju Pushola, Photographer, *Dainik Jagran*, Dehradun and various concerned forest officials and staff for providing help during the field investigations.

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1/4/2009