TABLE OF CONTENTS

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EXECUTIVE SUMMARY

1) The northern Bengal region in India, along the Himalayan foothills, experiences one the highest levels of elephant-human conflict in Asia. The elephant population estimated at about 300 individuals not only damages large areas of agricultural crops but also kills about 50 humans each year. The elephant's habitat here is mostly tropical moist deciduous and evergreen forest with some grassland along the flood plains of rivers. Although highly productive the habitat is also highly fragmented with a mosaic of forest, paddy fields and tea plantations.

2) Since September 2000, we have been studying the ecology of the elephant in relation to elephant-human conflict in the Buxa-Jaldapara Reserves in the eastern region bordering the state of Assam and Bhutan. Our study includes a classification of the vegetation and land use patterns through satellite imagery interpretation, a radio-telemetry study of the movement pattern of elephants and the monitoring of elephant-human conflict in several settlements across this landscape.

3) The satellite imagery analysis of the Buxa Reserve estimated the areas of various vegetation types to be : dense evergreen forest (56 km^2), semi-evergreen forest (92 km^2), deciduous forest (87 km^2), degraded forest (141 km^2), dry thorn forest (28 km^2), flood plains (50 km^2), and plantations and mixed forest (221km^2) in addition to area under tea, cereal cultivation and settlement.

4) Using the indirect dung count method we estimated the density of elephants in the Buxa Reserve to average 0.31 individuals per km^2 or a total population of over 200 elephants that is higher than earlier estimates. Elephant density was higher during the dry season than

during the wet season, and higher in natural forest than in plantations throughout the year. Our observations of the elephants here through direct sightings also showed that the male-biased sex ratios reported for the northern Bengal elephant population was incorrect; rather we found an adult male to female ratio of 1:2.8 that is consistent with the expectation for an elephant population not under serious pressure from ivory poaching.

5) Beginning in January 2001, seven elephants (four adult females and three adult males) have so far been fitted with radio-transmitters for monitoring their patterns of movement and studying their foraging ecology. Three of the female elephants collared in the Buxa Reserve have home ranges averaging nearly 700 km^2; two of these elephants also moved westward into the Jaldapara Reserve while the third has moved eastward into Assam and Bhutan. The fourth female collared in Jaldapara has largely confined itself to this reserve with a smaller range size of about 300 km^2. These observations have helped us identify precisely the "corridors" used by the elephant herds for moving between the Buxa Reserve and other areas. We have only limited data on male home ranges because two of the collared males removed their collars after three months of dry season observations; these had home range sizes under 200 km^2. The third collared bull has ranged over 400 km^2 in about four months of observation.

6) One of the collared bulls was fitted with a transmitter linked to the ARGOS satellite for retrieving location data on a daily basis. The locations were plotted on a map of the region and transmitted electronically to the wildlife managers in the region daily. This experiment proved very useful as an "early warning system" for tracking the movement of an elephant in conflict with people. The wildlife officials recognize the practical use of such information for taking pre-emptive measures to chase away notorious elephants that

are otherwise likely to come into serious conflict with people and agriculture.

7) Fifteen villages (later extended to 18 villages) located along the periphery of the reserve, inside the reserve and near a corridor have been regularly monitored for crop raiding incidents. Cultivated tracts located within the reserve suffered significantly higher damage compared to the other two categories; this was followed by settlements near a corridor and the peripheral villages. In terms of absolute area damaged, the corridor villages suffered the highest damage. Two peaks in crop raiding frequencies were observed, one during the maize harvest period in June and the second during the paddy harvest season in October-November because elephants preferred to feed on mature crop. Adult male elephants raided more frequently than did family groups on a per capita basis, though raids by groups comprising matriarchal families and associated bulls still caused over half the damage.

8) Considering that elephant-human conflict has a positive relationship to habitat fragmentation, we have made recommendations for the relocation of several small settlements that currently suffer substantial damage to the periphery. Such relocation would also be beneficial to people in providing better access to transportation and other modern facilities apart from increasing the value of their land. We have also suggested protection of the corridors used by the collared elephants for moving between the Buxa Reserve and adjoining forests. The forest department of West Bengal is presently incorporating many of these suggestions into their management plan for the Buxa Reserve. We expect to continue to monitor the radio-collared elephants as well as interact with the West Bengal Forest Department in implementation of our recommendations for improving the conservation prospects of elephants.

INTRODUCTION

The elephant habitat in northern West Bengal is characterized by a high degree of habitat fragmentation and severe man-elephant conflict resulting in not only loss of agricultural crops and property but also several human lives each year (Lahiri-Choudhury, 1975; Chowdhury *et al*., 1997). On the other hand, the elephant population here is believed to number under 300 individuals. Understanding the ecology of elephants here requires characterization of the region's mosaic of natural habitats, cultivation and land use patterns within and along the periphery of habitats, seasonal movements of elephant herds and bulls utilizing this area and detailed information on foraging strategies including crop-raiding behaviour. The intrinsic viability of the habitat and the elephant population here have to be evaluated as well as their connectivity to forests in Assam to the east and Bhutan to the north. As the northern Bengal region is known to be an area with a large number of bull elephants (D.K.Lahiri-Choudhury pers. comm. and Elephant Census data for 2000 from Field Director, Buxa Tiger Reserve) the demography of the elephant population has also to be studied in relation to their management implications.

In this context the present study was undertaken with the following objectives in the north Bengal region.

1. Develop a vegetation and land use map of Buxa Tiger Reserve and surrounding areas in relation to the elephant occupancy and utilization.
2. Assess the effect of direct forest workings, stand structure, tree regeneration and their relationship with elephant habitat use.
3. Identify man-elephant conflicts in and around Buxa Tiger Reserve, including assessment of damage and recommending various mitigation strategies.
4. Evaluate the existing elephant corridors for providing better viability of the elephant population in Buxa Tiger Reserve including migration of elephants into adjoining areas of northern Bengal, Assam and Bhutan.
5. Identify the major food species of elephants and evaluate their nutritive qualities on a seasonal basis.
6. Conduct wildlife training programmes for elephant census, chemical capture and other related field research methods for staff of Buxa Tiger Reserve and nearby forest divisions.

THE STUDY AREA

Location and geology

The moist tropical and sub-tropical forests along the foothills of the Eastern Himalayan Region have six designated National Parks and Wildlife Sanctuaries. Our main study area comprised the Buxa Tiger Reserve and the adjoining Jaldapara Wildlife Sanctuary (Fig. 2.1). The Buxa Tiger Reserve is the only reserve in the Dooars region designated as a Project Tiger Reserve in 1983. Subsequently in 1997, an area of 117 km^2 of the reserve was notified as a National Park. The Reserve is located between 89°25′ - 89°55′ N and 26°30′ - 23°50′ E and encompasses an area of 761 km^2 that includes a core area of 385 km^2 and a buffer area of 376 km^2. The Jaldapara Wildlife Sanctuary lies to the west of Buxa Tiger reserve, between 89° 15′ - 89° 35′ N and 26° 30′ – 26° 48′ E and covers an area of 217 km^2. The entire forest range along the foothills of northern Bengal, from the Mechi river in the west along the Indo-Nepal border to Sankosh river in the east along the border with Assam, was also believed to be a contiguous elephant range.

The northern Bengal region shows the typical sub-Himalayan geological formation (Wadia 1919). From the Archaean gneisses of the Darjeeling region at an altitude of about 1800m asl, the hills descend through the Great boundary fault of the Gondwanas to the timulences of the Shiwaliks, the well-drained Bhabar tract along the foothills and the moist Terai tract in the plains at about 100m asl. The lower hills along the southern parts of this area belong to the Upper Tertiary strata, while the upper hills consist of variegated slates, quartzites, and dolomites. The sub-mountainous part is made up of alluvium soils with the deposits of coarse gravel along the hills (Banerjee, 1998). The dolomites in the Jainty hills have been mined in the past.

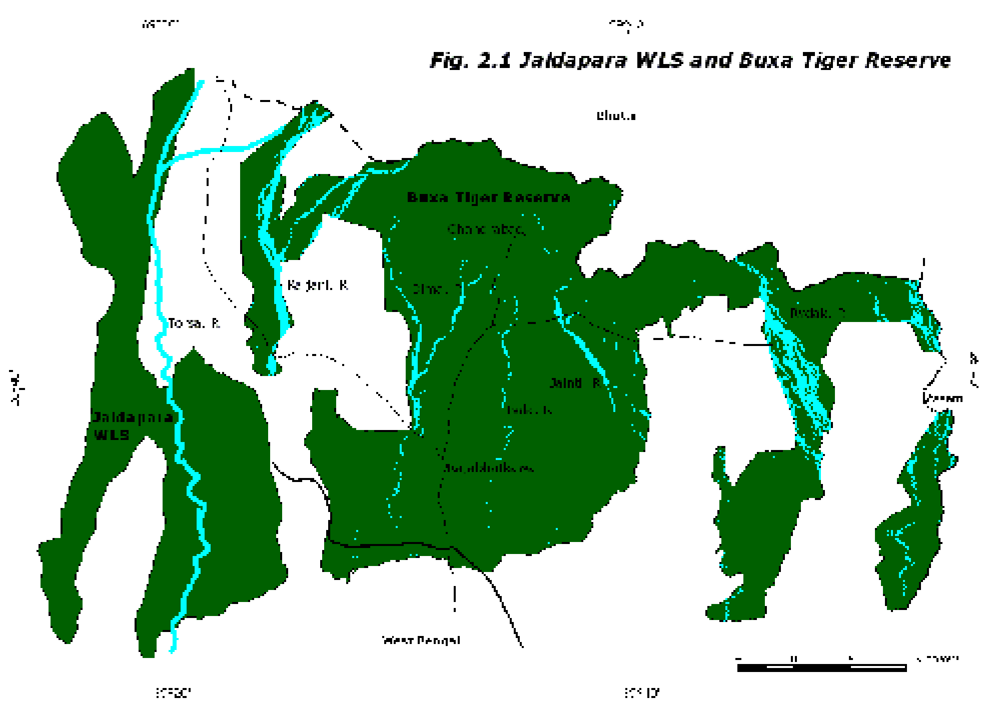


Fig. 2.1 Jaldapara WLS and Buxa Tiger Reserve

The region is dissected north-south by swift flowing rivers and alluvial floodplains that drain into the Brahmaputra-Gangetic delta. The major rivers of the northern Bengal region from the west are the Mechi, Teesta, Jaldhaka, Torsa and Sankosh. The Torsa river flowing between the Jaldapara Wildlife Sanctuary and Buxa Tiger Reserve is the boundary between eastern dooars and western dooars, while the Sankosh river is the border between West Bengal and Assam. Several smaller rivers and tributaries between the Torsa and the Sankosh in the Buxa region are the Pana, Dima, Bala, Jainty, Dhok, Rydak I & II, and Gholani, which are usually perennial in nature. The flow of water in the rivers and streams is unpredictable at times as its rise and fall are rapid. During summer, the surface water carried by the stream flows underground in the Bhabar tract because of its porous nature, making this tract devoid of water, only to reappear further south in the Terai as springs. Most of these rivers are flood prone and some of the rivers change their course regularly, resulting in large area under alluvial floodplains.

Climate

The climate of the northern Bengal region can be divided into the following distinct seasons (Figs. 2.2 & 2.3).

a) A cool, dry period from November to March. The mean maximum temperature during January is 23° C and the mean minimum temperature is 11° C. Some showers occur during the transitional month of March.
b) A warm, pre-monsoon period during April-May. The mean maximum and mean minimum temperatures during April are 30° C and 16° C respectively. Several spells of rain occur during this month, with the monthly rainfall during May being as high as 45 cm.
c) A hot, peak monsoon period from June to August. The mean maximum and mean minimum temperatures do not vary much during these three months, being 32° C and 25° C respectively during the month of July. Rainfall from the southwest monsoon is very heavy, with an average of 386 cm (or 70% of the mean annual) falling during this period. Torrential rainfall of 99 cm was recorded on a single day (19^{th} July 1993) causing devastating floods in this region.
d) A warm, late-monsoonal period during September-October. The mean maximum and mean minimum temperatures are 31° C and 21° C respectively during October. Considerable precipitation occurs during these months, and this can be especially heavy during October.

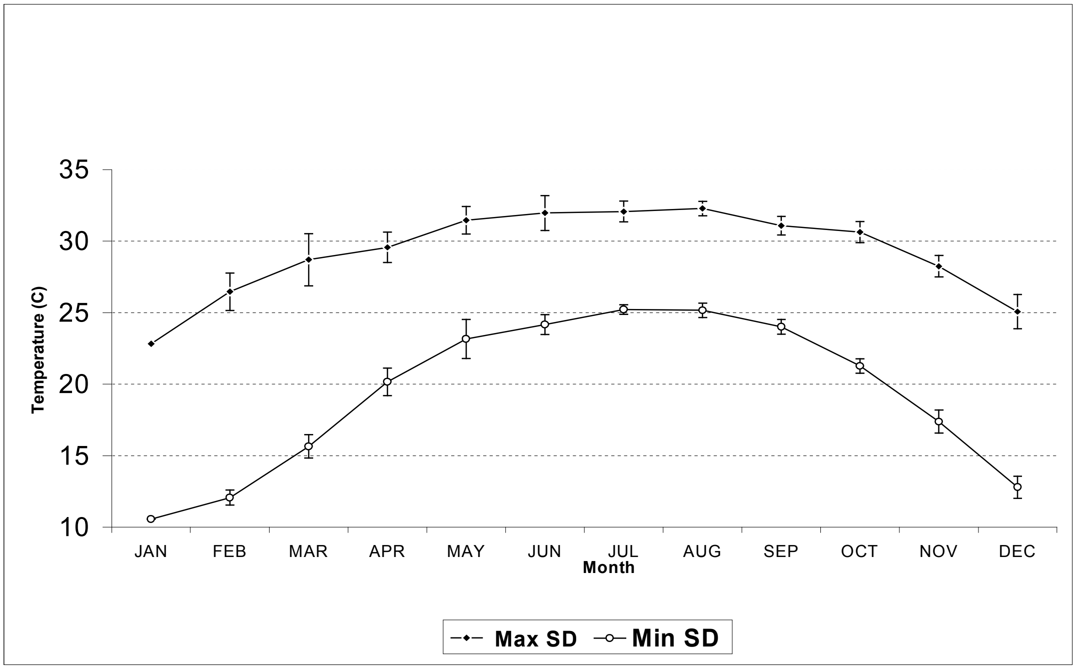


Fig. 2.2: Mean maximum and minimum temperature recorded between 1997-2001 in Buxa Tiger Reserve

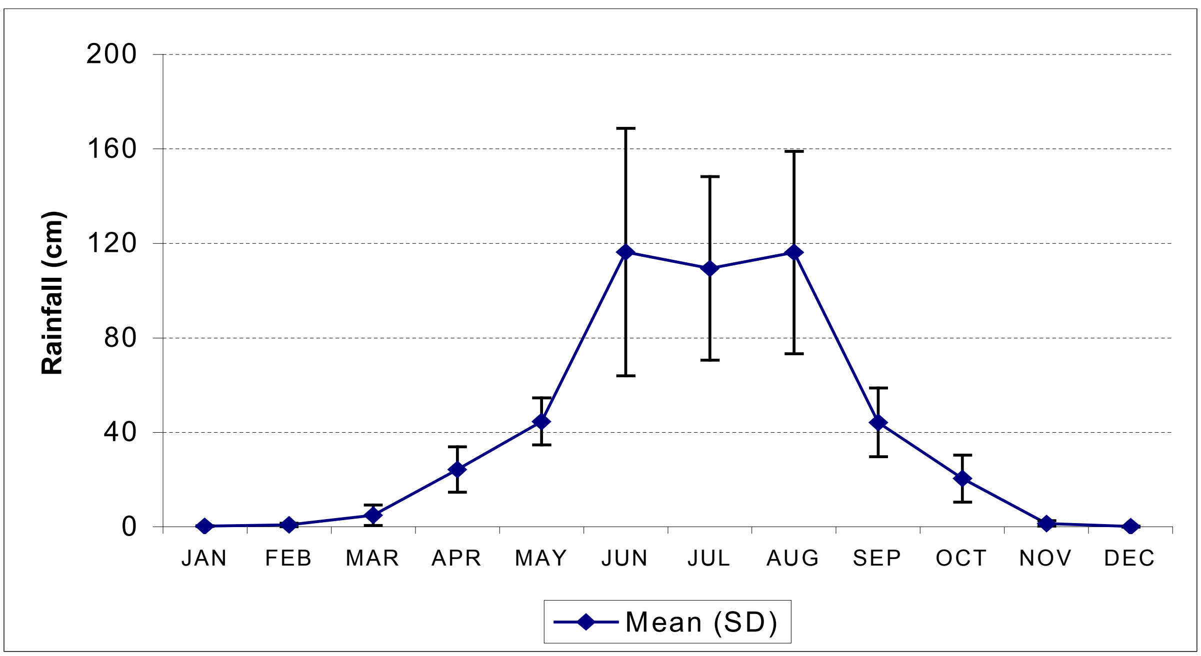


Fig. 2.3: Mean monthly rainfall recorded between 1998 - 2001 in Buxa Tiger Reserve

Vegetation

The northern Bengal region harbours a mixture of natural and man-made forests with a high diversity of plants. For Buxa Tiger Reserve, Das (2000) lists 352 species of trees, 189 shrubs, 108 climbers, 144 orchids, 46 grasses, 16 sedges, 6 canes and 4 bamboos based on an inventory by A.B. Choudhury. The major vegetation types and sub-types of Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary are listed in the Working Plan (Das, 2000) as follows with the corresponding classification of Champion and Seth (1968) given in brackets:

a) Riverine forests (the Northern Dry Deciduous Forest),
b) Sal forests (Eastern Bhabar & Terai Sal),
c) Dry mixed forests (East Himalayan Moist Mixed Deciduous Forest),
d) Wet mixed deciduous forest (Sub-Himalayan Secondary Wet Mixed Forest),
e) Semi-evergreen forests (Eastern Sub-Montane Semi-Evergreen Forest),
f) Evergreen forests (Northern Tropical Evergreen Forest),
g) Hill forests (East Himalayan Subtropical Wet Hill Forest),
h) Savanna or grassland (Moist Sal Savanna & Low Alluvium Savannah Woodland).

Details of the floral diversity of Buxa Tiger Reserve is given by Mukherjee (1965) and Jain and Sastry (1983).

