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Nutritional Ecology of Asian elephant (*Elephas maximus*) and Human- Wildlife Interactions

A thesis presented in partial fulfilment of the
Requirements for the degree of

Doctor of Philosophy

In

Conservation Ecology

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New Zealand.

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Extinction is forever, endangered means we still have time.

Alesander

Abstract

Reducing human-wildlife conflict has recently been recognised as an important aspect of wildlife management and represents one of the most complex challenges currently facing conservationists worldwide. Conflicts between humans and wild animals arise as a result of the loss, degradation and fragmentation of wildlife habitats through anthropogenic activities such as logging, animal husbandry, agricultural expansion and infrastructure development. Habitat fragmentation results in reduced areas of habitat and increased probability of contact between people and wild animals as the animals move in order to meet their nutritional and other ecological and behavioural requirements. Habitat degradation has led to food-related problems in populations of many species of wildlife, and the Asian elephant (*Elephas maximus*) is particularly vulnerable because it requires such a large amount of food per day. Large herbivores, such as elephants, are especially likely to suffer during periodic food shortages when they cannot meet their nutritional targets. Understanding the dietary and nutritional needs of elephants is crucial for managing habitats in ways that will ensure their survival, in particular by minimising conflict with humans. However, obtaining information about the dietary requirements of wild animals is difficult.

This thesis investigates the diets and nutritional priorities of captive, domestic and wild elephants through the application of nutritional geometry. Initially, I examined the food intake, food composition and the resultant dietary macronutrient and fibre intake in a captive female Asian elephant. My results showed that the proportions of the elephant's daily macronutrient and neutral detergent fibre (NDF) intake were different than the

proportions in the daily mixture of provisioned foods and were consistent across days, suggesting that she was selectively feeding on available foods. Results indicated that she prioritised the ratio of protein: non-protein energy in her diet, with the ratio of non-protein macronutrients (fats and non-structural carbohydrates) to digestible fibre (NDF) being varied so as to maintain a more constant proportion of dietary protein. Similar results in which the proportion of dietary energy contributed by protein was prioritised. This was revealed in my study on domesticated elephants, with most elephants maintaining constant proportional protein energy in their diet, but different individuals achieving this by consuming different ratios of non-protein energy (NPE) to neutral detergent fibre (NDF) energy. I also carried out a food preference survey for the wild elephants. I found that 57 species of fodder plants in 28 families were consumed by wild Asian elephants, including 13 species of grasses, five shrubs, two climbers, one herb and 36 trees. The feeding preference index further showed that browse species are preferred during the dry season, while a browse and grass combination is favoured during the rainy season. These findings were used to test the hypothesis that the elephants are selectively feeding against a null hypothesis that feeding is proportional to availability. The difference in the availability and the utilisation supports the alternative hypothesis of selective feeding to obtain the required macronutrient intake. An investigation of human–elephant conflict through a questionnaire survey showed that the depletion of natural forage inside and outside protected areas leads to an increase in elephants raiding crops because the grain-laden cultivated food plants are more palatable and more nutritious than wild browse plants. This study concluded that among the many factors, dietary requirements and selective browsing habits are believed to be the root causes in precipitating destructive behaviour in wild elephants, leading to fatal human-elephant conflict. This study also found that locally in central Nepal, crop

raiding was the main cause of conflict with humans. Respondents believed that human–elephant conflict could be minimised by re-vegetating internal parklands and park boundaries with native elephant food plants. The study also showed that regional conflict intensity as measured per elephant damage was high in western Nepal; however, conflict regarding human and elephant casualties was higher in central and eastern regions.

In summary, this study substantially advances our knowledge of the nutritional ecology of elephants and makes a significant contribution towards understanding the dietary and nutritional aspects of three different groups of elephants (captive, non-captive domestic and wild), as well as the nutritional drive of human–elephant conflicts. My findings have implications for the management of habitats for the conservation of Asian elephants and the mitigation of human–elephant conflict.

