Introduction

The Asian elephants in India are distributed in four distinct geographical areas in five isolated populations. There are two populations in southern India, one each on either side of the Palghat gap. The other three populations inhabit the central, northeastern and northwestern regions of the country. The northwestern elephant population is smallest comprising of about 1000 individuals. However, a larger part of the northwestern elephant population inhabit Rajaji and Corbett National Parks including the forested areas in between the two. Once contiguous, this stretch of elephant habitat off late has been facing peripheral pressures and fragmentation due to intense human dependence on forest resources and developmental activities. As a result of this, the elephant population in this stretch has been divided into three sub units with little or no movements between them. In such conditions, it was presumed that the confinement of elephant population in smaller areas would be detrimental to their long-term survival and wellbeing. Considering this, the present study was initiated in order to understand elephant-habitat interaction and its management implications in Rajaji National Park, which supports more than one third of the total elephant population in northwestern India. The study had specific objectives to understand the elephant habitat composition and structure, movements and habitat utilization patterns, dietary spectrum and impact of elephant feeding on vegetation and to work out social organization of elephants in Rajaji National Park.
Methodology

In order to achieve the objectives of the study several sets of methods were used to collect field data. In addition to the field data I have reviewed the status of the Asian elephant populations in the range countries, which was mainly based on the available literature.

The data on vegetation composition and structure was collected using Point Centred Quarter Method along the stratified transects laid in proportion of availability of different vegetation types. Tree and shrub diversity, richness and evenness values were calculated using Shannon-Wiener diversity, Margalef’s species richness indices and Shannon-Weiner function respectively. Sorenson’s similarity index (SI) was used to calculate similarity among different habitat types.

To compare the structure and dominance of various species among different vegetation types, Importance Value Index was computed for tree species in different vegetation types. The relationship between tree densities and other habitat parameters was quantified by performing correlation using the Spearman Rank Correlation Coefficient. Tree and shrub density values were statistically compared to understand the differences between different strata, terrain and administrative blocks using one way ANOVA. All statistical tests were performed using computer programme SPSS for Windows (version 10.0).

The data on ranging and habitat utilization pattern of elephants in Rajaji were collected by fixing four radio-collars on different individuals. Locations of each radio-collared elephant were obtained by homing in and were fixed on 1:50,000 scale topographic map of the study area. Home range areas were delineated using Harmonic Mean Transformation method and 90% isopleths were generated. The
95% Bonferroni confidence intervals were constructed to understand the elephant preference to different habitat types.

Data on elephants’ dietary spectrum were collected during daytime through direct observations on feeding individuals. The impact of elephant feeding on vegetation was assessed by enumerating damage caused to the trees along 10 m wide belt transects.

The social organization of elephants in Rajaji was studied by recording data through direct sightings of individuals in a group. Whenever, a solitary elephant or a group was encountered its composition and size was recorded. Chi-square goodness of fit test was used to see the differences in the distribution of frequency of sightings between different types of elephant groups. The Kruskal-Wallis one way ANOVA was used to test the differences in the median group size among different seasons.

Results

Population status of the Asian elephants

The total population of Asian elephants in the wild is between 33,600 and 47,835.

There are considerable discrepancies as far as number of elephants in the wild are concerned, mainly due to the lack of proper surveys and inadequate information from several range countries. Most of the information on population size before 1980’s, barring a few, is based on educated guesses and hence does not allow to draw any meaningful conclusion on the population trend. However, an analysis of available accounts on the population size of last three decades reveals that in most of the range countries of continental south-east Asia, elephant populations have reduced mainly due to the loss of habitat and fragmentation. Elephant populations in the Indian sub-continent seems to be increasing however in my opinion this may not be a virtual increase in population but more so due to their compression within the
protected areas and systematic and consistent efforts in estimating numbers. Population of elephants in Andaman Islands has certainly increased, while no conclusion on the population trend of island Asia (Sri Lanka, Sumatra and Borneo) can be drawn as the existing information is either insufficient or highly discrepant. This certainly calls for consideration of a policy to initiate planned studies to find out the current population status, trends and also monitor population size in various range countries. Concerted efforts for such study are urgently required.

**Habitat structure and composition**

The vegetation of Rajaji is homogeneous in nature and species are not distinctly arranged in space to form definite vegetation classes. Sal (*Shorea robusta*) is the dominant species occurring all over the area in differential densities. The topographical variation seems to be influencing the density, growth and spatial distribution of various species. A total 71 tree and 46 shrub species were recorded during the study, however, the numbers could be more as rare or less frequent species are likely to be missed in such a large area during sampling. Sal forests were less diverse as compared to mixed forest. The management interventions by the Forest Department had a positive effect on the vegetation, especially the gap filling exercises by raising plantations within the natural forests, have increased the density and diversity of the forest stands. The standing crop is better stocked on the flat and undulating terrain as compared to the slopes and the valleys. Forest blocks such as Gholna, Bam, Betban, and Chillawala had high lopping pressure, which may create an adverse impact on the forests in the form of low regeneration and retardation of tree growth. If the similar trend continued, it would lead to further degradation of the forest stand. Low regeneration of *Shorea robusta, Anogeissus latifolia, Terminalia alata, Dalbergia sissoo* and *Pinus roxburghii* may cause gradual replacement of
these species by those species showing high regeneration such as *Acacia catechu*, *Ougeinia oogeinsis*, *Mallotus philippensis*, and *Ehretia laevis*. High densities of *Lantana camara* and *Adhatoda zeylanica*, at several places especially in forest blocks such as Baniawala, Lalwala and Tira had outcompeted other species contributing low richness and diversity at shrub level.