The forests of northern Bengal has been intensively exploited and managed from the mid-19th century onwards, and the Buxa region has been no exception. A more detailed account is given by Das (2000). The first working plan for this region (for 1874-75 to 1905-06) by Dr. William Schlich prescribed the systematic removal of Sal trees above 5 ft girth. Since 1900 the extraction was mostly for providing sleepers for the Eastern Bengal Railway. This plan was followed by a selective felling system on a 15-year cycle. It is obvious that areas were also clear-felled because the Third Working Plan of Shebbeare (1920-21 to 1924-25) prescribed artificial regeneration of such areas by *taungya* plantations. By this time there was demand from the tea gardens here for fuel wood that had to be catered to from the forests. The Fourth Working Plan (1929-30 to 1948-49) was much more comprehensive in that it set up ten working circles to manage the different vegetation and topographical formations in the region. This system seems to have largely continued into the Fifth Working Plan (1945-46 to 1964-65). Conversion of the forests to plantations of Teak seems to have begun with the Sixth Working Plan (1945-46 to 1964-65) and continued into the Seventh Plan (1975-76 to 1984-85). At the same time, soft wood plantations to cater to demand from local wood-based industry were also created on a significant scale. For the first time a protection working circle comprising the present Jaldapara Wildlife Sanctuary was also set up during the Sixth Plan. The intensive exploitation of the forests obviously had a major impact on vegetation structure and consequently for the wildlife population.

Photo: Mukti Roy

Rydak river down the Himalayan Foothills

The Buxa Tiger Reserve was constituted in 1983 and the First Management Plan for this reserve was prepared at this time. Protection from poaching and fire, eradication of weeds, and soil conservation measures along river courses were given priority. The Second Management Plan (1989-90 to 1999-2000) prescribed strict protection of the core areas, including a ban on thinning of existing plantations here. The buffer areas were divided into a Sal Working Circle and a Miscellaneous Working Circle in which clear felling followed by artificial regeneration was prescribed, and a small area under the Riverine Working Circle in which no felling was prescribed. At present the Management-cum-Working Plan of Das (2000) is in force for the period 2001-02 to 2009-10.

In recent years conservation programmes have given priority to habitat management by checking the felling of natural forests, cane/bamboo harvesting and putting a stop to dolomite mining in the early 1980s. Carefully planned strategies for eco-development with emphasis on effective land-use is also an important aspect of management and conservation of the forests.

Fauna

Several endangered faunal species are known to occur within the reserve apart from a sizeable population of tiger, approximately 390 bird species, 73 mammal species (including elephant, tiger, wild dog, leopard cat, gaur, wild boar, sambar, hog deer, Chinese pangolin), 76 reptile species and 5 species of amphibians (this would be much higher) have also been identified (West Bengal Directorate of Forests).

There are four major studies or reviews of the history and ecology of the elephants of the northern Bengal region. D.K. Lahiri-Choudhury's survey of the Jalpaiguri Division during June-July 1975 seems to be the first attempt to document in some detail the basic movement pattern of elephants, the use of corridors, the problem of elephant-human conflict and experimental trials of measures to contain the conflict (Lahiri-Choudhury 1975). S.C. Dey explored the causes of elephant-human conflict, including crop depredation and manslaughter by elephants during the decade of the 1980s (Dey, 1991). An excellent history of the elephants of northern Bengal during the 20th century, including past distribution, population status and capture operations, is provided by Barua and Bist (1995). The overall picture that emerges from these documents is increased fragmentation of the habitat, a sharp escalation in elephant-human conflicts, an initial reduction of the elephant population and then possibly an increase following protection and cessation of capture. A study by the Wildlife Institute of India (Chowdhury *et al*., 1997) provided the first account of home range sizes and movement patterns of elephants followed through radio-telemetry. This study will be referred to at several places in this report.

LANDSCAPE AND VEGETATION STRUCTURE

The northern Bengal region has a complex mosaic of vegetation types, including both natural forest and plantations, in addition to settlements and cultivation. The forests here are broadly classified as *Northern tropical semi-evergreen* and *Northern tropical moist mixed deciduous forest types* according to forest classification of Champion and Seth (1968). Banerjee (1998) recognized five different types of natural vegetation. These are (1) Sub-Himalayan semi-evergreen type, (2) Moist mixed deciduous formation, (3) Eastern Himalayas upper and lower *bhabar* 'Sal' formation, (4) Sub-Himalayan terai formation, and (5) Moist temperate formation. This classification is not easily discernable in the field, as there is tremendous amount of species overlap. The various monoculture plantations and mixed plantations/natural vegetation as well as degradation stages of primary evergreen forest make it difficult to arrive at a distinct classification of vegetation here.

Our classification of the vegetation types in Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary, and the studies of woody plant diversity were largely aimed to complement the study of elephant ecology, in particular the patterns of seasonal movement and habitat utilization. We therefore used a system of classification that would be simple and consistent with accurate satellite imagery classification as well as serve the purpose of understanding the elephant's use of habitat types.

METHODS

Landscape Elements

Ground-truthing

The landscape of Buxa Tiger Reserve (BTR) was surveyed to classify the land cover of the reserve. Different elements of the landscape were identified using differences in canopy structure, phenological characteristics, land use pattern and degree of disturbance in the landscape. The earlier classifications of the Forest Department (Das, 2000) and the Wildlife Institute of India (Chowdhury *et al*., 1997) were used as guidelines in the classification. Ground-truthing was carried out using a Global Positioning System (GPS). Multiple GPS points were collected from the different landscape element (LSE) types. For each GPS location the following information was recorded: a) Latitude and longitude, b) elevation, c) type of landscape element (for forest vegetation type elements many of the GPS points also coincided with transect sampling locations), and d) details of terrain characteristics of the adjacent land. Based on ground truthing survey, eleven landscape elements were identified, which include, 1) Semi-evergreen vegetation forest, 2) dense evergreen forest, 3) deciduous forest, 4) dry thorn forest, 5) mixed vegetation and plantations, 6) degraded forests, 7) tea gardens, 8) teak plantations, 9) flood plains of the different rivers present in the reserve, 10) water bodies and 11) cultivation/settlements.

Satellite Imagery

Satellite data of IRS (Indian Remote Sensing) 1D/L-III, bearing paths and row 108-53 and 109-53 were acquired. The dates of pass of the imagery were 16th March 2001 and 13th March 2001, respectively. The Buxa Tiger Reserve falls in the scene 109-53. The topographic sheets 78F/6, 78F/7, 78F/11 and 78F/13 were utilised in the preliminary processing of the satellite data.

A false colour composite (FCC) was generated using the different bands of the satellite data. Geometric corrections were performed using ground control points (GCP's) obtained from topographic sheets of the region. GCP's were collected such that points were spread uniformly over the entire scene. Points such as the intersection of roads and railway lines were identified on the topographic sheets as GCP's. Using a polynomial equation the scene was geometrically corrected and geo-referenced into latitude/longitude coordinate system. The pixels were re-sampled using the maximum likelihood algorithm and the study area was extracted from the scene using standard techniques in ***ERDAS*** Imagine. Using ground truth points collected from the study area, training sites were generated for eleven landscape element (LSE) types of Buxa Tiger Reserve. From the spectral information obtained from each of these signature files the study area was delineated into the different LSE types using standard supervised classification techniques.

Vegetation studies

A standard belt transect method was employed to characterize the vegetation of BTR. Belt transects of 250 m x 4 m (1000 m^2 or 0.1 ha) were laid randomly in all vegetation types and in various geographical locations. Geo-coordinates (latitude and longitude) and altitude were taken with the help of GPS. All woody stems above 1.0 cm DBH (diameter at breast height) along the transect were enumerated for the GBH (girth at breast height), species identity and height was also estimated visually. At every 10 meters along the transect an estimate of the canopy coverage was also made qualitatively into 10% class intervals.

RESULTS AND DISCUSSION

Landscape elements

The different landscape elements are spatially well distributed in the reserve (Fig. 3.1a). The northern parts of the reserve have dense evergreen forest as the major landscape element, while the semi-evergreen forest dominates the central part of the reserve and the deciduous and degraded forests are spread along the western part of the reserve. Fig. 3.1a shows the spatial extent of the different landscape elements in the Buxa Tiger Reserve. Landscape elements such as tea gardens, teak plantation, dry thorn forests, settlements/cultivations and degraded forests have the maximum accuracy of classification of 100%, while this is lower but within acceptable limits in the case of certain other landscape elements such as deciduous forests (78%), semi-evergreen forests (66%), evergreen forests (75%) and flood plains (67%). The reduced accuracy in some of these elements can be attributed to the extremely mosaic condition of vegetation in these forests, which in turn leads to mixing of spectral signatures of the different landscape elements. For example some patches of the LSE type floodplains have been misclassified into the LSE settlements/cultivations in the landscape. This lacuna can be overcome by merging satellite data sets of wet and dry seasons thereby leading to increased levels of accuracy. The extent of area under each of the landscape elements is given in Table. 3.1. We would like to note here that the area under natural vegetation types and plantations according to our classification corresponds extremely well with the records maintained by the forest department on the extent of plantations in the reserve.

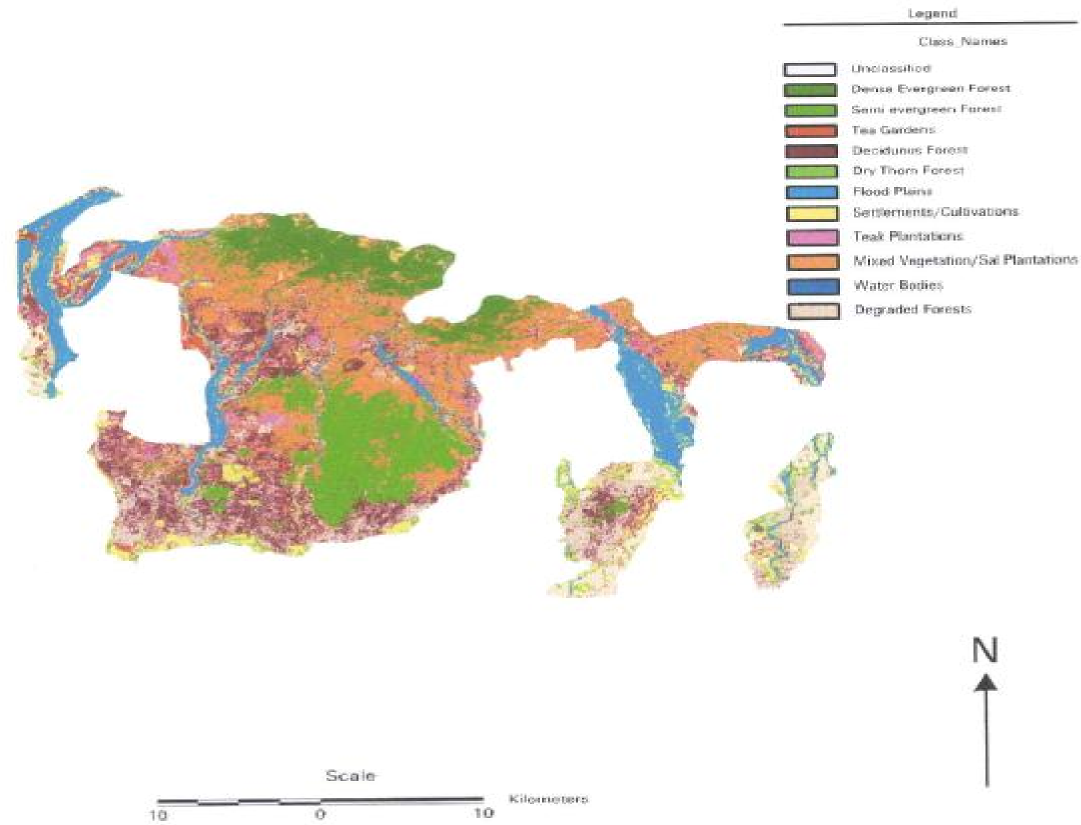


Fig. 3.1a: Landscape Element Types of the Buxa Tiger Reserve

Table 3.1: Area under different landscape element types in and around Buxa Tiger Reserve

S. No.	Land Cover	Area (km^2)
1	Dense Evergreen Forest	56.1
2	Semi Evergreen Forest	91.7
3	Tea Gardens	11.4
4	Deciduous Forest	86.9
5	Dry Thorn Forest	28.0
6	Flood Plains	50.4
7	Settlements/Cultivations	124.0
8	Teak Plantation	41.0
9	Mixed Vegetation	179.6
10	Water Bodies	90.0
11	Degraded Forest	140.8

Landscape metrics of the Buxa Tiger Reserve

Our classification of the satellite imagery delineated approximately about 92,000 patches among the different landscape element types in Buxa Tiger Reserve. The mean patch size is 0.88 ha and edge density in the landscape is 342 m/ha. The mean shape index of the various fragments in the landscape is 1.31. The landscape has a Shannon diversity index of 2.09 while the Shannon evenness index is 0.87. More details of each landscape element are given below.

Landscape metrics of the various landscape element types

Dense Evergreen Forest

The area under the LSE type dense evergreen forest is 56.1 km^2. This LSE type is spatially distributed mostly in the northern parts of the BTR. The number of fragments in this LSE is 1833. The mean patch size of the various fragments is 3.06 ha, with a total edge of 926 kms, having an edge density of 11.45 m/ha. The LSE has a mean shape index of 1.33.

Semi evergreen Forest

The area under this LSE type is 91.7 km^2, spatially distributed in the central part of the reserve. The number of fragments in this LSE is 5135. The mean patch size of the fragments is 1.78 ha, having a total edge of 1886 kms with an edge density of 23 m/ha. The fragments in the LSE have a mean shape index of 1.32.

Deciduous Forest

The area under this LSE type is 86.9 km^2. The number of fragments in this LSE type is 23692. The mean patch size of the fragments is 0.35 ha. The LSE has a total edge of 5630 kms with an edge density of 69 m/ha. The LSE has a shape index of 1.31.

Dry Thorn Forest

The area under this LSE type is 28 km^2. The number of fragments in this LSE type is 8402. The mean patch size of the fragments is 0.32 ha and the total edge of the LSE is 1879 kms with an edge density of 23.2 m/ha. The LSE has a shape index of 1.29.

Flood Plains

The area under this LSE type is 50.4 km^2. The number of fragments in this LSE type is 2075. The mean patch size of the fragments is 2.42 ha. The LSE has a total edge of 1077 kms with an edge density of 13.3 m/ha. The LSE has a shape index of 1.38.

Degraded Forests

The area under this LSE type is 140.8 km^2. The number of fragments in this LSE type is 19432. The mean patch size of the fragments in this LSE type is 0.72. The LSE has a total edge of 5760 kms with an edge density of 71.2 m/ha. The LSE has a mean shape index of 1.30.

Tea Gardens

The area under the LSE type is 11.4 km^2. The number of fragments in this LSE type is 4305. The mean patch size of the fragments in this LSE type is 0.25 ha. The total edge of this LSE is 810 kms having an edge density of 10 m/ha. It has a shape index of 1.24.

Settlements/Cultivation

The area under this LSE type is 124 km^2. The number of fragments in this LSE type is 5118. The mean patch size of the fragments is 2.43 ha and the LSE has a total edge of 2645 kms with an edge density of 32.7 m/ha. The LSE has a shape index of 1.35.

Teak Plantations

The area under this LSE type is 41 km^2. The number of fragments in this LSE type is 8296. The mean patch size of the fragments in this LSE type is 0.48 ha. The LSE has a total edge of 2068 kms having an edge density of 25.5 m/ha. The LSE has a shape index of 1.29.

Mixed Vegetation/Sal Plantations

The area under this LSE type is 179.6 km^2. The number of fragments in this LSE type is 13081. The mean patch size of the fragments in this LSE type is 1.37 ha. The LSE has a total edge of 4985 kms with an edge density of 61.62 m/ha. The LSE has a mean shape index of 1.32.

Water Bodies

The area under this LSE type is 90 km^2. The number of fragments in this LSE type is 236. The mean patch size of the fragments in this LSE type is 0.37 ha. The LSE has a total edge of 61 kms with an edge density of 0.76 m/ha. The LSE has a mean shape index of 1.32.

Vegetation structure

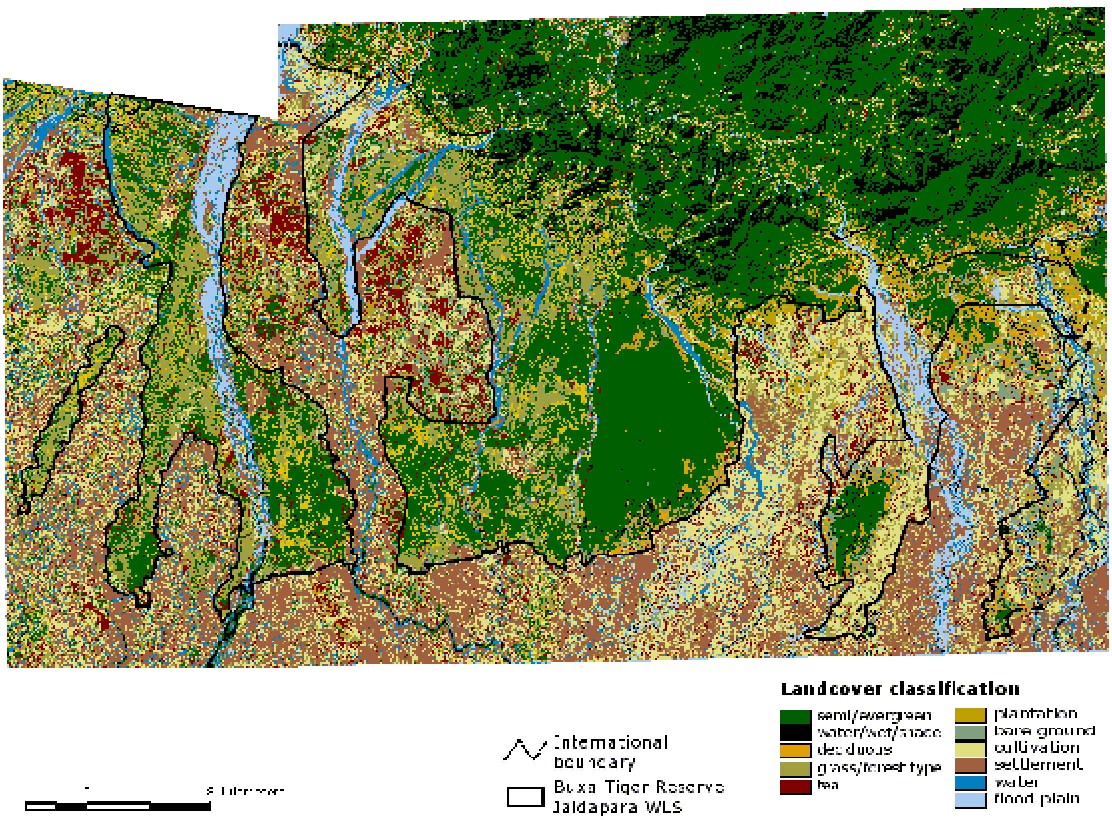
A total of 37 transects were laid in BTR. A total of 5260 individuals above 1.0 DBH belonging to 282 morpho species were enumerated. We have classified the forests of BTR into three broad categories of natural forest formations in accordance with Champion and Seth (1968). They are Dry deciduous (Sal *Shorea robusta*) forest, the Moist deciduous forests and the Semi-evergreen forests. There are also plantations of Teak (*Tectona grandis*), Sal (*Shorea robusta*), and Mixed species (*Lagerstroemia, Terminalia* and *Gmelina*, Champ *Michelia sp*. and Holong *Dipterocarpus macrocarpus*). An ordination of the sample sites based on the simple abundance of various species in each transect indicated that there are no distinct clusters of sites based on the species composition, though there seems to be some associations of sites. Some sites show a transition type of vegetation reflecting perhaps the past history of disturbance that the forests of BTR would have experienced. An understory tree *Litsea sp.* (Lauraceae) with relative abundance of 7.1% dominated the floristic composition followed by *Polyalthia sp.* (*Annonaceae*) with 5.0% of the total abundance. The most dominant canopy tree was Sal (*Shorea robusta*), which accounted for 2.9% of the stand. Other dominant canopy trees include Jarul (*Lagerstroemia speciosa)* 2.4%, Lasunelali (*Amoora wallichii*) 2.1%, Gokul (*Ailanthus grandis)* 1.8% and Teak (*Tectona grandis*) 1.2% of the stand. Important elephant food plant species such as Sindhure (*Mallotus philippenensis*) 0.9%, and Patkasiris (*Albizia lucida)* 0.4%, were present in the forest but in low numbers.

