ROLE OF ASIAN ELEPHANT (*Elephus maximus*) IN DISPERSING *Mallotus phillipinensis* IN BARDIA NATIONAL PARK, NEPAL

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Letter of Recommendation

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This dissertation work embodies her own work and is in the form as required by Central Department of Environmental Science, Tribhuvan University**.**

I therefore recommend this dissertation for approval and acceptance.

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I, Ms. Pragya Bhatt, hereby declare that the work presented herein is genuine work done originally by and has not been published or submitted elsewhere for the requirement of a degree program. Any literature data works done by others and cited within this dissertation has been given due acknowledgement and listed in the reference section.

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ABSTRACT

Mallotus phillipinensis is one of the most preferred food tree species of Asian elephant. This herbivorous interaction can largely influence the evolution of plant life histories. The Asian elephant is currently recolonizing in BNP in lowland Nepal, concurrently the density of this most preferred Mallotus phillipinensis is increasing and that of hardly utilized Shorea robusta is decreasing. Pradhan et al. thus speculated that rapidly growing elephant population might be playing role in dispersing Mallotus phillipinensis and thus modifying the forest composition by increasing its preferred food species. This study was thus carried out to test this speculation with major objectives of testing the elephant's role in dispersing Mallotus phillipinensis seeds through defecation and fostering regeneration of Mallotus phillipinensis either by dispersing seeds or by helping aerial buds to regenerate through coppicing in damaged trees.

Experiments of the study were carried out from the month of September 2008 to June 2009. For seed dispersal through defecation, 37 and 40 dung piles were collected and sown into the soil respectively for two consecutive seed ripening seasons and observed for the germination of seedlings. One single separate control plot was also set in each season by directly sowing seeds of Mallotus phillipinensis in the same environmental conditions as for dung piles. For regeneration of Mallotus phillipinensis in sal forest juveniles of Mallotus phillipinensis in 100 circular plots of 15 m radius were observed in 10 systematic parallel transects and 100 such plots in 10 elephant tracks randomly selected in same block of forest. A total area of 14.3 Km^2 was observed in the whole block. Student's 't' test was applied for analyzing the data for regeneration.

Among all 37 and 40 dung piles sown in the soil in two seasons there were not found any seedlings germinated but more than 90% of Mallotus phillipinensis seeds in control plot were germinated. Among the 100 circular plots in 10 elephant tracks and 100 such plots in 10 systematic parallel transects no significant difference was found in Mallotus phillipinensis regeneration. Among all circular plots very few damaged trees with few average coppiced aerial buds were found.

No germination of any Mallotus phillipinensis seeds in elephant dung piles, no significant difference found in the regeneration of Mallotus phillipinensis in elephant tracks and systematic parallel transects and very few trees of Mallotus phillipinensis *damaged by elephants, with few coppiced aerial buds, indicate that the recolonizing elephant population in BNP could not be playing any role in the shifting forest composition. The actual reason behind such shift in forest is speculated to be increased flooding and ecological succession. Further research is recommended to find the actual cause of such shift.*

Key words- Asian elephant, ecological succession, Mallotus phillipinensis, regeneration, seed dispersal

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Acronyms and Abbreviations

BNP	Bardia National Park
^{0}C	Degree Celsius
CITES	Convention on International Trade in Endangered species of Wild Flora and Fauna
CNP	Chitwan National Park
DNPWC	Department of National Park and Wildlife Conservation
E	East
GIS	Geographic Information System
GPS	Global Positioning System
Ha	hector
IUCN	International Union for Conservation of Nature and Natural Resources
Km	kilometer
Km^2	square kilometer
m	meter
m^2	square meter
mm	millimeter
N	North
NTNC	National Trust for Nature Conservation

CHAPTER 1

INTRODUCTION

1.1 Background

The interaction between elephant and *Mallotus phillipinensis* is an example of herbivory. *Mallotus phillipinensis* belonging to Euphorbiaceae family, a small evergreen tree growing in tropical to sub-tropical habitat (Baral *et al*. 2006) is one of the most preferred food species of elephant (e.g. Williams 2003, Pradhan *et al*. 2007, Pradhan *et al*. 2008, Prajapati 2008 etc.).

Herbivory can largely influence the evolution of plant life histories (Herrera & Pellmyr 2002). The influence of the mega herbivores, like elephant, in shaping life histories of their food plants may have been enormous and can still be detected in fruits being specially adapted for dispersal by these animals (Janzen & Martin 1982). Elephants function as important seed dispersal and germination agents. (Gibson *et al*. 2006).

Seed dispersal by animals is often a superior way to the whims of winds, water or other environmental methods (Daniel *et al.* 2008). Many tropical forest tree species are dependent on animals for dispersal (Babweteera *et al.* 2007). Elephants are known to eat fruits and pass the seeds in germineable conditions (Joshi 1986). The digestive system of elephant is relatively inefficient (Benedict 1936) and much course undigested material in its droppings also contains resistant seeds, however the role of Asian elephants as seed dispersers is not adequately understood. There was no evidence for the Asian elephant being exclusive disperser of any plant species in contrast to the more frugivorous African elephant, *Loxodonta africana* and *L. cyclotis* (Sumpei *et al*. 2007).