**Ranging and habitat utilization patterns**

The ranging pattern of elephants in the Rajaji indicated that there were marked variations in the home range sizes of male and female groups. The home ranges of males were larger than that of the females and the reasons attributed to this include; restricted movements of female groups due to the presence of juveniles, maintenance of cohesiveness among the members of the group, male’s strategy to explore new areas and finding mates. The seasonal variation in range sizes and habitat use patterns were largely due to the differential availability of good quality forage among different habitat types when water was available at a convenient distance from the foraging sites. During summer, when most water bodies dried up, the elephants were observed compromising the quality of habitat they occupy over the availability of water. Female choice of mate may influence range size among males.

Apart from the above it was also conclusively established that the genetic continuity among the two sub groups of elephants inhabiting Rajaji-Motichur and Chilla units is maintained by occasional movements of solitary males and hence protection of corridor between the two units is of utmost important. However, the movement of female groups through the corridor was not evident. It is discernible from the movement pattern of elephants that the year round utilization of the resources of Rajaji WLS by the present population may not be sustainable and therefore part of
Summary

the elephant population moves during summer to areas not frequented by elephants at least in the recent past.

**Feeding ecology and its impact on vegetation**

The bulk of elephant diet in Rajaji was composed of browse material. Grasses constitute only about 5% of elephant diet. Such low proportion of grasses in the diet was due to the low availability of grasses in the Rajaji as compared to other elephant areas. There were seasonal fluctuations in the consumption of grasses. Grasses were eaten in higher proportions during monsoon and least during summer. The reasons for seasonal variations in grass consumption were palatability and nutritive values, which differ seasonally. Elephant browse component of diet was comprised of 38 species, of which 33 were recorded eaten through direct observations while rest five species were recorded through evidences. However, the bulk of elephant diet was composed of 10 browse species accounting for more than 70% of the diet. Only four browse species were recorded eaten by elephants in higher proportions while 17 species were eaten in equal proportions and 6 species were consumed in lower proportions to their availability in Rajaji. *Mallotus philippensis, Aegle marmelos, Bauhinia malabarica* and *Stereospermum suaveolens* were the preferred food species of elephants. Among the different plant parts, bark consumption was highest followed by branches and leaves. However, there were seasonal fluctuations in the proportions of different plant parts in the diet of elephants. Pushing over was the most frequent type of damage to the trees caused by elephant feeding and was the reason for tree mortality. Stem twisting was recorded in low percentage, a few trees were also found dead due to this. Other type of damage such as crown breaking and debarking did not cause tree mortality and had minimal impact on trees. The overall mortality caused by pushing over and stem twisting was 5% but the mortality in
certain species such as *Mallotus philippensis*, *Bauhinia malabarica* and *Garuga pinnata* was recorded between 6% and 8%. The populations of tree species such as *Aegle marmelos*, *Garuga pinnata* and *Dalbergia sissoo* were adversely affected due to mortality inflicted by elephant feeding and poor regeneration. If the damage to these trees continued with the present rate than it is expected that the populations of these tree species would eventually be replaced by other species or would simply be reduced to an alarming level in near future.

**Social Organisation**

Asian elephant in the Rajaji National Park forms small groups. The majority of groups are comprised of up to 15 individuals and the mean group size of female groups ranges between 7.66 and 8.37. The mean group size seems to be influenced only by the availability of water as during summer comparatively larger groups were observed. Other parameters, such as season, vegetation type and terrain types, do not influence the group size. The adult males usually remain solitary but some time form small groups up to 7 individuals, however, the association between the individuals is just by chance encounters. Majority of female groups accompany male(s) but the males do not show any fidelity towards a particular female group. The stable relationship is between a female and her one offspring usually either a small or a large calf and can be regarded as family unit. All other associations either between individuals of cow-calf groups, male-female groups or mixed groups are due to chance encounters and do not show any definite pattern that can explain certain relationship.

**Status of Rajaji-Corbett Corridor (KEC)**

The belt of reserved forest between Rawasan and Saneh rivers form the corridor between Chilla and Kalagarh Forest Division, which is contiguous with Corbett NP.
Of importance, within the corridor is the area between Malan and Khoh rivers (section II). The forest within corridor area is degraded as evident by low densities of tree species. There are pockets within the corridor especially in section II where the biotic pressures are concentrating and as a consequence of it elephant movement and utilization in such areas is adversely affected. Given proper protection and management of biotic pressures, the habitat can recover from its present state, which in turn would facilitate frequent elephant movements through the corridor.