This forest is characterized by the presence of numerous lianas and in this respect it differs from similar forest types in southern India. The density of lianas vary from 0 in one of the dry deciduous forest transects to 34/0.1 ha in a semi-evergreen forest patch. Some of important species of lianas are Gawju *Mucuna prureita* (53; 1.0% of sample), Charchare *Cissus sp* (41; 0.8%), Loharesiris *Dalbergia sp.,*(22; 0.4%) and Ararekanta *Acacia pennata* (21; 0.4%). Of the 54 angiosperm families represented in our samples, the families *Fabaceae, Lauraceae*, *Euphorbiceae, Rubiaceae* and *Moraceae* dominate floristics of BTR. There were twenty-nine families with either one or two species each. The most speciose family is *Fabaceae* (20 species) followed by

Euphorbiaceae (15 species) and *Lauraceae* (13 species). The order *Malvales* (*Malvaceae, Sterculiaceae* and *Tiliaceae)* that includes preferred browse species for elephants is represented by a total of 7 species. Important browse species of elephants in southern India such as *Kydia calycina* and *Helicteres isora* were not represented in the samples, even though the former is represented in the forest.

We are in the process of developing the land use pattern map for the adjoining areas of Buxa Tiger Reserve. A draft landscape elements of Buxa Tiger Reserve with its adjoining area is projected in Figure 3b.

Fig. 3.1b Land cover classification of the eastern part of North Bengal



ELEPHANT POPULATION AND DEMOGRAPHY

A reliable estimate of population size and assessment of the population structure as related to demography are important to planning for the conservation of a species, especially in a protected area that is under intensive management. The viability of a relatively small elephant population ranging over a fragmented landscape is always in doubt, and objective information on its demography helps in making decisions about its management. A clear picture of the demography of the elephants of northern Bengal is needed for several reasons. In the past, this population has been variously estimated to number between 150 and 300 individuals with a male-biased sex ratio. The viability of a population of this size and male-biased structure, in severe conflict with people within a fragmented landscape, can be questioned. The present study has therefore tried to obtain an objective picture of the elephants of the Buxa-Jaldapara region of northern Bengal to provide the baseline data for assessing viability.

METHODS

Elephant density estimation

The past censuses in the Buxa Tiger Reserve have relied on direct count methods such as the "rolling block count". The dense vegetation coupled with low elephant density in the Buxa Tiger Reserve, however, makes direct count methods inappropriate for a small research team. Therefore, the indirect–dung count method pioneered by Barnes & Jenson (1987) on African elephants and later used by several researchers in Asia (Dawson 1990, Varma *et al*., 1995) on Asian elephants was employed in the present study. This method estimates the density of dung piles in a given area using the line transect method and converts the dung density into elephant density using defaecation and decay rates with the following formula.

$E = (Y \times r) / D$

where, E = Density of elephants, Y = density of dung, r = daily rate of decomposition and D = the number of dung piles deposited per elephant per day.

The line transect method described by Burnham *et al*. (1980) was used to estimate the dung density. A total of 24 transects with varying lengths of 1 to 2 km were laid covering all major vegetation types in Buxa Tiger Reserve. All transects were traversed along a straight line placed across the altitude gradient and perennial water sources. Dung piles seen from the transect line at any distance were recorded and for each dung pile, perpendicular distance from the transect line to the centre of the dung pile was measured. In the analysis the piles at greater than 18m distance from the line were considered as outliers and discarded. All transects were surveyed twice, once between February and April (dry season enumeration) and another time between October and November 2001 (wet season enumeration). In order to obtain sufficient sample size for robust statistical analysis, we laid an additional 3 transects (total length 5.3 km) during the wet season. The dung density was calculated from the line transect data using '*Distance Version 4.0 Beta 1*' software for each vegetation type separately and overall for the entire reserve by pooling data from all the vegetation types.

In order to estimate the rate of dung decomposition, very fresh dung piles were located by following fresh wild elephant tracks and marked with a peg on which date and sample number were indicated. A total of 88 and 92 fresh dung piles from three different habitats were marked and monitored respectively between January and April, and May and September 2001. At every visit, dung piles were classified in any of the following six decomposition stages

A = All boli intact, fresh, moist with odour
B = All boli intact, dry with odour
C1 = More than 50% of the boli intact
C2 = Less than 50% of the boli intact
D = All boli broken up and or flat amorphous mass
E = Dung piles no longer visible

Due to poor visibility all our attempts to estimate defaecation rate of wild elephants in Buxa Tiger Reserve were unsuccessful (this could possibly be attempted for another area such as Mahananda at a later time). Therefore, for the present analysis we use a defaecation rate estimated from southern Indian elephant populations.

There are several statistical problems in estimating an unbiased variation on the mean elephant density through the basic formulation of the indirect count method (see Sukumar *et al*., 1991 for a discussion). There are also problems with assuming a "steady state of dung" in the habitat as well as estimating the dung decay rate (Sukumar 1998). Our research group has been developing Monte Carlo simulation methods to overcome the problem of estimating variance in elephant density, and we decided to adopt this method to the data from Buxa. For estimating the elephant density, incorporating the three variables (dung density, daily defaecation rate and daily dung decay rate), we have used a Monte Carlo simulation method (*GAJAHA* ver. 1.0) developed by Santosh and Sukumar (1995). This method has the advantage of being robust to variations from normality in the distributions of the three variables. We believe that it provides more realistic statistical confidence limits on the estimates of the mean elephant density. We also combined data on dung density and on dung decay rates from the two seasons, wet and dry, in order to fulfill the assumption of steady state.

Age-sex composition of elephant population

Data on age-sex were collected whenever an elephant herd or bull was sighted during fieldwork. At every sighting, information such as date & place of sighting, group size and age-sex composition, etc. were recorded. Characteristic features of individual elephants (if any) were also recorded in order to differentiate individual herds and bulls.

Age estimation was done based on shoulder height described by Sukumar *et al* (1988) and D. K. Lahiri-Choudhury (typescript). All elephants that were sighted were classified into calf (<1 year), juvenile (1-5 years), sub-adult (5-15 years) and adult (>15 years). According to Lahiri-Choudhury this translates into height classes of 3-4 ft, 4-6 ft, 6-7 ft and >7 ft, respectively. We modified this slightly for the male segment of the population for the sub-adult class (6-8 ft) and adult class (>8 ft).

Sex differentiation was not possible for elephants below 2 years. A special effort was made to identify tuskless males (*Makhnas*) based on characteristics such as trunk musculature, presence of penis sheath and the social context of the individual (a sub-adult or adult solitary elephant without tusks was suspected to be a *makhna* and an effort made to confirm this). This was only reliable in the case of adults and sub-adult age classes, as differentiating a makhna from a female at the juvenile stage is not always possible due to poor visibility.

Types of classification

All elephant herds or solitaries sighted were classified under three types *viz*.:

Type 1: Sightings in which all the individuals in the herd were aged and sexed,

Type 2: Sightings in which all the individuals in the herd were not classified but it was sure that there was an adult male or no adult male, and

Type 3: Sightings in which all the individuals in the herd were not counted or aged and sexed.

Type I and Type II sightings were used to derive the proportion of adult males in the population, while Type I sightings were then used to derive the age and sex structure of the total population. Type III sightings were excluded from the analysis because their inclusion could have caused bias in arriving at the age-sex composition (typically, only larger animals would have been visible) even though these would have added to the overall sample size.

RESULTS AND DISCUSSION

Elephant density estimation

For density estimation, Buxa Tiger Reserve was broadly classified into three vegetation types:

(i) Open mixed forests (includes Semi-evergreen, open canopy and Deciduous forest),

(ii) Dense mixed forests (Semi-evergreen closed canopy) and

(iii) Plantations (Teak, Sal and Mixed plantation).

For density estimation, a very detailed level of vegetation classification was not followed, as obtaining minimum sample size for each category is difficult. This may also not be relevant to a long-ranging species. In order to estimate the dung decay rate during dry season, we marked and monitored 88 dung piles between January and April. Out of 88 dung piles monitored, 76 dung samples (86%) decayed completely and reached stage E. The remaining 12 dung piles (14%) were disturbed due to humans or burnt in forest fires. Time taken for the 76 samples to reach the stage E varied considerably (from 56 to 212 days) with a mean value of 128 days, which gives daily rate of decay of 0.0077 units per day (SE of 0.0003).

Similarly, during the wet season a total of 92 dung piles were marked and monitored to calculate the dung decay rate. Of the 92 dung piles, 89% decayed completely with an average of 97 days (varied from 22 to 132 days) and the remaining 11% are still in D stage. A daily decay rate of 0.0096 units per day with a SE=0.0002 was calculated for the wet season.

The defecation rate 16.33/day (SE=0.8) estimated from a southern Indian population (see Watve 1992; Varman *et al*., 1995) was used in the current density analysis. In total, 24 line transects with a total length 40 km were surveyed during the dry season and 27 transects of 45.3 km were surveyed during the wet season. Dung piles recorded per unit distance was lesser during wet season (3.9 piles/km) compared to the dry season (13.5 piles/km). Therefore, an extra 5.3 km distance was surveyed during the wet season in order to obtain sufficient sample size of dung for the density analysis.

It is apparent from the results that elephant density dropped from dry season (0.36 individuals/ km^2) to wet season (0.16 individuals/ km^2) (Table 4.1). However, both during the dry and wet seasons, natural habitat types such as open mixed and dense mixed forests supported higher elephant density compared to man-made habitats (plantations). Among the three forest types, open mixed forests supported the highest density (0.47 individuals/km^2) of elephants followed by dense mixed habitat (0.39 elephant/km^2) during the dry season. Similarly, during the wet season too the open mixed forests supported the highest density (0.27 elephant/km^2) followed by dense mixed forest (0.25 elephant/km^2). On the other hand, plantations (Teak, Sal and Mixed species plantations) had much lower densities of 0.20 & 0.07 elephant/km^2 during the dry and wet seasons, respectively.

Table 4.1: Density of elephants estimated using dung count method in Buxa Tiger Reserve

Season	Habitat (Forest types)	Transect Length (km)	No. of Dung piles	Dung/ km^2		Mean elephant density/ km^2	95% Confidence Interval	
				Density	Std. Error		Lower	Upper
Dry	Dense Mixed	8	128	832	88.85	0.39	0.36	0.43
	Open Mixed	17	301	1004	66.72	0.47	0.44	0.50
	Plantation	15	113	420	45.27	0.20	0.18	0.21
	Overall	40	542	751	37.51	0.36	0.33	0.38
Wet	Dense Mixed	11	39	426	88.40	0.25	0.21	0.28
	Open Mixed	17.3	123	462	45.03	0.27	0.25	0.29
	Plantation	17	15	119	41.90	0.07	0.05	0.09
	Overall	45.3	177	267	21.19	0.16	0.15	0.17
Annual	Dense Mixed	19	167	505	45.01	0.31	0.29	0.34
	Open Mixed	34.3	424	731	40.11	0.45	0.43	0.48
	Plantation	32	128	233	23.16	0.14	0.13	0.16
	Overall	85.3	719	494	20.88	0.31	0.29	0.32

The lower density of elephants in plantation areas compared to open mixed and dense mixed habitats could be a function of forage resource availability. The plantations have poor growth in the understory and a paucity of food plants for elephants. It is however well established that elephants prefer secondary forest to primary forest (Olivier 1978, Sukumar 1989, Struhsaker *et al*., 1996). In line with this expectation, the open mixed forests of Buxa had the highest elephant density of 0.45 elephant/km^2 on an annual basis irrespective of season. This was followed by the dense mixed forest (0.31 elephant/km^2) and plantations (0.14 elephant/km^2). The average annual density for Buxa Tiger Reserve for the pooled data worked out to 0.31 elephant/km^2. The accuracy and precision of population estimate in line transect sampling method depends on the sampling area distribution, sampling intensity and sample size. The widely placed transects all over the Park, without biasing towards any area, and sufficient sample size of dung piles (719) in the present study gives a robust density estimate. The narrow difference between the lower (0.29 elephant/km^2) and upper (0.32 elephant/km^2) 95% confidence interval indicates a high precision of the present estimate.

We also estimated the relative abundance of elephant dung pile/km transect distance in different plantations and the results are presented in Table 4.2. It is apparent that Mixed species plantation and Sal plantation seems to be used more than the Teak Plantation. Our vegetation study shows that diversity of other plant species is generally lower in Teak plantation compared to Mixed plantation and Sal Plantation. Therefore, lack of plant species that are palatable to elephants in teak plantation could be the reason for their lower use by elephants compared to other two plantation types. However, we should keep in mind that the differences are not high and that plantations as a whole are a poor habitat for elephants. It is of course, entirely possible that with further regeneration and plant succession, the mixed plantations could become more attractive for elephants in the future.

Table 4.2: Encounter rate of dung per kilometer of transect in different plantation types in Buxa TR

S. No	Distance (km)	Plantation type	No. of dung piles	Dung/km
1	13	Sal	56	4.31
2	6	Teak	16	2.67
3	13	Mixed	56	4.31

The present density estimate of elephants is higher compared to earlier estimates by the Forest Department, which used total count method. This variation could be due to methodological differences between the current and earlier estimates, as total counts generally tend to be under estimate of elephant numbers as some animals are missed during the counts due to dense undergrowth. Our extensive field surveys in Buxa indicate that the higher densities shown by the indirect count method are certainly possible in Buxa. For instance, during January 2002 our surveys in the region showed the simultaneous presence of elephant herds in places as far apart as South Rydak (50-60 elephants) to Rymatang (15-20 elephants) apart from the two radio-collared elephants (part of groups totaling over 30 elephants) operating in the central area of Buxa. There were also fresh signs and other evidence of other elephant groups that were not sighted. There is also the possibility of significant numbers of elephants coming into Buxa, at least on a seasonal basis, from the disturbed forests of Assam. One of the herds radio-collared in the Rydak forests during January 2002 has since moved eastward and crossed over into Assam. The lower elephant density during the wet season could thus result from dispersal of elephants into adjoining areas of Buxa Tiger Reserve.

Age-sex composition

Elephant sightings

In total, 64 direct sightings of herds and solitary individuals comprising 383 elephants were obtained during the study period in Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary. Thirty-five sightings comprising 167 individuals belonged to Type 1 classification, where information on age and sex was collected for all the individuals sighted. The remaining 29 sightings were Type 2 and Type 3 classifications (Table 4.3) where not all individuals were aged and sexed due to very poor visibility. The thirty-five sightings of Type 1 classification include four re-sightings of three identified adult males; these re-sightings were excluded from the analysis.

Table 4.3: Details of direct sightings of elephants recorded for age-sex structure in Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary

Details	Type 1	Type 2	Type 3	Total
Total number of sightings	35*	14	15	64
Total number of animals counted	167	125	91+	383
Total number of animals age/sexed	167	72	53	292
Percentage of animals age sexed	100	60	58	77

* Includes four re-sightings of three solitary males

Proportion of adult males in the population

Proportion of adult males was computed using Type 1 and Type 2 classification data. In total 288 elephants were recorded in Type 1 & Type 2 classification during the study period. Out of these 288 elephants, 26 were adult males. Therefore, proportion of adult males was 0.09 (9%) of the total population. Similarly, we were able to record the age/sex composition of elephants in six sightings in the other parts of northern Bengal (Gorumara NP, Chapramari WLS and Mahananda WLS) comprising 82 elephants. Of these six sightings, three sightings belonged to Type 1 classification and the rest Type 2 classification. Pooled data for entire northern Bengal area is shown in Table 4.4. The proportion of adult males in the population did not change (0.09) after including the western part of northern Bengal.