Besides being effective seed disperser, elephants (both Asian and African) are powerful browsers that largely affect living condition of the trees from which they feed (Hemberg & Bond 2006). The type of browsing can result in fairly rapid responses like regrowth of leaves and shoots and rapid chemical changes (Miquelle 1983). The African elephant have long been recognized as being playing a role of ecosystem engineers (Jones, Lawton & Scachak 1997).

The elephant (African) is capable of extensive habitat modification (Gibson *et al*. 2006).

Most studies have concluded that the forest elephant could play on essential role in the regeneration of certain tree species (e.g. Alexandre 1978, Merz 1986, Short 1983, Wait Kuwait 1992).

Pradhan *et al*. in their study regarding effects of recolonising Asian elephant population in forest habitat speculated that Asian elephant might be playing some role in dispersing the *Mallotus phillipinensis* in Bardia National Park. Thus this study was conducted to further investigate whether the Asian elephant plays any role in dispersing *Mallotus phillipinensis* or not.

1.2 Asian elephant (*Elephus maximus)*

The Asian elephant, one of the 3 living species of elephants, were once distributed over a large area extending from the Tigris –Euphrates basin, eastward through the Indian sub -continent and south east Asia to north of the Yangtze river in china. The survival of them is threatened by excessive clearing of its habitat for development (Ishwaran 1993, Johnsingh & Williams 1992, Hedges *et al*. 2005), which has led to compression of population in small-protected area (Owen-Smith, 1988, Sukumar1989). Despite playing such crucial roles and designated as key stone species in the forest ecosystem, the species is now disappeared from 95% of its historical ranges (Sumpei 2007). Designated as endangered in IUCN's list of threatened species since 1986 (IUCN 2004), this species is also protected from international trade by its listing on Appendix I of CITES, (CITES, wikepedia the free encyclopedia 2007).

The lowland of Nepal used to harbor a large resident population of Asian elephant. The malaria eradication program in the 1950s led to heavy loss of continuous forest for settlement purpose, which reduced the elephant population into small isolated fragments.

In the present time, elephants in Nepal are found in Bardia National Park, Suklaphanta Wildlife Reserve, Parsa Wildlife Reserve and Chitwan National Park. Bardia National Park is home to about more than 80 individuals but this population is of recent origin. Here the population has increased from just 2 males in 1992 due to recent immigration, probably from Dudhuwa and Corbett National Park in India

(Pradhan *et al*. 2008), as narrow natural corridors connect it with other protected areas in Nepal and India.

Mallotus phillipinensis is one of the dominant plant tree species in evergreen riverine forest and mixed hardwood forest (Jnawali 1995) along with this *Mallotus phillipinensis* is also found to have association with sal forest (Chaudhary 1998).

Thus, abundant *Mallotus phillipinensis*, one of the most preferred elephant food tree and presence of major herd of elephant, Bardia National Park provides a good opportunity to study the interaction within in them.

1.3 Objectives of the study

The broad objective of this research was to find out the role of Asian elephant (*Elephus maximus)* in modifying the forest composition by influencing the seed dispersal and regeneration of *Mallotus phillipinensis* in Bardia National Park.

More specifically the study was carried out to:

- test whether Asian elephant through defecation disperses the *Mallotus phillipinensis* seeds

- test if the recolonizing elephant population fostering the regeneration of *Mallotus phillipinensi*s in sal forest, either by dispersing the seeds or by helping to regenerate aerial buds through coppicing in damaged trees.

1.4 Justification of the study

Mallotus phillipinensis has been reported as one of the most preferred food tree species of elephants. It has also been documented that the abundance of this plant species in sal forest of Bardia National Park has dramatically increased during last three decades from a relative density of 1.0. (Jnawali 1995) to a relative density of 14.3 till 2007 (Pradhan *et al*. 2007) and *Shorea robusta*, a dominant species in sal forest has decreased from a relative density of 26.7 (Jnawali 1995) to 18.4 till 2007 (Pradhan *et al*. 2007).

Thus, regarding the concurrent occurrence of recolonization of elephant population in Bardia National Park, increase in the relative density of most preferred *Mallotus* *phillipinensis* and decrease in the relative density of less utilized *Shorea robusta* (thus resulting a shift in forest composition) Pradhan *et al.* 2007 speculated the elephants being playing a crucial role in all this.

The seeds of *Mallotus phillipinensis* are small and situated at the end of small twigs, it has been speculated that along with the ingestion of these food plants probably the seeds of the plant are passively ingested when elephants bark strip such twigs and thus may be spreading those seeds through defecation.

It has also been documented that *Mallotus phillipinensis* is a good coppicing species (Kanode *et al*. 2008) and the tree survives well after having been pushed over (Pradhan *et al*. 2007). In Bardia National Park, among the most pushed trees, this highly preferred *Mallotus phillipinensis* alone accounted for 64% (Pradhan *et al*. 2007)

Being most impacted by elephants and a good coppicer the *Mallotus phillipinensis* may be increasing in density by regenerating more aerial buds from a single tree.