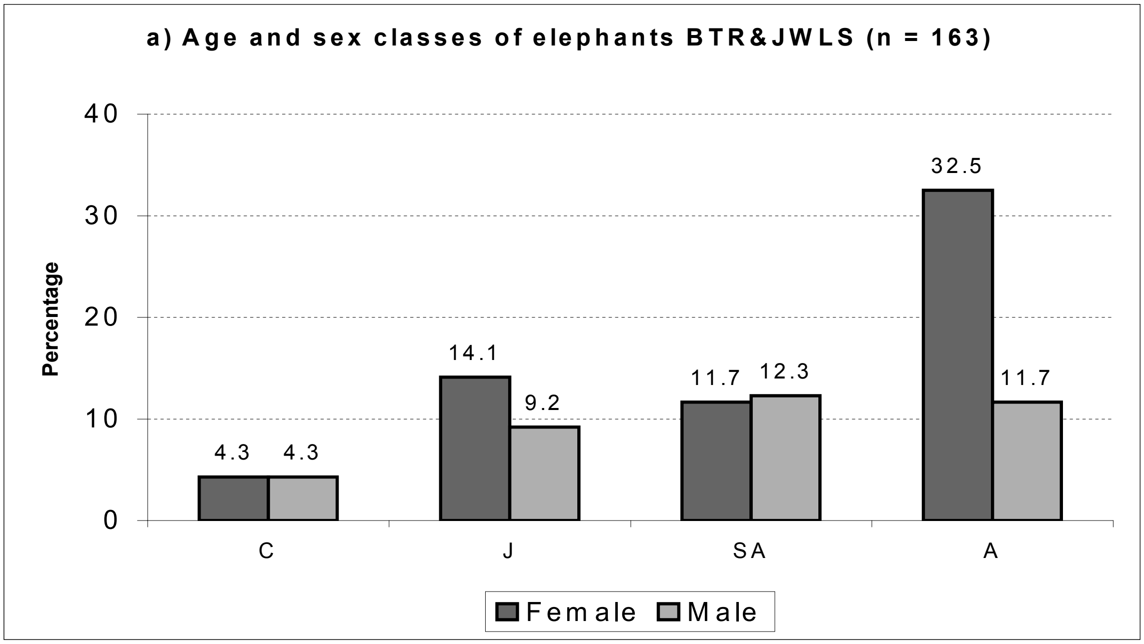
Table 4.4: Details of direct sightings of elephants recorded for age-sex structure in North Bengal region

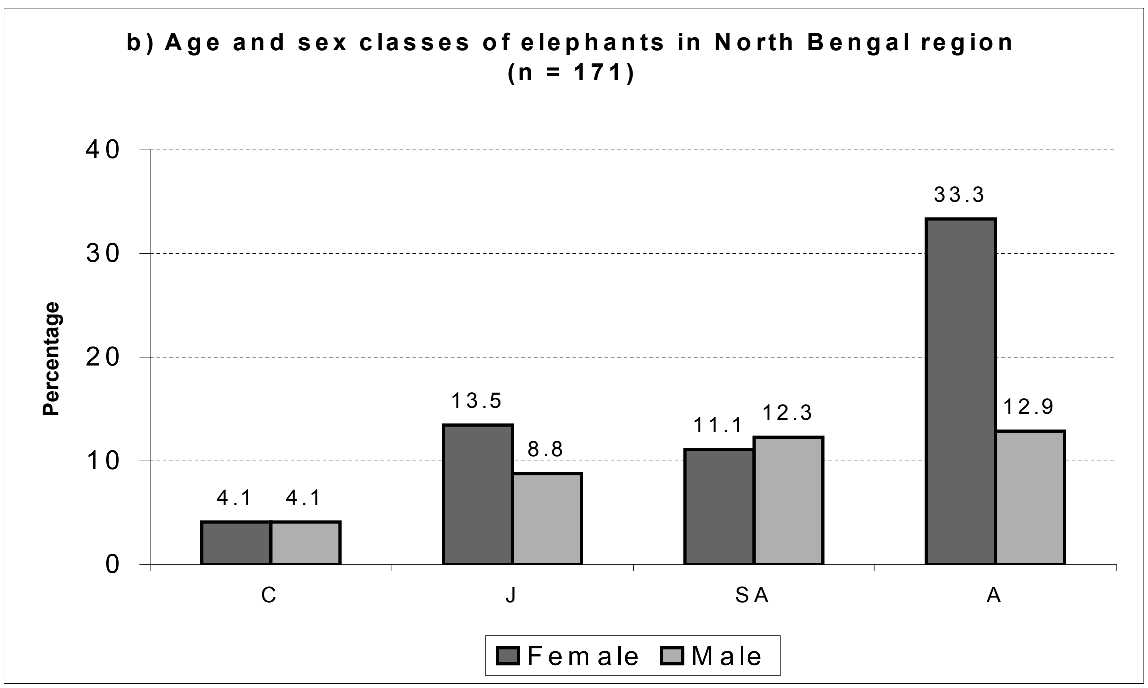
Details	Type 1	Type 2	Type 3	Total
Total number of sightings	38*	17	15	70
Total number of animals counted	175	199**	91+	465
Total number of animals aged/sexed	175	97	53	320
Percentage of animals age sexed	100	49	58	69

* Includes four re-sightings of three solitary males
** Includes one re-sighting of herd

Percentage of various age/sex classes

A detailed age structure of male and female elephants in the Buxa and Jaldapara population is given in Figure 4.1a. Adults constitute nearly 45% of the population and the rest of the population comprises sub-adults (24%), juveniles (23.3%) and calves (8.6%). A similar trend in age sex composition was observed when we included the western areas into the analysis (Fig. 4.1b) suggesting that there was not much variation overall in the population structure of elephants across northern Bengal.





*C = Calf, J = Juvenile, SA = Sub-adult, A = Adult

Fig. 4.1 a & b: Percentage of various age and sex classes of elephants observed in different places of the study area

The percentage of calves (8.6%) in the population indicates a high birth rate and perhaps an expanding population on the basis of population dynamics models and simulations carried out by Sukumar (1985, 1989). The percentage of calves can be expected to naturally fluctuate from one year to another. This is because of the long inter-calving interval in elephants resulting in only a small and varying percentage of adult females calving in any given year. High calving rate in any year is usually followed by lower calving rate in subsequent years because of lactational anoestrous and long gestation (Douglas-Hamilton, 1972; Sukumar, 1985; Daniel *et al*., 1987). Therefore, a more accurate assessment of birth rate can be obtained only from data on calf percentage for at least 3 years (Laws *et al*., 1975; Sukumar, 1989).

Sex ratio

Overall, the male to female ratio at the population level was 1: 1.67 (Table 4.5). However, the ratio varies between the age classes with a slightly male-biased ratio in the sub-adult class (1: 0.95), and females being more frequent than the males among adults (1: 2.8). Since it was not possible to sex calves (n=10), an equal sex ratio was assumed. A similar trend was observed even when we pooled the data for the entire northern Bengal area except for an insignificant variation in the sex ratio of male and female for overall (1:1.63), sub-adult (1:0.9) and adult (1:2.6) classes.

Table 4.5: Sex ratio of elephants in different age classes in Buxa Tiger Reserve and Jaldapara, and in north Bengal Region

Major age classes	Buxa Tiger Reserve & Jaldapara WLS		Northern Bengal region	
	Male	**Female**	**Male**	**Female**
Juvenile	1	1.5	1	1.5
Sub-adult	1	0.9	1	0.9
Adult	1	2.8	1	2.6
Overall	1	1.7	1	1.6

The sex ratio observed in the present study based on a moderate sample size (n=171) appears to be more equitable than reported elsewhere in India (Ramakrishnan *et al*., 1998; Baskaran & Desai 2000). Our data on the population age structure and sex ratio are quite different from those reported by Chowdhury *et al*. (1997) for the northern Bengal region. They reported the population to consist of 56% adults, 20.7% sub-adults, 15.5% of juvenile and 7.7% of calves in the northern Bengal population. We think it is unlikely for an elephant population to consist of greater than 50% adults except in the extreme case of a highly aging population, *i.e.,* a population in which birth rate has fallen drastically and the age structure is skewed in favour of older individuals (Laws *et al*., 1975; Sukumar, 1989; Ramakrishnan *et al*., 1998). There is no evidence of such a reduction in the birth rate of the northern Bengal elephant population. We feel therefore that the

Photo: Arun Venkataraman

Tusker in semi-evergreen forest of Buxa Tiger Reserve

Chowdhury *et al*. (1997) study has underestimated the sub-adult and juvenile segment of the population.

Adult sex ratio reported by Chowdhury *et al*. (1997) for the northern Bengal elephant population was 1: 0.65 (male:female), which is totally different from the present estimate (1:2.8 for Buxa Tiger Reserve and Jaldapara and 1:2.6 for the north Bengal). Such a difference could be due to two reasons. First, it could be due to the fact that Chowdhury *et al*. (1997) calculated the sex ratio based on fully and partially identified elephant groups, while the present study only used the first category. Secondly, though it is unclear what methodology was used by Chowdhury *et al*. (1997) for age/sex classification of elephants and data analyses, it seems apparent from the report (page 65) that at least some of these pertain to sightings of crop raiding elephants at night. It is known that adult bulls raid crops more frequently than female herds in most regions of Asia and Africa (Sukumar, 1989 and unpublished; Hoare, 1999; and present study) and therefore could be one reason for male-biased sex ratio recorded by the Chowdhury *et al*. (1997). The current study intensively sampled the Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary, while Chowdhury *et al*. (1997) mainly sampled the region west of Teesta River. Therefore, these differences could be due to variation in the area of study, provided there is such a variation between these two areas. But considering the fact that sex ratio would be equal or female-biased in polygynous species, as can be seen in all elephant populations studied elsewhere in Africa and in Asia, we feel it highly unlikely that a significantly male-biased adult sex ratio exists at the population level even west of the Teesta River. More objective sampling of the elephant population structure is needed for the northern Bengal region.

HABITAT UTILIZATION AND FEEDING HABITS OF ELEPHANTS

Elephants found in relatively seasonal, dry tracts of Asia and Africa are known to show distinct seasonal preference for plant types such as grasses or woody plants (Field and Ross, 1976; Barnes, 1976; Sukumar, 1985 & 1989). In such habitats the proportion of grass in the diet may vary from about 25% to 75% or more of the total diet. In the more seasonal habitats, the changing protein content of grass and other plants is a strong determinant of dietary preference by elephants. A predominantly grass diet during the wet season and a browse diet during the dry season are indicated in several studies. Mineral content may also influence choice of certain plant species and parts such as bark.

However, in evergreen forests the feeding strategy of elephants may be quite different because of the relatively low quality of many plants, the presence of plant secondary compounds that deter feeding, and the higher dispersal of food plants. The diet of elephants may also be quite diverse in the number of plant species sampled. In such habitats, the seasonal availability of fruits influences elephant feeding and fruits may constitute a substantial part of its diet (White *et al.* 1993). Studies based on stable carbon isotopes in bone collagen show that C3 plants (or browse plants) predominate the diet of rainforest elephants (van der Merwe et al. 1988; Sukumar, in press). The diet of elephants in the high rainfall, tropical moist forests of Buxa has to be evaluated in the light of these observations.

METHODS

Habitat utilization

Relative use of different habitats was studied both for dry and wet seasons for the Buxa Tiger Reserve to understand which habitat is preferred or is crucial to the elephants during a given season. The habitat utilization pattern can be studied by estimating elephant abundance in different habitats using direct sighting method or using indirect evidence such as dung piles, feeding signs and tracks signs in places where the visibility is poor and population density is low. We used the indirect method *i.e.*, relative abundance of dung piles in different habitats due to the poor visibility and low density of elephant in the study area as a measure of habitat utilization. A systematic survey was carried out both during dry and wet seasons to estimate the relative abundance of dung piles in all the habitats.

Feeding behaviour

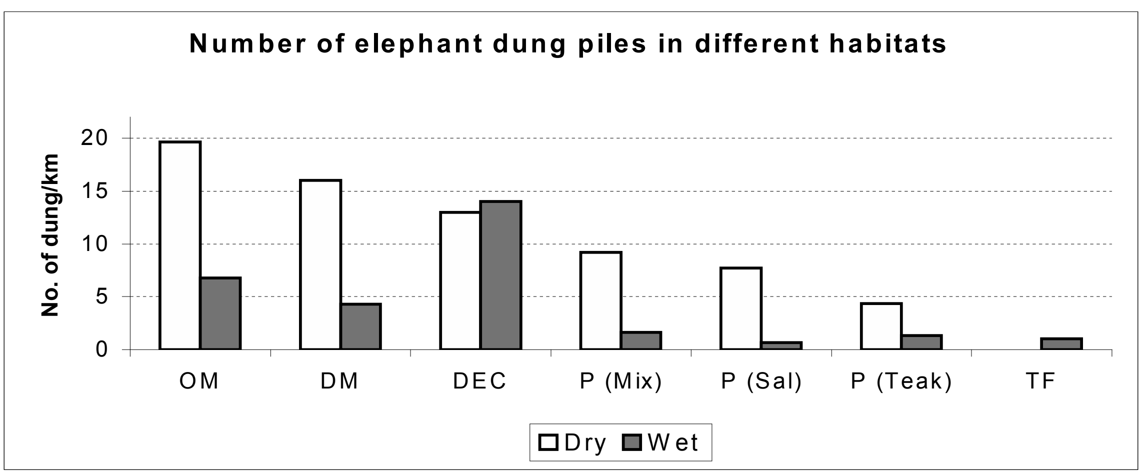
Data on feeding behaviour of elephants were collected mostly by following fresh feeding trails, as direct observation (scan and focal sampling) methods were not possible due to poor visibility. Along every fresh feeding trail, details such as plant species eaten, plant parts consumed and discarded, etc have been recorded. Unidentified food plants were collected and preserved for identification. The preference of a particular plant species by elephants can only be assessed in relation to the availability of that plant in the region. We have therefore compared the relative proportion of plant species in the diet as recorded from feeding trails with the relative abundance of the plant species recorded in the transects for characterizing vegetation.

Dung samples have also been collected, dried and preserved for further identification of plant parts. We have also collected the bone samples of elephants during post-mortem in some cases for carrying out the analysis of stable carbon isotope ratios in collagen to derive proportions of C3 (browse) and C4 (grass) plant types in the overall diet (Sukumar *et al*., 1987 and Sukumar & Ramesh, 1992). These analyses require the use of a mass spectrometer and will be reported at a later date. Apart from these, fresh elephant dung piles were examined to find out the fruit species eaten by elephants.

RESULTS AND DISCUSSION

Habitat utilization

All the habitat types were visited at least once during dry season and wet season for recording the number of dung piles per km walk. The results of dung pile records in different habitat types are plotted in Fig. 5.1. It appears that among the seven habitat types, elephants predominantly used the open mixed, dense mixed and deciduous forests both in dry and wet seasons, while the rest of the habitats are used occasionally. However, the intensity of use varied considerably between seasons (Fig. 5.1). During the dry season, elephants utilized open mixed and dense mixed habitats more intensively and these two habitats had the highest elephant concentration (as seen from abundance of dung) followed by deciduous forest. On the other hand, during the wet season the elephants shifted their movement to deciduous and open mixed habitats. The more intensive use of the deciduous forests as compared to other habitat types is especially striking during the wet season. We should also note that the abundance of dung during the wet season comes down in all habitats; this could reflect both the higher decay rate of dung during this season as well as a lower elephant density as seen from the estimate reported earlier. It is also important to note that among the three plantation types, mixed and sal plantations were used considerably by elephants during dry season, while they were almost avoided by elephants during the wet season.



*OM = Open mixed, DM = Dense mixed, DEC = Deciduous forest, P (Mix) = Plantation mixed, P (Sal) = Plantation Sal, P (Teak) = Plantation Teak, TF = Thorn forest

Fig. 5.1: Number of elephant dung piles recorded per km distance as an index of habitat use pattern of elephants in dry and wet season in Buxa Tiger Reserve

In general, food, water and shade are the three basic resources that can be expected to influence the movement of a large herbivore such as the elephant. These resources are generally abundant and widely available in all habitats during the wet season but in the dry season these resources may be in short supply and available only in some habitats. For instance, the *bhabar* tract along the foothills is devoid of water during the dry months while the *terai* tract further south is still quite moist at this time. Therefore, animals have to move between habitats according to season. In the study area, elephants showed high preference for dense mixed and open mixed forests along the *terai* tract during the dry season. On the other hand, during the wet season elephants shifted their concentration to deciduous forest, a habitat relatively more open than the dense mixed and open mixed forests. Such preference for open mixed forests during the wet season could be due to availability of freshly growing fodder species as the other two crucial resources such as water and shade are abundantly available in all habitats and thus may not be a limiting factor in wet season. The *terai* tract is also too wet during the monsoon season. The influence of food, water and shade on elephant movement in different contexts has been well documented elsewhere in Africa (Buss, 1970; Buechner *et al*., 1963; Western, 1975) and in Asia (Eisenberg & Lockhart, 1972; Sivaganesan, 1991; Baskaran, 1998).

Further, the presence of relatively more number of dung piles in all the habitats during dry season compared to wet season could be due to two possible reasons. Firstly, there may actually be more elephants in Buxa Tiger Reserve during dry season compared to wet season. It is possible that elephant from adjoining areas (Jaldapara WLS, Bhutan and Assam), may move into Buxa Tiger Reserve during the dry season as this area has more water sources and optimal habitats. Secondly, the lower dung decay rate during the dry season could have increased the number of dung piles in all the habitats. However, the difference in daily decay rate between dry (0.0077) and wet season (0.0096) is insufficient to make a substantial difference in dung density. Therefore, it appears that elephants from adjoining areas immigrate into Buxa Tiger Reserve during the dry season. Such movement highlights the importance of Buxa Tiger Reserve in terms of elephant habitats in northern Bengal.

Feeding behaviour

In total, 748 feeding scores were collected from the fresh elephant feeding trails. Forty-eight food plant species were recorded from these feeding scores. Among the 48 food plants, *Acacia pennata* a thorny shrub, was eaten by elephants most frequently. Food plants such as *Cayratia japonica*, *Leea* sp., *Albizia* sp. and *Clerodendrum viscosum* were also consumed often by elephants during this period. But the remaining 43 plant species recorded seemed to be consumed by elephants only occasionally. It was apparent from the results that *Acacia pennata* was the most preferred food species as it was eaten far more frequently (27.1% of diet) as compared to its relatively low availability (0.38%) in the stand. Similarly, all the other species with the exception of *Tectona grandis* were used proportionally more than their availability indicating that elephants are very selective in their feeding in this predominantly evergreen forest habitat.

Consumption of major plant species varied considerably during dry and wet season. For example, during the dry season elephants ate *Albizzia lucidor, Clerodendrum viscosum and Tectona grandis* predominantly. On the other hand, during the wet season, plant species such as *Acacia pennata*, *Cayratia japonica* and *Dendrocalamus stictus* were frequently consumed by elephants. Total number of plant species that constituted the elephant’s diet was more during wet season (39 spp.) compared to dry season (17 spp.).

Plant parts eaten by elephants from the major food species are shown in Table 5.1. These seven plant species each account for more than 4% of the overall diet of elephants. Elephants seem to have preference for specific parts in different plants. For example from *A. pennata* elephants selected twigs with leaves, but in the case of *T. grandis* the bark was selected and the leaves discarded. Similarly, from *Musa* sp. elephants fed only on the inner stem (pith) and discarded all other parts. Overall, from these records it was found that plant parts such as twigs with leaves dominate the elephants’ diet (Fig. 5.2). From the tree species, elephant mostly selected twigs, twigs with leaves and bark and in the case of shrubs, stem or stem with leaves. But in the case of stragglers, elephants consumed, in most cases, all parts.

Photo: Mukti Roy

Debarking of Tectona grandis by elephants

Table 5.1: Percentage of major food plant parts eaten by elephants in Buxa Tiger Reserve

Species	Stem	Bark	Twigs	Entire	Twigs & Leaves	Stem & Leaves
Acacia pennata	-	-	-	-	100	-
Cayratia japonica	9.1	-	-	90.9	-	-
Leea sp. (tree)	-	-	100	-	-	-
Albizzia lucidor	-	4.7	95.3	-	-	-
Cledendron viscosum	100	-	-	-	-	-
Dendrocalamus stictus	-	-	-	-	-	100
Mallotus phillppensis	-	48.6	51.4	-	-	-
Others	34.7	48.6	5.6	4.1	7.5	45.5
Total	18.7	4.7	16.4	10.7	33.2	16.4

Over the study period, 125 elephant dung piles were examined for fruit remains between December 2000 to March 2001. Of these, more than 90% of the dung piles contained fruit remains of *Dillenia indica* indicating the importance of this fruit in the diet of elephants during the dry season.

Seasonal selection of food plants by Asian elephants has been observed earlier (Sukumar, 1985, 1989; Sivaganesan, 1987; Baskaran, 1998). Chowdhury *et al*., (1997) identified 78 food plants eaten by elephants in northern Bengal region which is very high compared to 39 plant species identified in the present study. Unlike Chowdhury *et al*., (1997) who used direct observation method on captive elephants, we recorded the food species consumed by wild elephants using feeding trail observation method. In this method it is possible that smaller species like grasses, and forbs could have been unnoticed, as they were collected along with bigger sized plants. However, the proportion of grass species in the elephant's diet in Buxa could be insignificant as compared to browse because of the evergreen forest nature of the Buxa habitat. Elephants are known to survive predominantly on browse (93%) in lowland evergreen forest of Gabon (White *et. al*., 1993). The body size and dental features suggest that elephants are highly adapted to grass feeding (Olivier 1978). However, their ability to survive in the evergreen forest like Buxa where grass availability is very low, indicates that they can adapt to exploit browse in the absence or insufficient grass supply. We hope to resolve the question of grass versus browse in the diet through carbon isotope analysis of bone collagen (Sukumar and Ramesh 1992).