But an in-depth study regarding all this was yet to be done. So this study attempted to verify the afore made speculation. The results of this study will help to guide management decisions in term of shifting vegetation composition and recolonizing elephant population.

CHAPTER 2

LITERATURE REVIEW

Both Asian and African elephant have been reported to play an important role in seed dispersal. Many authors have documented *Mallotus phillipinensis* as elephant's most preferred food species.

Joshi R. and R. Singh. (2008) studied the feeding behavior of wild Asian elephant in the Rajaji National Park. During their eight years study they found that the elephant diet consisted of 74% of tree species among which *Mallotus phillipinensis* was the most favored.

Pradhan *et al*. (2008) in their study in feeding ecology of Asian elephants and greater one horned rhinoceros in lowland Nepal reported that in cool-dry season, an estimated 83% of the elephants' diet consisted of browse, of which as much as73% was bark and stated that 42% of the elephant food trees were *Mallotus phillipinensis*.

Prajapati A. (2008) conducted nutrient analysis of important food tree species of Asian elephant in hot dry season in Bardia National Park. His study revealed *Mallotus phillipinensis* as maximum preferred food tree species of elephant with preference value of 61.54%.

Babweteera *et al*. (2007) studied the regeneration of *Balanites wilsoniana* with and without elephant in three tropical rain forests in Uganda, namely Mabira, Budonga and Kibale forest. They found elephants as the only frugivores feeding and thus dispersing *Balanites wilsoniana* seeds. They compared the gut passed and unpassed *Balanites wilsoniana* seeds and deduced that elephant gut treatment-enhanced germination.

Pradhan *et al*. (2007) in their study on impact of recolonizing population of Asian elephant in the forest habitat in Bardia National Park have reported that out of 85 tree species recorded in the study area, 62 species (73%) were impacted by elephants among which *Mallotus phillipinensis* alone accounted for 56.4%. In another study in 2008, the same authors documented that 43% of elephant food trees were *Mallotus phillipinensis.*

Shumpei *et al*. (2007) studied the frugivory and seed dispersal by Asian elephant in moist evergreen forest of Thailand. They reported that there was no evidence for them being exclusive dispersers of any plant species, in contrast to the more frugivorous African elephant *Loxodonta afriana and L. cyclotis.*

Dudley (2003) studied seed dispersal of *Acacia erioloba* by African bush elephants in Hwange National Park, Zimbabwe. They found, 64% of all dry season samples of elephant dung analyzed during a three-year study, contained seed and/or pod materials of *Acacia erioloba.* Potential elephant dispersal distances of 20-50 Km were predicted for the seeds in the Kalahari sands landscapes of Southern Central Africa.

Nchanji *et al*. (2003) investigated the effects of elephant gut and elephant dung on seed germination and early seedling growth in Banyang-Mbo Wildlife Sanctuary using undestroyed seeds of 14 plant species sorted from fresh elephant dung and similar seeds extracted from fresh ripe fruits fallen on forest floor, both were sown in fresh elephant dung and forest soil. Parameters measured were final germination success, germination time and seedling growth rate. Their results indicated germination success observed in ingested seeds was significantly different from that observed in seeds from fresh fruits. Germination success observed in elephant dung was not significantly different from that in forest soils. Mean germination time was shorter in seeds that passed through the elephant gut than those collected from fresh ripe fruits. Growth rate from ingested seed were higher than those from ripe fruits. They concluded that ingestion of seeds by the elephant is important in the germination of some rain forest species and elephant dung that contains dispersed seeds is very important in the rapid growth of seedling. They also reported that plants species absolutely or exclusively dependent on elephants for dispersal/germination are absent in Banyang-Mbo Wildlife Sanctuary.

Williams (2003) reported that *Mallotus phillipinensis* was the most important woody plant for elephants during dry season in Northern India.

Yumoto *et al*. (1995) studied seed dispersal by elephants in tropical rain forest in Kahuzi-Biega National Park, Zaire. They performed the dung analysis and found several plant species in Eastern Zaire, which are dispersed only by elephants.

Chapman *et al*. (1992) studied that forest elephant (*Loxodonta africana*) plays a key role as seed dispersal agent for the upper canopy forest tree *Balanites wilsoniana*. Seed that passed through elephant gut had a much greater probability of germinating (50.7%) than seeds from fruits collected directly from the tree (3%). Similar study by Cochrane (2003) concluded that elephant seed dispersal is vital for *Balanites wilsoniana*, a forest canopy tree with no other effective dispersers. Their study revealed very low germination (3%) and high mortality (84%) of non-dispersed seeds. Seeds passed through elephant gut had improved germination (54.9%) and reduced time to germination (82 days vs. 132 days) Their study provided strong evidence that *Balanites wilsoniana* is dependent on elephants for its long term persistence.

Dhakal (1992) in his study on diet preference of the elephant (*Elephus maximus*) in Chitwan National park, has reported that one of the most important woody food plants of riverine forest in the diet of elephant is *Mallotus phillipinensis*.