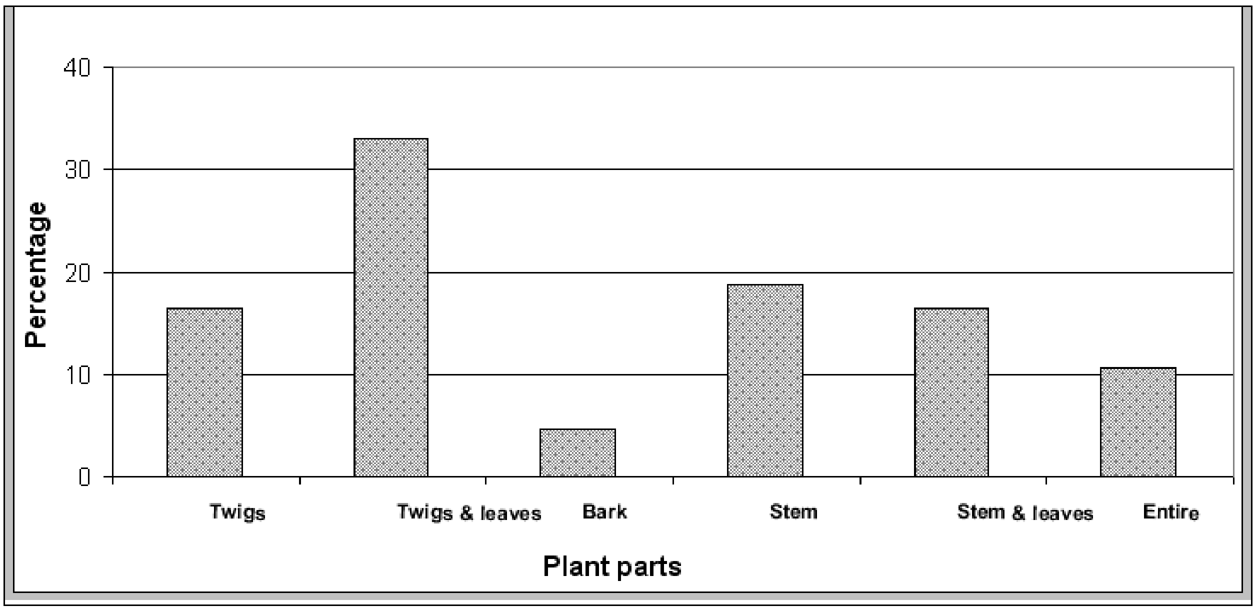


Fig. 5.2: Percentage of various plant parts eaten by elephants in Buxa Tiger Reserve

RANGING BEHAVIOUR OF ELEPHANTS

The use of space and habitat types, both on a seasonal and an annual basis, by elephants is an important consideration in planning their conservation. In a relatively fragmented landscape, it is also important to identify the possible use of specific corridors by elephants in the course of their seasonal, long distance movements. Studies of the ranging patterns of African elephants (e.g. Douglas-Hamilton 1972; Leuthold 1977; Lindeque and Lindeque 1991; Thouless 1996) and Asian elephants (Baskaran 1998; Fernando and Lande 2000) through telemetry have shown enormous variation in the home range sizes. For instance, the recorded home range size of African elephants vary over two orders of magnitude (from about 14 km^2 to over 10,000 km^2), while even those of the Asian elephant varies from about 100 km^2 to about 800 km^2 (the above references). There is considerable variation even in the home range size within a population (Thouless 1996).

The Jaldapara-Buxa landscape is relatively fragmented with only the central region of Buxa TR having over 400 km^2 of a compact forest block, though with several settlements. Our objective was to study the ranging patterns, habitat use and use of corridors by elephants across this landscape by radio-collaring elephants at various places including Jaldapara in the west, the central block of Buxa and the eastern intrusion of the Rydak forests that lie closer to the border with Assam.

METHODS

A total of seven elephants were radio-collared between January 2001 and January 2003. Of these, five elephants (three females from three different herds and two bulls) were collared in Buxa Tiger Reserve and two elephants (one female and one bull) in Jaldapara wildlife sanctuary. Completely assembled VHF (with frequency 151) radio-collars manufactured by the Telonics Inc., USA was used in the present study. The radio-collar is made of two layers of machine belts. A sealed transmitter is embedded in acrylic and mounted in between the two layers of the belt. The antenna projecting from the transmitter was sewn in between the two layers of the belt. The two layers of the belt were machine stitched and riveted at uniform intervals to avoid separation of the two layers. The radio-collar was placed around the neck of the elephant. Two brass plates with four stud bolts protruding outward were placed against the elephant's hide. Both the ends of the collar had holes cut to match the bolt pattern. After each end of the collar fitted over the bolts, a second brass plate was fitted, sandwiching the collar ends. Eight self-locking nuts were fitted

Photo: Ashish & Shanthi Chandola

Radio collaring a makhna in Buxa Tiger Reserve on to the plate to secure the assembly. TR-4 model receiver, hand-held "H" type antenna and earphones manufactured by Telonics Inc., were the receiving equipment used in radio tracking.

Locations of the radio-collared elephants were collected regularly using direct sighting and triangulation methods. In direct sighting (homing in on the animal) method, the observer picks up signals from nearby vantage points of earlier locations and then follows the direction of the signal up to the location of the collared elephant. In the triangulation method, at least three radio-signal bearings are ideally collected from different vantage points and the intercepting point (animal location) of bearings calculated using Global Positioning System (GPS) readings by a trigonometric formula. For every direct sighting location, the latitude and longitude of the collared animal was recorded using GPS. In some cases however the signals could be obtained only from two points at a time for an animal. An attempt was made to collect a minimum of four locations per month for each elephant. The location data was analyzed using the computer program *ANIMAL MOVEMENT SA Version 2.4 Beta* (an extension to Arc View 3.2 a) and the home range and seasonal (dry season – November to April and wet season – May to October) ranges were estimated using Minimum Convex Polygon (MCP) method (Jennrich & Turner, 1969).

Photo: Netro Sharma

Radio tracking in Buxa Tiger Reserve

Results and discussion

Details of radio-collared elephant such as place of collaring, duration of tracking and sample size (number of locations) are given in Table 6.1. The movements of female herds 23, 50, 63 and 73 have been tracked for more than a year. The bull 50 was only tracked for a period of three months from 19th January until 7th April (the male subsequently seems to have pulled off the radio-collar which was recovered intact) and the bull 91 that was fitted with a satellite collar during January 2003 damaged the collar after a three month period. During this period, a total of 23 and 90 locations were obtained for the bulls 50 and 94, respectively. The bull 13 collared during January 2003 has been located 29 times so far.

Table 6.1: Details of radio-collared elephants in North Bengal

S. No.	Elephant id	Place of collaring	Duration of data collection	Sample size obtained
1	Female herd - 23	Buxa Tiger Reserve	29 months	166
2	Female herd - 50	Jaldapara WLS	20 months	94
3	Female herd - 73	Buxa Tiger Reserve	17 month	101
4	Female herd - 63	Buxa Tiger Reserve	17 month	59
5	Bull – 50[1]	Buxa Tiger Reserve	3 months	23
6	Bull – 94[2]	Jaldapara WLS	4 months	90
7.	Bull – 13	Buxa Tiger Reserve	5 months	29

[1] Pulled off the collar after 75 days
[2] Tore off the satellite collar after 90 days

In order to know whether home range size has reached a saturation, we plotted the cumulative monthly home range sizes of the collared elephants in chronological order against the duration of the tracking period (Fig. 6.1). It is quite clear from the figure that the area curves have not stabilized for all the animals (except female herd 50) indicating that home ranges are yet to be completely defined.

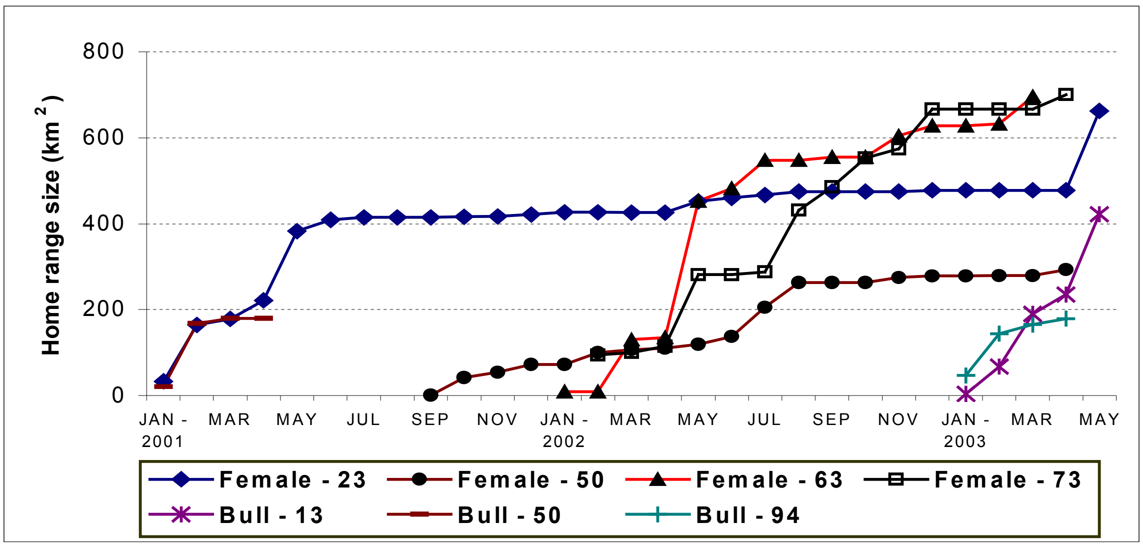


Fig. 6.1: Cumulative increase in home range size of radio-collared elephants in Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary

Figure 6.2 shows the spatial location of the home ranges of the study animals. The female herds 23 and 73 ranged over the central and western parts of Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary. These two herds overlapped extensively in space. The female herd 23 ranged only in the Buxa Tiger Reserve for the first two years (2001 & 2002) and extended her range to Jaldapara during 2003. The female herd 50 collared at Jaldapara Wildlife Sanctuary restricted its range to Jaldapara and did not make any attempt to move eastward into Buxa Tiger Reserve or westward to Jalpaiguri Forest Division over the study period. Female herd 63 ranged over the eastern forest patches of Buxa Tiger Reserve in addition to moving into Assam and Bhutan. Over about a three-month period, the bull 50 basically ranged over central areas of Buxa Tiger Reserve (Jainti, Rajabhatkawa and Nimati), overlapping extensively with female herd 23. The bull 13 used the central and eastern areas of

Buxa Tiger Reserve. Bull 94 restricted its movement only within the Jaldapara Wildlife Sanctuary but extensively overlapped in space with female herd 50's home range.

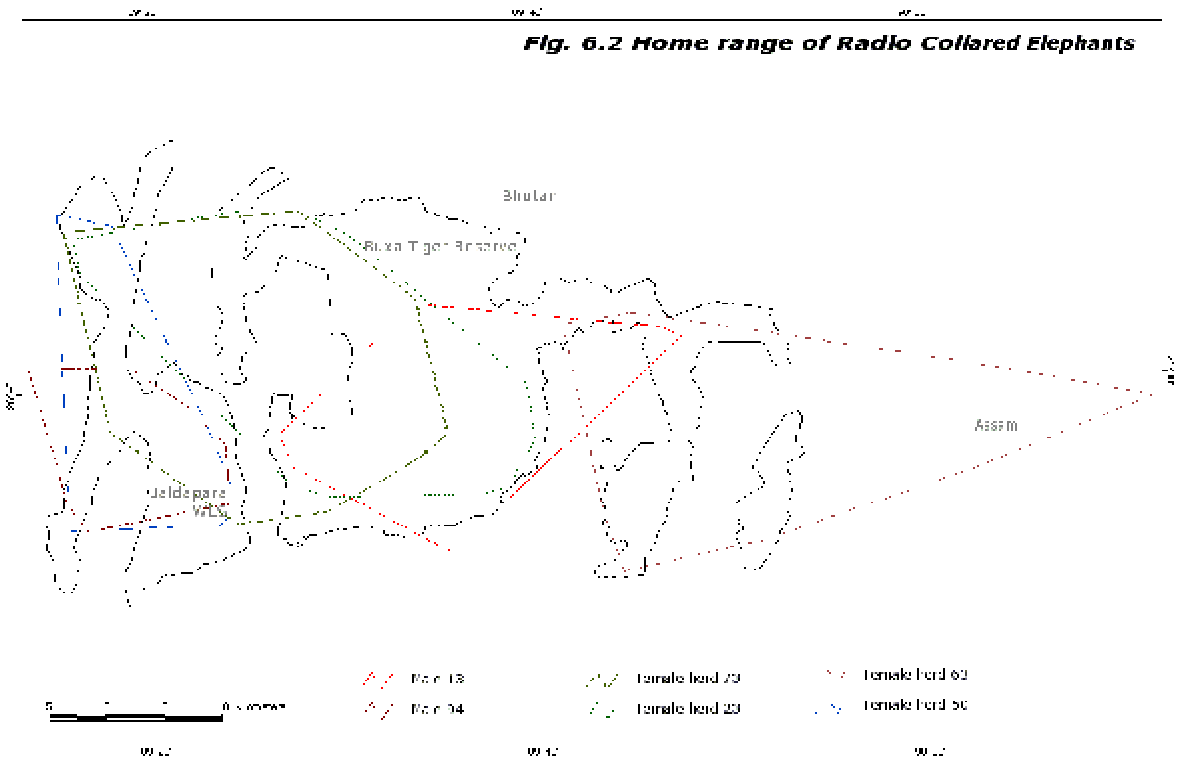


Fig. 6.2 Home range of Radio Collared Elephants

The home range sizes estimated for all the study animals are given in Table 6.2. Among the seven collared elephants, female herd 73 ranged over largest area (701 km^2) in 17 months of tracking while the female herds 23 & 63 had slightly smaller home range sizes of 663 km^2 and 696 km^2 respectively. Despite the fact that the female herd 50 has been tracked since September 2001, she had a substantially smaller home range (293 km^2) compared to that of other female herds some of which have been tracked for shorter periods. A mean home range size of 588 km^2 was estimated for female herds based on the current data, which is comparable with mean range of 677 km^2 estimated for three female clans in a southern Indian population (Baskaran 1998).

During the 3-4 month dry seasons that bulls were tracked (bull 50 – 78 days; bull 13 – 103 days and bull 94 – 91 days), the bull 50 (180 km^2) and bull 94 (179 km^2) ranged over a similar area, while the bull 13 ranged over a large area of 444 km^2. The home range size of all the three bulls would obviously be greater if they were tracked for a year.

Table 6.2: Details of radio-collared elephants home range estimate (minimum convex polygon) in the study area

S. No.	Elephant id	Duration of data collection	Sample size obtained	Home range size (km^2)
1	Female herd - 23	29 months	166	696
2	Female herd - 50	20 months	94	293
3	Female herd - 63	17 month	101	701
4	Female herd - 73	17 month	59	695
5	Bull – 50	3 months	23	180
6	Bull – 94	4 months	90	179
7	Bull – 13	5 months	29	444

We have also analyzed the home range sizes for the female herds for the two major seasons (Table 6.3 & Fig. 6.3 a, b, c, d). The months November to April were treated as dry season, and May to October as the wet season. Wet season ranges were larger than dry season ranges for all the female herds (except herd 73).

Table 6.3: Seasonal home range estimated for the radio-collared elephants in the study area

S. No.	Elephant id	Dry season		Wet season	
		Sample size	Range size (km^2)	Sample size	Range size (km^2)
1	Female herd – 23	89	390	77	477
2	Female herd – 50	56	124	38	231
3	Female herd – 63	37	252	22	449
4	Female herd – 73	65	515	36	444

In general, home range size has been related to habitat quality in many large mammals, with range size being smaller in regions of superior habitat quality. For instance, a clear negative relationship between home range size and annual rainfall (which is a proxy for primary productivity) is seen among elephant populations of Africa (Thouless 1996). This relationship however only holds good from the semi-arid (< 20 cm annual rainfall) to the medium rainfall regions (between 100-120 cm) (Sukumar, in press). Beyond this there may again be an increase in range size, especially in rainforest with rainfall over 150 cm as the quality of forage for elephants decreases. Elephants in secondary forest habitat, in which palatable species are more abundant, may also tend to have smaller home range than in primary forest.

None of the earlier home range estimates for elephants from northern Bengal by Chowdhury *et al.* (1997) are based on at least a year's tracking; most of these were followed for less than six months. One female elephant (F1) that was tracked for nine months ranged extensively over a very large area (100% MCP of 3708 km^2 and 95% MCP of 1925 km^2). The range of this elephant included a substantial area under cultivation and settlement in the more fragmented western part of northern Bengal. The home range of this female still appears to be undefined in spite of covering a large area. It is likely that elephants in the western region in Dooars move extensively between forest patches, which are fragmented heavily and no single fragment can support a herd throughout the year. Therefore, comparing this home range with the present study animals may not be an appropriate choice.