Caughley (1976) proposed a new hypothesis to explain the ultimate factors behind elephant damage to woody vegetation, the limit cycle hypothesis. According to which there exits no stable equilibrium between elephants and forest in parts of Africa. But a cyclical relationship. Elephants increase in number and forests are thinned out, then number decrease and forest are allowed to regenerate.

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Bardia National Park

Bardia National Park ($28^0$35' N & $81^0$20' E) is the largest park in the lowland terai, situated on the east of Karnali River at Midwestern Development region of Nepal, with an area of 968 Km^2. The park lies at an altitude of 100-200 m above sea level.

Gazetted as Royal Karnali Wildlife Reserve in 1976 with small area of 347 Km^2 to protect representative ecosystem and conserve tigers and its prey species it was renamed as Royal Bardia Wildlife Reserve in 1982. When this area was protected, approximately 1500 people of the Babai valley were resettled outside the park allowing the vegetation and wildlife to flourish. The reserve was extended to its current size of 968 Km^2 in 1984 and it was given the status of National Park in 1988.

In 1997, an area of 327 Km^2 surrounding the park was declared as a Buffer Zone, which consists of forest and private lands. The park officials and local committees jointly manage the Buffer Zone by initiating community development activities and managing natural resources in the area. (DNPWC 2006)

3.1.2 Climate

The park area experiences sub-tropical monsoonal climate with three distinct seasons. Cool dry weather exists from November to February with warm days and cool and pleasant nights. Temperature may gradually drop to 5^0C during December and January. Hot dry season persists from March to June with temperature rising up to 45^0C. The hot sticky days give way to the monsoon that starts from July and lasts until October (DNPWC 2006) Most of the rain, 1560-2230 mm, falls between June and September (Bolton 1976), somewhat later than the eastern part of country. The climate of Bardia National Park is also changing along with the globally changing climate.

3.1.3 Vegetation

The vegetation is sub-tropical type ranging from mosaic of early successional flood plain communities along the large Karnali and Babai rivers to a mature climax sal (*Shorea robusta*) forest on the upper, drier areas. About 70% of the forest consists of sal trees with a mixture of grassland and riverine forests. Jnawali and Wegge (1993) described seven distinct vegetation types for the Karnali flood plain and the nearby sal forest area.

Table 3.1**:** vegetation types of the Karnali flood plain area in the southwestern part of the park [Jnawali and Wegge (1993)].

Vegetation type	**Area (%)**	**Description**
Sal forest	59.4	Dominated by *Shorea robusta* with associated species such as *Terminalia tomentosa*, *Buchanania latifolia* and *Lagerstroemia parviflora.*
Mixed hardwood forest	18.0	Comprises of *T. tomentosa*, *Schleicheria trijuga, Adina cordifolia* and *Mitragyna parviflora*. These species intermingle, often with a distinct shrub layer of *Colebrookia oppositifolia*.
Riverine forest	4.6	Distributed in patches along the watercourses and consists mostly of evergreen trees like *Syzizium cumini, Ficus racemosa*, *Desmodium oojeinense* and *Mallotus phillipinensis* and species able to withstand water logging. *Callicarpa macrophylla* and *C. oppositifolia* are common shrubs found in this vegetation type.
Khair-sissoo forest	4.8	The pioneer association on riversides dominated by *Dalbergia sissoo* and *Acacia catechu* trees.
Tall grassland	5.7	Consists of a mixture of perennial tall grasses in the floodplain where *Saccharum spontaneum* is the dominant species, other associated grass species are *Saccharum bengalensis*, *Phragmites karka*, *Arundo*

		donax and *Imperata cylindrica*.
Short grassland	3.2	Open or sparsely tree covered man-modified grasslands with short grasses, mainly *Imperata cylindrica*. Includes patches of phanta (previously cultivated fields).
River and river beds (exposed surface)	4.2	Sandy and stony areas along the rivers and its tributaries.

3.1.4 Fauna

The park offers a variety of experiences in its vast undisturbed wilderness. More than 30 different mammals, over 400 species of birds and several species of snakes, lizards and fish have been recorded in the park. The park is home to endangered animals such as Royal Bengal tiger (*Panthera tigris tigris*), one-horned rhinoceros (*Rhinoceros unicornis)*, Asian elephant *(Elephus maximus*), Swamp deer (*Cervus duvaucelii*), Gharial crocodile *(Gavialis gangeticus*) and Gangetic dolphin *(Platanista gangetica*). Endangered birds found in the park are Bengal florican (*Eupodotis bengalensis*), Lesser florican (*Falco cherrug*) and Sarus crane *(Grus antigone*). In addition to the resident species, several migratory birds visit the park. Two species of monkeys, the Langur monkey (*Semenopithecus entellus*) and Rhesus monkey (*Macaca mulata*), are also present here. Bardia also boasts the greatest number of deer species in Nepal. (DNPWC 2006).

The population of Greater one-horned rhinoceros, *Rhinoceros unicornis*, in Bardia National Park originates from 12 individuals that were translocated from Chitwan and released during the dry season of 1986.

The rhinoceros were translocated from Chitwan National Park to Bardia National Park in 1986, 1991, 1999, 2000, 2001, and 2002, altogether 83 rhinoceros have been translocated to Bardia National Park, since 1986, only 31 rhinoceros existed in Bardia National Park till 2007 (Prajapati 2008).