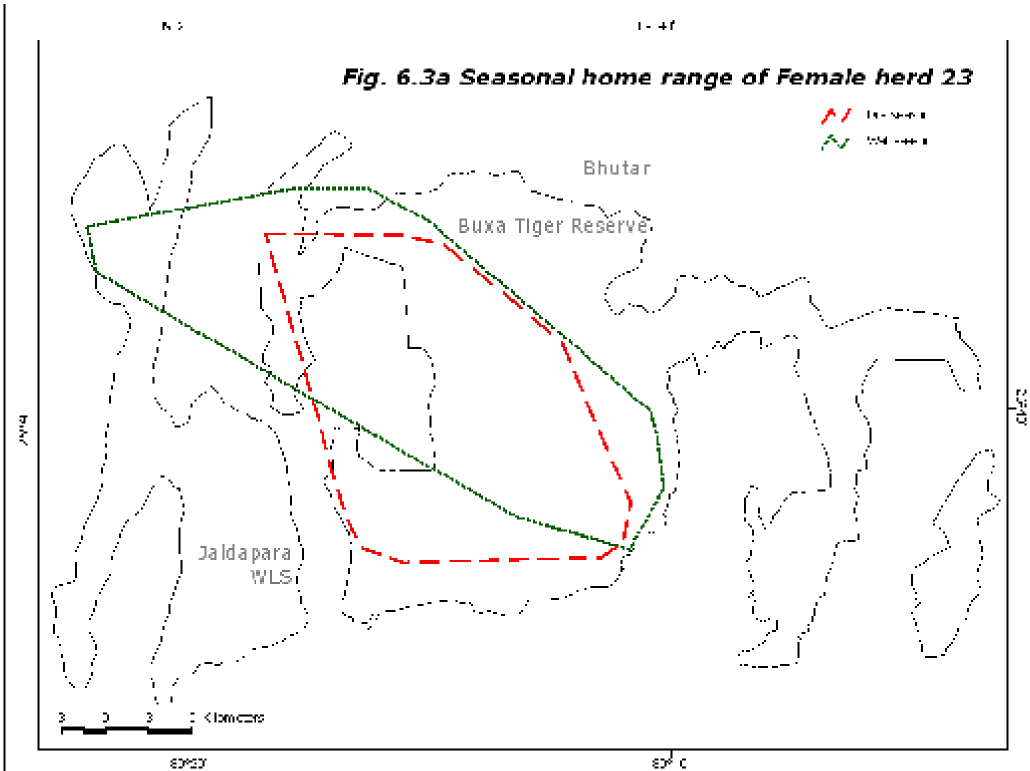


Fig. 6.3a Seasonal home range of Female herd 23

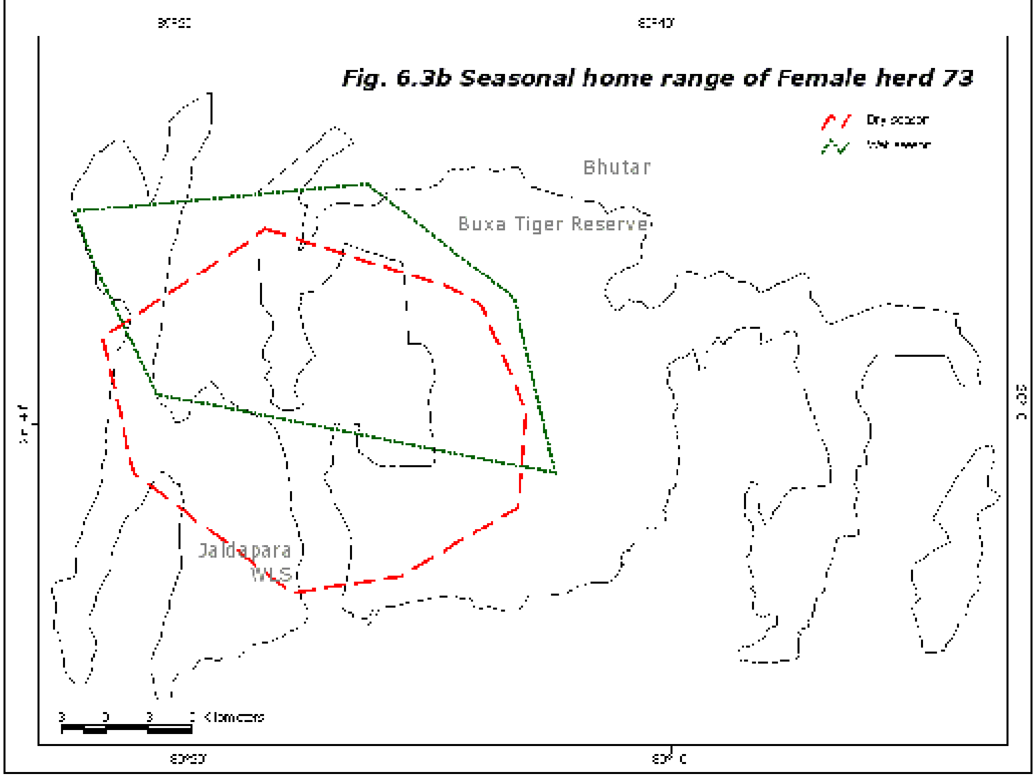
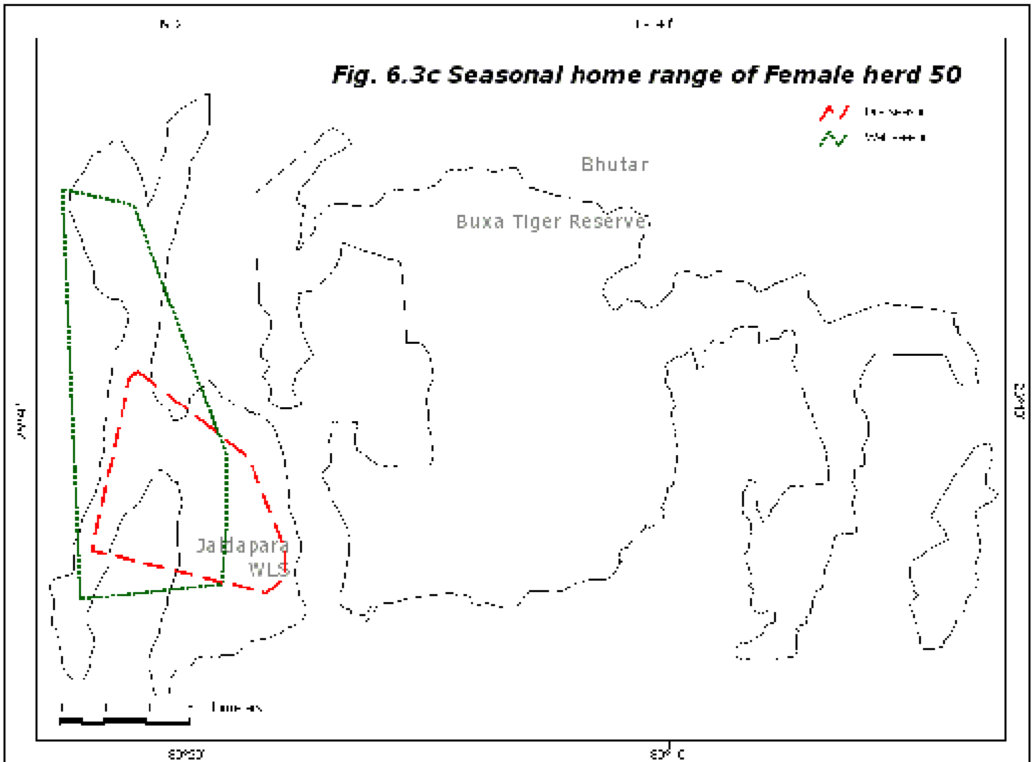
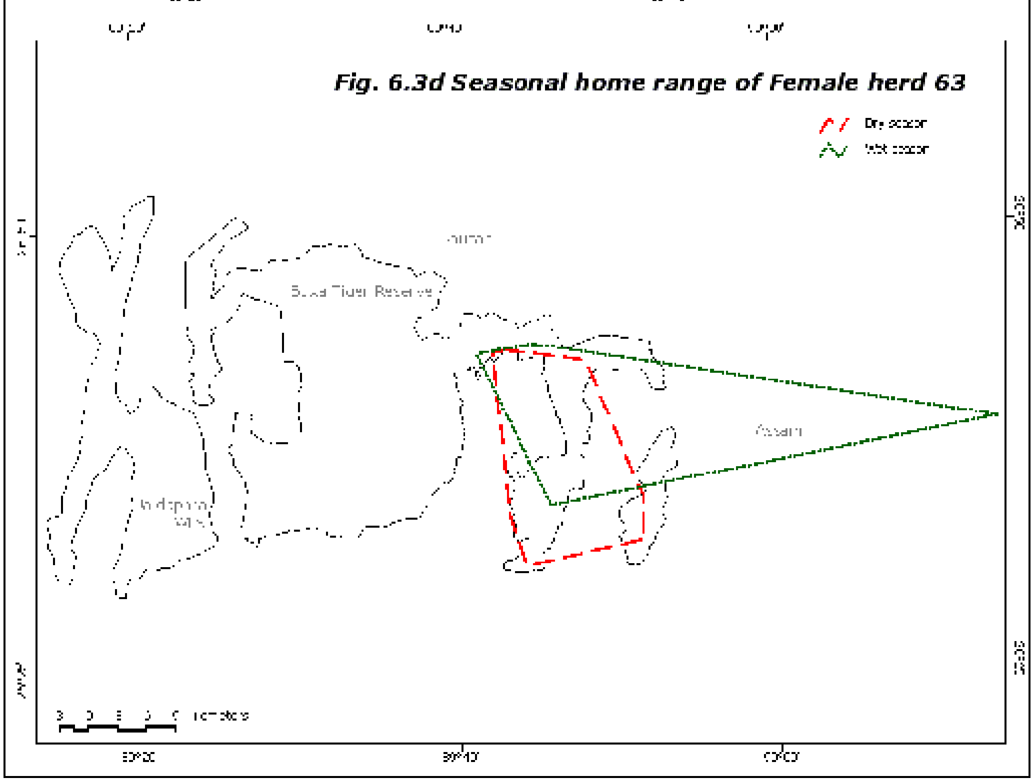


Fig. 6.3b Seasonal home range of Female herd 73





Home range size estimated by Baskaran et al. (1995) for elephant herds (mean of 677 km^2) in relatively undisturbed secondary forest of southern India is comparable with the present study (588 km^2). The female herds 23 and 73 move into Jaldapara Wildlife Sanctuary during the wet season and get back to Buxa Tiger Reserve during the dry season through non-forested area (Tea Estate). Similarly female herd 63 moves out from Buxa Tiger Reserve to Assam Forest Division in wet season and returns to Buxa Tiger Reserve in dry season. Such observations suggest the need for maintaining large areas for elephant conservation and Buxa Tiger Reserve can't support all the elephants on its own throughout the year. Historical records of elephant movement in this area (O' Malley, 1907) also reveal that there may have been traditional elephant migration routes running in an east-west direction.

Experiment with an "early warning system' through a satellite collar

A satellite collar was fitted during January 2003 on one bull elephant (a tuskless male) known to be a regular crop raider ranging in the Jaldapara Wildlife Sanctuary in order to test how far such a system can be used as an early warning system for minimizing the human-elephant conflict. The animal's movement in the sanctuary and adjoining areas was monitored with the help of 6 satellites that comprise a part of the ARGOS network. Satellite overpasses occur in India about 25 times per day, each pass lasting about 10 to 15 minutes. In order to conserve transmitter batteries, the transmitter was programmed to broadcast during windows of eight hours alternating with a switch of eight hours. As a result, five to seven locations were received per broadcast day from ARGOS network of satellites with information about the location, temperature of the surroundings, elevation and activity of the animal was obtained through a web site. The locations were plotted using GIS software and the resulting maps were sent to the park managers through email daily in order to alert their field staff about the possibility of this bull raiding the nearby villages. The animal was tracked using this technology up to 24th April 2003 and subsequently the bull managed to tear its collar. During this period, in total about 500 locations were obtained, of which nearly 60% of the locations were as close to 150m from the transmitter position. The bull moved over an area of 179 km^2 during the three months period it was tracked.

Photo: Ashish & Shanthi Chandola

Fitting of a satellite collar to a makhna in Jaldapara WLS

The wildlife officials expressed great satisfaction with the progress of this experiment and they would like to extend this work to other parts of northern Bengal where conflict levels are high. The idea is to have the ability to track notorious elephants on a day-to-day basis so that the wildlife manager would have the option of alerting his staff and local villagers if any of these elephants were to approach a settlement for crop raiding (that also may result in manslaughter).

Photos: R. Sukumar

Different stages of the Makhna recovering after being fitted with a satellite collar

ELEPHANT-HUMAN CONFLICT

It is now recognized that the elephant's impact on humans through crop raiding, destruction of property and manslaughter is a major stumbling block to conservation efforts for the species in both Asia and Africa (Sukumar 1989; Hoare 1999). While crop losses in India run into several crores of rupees each year, the number of people killed by elephants average 150-200 each year (Project Elephant Directorate). The northern Bengal region experiences some of the most intense conflict between elephants and people seen anywhere in Asia (Lahiri-Choudhury 1980). This is exemplified by the fact that 45 people were killed on average annually by elephants here during 1980-2000, the highest number for any elephant region in the two continents.

Photo: Mukti Roy

Dismembered body of a victim of elephant manslaughter in Buxa Tiger Reserve

We can ask broader questions relating to elephant-human conflict such as why do elephants raid crops, as well as try to understand the reasons as to why conflict seems more intense in northern Bengal. Across the landscape of Jaldapara-Buxa, is there a greater likelihood of crop raiding in villages that are located in corridor areas or other regions of more intensive use by elephants? Does habitat integrity influence the intensity of crop raiding? How does conflict here compare to other regions further west in northern Bengal? These are some of the questions we try to answer in this study.

METHODS

In order to collect detailed information on human-elephant conflict, a total of fifteen agricultural villages situated in and around Buxa Tiger Reserve were selected for monitoring crop raiding in detail. The fifteen villages include five enclave villages (surrounded by forest), five peripheral villages along the border of Buxa Tiger

Reserve (one side bordered by forest) and another five villages in the corridor areas at the eastern and western ends of the Buxa Tiger Reserve. Three more villages were added for the monitoring during 2002. Details such as type of crops cultivated, extent of different crops cultivated, month of cultivation, extent of different crops damaged by elephants etc, were collected by visiting the villages once a fortnight. To estimate the area of cultivation and damage, length and width were measured using a measuring tape. In the case of irregular shape of damage, the area was divided into regular shapes, which were measured by the above procedure.

Monitoring of crop damage was started in January 2001. Damage occurring prior to February was also recorded and the actual date of raiding was ascertained through local enquiry. Apart from the above variables, data on crop biomass and crop grain production per unit area of different crops were also collected from sample fields to estimate the biomass consumption and the economic loss by elephants. Apart from these, data on crop raiding claim was collected from forest department records to know the trend of conflict over the period of time.

RESULTS & DISCUSSION

Area cultivated in different villages

In total 986 hectares (15 villages) and 1745 hectares (18 villages) of crop fields were monitored in and around Buxa Tiger Reserve during 2001 and 2002 respectively (Table 7.1). Overall, elephants damaged 4.6% of the cultivated area during 2001 and 3.4% during 2002. The proportion of cultivated crops damaged by elephant in Buxa Tiger Reserve is more than double the proportion damaged by elephants in a southern Indian population (Balasubramanian et al. 1995).

Table 7.1: Villages selected and area monitored for the elephant crop damage data collection during 2001 and 2002 at Buxa Tiger Reserve

		Area under Cultivation (ha)	
S. No.	**Village name**	**2001**	**2002**
1	28th Mile Basti	30.07	32.84
2	Ambari	17.36	12.22
3	Bhutia Basti	22.03	13.83
4	Bhutri	21.51	26.12
5	Cheko	33.73	31.24
6	Chipra	18.41	22.12
7	Dolbadol	45.05	29.36
8	Gadadhar	147.16	181.16
9	Gangutia	33.90	36.99
10	Gopal Bahadur	282.20	257.68
11	Lapragudi	44.15	40.91
12	Pumpy Basty	35.77	36.00
13	S. Patkapara	81.02	Not monitored
14	S. Poro	151.42	146.97
15	Tiamari	22.50	23.31
16	Mainabari	Not monitored	394.18
17	Newlands	Not monitored	28.48
18	Sankosh	Not monitored	131.95
19	Nimathi Dohomoni	Not monitored	301.60

The distribution of the damage was extremely skewed, with a few villages suffering considerably more damage than the others. Two of the most affected villages were Pumpy Basti (37% of crop fields) and Teamari Forest Village (12%) during 2001, while in 2002, Newlands (28.7%) and 28th Mile Basti (7.9%) topped the list. The damage at Pumpy Basti during the 2001 maize season was as much as 98% (with 11.7 out of 11.9 ha being damaged by elephants, mainly during the month of June). The actual damage by elephants could not be accurately judged in the case of Bhutri and Bhutia Basti, during the maize season, as cattle were allowed to consume most of the remaining crops. The villagers in these two settlements claim that the raiding is so intense that it is better to allow cattle to eat the maize.

Elephant damage in Relation to Location of Village

It appears that crop fields in enclave villages were affected to a significantly higher extent, with a mean damage of 12.4% of cultivated area, as compared to the corridor villages (3.9% of area) and peripheral villages (2.5% of area) during 2001 (Table 7.2) as well as in 2002. Enclave villages are expected to have higher damage as elephants can enter crop fields from all directions. In peripheral villages, the entry of elephants is restricted to only one side. Extent of crop damage in the villages situated in the corridor area depends on the functionality of the corridor. It may appear that the percentage of elephant damage in the corridor villages (3.9%) was not much higher from peripheral villages (2.5%). However, if we consider the absolute area damaged, the extent of damage in the corridor villages was 17.5 ha, which is almost double that of peripheral villages (10.3 ha) although the area monitored in the corridor sites (447 ha.) was only higher by 12% as compared to the peripheral villages (399 ha).

Photo: Arun Venkataraman

Paddy cultivation in the Himalayan foothill forests of Buxa Tiger Reserve

Table 7.2. Percentage of crops damaged by elephants at Buxa Tiger Reserve during 2001 and 2002

Sl. No.	Village Location	Percentage of damage		
		Trampled	Eaten	Total
1	Corridor(2001)	0.73	3.19	3.91
2	Corridor(2002)	0.33	3.72	4.05
3	Enclave(2001)	1.16	11.22	12.38
4	Enclave(2002)	0.59	5.81	6.40
5	Periphery(2001)	0.60	1.98	2.58
6	Periphery(2002)	0.31	1.37	1.68

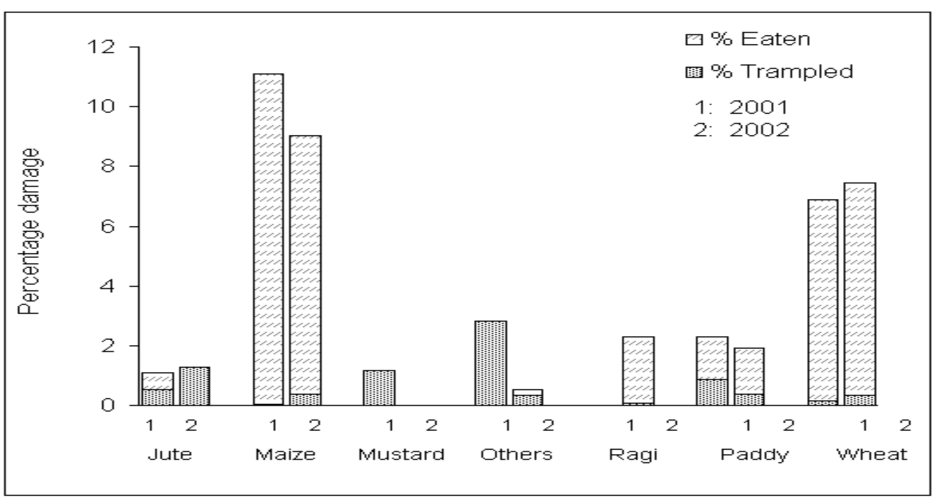
Further, among the corridor villages selected for this study, those situated in the western side corridor experienced very high levels of damage as compared to village in the southwest and eastern side. These observations indicate the likely places where elephants could have lost their habitat in the recent past.