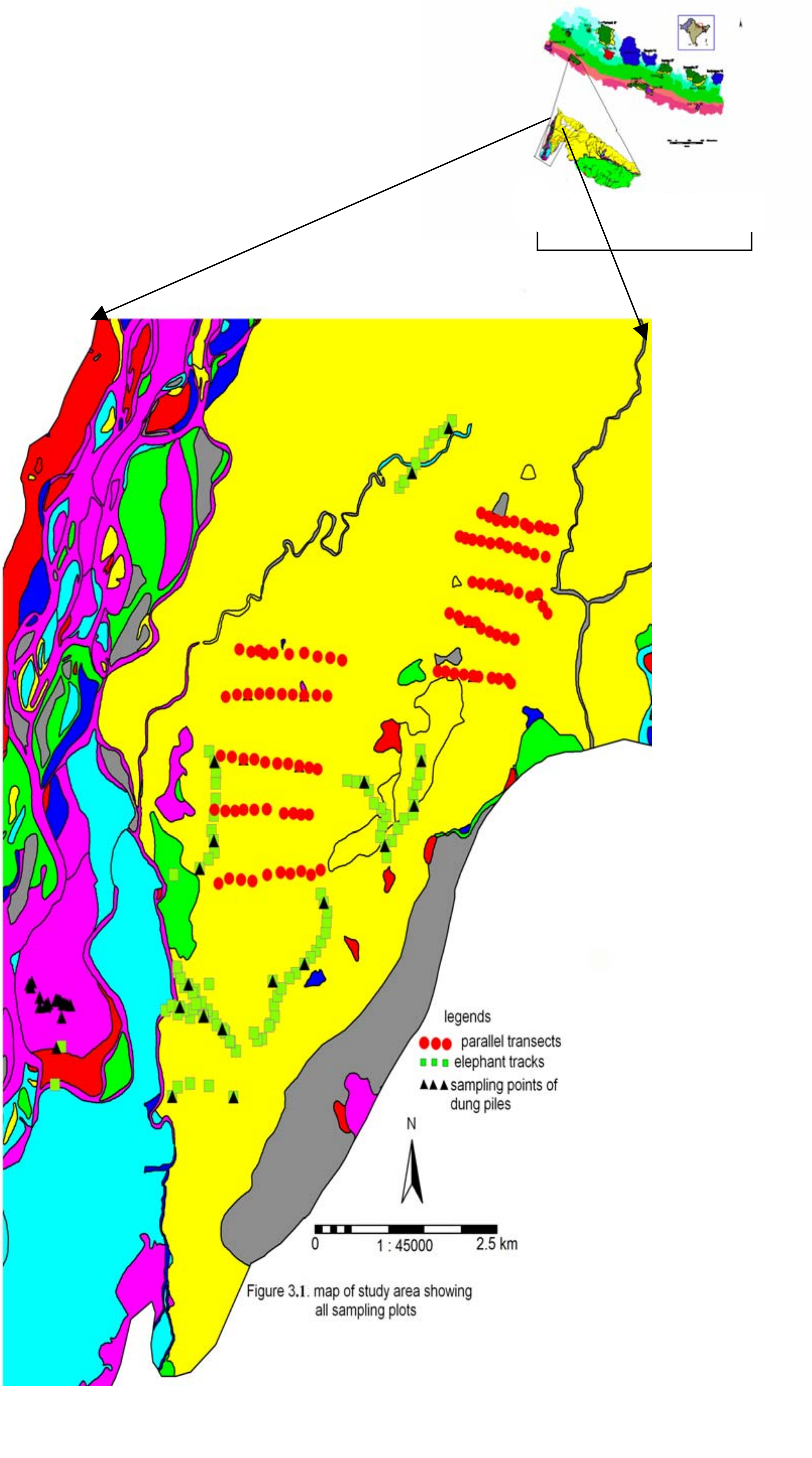

Figure 3.1. map of study area showing all sampling plots

3.1.5 Selection criteria of the study area

Bardia National Park in Nepal provides a unique opportunity to study the behavior of Asian elephants because here they exist in a comparatively small area and are also increasing in number due to immigration from India (Velde 1997, Pradhan *et al*. 2007). The study was conducted in the Southwestern part, East of Karnali River of Bardia National Park. Since this study was carried out to verify whether the elephant is modifying the forest composition by helping dispersal and regeneration of *Mallotus phillipinensis* in sal forest, this study was conducted in the sal forest lying East of Geruwa River in the Southwestern part of Bardia National Park as did Pradhan *et al*.

For the verification of seed dispersal through defecation the floodplain ecosystem to the sal forest in the Southwestern part of Bardia National Park was selected for the collection of dung piles.

3.2 Research design

The study was carried out from the month of September 2008 to June 2009. The sequential steps followed during the study are:

3.2.1 Extensive survey of literature: Several articles, research papers and books related to elephant, their role as seed dispersers, their interaction with *Mallotus phillipinensis* and their role in changing vegetation composition all over the world were gone through.

3.2.2 Experiments and data collection

a. For dispersal of seeds through defecation

This experiment was carried out in two consecutive seed-ripening seasons of *Mallotus phillipinensis.* For the first time the experiment was carried out during September 2008 and for the second time on next fruiting season on March 2009 [(the fruiting season of *Mallotus phillipinensis* is from March to September (Noatay 2002)].

During the experiment the current elephant dwelling areas in the park were confirmed from reliable source (e.g. Range post, game scout etc.). Fresh elephant tracks were followed and dung piles, not more than three days old, were collected. Thirty-seven dung piles were collected during the first experiment and 40 dung piles were collected for the second time. Each dung pile was collected at least 5 m apart from one another so that all samples could be considered as independent deposits. GPS location of all the dung piles collected was noted down (as plotted in the map). All dung piles were collected in separate sample bags, tagged properly and brought to the camp, lying at the edge of the forest near the park head quarter in the office area of National Trust for Nature Conservation. All dung piles were mixed with soil and sown into separate plots pre-prepared in the camp.

Similarly ripened fruits of *Mallotus phillipinensis* were directly harvested from the branches, dried and then sown into the soil in single plot prepared under similar environmental conditions as the dung piles. The sowing of seeds was done as according to the silviculture techniques of *Mallotus phillipinensis* (Noatay 2002). These were control plots set for observing the germination of *Mallotus phillipinensis*.

Natural environment was maintained within the plots and the plots were protected against insects or any other casualty. Germination of seeds was observed in all the plots.

b. Vegetation survey for regeneration of *Mallotus phillipinensis.*

This study was conducted in the sal forest in the southwestern part of Bardia National Park during the fruiting season of *Mallotus phillipinensis* in the month of March 2009.

Survey block was first determined in the topographic map. The regeneration of *Mallotus phillipinensis* was observed along the elephant's tracks and systematic parallel transects both in sal forest. Ten elephant tracks, currently in use were randomly searched in the sal forest on foot and also by asking the park personals.

Along each of these tracks 10 circular plots of 15 m radiuses were established at an interval of 200 m. Altogether, 100 such circular plots were established in 10 tracks and within each plot the juveniles (seedling, sapling and pole trees) and trees of *Mallotus phillipinensis* were counted.

Similarly in the same sal forest, systematic sampling was applied for data collection. The first transect line was randomly selected in east-west direction in the survey block. Other transects were drawn parallel to the first transect line by taking bearing with the help of Sylva compass. Transects were 1 km apart from each other and were 2 km in length.

Ten circular plots of 15 m radiuses, each 200 m apart from each other, were established along all these transect. Hundred such circular plots were established in 10 transects and within each plot juveniles and mature trees of *Mallotus phillipinensis* were counted, similarly as done in elephant tracks.

The GPS locations of the center point of all the 200 plots (100 along elephant tracks and 100 along parallel transects) were noted down (as plotted in the map).

All together 100 plots with area of 706.5 m^2 each were observed in elephant tracks and 100 plots with same area were observed in parallel transects.

A total area of 14.3 km^2 was observed in the whole block.

Also in all the circular plots, all the elephant damaged trees of *Mallotus phillipinensis* were observed and coppiced aerial buds were counted in each.

3.2.3 Analysis of data

For analysis of data of the regeneration of *Mallotus phillipinensis* in elephant tracks and systematic parallel transects, "Students t-test for testing the significance of difference between two means" was applied with following hypothesis:

Null hypothesis. H_0: $\mu_1 = \mu_2$, i.e. there is no significant difference in the regeneration of *Mallotus phillipinensis* in elephant tracks and non-elephant tracks (systematic parallel transects) in the sal forest. In other words, there is no significance evidence that the elephants have been contributing to increase the density of *Mallotus phillipinensis* in sal forest.

Alternative hypothesis. H_1: $\mu_1 > \mu_2$, (right angled test) i.e. the elephants have been contributing to increase the density of *Mallotus phillipinensis* in the sal forest.

Microsoft excel 2003 was used to do all the calculations.

CHAPTER 4

RESULTS

Among the 37 dung piles sown in the month of September 2008 and 40 dung piles sown in the month of March 2009, next fruiting season, there was not found any seedlings germinated. More than 90% of the *Mallotus phillipinensis* seeds sown in the control plot showed germination. During the month of September the seeds in control plot started germinating after 17 days of sowing and during the month of March the seeds started germinating after 21 days.