Elephant damage to different crops

Of the crops cultivated, maize and wheat suffered the highest proportion of damage both during 2001 and 2002 (Fig. 7.1) mostly through feeding. The damage to paddy was much less with only about 2% and 1.5% of the total crop being affected by elephants during the years 2001 and 2002, respectively. Of this elephant feeding accounted nearly 60% - 80% of damage and the rest was by trampling. Other major crops like jute, vegetables and mustard suffered little damage; this was mainly through trampling (though some sporadic feeding on jute and vegetables may have occurred). Since elephants do not seem to be getting any nutritional advantage from these crops it is likely that raiding in these fields is mainly incidental. In Teamari, for example, most damage to the jute crop was due to elephants trampling it on their way to the maize crop, which is cultivated towards the village centre. But the higher proportion of feeding than trampling in the case of maize, wheat and paddy crops indicates that elephants have preference for these crops and they deliberately entered these fields to feed on the crops.

Photo: Mukti Roy

Maize cultivation damaged by elephants in Buxa Tiger Reserve



Note: Ragi cultivated in very small area during 2001

Fig. 7.1: Percentage of different crops damaged by elephants in the study villages during 2001 and 2002

Elephant damage to crops in different months

The crop damage during different months of the study period is depicted in Figure 7.2. Crop damage was highest during May and June both during 2001 and 2002. During the month of March, crop raiding was very low, probably because most crops were in vegetative phase. Raiding gradually increased and peaked during May and June. The higher proportions consumed between April and June coincides with the reproductive stages of wheat in April and maize in the month of June. Similarly, damage gradually increased from August and reached a peak during October and November, which again coincides with the reproductive phase (flowering and grain stage) of paddy crop. Damage to individual crops varied considerably across months. For example, damage to wheat progressively increased from February and reached a peak by April, during 2001 and March during 2002, a period coinciding with the mature crop stage. Similarly, damage to maize and paddy also gradually increased and reached a peak during the reproductive period. In general, elephants were extremely selective of the phenology of the crop, with raids being most frequent after maize, wheat and paddy reached reproductive stage (cob or grain stage, respectively). This is likely to be due to the greater nutritional benefit that they get per unit time effort during the reproductive stage of the crop. In support of this, the pattern of feeding on maize wheat and paddy was invariably very selective with elephants foraging on the stalk bearing grain or cob alone and discarding the rest of the plant.

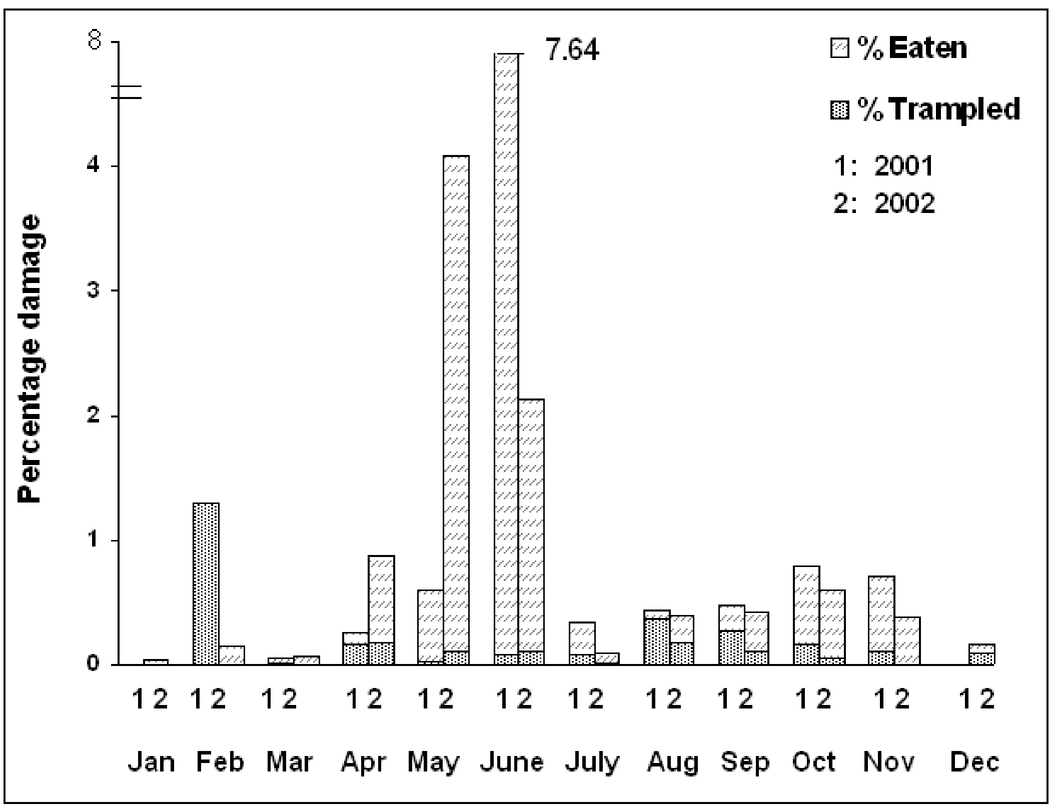
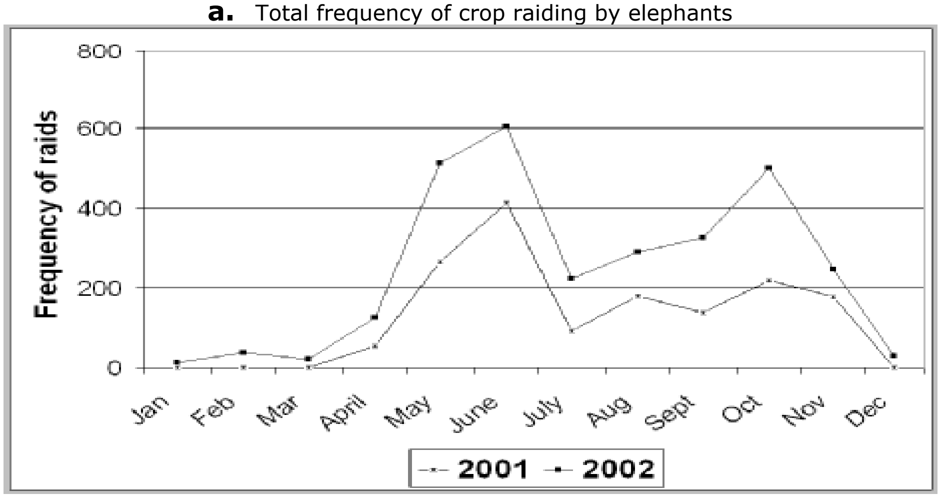


Fig. 7.2: Percentage of crop damage reported in different months in the study villages during 2001 and 2002

Frequency of crop raiding in different months

The pattern of crop raiding frequency recorded during 2001 and 2002 was almost similar although the actual number of raids was more during 2002 compared to 2002 (Fig.7.3a). This could be due to the selection of three more villages during 2002. The observed two peaks in the raiding frequency coincide with the flowering/grain stage of maize and paddy. It appears that male raided crops in all the months, but female raided crops mostly between April and November and that the raiding frequency of female groups was extremely high in June both during 2001 and 2002 (Fig. 7.3b).

a. Total frequency of crop raiding by elephants



b. Frequency of crop raiding by bull and female herd

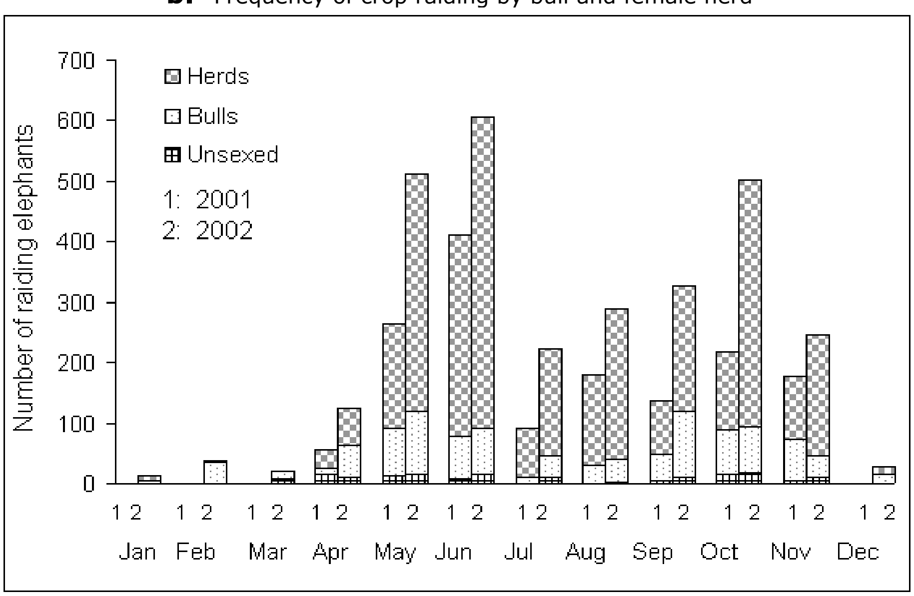


Fig. 7.3 a & b: Frequency of crop raiding by elephants in different months during 2001 and 2002

Crop biomass consumption

Elephants damaged crops by both eating and trampling. Out of the total damage, about 60% of damage through consumption and the remaining through trampling has been observed in an earlier study in southern India (Sukumar 1985). In Buxa the trend is similar, with an average of 46% damage due to trampling and 54% due to feeding in the case of maize. In the case of paddy, however, the proportion eaten is higher being 80% of the total wet weight of the plant.

Crop biomass consumption was also calculated whenever very fresh raids were obtained during routine village surveys. In the case of paddy, the average biomass (wet weight) consumed per elephant per raid was 111 kg in the case of bulls. Female-led herds, in general, ate less crop per capita though this was surprisingly high (82 kg/animal/raid). However, we must keep in mind that the biomass consumption figure for female-led groups may have been inflated by the presence of sub-adult and/or adult bulls. It was interesting that bulls consumed similar quantities of maize per raid (106 kg), but female-led herds consumed only half (43 kg/animal/raid) as much they consumed in paddy fields (as can be expected from the lower mean body weights of the two groups).

Since the actual number of elephants in female led groups (1088) that raided the crops in the fifteen villages over the eight month period was almost triple the time of male number (385), herd members were still responsible for over 58% of the total damage even if they consume only half as much as the adult males. Thus, capturing males for reducing crop damage would only bring down the problem by about 40% in this region. Capturing females in these areas to reduce crop raiding may not be an appropriate strategy considering that the northern Bengal region has a small effective population size of elephants. So it is more appropriate at this stage to think of resettling some severely affected villages from the enclaves and corridor areas for the long-term conservation of elephants with minimal conflict.

We have also collected records from the Forest Range offices on the number of crop compensation claims filed by the villages in and around the Buxa Tiger Reserve. Our continuing data collection and more in-depth analysis of the crop raiding data will give us a clearer picture and help in answering the crucial question as to why elephants raid crops. This understanding will help in planning the most appropriate management that will also meet long-term conservation goals.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

The following preliminary management recommendations are based on the findings of the work carried out so far.

EVALUATION OF THE ELEPHANT POPULATION OF BUXA

1) Our density estimates based on the indirect count method show that the elephant population in Buxa may be higher than earlier believed. The precision of our estimate is also quite high in statistical terms. If we take the mean density of 0.31 elephant/km^2 for the pooled data from the dry and wet seasons, we arrive at an estimate of 217 elephants for Buxa TR assuming that this density prevails over a 700 km^2 area of the reserve (the rest being too hilly and inaccessible). We can also take an average of the dry season (0.36) and wet season (0.16) densities to arrive at an average annual density of 0.26 elephant/km^2 for the reserve. This translates into a population size of 182 elephants for a 700 km^2 area of the reserve. In either case, the population size is higher than earlier estimates. As explained in this report we believe on the basis of our fieldwork that these numbers are certainly plausible for Buxa.

2) The higher numbers indicated for Buxa also means that the elephant population here is more likely to be a viable population demographically in the short to medium-term, even if habitat contiguity with other areas is not assured. The population structure also indicates a healthy birth rate and a sex ratio not atypical of elephant populations. We did not find the male-biased sex ratio that has been earlier reported for northern Bengal.

RANGING PATTERN OF ELEPHANTS AND MANAGEMENT IMPLICATIONS

The radio-telemetry study has provided interesting insights into the strategy of movement and use of corridors by elephants. This has important implications for the design of the protected area network in northern West Bengal.

1) The ranging pattern of the family herd 23 over a period of about 24 months indicated that its range was probably entirely within the central block of Buxa Tiger Reserve. This was not surprising considering that this central block represents not only one of the least fragmented tracts of forests in Buxa Tiger Reserve but also in the northern Bengal region as a whole. During the first two years this herd was confined to the central block in spite of the animals moving both to the northwestern periphery, where tenuous corridors link the Buxa Reserve to Jaldapara Sanctuary, as well as to the northeast which links to Rydak and to Assam. However, during the third year (2003) of our monitoring this family group moved rather unexpectedly out of Buxa westward into the northern part of Jaldapara. During this foray the herd (23) seems to have joined with another radio-collared herd (73) that has in the past moved between Buxa and Jaldapara. However, the herd 23 returned to

Buxa in about two weeks, implying that the central block of Buxa constituted its core home range.

2) Although the home range of female herd 50 is fully defined, its home range (293 km^2) so far appears to be much less compared to the two female herds collared within the Buxa Tiger Reserve. This herd has not made any attempt so far to move out of the Jaldapara-Chilapatha tract, either westwards or eastwards into Buxa.

3) The female herd 63 collared in the South Rydak forests in January 2002 spent about two weeks here before moving north to Kumargram and then east into the forests of Assam. This clearly confirms earlier suspicions of movement of elephants from Assam into the Buxa region of northern Bengal. It has repeated this pattern during the dry season of 2003.

4) The ranging behaviour of three of the family herds can be contrasted with that of another family group followed by Chowdhury *et al*. (1997) that moved over a much longer east to west distance (over 3000 sq. km) in the relatively fragmented forests of western part of northern Bengal. The implications of this finding are that maintenance of unfragmented, compact forest tracts are needed to confine elephant herds within them, and reduce the possibilities of contact with agriculture and conflict with people.

5) From the density estimates of elephants made in different vegetation types it is clear that elephants utilize the plantations much less than they use either open mixed or dense mixed forests. Though this may be intuitively suspected, the present study gives clear evidence of this pattern. Elephants prefer habitats with diverse vegetation, especially in the undergrowth. The importance of a vegetation undergrowth is underlined by the fact that teak plantations, which had the least understory as compared to *Sal* and mixed plantations, were less utilised by elephants as shown by the low encounter rate of elephant dung per km of transect in this habitat. Thus, it is likely that by continuing the canopy opening projects that are already being undertaken by the Forest Department at Buxa Tiger Reserve, other species would be able to invade into the plantation area and thereby increase vegetation diversity and habitat quality, at least from the perspective of elephants. It is important that noxious weeds do not establish in the plantation area in the process, but that the native plants do so.

EVALUATION OF CORRIDORS

The Buxa Tiger Reserve is bound by the international border of Bhutan on the northern side (a contiguous forested tract but with hilly terrain), state border of Assam on the eastern side (a contiguous forested tract), Jaldapara Wildlife Sanctuary on the west (but forest contiguity to Jaldapara Wildlife Sanctuary has been lost by villages and tea estates) and villages of Jalpaiguri district on the southern side. Since the northern side of Buxa Tiger Reserve is contiguous with forested area of Bhutan (though very steep and inaccessible to elephants in many areas), connectivity on the eastern and western side of Buxa Tiger Reserve was examined to know the present status of habitat contiguity.

1) The contiguity between Buxa Tiger Reserve and Jaldapara has been cut off in the plains south of Phoenciling town in Bhutan. A highway from Hasimara runs towards north to Phoenciling, which goes along western border of the Buxa Tiger Reserve. There are some tea estates (Satali, Malangi, Beech Bharanabari, Dalsingpar and Torsa) and settlements further north of the Tea estates up to the foothills on either side of the road. The developments in this area have cut off the forest corridor. However, at present there are two places through which elephants move occasionally between Jaldapara WLS and Buxa Tiger Reserve (Fig. 8.1). The first of these lies south of Dalsingpara Tea Estate settlement, a narrow stretch of Hasimara – Phoenciling main road without any human settlement on either side (with Baranbari tea estate to its east and Beech Tea estate to its west). During the two years tracking female herd used this particular corridor for moving to Jaldapara and back into Buxa. Similarly the herd 23 also used the same corridor for moving into Jaldapara Wildlife Sanctuary and back to Buxa Tiger Reserve. Local forest officials reported that mostly solitary elephants use this route and that too only during nighttime, as traffic is very heavy during the day. The second passage lies to the north of Dalsingpara Tea estate. A small Jhora (stream) flowing east-west cuts across the Hasimara – Phoenciling main road before joining the Torsa River about three km further west. Elephant groups and solitary elephants use this stream to move between Buxa Tiger Reserve and Jaldapara during the night. There appears to be forest contiguity from Buxa to Jaldapara on the northern side of Phoenciling town through Bhutan, but this route is very steep and there is no evidence for the use of these areas by elephants in the recent past.

2) On the eastern side of Buxa Tiger Reserve there is forest contiguity to the forests of Assam State, but the accessible place through which elephants can move is already very narrow. Two villages, Kumargram and Sankosh that lie in the narrow corridor area further reduce its width (Fig. 8.2). Though at present a two-way movement of elephants is taking place through this corridor, the presence of these two villages in this crucial area is always a threat to their continued movement.