The average regeneration, total trees, damaged trees and coppicing and density of *Mallotus phillipinensis* along elephant tracks and systematic parallel transects is represented in the tables below:

Table 4.1: Average regeneration and 't' values for regeneration of *Mallotus phillipinensis* between elephant tracks and systematic parallel transects

	Mean Regeneration		Calculated value of 't'	Tabulated value of 't'
	Seedlings	Saplings		
Elephant track	0.49	1.16	Seedlings =0.2640	$t_{0.05, 18}$=1.734
Systematic parallel transects	0.41	1.14	Saplings =0.47554	

Table 4.2: Density and average coppicing of *Mallotus phillipinensis* in elephant tracks and systematic parallel transects

	Regeneration (ha^{-1})		Total trees(ha^{-1})	Damaged trees(ha^{-1})	Average Coppicing
	Seedlings	Saplings			
Elephant track	6.65	165.46	18.96	1.98	9.64
Systematic parallel transects	5.80	161.50	16.56	1.55	12.18

Among the 100 circular plots in 10 elephant tracks and 100 circular plots in 10 systematic parallel transects, there was not found any significant difference in

Mallotus phillipinensis regeneration. The calculated value of ‘t’ for the regeneration of seedlings of *Mallotus phillipinensis* in elephant tracks and systematic parallel transects was 0.2640 and that of saplings was 0.47554 and tabulated value of ‘t’ at 5% level of significance and 18 degrees of freedom is 1.734. Calculated value of ‘t’ is less than tabulated value, hence null hypothesis was accepted which proved there is no significant difference in the regeneration of *Mallotus phillipinensis* in elephant tracks and non-elephant tracks (systematic parallel transects) in the sal forest and hence no significant evidence that the elephants have been contributing to increase the density of *Mallotus phillipinensis* in sal forest.

The density of *Mallotus phillipinensis* seedlings in elephant track and systematic parallel transects was found to be 6.65 stems/ha and 5.80 stems/ha respectively and the density of saplings was found to be 165.46 stems/ha and 161.50 stems/ha respectively (table 4.2). This data does not signify any significant difference in *Mallotus phillipinensis* density between elephant tracks and systematic parallel transects. Regarding the trees of *Mallotus phillipinensis* density of 18.96 stem/ha was found along elephant tracks and 16.56 stem/ha was found along systematic parallel transects. Along elephant tracks the density of elephant damaged trees was found to be 1.98 stems/ha with average coppiced aerial buds 9.64 and the density of damaged trees along systematic parallel transects was found to be 1.55 stems/ha with average aerial coppiced aerial buds 12.18 (table 4.2).

All the elephant damaged trees of *Mallotus phillipinensis* were found within damage level A (Killed: tree dead due to elephants) and B (Broken: main tree trunk broken, but the remaining portion still alive), (Pradhan *et al*. 2007). This data for coppicing of aerial buds in damaged tress of *Mallotus phillipinensis* was very less to use any statistical tool, hence analyzed from the data itself. The difference of damaged tree density and coppiced aerial buds between elephant tracks and systematic parallel transects is not found significant to conclude that elephants could be contributing to increase the density of *Mallotus phillipinensis* through coppicing in damaged trees.

No germination of any *Mallotus phillipinensis* seedlings in elephant dung piles sown in the soil, no significant difference found in the regeneration of *Mallotus phillipinensis* along elephant tracks and systematic parallel transects in sal forest and very few trees of *Mallotus phillipinensis* damaged by elephants, with few coppiced aerial buds and no significant difference of damaged tree density and coppiced aerial buds between elephant tracks and systematic parallel transects, indicate that the recolonizing elephant population in Bardia National Park, could not be playing any role in the shifting forest composition regarding increasing *Mallotus phillipinensis* and decreasing *Shorea robusta* . Absence of seed germination in the elephant dung piles sown in soil signified that elephant though prefer the *Mallotus phillipinensis* bark most as its diet it does not ingest its fruits and help dispersing the seeds.

CHAPTER 5

DISCUSSION

The results of the study signified that elephants though prefer *Mallotus phillipinensis* bark most as its diet it does not ingest the fruits actively or passively and thus does not help dispersing the seeds.

The seeds of *Mallotus phillipinensis* are small and situated at the end of small twigs which elephant breaks. Elephant prefers *Mallotus phillipinensis* most as its diet but the preference is not in the fruits but in its barks (Prajapati 2008). The preference on bark is because it contains higher nutrients (dry matter and crude fiber) and minerals (calcium, phosphorus and sodium). Elephant breaks the twigs at the upper canopy part of *Mallotus phillipinensis* because phosphorus content was found to be more in the upper part then in the bottom (Prajapati 2008). While feeding on barks it removes all the leaves and fruits. As elephant does not feed on the fruits of *Mallotus phillipinensis* directly only passive ingestion of seeds was speculated but the results indicated no such ingestion. Also higher impact of elephants was found in the floodplain complex, probably due to higher density of preferred food trees in a comparatively small area (Pradhan *et al*. 2007). The density of *Mallotus phillipinensis* could not be increasing due to coppicing of aerial buds from damaged trees. Pradhan et al. reported 39 % of trees impacted by elephants were killed in sal forest and high proportion of the killed trees was *Mallotus phillipinensis* from which aerial buds cannot be regenerated. The results of the study also showed no any significant difference in regeneration of *Mallotus phillipinensis* along elephant tracks and systematic parallel transects and thus no significant evidence that the elephants have been contributing to increase the density of *Mallotus phillipinensis* in sal forest. This variation in results with that of Pradhan *et al*. may be because of smaller sampling size in this study.

The most probable cause behind the increasing density of *Mallotus phillipinensis,* decreasing density of *Shorea robusta* and thus shift in forest composition may be due to ecological succession. *Mallotus phillipinensis* is a pioneer species (Kanode *et al*. 2008) and sal is climax species (Sharma 2002). This rapid succession in the area may be due to increased flooding. Three major factors that played major role in shaping vegetational composition in Karnali- Bardia area were fire, heavy grazing and flooding (Dinerstein 1979). Among these fire and grazing have been controlled but intensity and duration of flooding has been increased (DNPWC 2006-2009). Seasonal flooding can bring about dramatic change in vegetational pattern much more rapidly (Dinerstein 1979). Flooding results deposition of silt, erosion, water logging in the forested and semi forested area (Dinerstein 1979). Poorly drained soils along small streams, rivers and in depressions favors the development of *Mallotus phillipinensis* forest (Dinerstein 1979). Poorly drained soil provides habitat for pioneer species that grow faster (Hosner & Minkler, 1963). *Mallotus phillipinensis* also is a pioneer species hence may be spreading in the new soil environment created by flooding.

Regarding Shorea robusta forest, soil with higher clay content on flat terrain favours its growth (Dinerstein 1979). Poor soil aerations and high organic matter in soil (that flooding may result) results poor regeneration in sal forest (Shet & Bhatnagar 1959).

Besides these consequences of flooding, the decreasing density of Shorea robusta may be probably due to die back phenomena of sal regeneration where seedlings of the species germinate well in number but the number greatly decreases at the sapling stage (Jakson 1994, Rautiainen 1994). Giri *et al*. (1999) in their research regarding regeneration of *Shorea robusta* in forest in Bardia National Park have reported the regeneration status of the species that had shown highest number of seedlings (13166.66 ha^{-1}) but the number greatly decreased at the sapling stage.

Seedlings exposed to unfavorable conditions such as frost, drought and fire frequently die back. In nature many die completely but in others the root remains alive and continues to send up new shoots each year until eventually a very strong rootstock develops which produces a shoot, which continues to grow, and eventually forms a tree (Jakson 1994). May be due to change in soil conditions along with changing climate and increased flooding the died back roots may not be getting favorable environment to develop new shoots and hence resulting decrease in density.

The sal may also be decreasing in density may be due to failure of seed germination as a consequence of irregular and untimely rainfall occurring few years back. Rainfall soon after the seed falls is the most basic requirement for seed germination of sal, if there is no rain the seed will die (Jakson 1994).

CHAPTER 6

CONCLUSIONS AND RECOMENDATIONS

6.1 Conclusion

Experimental analysis of the study showed no germination of any *Mallotus phillipinensis* seedlings in elephant dung piles sown in the soil. Also there was not found significant difference between the regeneration of *Mallotus phillipinensis* in and around elephant tracks and systematic parallel transects in sal forest. Very few trees of *Mallotus phillipinensis* were found damaged by elephants in the sal forest with few coppiced aerial buds. Thus from the research it is concluded that Elephants though prefer the bark of *Mallotus phillipinensis* as its most preferable diet, there could not be any role of elephant in such shift in forest composition.

6.2 Recommendation

The actual reason behind the shifting forest composition has yet not been accurately found. It is only predicted that the vegetational composition in the park is changing may be due to succession. For better understanding of the shifting forest composition is either successional or due any other reason further study should be carried out. Analysis of soil should be carried out to find the impacts of flooding. This type of study will be helpful to guide management decisions in the park, as elephants and sal both are important in forest ecosystem.

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Annex 1: Raw data for the regeneration of *Mallotus phillipinensis* in elephant tracks and systematic parallel transects

Table: average regeneration and coppicing of *Mallotus phillipinensis* in 10 elephant tracks

Tracks	Regeneration		Total trees	Damaged trees	Coppicing
	Seedling	Sapling			
1	0.5	3.7	0.6	0.5	0.7
2	0.5	20.7	0	0	0
3	0	11.4	0	0	0
4	0.3	9.3	0.4	0.4	5.3
5	0	0.7	0.1	0.1	3.8
6	0	18.4	1.7	0	0
7	0.2	8.3	0.2	0	0
8	0	30.6	6.6	0.3	1.7
9	1.5	7.3	2	0.2	2
10	1.9	6.4	0.8	0	0

Table: average regeneration and coppicing of *Mallotus phillipinensis* in 10 systematic parallel transects

Transects	Regeneration		Total trees	Damaged trees	Coppicing
	Seedling	Sapling			
1	1.2	9.6	0.8	0.2	1.9
2	0.4	7.9	1	0.1	0.6
3	0.2	2.2	0.8	0	0
4	0.3	0	0	0	0
5	0	0.6	0	0	0
6	0	15	4.7	0.2	1.8
7	0.9	31.5	2	0.3	7.4
8	1.1	25.4	1.5	0.3	1.7
9	0	12	0	0	0
10	0	9.9	0.9	0	0

Researcher collectiong dung pile

Germination plots

Dung piles in sampling bags

Elephant dung pile

***Mallotsus phillipinensis* seeds**

Seedlings in control plot

Annex 2: plates

Herd of Asian elephant in BNP

***Mallotus phillipinensis* tree with ripened fruits**

Coppicing in *Mallotus phillipinensis*

Elephant track in BNP