Fig. 8.1 Corridor between Jaldapara WLS and Buxa Tiger Reserve

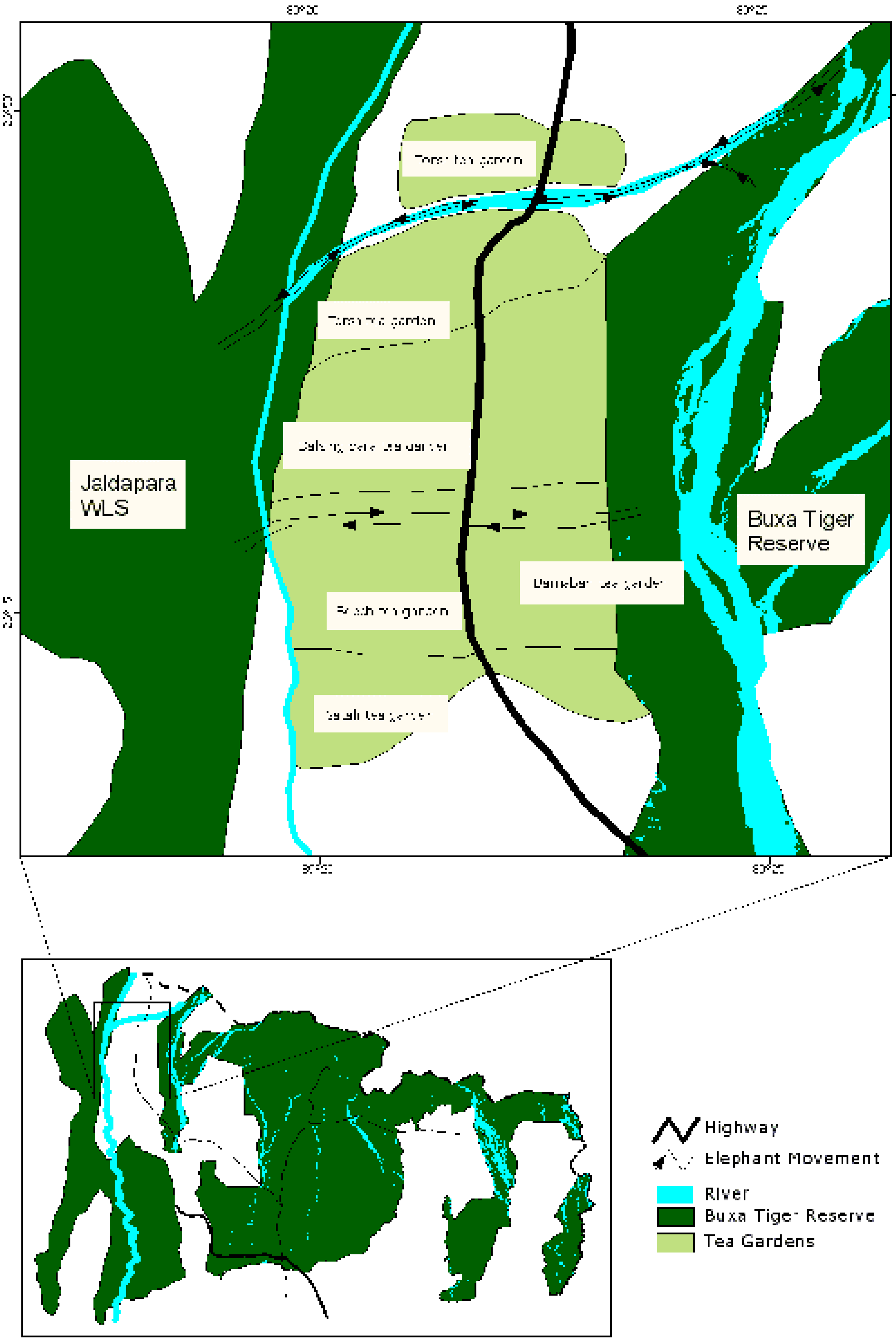
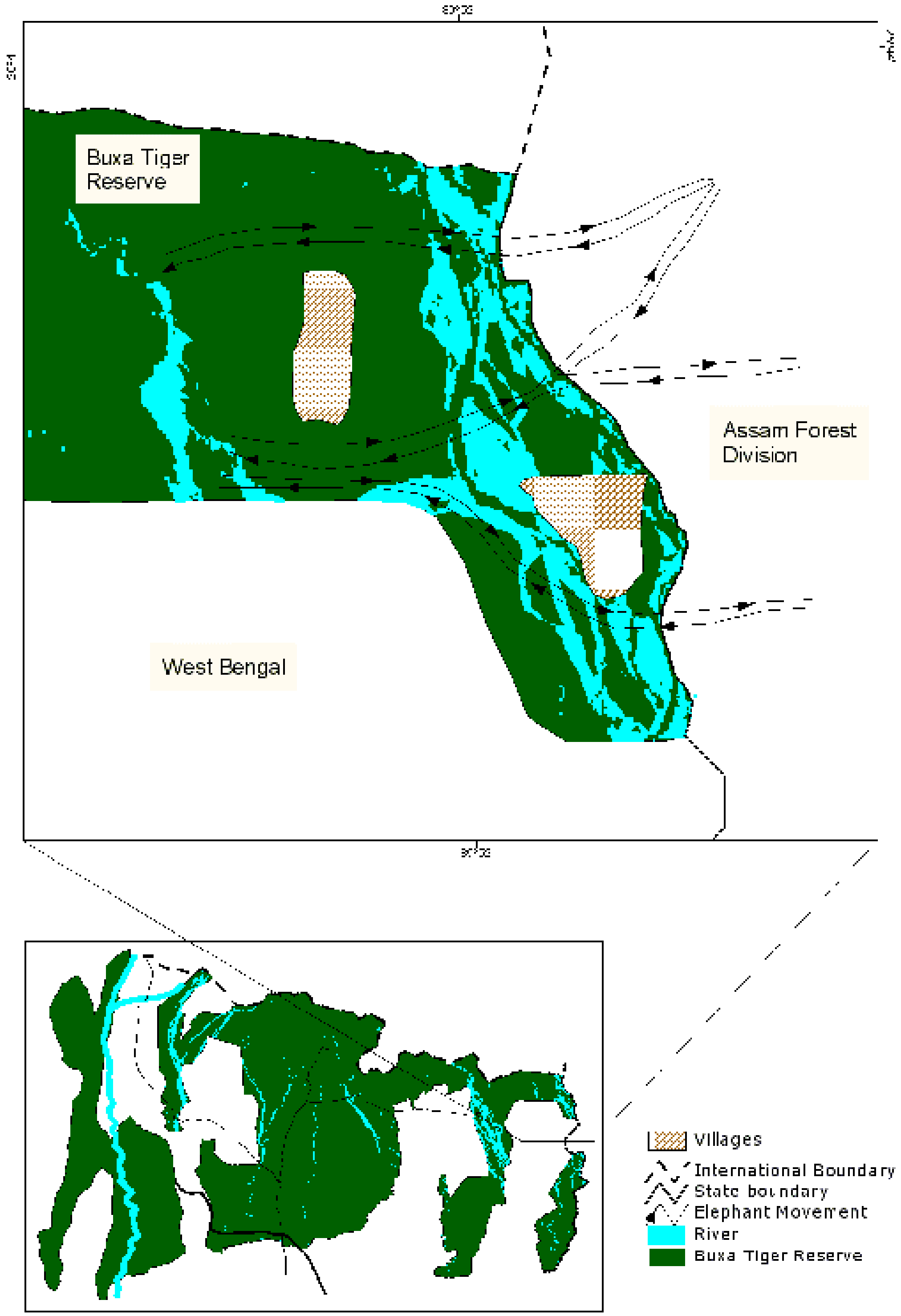


Fig. 8.2 Corridor between Buxa Tiger Reserve and Assam Forest Division



REDUCING ELEPHANT-HUMAN CONFLICT & RESETTLEMENT OF VILLAGES

Elephant-human conflict in the Buxa region is moderate and is comparable to other regions of the country such as southern India (Balasubramanian *et al*. 1995). This appears to be different from the western part of northern Bengal where crop raiding frequencies seem higher (though yet to be properly quantified) and cases of manslaughter are certainly one of the highest of any region in Asia. Therefore, very expensive measures to contain conflict may not be necessary within or along the borders of the Buxa Tiger Reserve. However, at least those enclosures that suffer very high levels of damage may require to be relocated either to lands outside the park or to the park fringes. It is probable that this action would not only reduce man-elephant conflict, but more importantly, would directly benefit wildlife by increasing the effective potential habitat available for them, and indirectly by reducing the biotic pressure on the habitat surrounding these settlements. We realize, however, that land is a rare commodity and thus relocation of whole villages to non-forest lands may not be practicable.

One alternative is to relocate these villages to degraded forests or plantations at the periphery of the park. For example the portions of Buxa just south of the National Highway No. 31 could be utilized for this purpose. As the highway cuts this land off from the major portion of the Tiger Reserve, it is less accessible to elephants and other wildlife, and thus the loss of this land would probably affect Buxa's fauna minimally. This is an additional advantage to the relocated villagers for whom protection of crops from wildlife would be made easier by the presence of the highway. That the highway acts as an effective barrier for elephant is supported by the fact that the Poro village (whose agricultural land is completely on the south of the highway) was least affected (total damage being only 0.6%) by elephants as compared to any of the other 14 surveyed villages. This finding is also supported by the fact that the Gadhadhar village, for which a similar agricultural land area was monitored (137.5 ha vs 145.7 ha in Poro), showed an almost threefold increase in percentage of total area damaged (1.9%). It is also likely that once all the forest land to the south of the highway are converted into agricultural lands, elephant crop-raiding here will decrease even further as elephants will necessarily have to cross the highway to raid crops and will additionally have no forested patches nearby for shelter. Additionally these patches are under great pressures as they are surrounded by settlements on three sides. Thus, from the management perspective relocating some enclosure villages from the central block of the Tiger Reserve to these patches seems to be a viable option. The effort for monitoring these small forest patches by the forest department staff would also be disproportionately large as compared to monitoring other more contiguous forest areas. We would also like to note that relocation to places adjoining the national highway or to more accessible locations (in terms of transport and communications facilities) should be attractive to villagers, as the value of land in the new location would be significantly higher than their present locations. This should be the economic incentive that the department/voluntary agencies should project to the people in order to persuade them to relocate.

Based on the findings of the crop raiding study we suggest that the following villages are relocated as these suffer from serious damage to crops from elephants, being either an enclave village or being located within a corridor area and obstructing the free movement of elephants.

1. Pumpy Basti - Urgent
2. Garo Basti - Urgent
3. Bamini Basti - Urgent
4. 28th Mile Basti - Urgent
5. Santalabadi - Urgent
6. Pannijhora Basti - Urgent
7. Bhutri – Very urgent
8. Kumargram – Very urgent
9. Sankosh – Very urgent
10. Teamari – Preferable
11. Bhutia Basti - Urgent

The list of these villages, reasons for relocating them and the people's opinion are summarized in Table 8.1. The possible location where these villages could be relocated was also examined and a few ideal sites are suggested in Fig. 8.3 based on their advantages for people (Table 8.2) and lack of importance for the elephant. If the relocation is successfully completed, elephants can be conserved with minimal conflict in the long term as well as benefit people.

Fig. 8.3 Proposed villages and Sites for Relocation

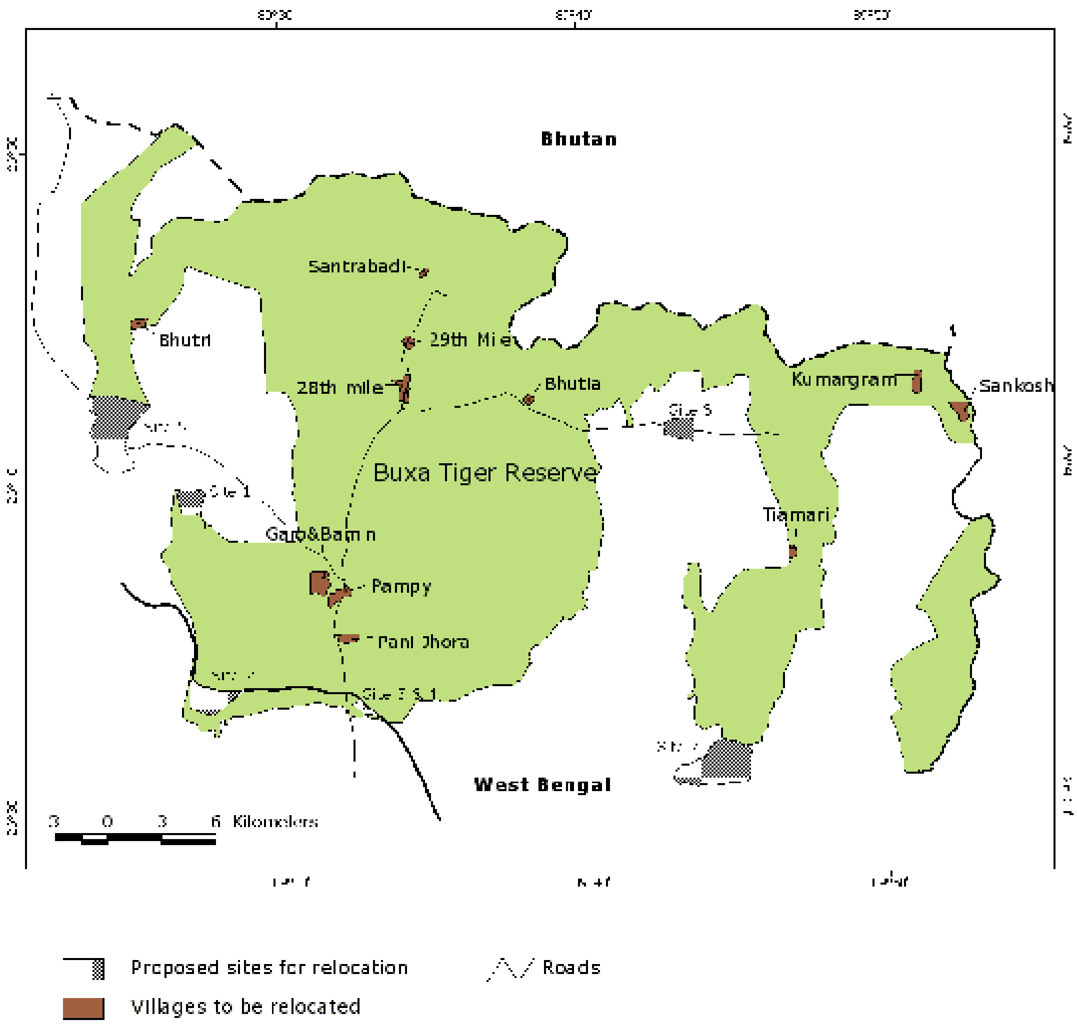


Table 8.1: List of village that have to be shifted from the Buxa Tiger Reserve for reducing the man-elephant conflict and for ensuring the habitat contiguity of Buxa Tiger Reserve with the adjoining forested areas in North Bengal, Assam and Bhutan

Name (approx. area given in map and in baseline info document)	Need to shift	Major reasons to relocate	Are the people likely to shift (unofficial impressions)
Pumpy	URGENT	High depredation Enclosure Close to core area & high pressures on forest (legal & illegal).	Yes - (if given good land e.g. area 3)
Garobasti	URGENT	" (additionally it is a very large village)	No - (large number of illegal wood cutters etc. (Unofficial info.) many houses occupied by forest dept. staff, general attitude of the people is not favourable to relocation)
Bamini	URGENT	"	Probably yes - if Garo &/or pumpy shift.
28th mile	URGENT	"	Probably No - (large number of cattle, high milk dependence of economy (our impression), raising of alternative crop during paddy season because of water shortage reduces elephant raiding to maize season only)
29th Mile	URGENT	"	" (these people will shift if 28th mile shifts)
Santalabadi	URGENT	"	"
Panijhora	URGENT	"	No idea
Bhutri	V. URGENT	Corridor area, High depredation	Yes - (people are very tired of the high levels of raiding. There is water shortage and they are cut off from the rest of the world during the rains by rivers on both sides of the village). This is confirmed by the village headman and they have approached forest department for relocation.
Kumargram	V. URGENT	"	No
Sankosh	V. URGENT	"	"
Taemari	Preferable	Bottleneck in forest narrowed further by this village	Unlikely to shift - They are doing little damage by remaining here, elephants seem to move freely between North and South Rydak in spite of this village. Also since this is so near the tea estates. The forests also being very narrow at this point, removing this village will have no benefit as far as reducing pressures on the forest.

Bhutia Basti	Urgent	? people have already been given alternative land and are being prevented from going there by local political leader (unofficial information)	Yes – People want to move but are afraid of the local leader. (Some of the households have shifted to the new location in area 2 just on the border of BTR and Patkapara TE (near south Patkapara). However many of the houses are still to move. In the meantime the remaining houses at Bhutia Basti, which were vacated by the people who shifted and their lands seem to have been occupied (illegally) by other people. ADDITIONALLY many pattas given to these people near South Patkapara have been taken over illegally by people from other villages like Pumpy basti.

Table 8.2: Possible areas and their Pros and Cons for relocating the villages from the Buxa Tiger Reserve (See map – for location)

S. no	**Area**	**Pros**	**Cons**
1	Site 1	• Degraded forest • Outcrop from main forest = less likely to be used by elephants • Next to tea garden = high pressure • Next to tea garden = employment opportunity (at least casual labour during peak seasons) • Falls in terrain = high water table = no water problems (see latest WP pg 11) • Fertile soil • Very close to Kalchini road and Nimati RO/ village.	None
2	Site 2	• Degraded forest • Small patch • Cut off from main forest by national highway = less protection & less accessibility to wildlife • Next to tea garden = high pressure • Next to tea garden = employment opportunity (at least casual labour during peak seasons) • Falls in terrain = high water table =no water problems • Fertile soil • Moderately to very close to national highway • Easily protected by fencing along highway	Being close to the Chilapatha forest area it may be argued that it is a potential corridor. But the degraded nature of the forests here and the high levels of human occupation of the landscape surrounding this patch along with the reduced protection provided as it is cut off from the main forest all point to an uncertain future for this forest. There is no evidence that elephants are using this area to cross to Jaldapara, though more work has to be done to confirm this.

3	Site 3	• Degraded forest • Small patch • Cut off from main forest by national highway = less protection & less accessibility to wildlife • Next to tea garden = high pressure • Next to tea garden = employment opportunity (at least casual labour during peak seasons) • Falls in terrain = high water table = no water problems • Fertile soil • On the national highway • Easily protected by fencing along highway	• Area is small • Numerous rivers reduce effective area more
4	Site 4	• Slightly degraded area • It is on the periphery of the park • Being below the 18th mile road it will be bounded definitively thus reducing encroachment etc • Other advantages same as above	• Some patches of natural forests • May not be sensible to relocate villagers here as it is still close to the main core area and will probably face high depredation as seen in Checko. However, the presence of NH may reduce the elephant damage as compared to Checko.
5	Site 5	• Mainly plantation area of lesser ecological significance • Out crop from the main forest area = less accessibility to wildlife • Very close to tea gardens = high pressures/ possible employment • Close to Kalchini road and Kalchini town	• Bhabar tract = less ground water table levels, villagers are unlikely to move to this place willingly. Dolbadol inhabitants close to this area have high water problems and also face elephant depredation.
6	Site 6	• Mainly plantation area of less ecological significance • Isolated from the main forest area = less accessibility to wildlife • Very close to tea gardens = high pressures/ possible employment • Close Samutkala road and Samutkala town	• Bhabar tract = less ground water levels, villagers are unlikely to move to this place willingly. The only people likely to move here will be those in Turturi Kanta and Kanjali Basti, but both these are revenue villages and thus may be even more difficult to shift as compared to the forest villages.
7	Site 7	• Mainly plantation area of lesser ecological significance • Isolated from the main forest area = less accessibility to wildlife • Close to Barobisha road and	• Bhabar tract = less ground water levels, villagers are unlikely to move to this place willingly. • Political and militancy problems due to Assam

	Barobisha town	border. • The only people who may be willing to shift here are those in this region itself (i.e. enclosures may be made peripheral villages) but the effort may not be worth it as the future of this forest is questionable. If Kumargram and Sankosh people would be willing to come here it would be ideal, as it would free the corridor on the north between Assam/Bhutan and BTR. This may be tried even if it means giving the people more land than they presently hold etc. However, due to the high levels of illegal smuggling etc (hearsay information) it is unlikely that Kumargram/ Sankosh people will be willing to leave the international border area.

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