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List of abbreviations

Item	Term
ADIN	acid detergent insoluble nitrogen
AOAC	association of official analytical chemists
AP	available protein
ADF	acid-detergent fibre
ADL	acid-detergent lignin
BW	body weight
CF	crude fat
CINE	classical insect nutritional ecology
CI	conflict intensity
CP	crude protein
CV	coefficient of variation
DE	digestible energy
DM	dry matter
DMD	dry matter digestibility
DMI	dry matter intake

Item	Term
EE	ether extract
ES	ecological stoichiometry
GF	geometric framework
IVI	important value index
ME	metabolised energy
N	nitrogen
NDF	neutral detergent fibre
NG	nutritional geometry
NSC	non-structural carbohydrates
OFT	optimal foraging theory
PI	preference index
r	correlation coefficient
RMT	right- angled mixture triangle
TB	tuberculosis
VDC	village development committee

Preface

Human-wildlife conflict has recently become a fundamental aspect of wildlife management. It represents the most complex challenge currently faced by conservationists worldwide. Conflict arises mainly because of the loss, degradation and fragmentation of habitats through human activities such as logging, animal husbandry, agricultural expansion and infrastructure development projects (Fernando et al. 2005). When habitat becomes fragmented, smaller wilderness areas allow greater contact and therefore conflict with humans as wild animals seek to fulfil their nutritional, ecological and behavioural needs (Sukumar 1990).

Destruction of human assets brought about by the wild elephant is the most inescapable conflict because of this megaherbivore's wide-ranging behaviour, fidelity to its home range, large appetite and propensity and ability to destroy human property. Among the many factors precipitating wild elephants' destructive behaviour, dietary needs are believed to be the root cause. Indeed, crop raiding sometimes leads to fatal human-elephant conflicts. The wild elephant is a selective herbivore which is attracted to crops, purportedly because cultivated plant foods are palatable and nutritious and have lower secondary defences than wild browse plants (Sukumar 1990).

In Nepal, remote village communities with inadequate resources frequently fall victim to conflicts with wildlife (WWF Nepal 2007). Habitat degradation due to the increasing human population in Nepal has given rise to food-related problems in wildlife populations, and the Asian elephant is particularly vulnerable because it requires an

average of 150 kg per day to survive (WWF 2016). Large herbivores like elephants are therefore more likely to fall victim to periodic food shortages. This food deficit triggers the dispersal of elephants, and they raid crops and create havoc around outlying human settlements when they cannot meet their nutritional targets (Parker et al. 2007).

Understanding wild elephants' dietary needs are crucial for mapping the conservation ecology of elephants and for managing habitats in ways that will ensure their survival by minimising conflicts with humans. However, obtaining information about the dietary needs of wild animals is difficult. Thus, I started my study of wild elephants by investigating the diets of captive and domestic elephants. My captive/domestic elephant studies provided an opportunity—in a controlled situation—to validate key research methods before using lower-resolution measures to study wild populations. In addition, my initial studies of captive and non-captive domestic elephants allowed us to gather important information on the management of elephants' dietary needs and husbandry practices under captive conditions.

This thesis investigates the dietary and nutritional aspects of three different groups of elephants (captive, non-captive domestic and wild), ranging patterns of the Asian elephants and the human factors in the human-elephant conflicts and elephant conservation. It provides important baseline information for addressing further questions around the role of nutrition in human-elephant conflict, developing predictive models for managing human-wildlife conflict and to help formulate strategies for balancing the elephant's needs and human survival.

This dissertation is original and consists published and unpublished chapters, independent work by the author, Koirala RK. The data collection for chapter 2 was

permitted by the Auckland Zoo's animal ethics committee (AEC) on 7th August 2012. The fieldwork for Chapters 3, 4 and 6 was permitted by DNPWC (Department of the national park and wildlife conservation) government of Nepal (ref numbers 3300, Chitwan national park; and 873, Parsa wildlife reserve, whose status is recently upgraded to the national park) respectively. The permission covers both biological and social data collection as well as animal and human ethics.

I was the lead investigator for the projects covered by Chapters 1, 2, 3 6 and 7 where I was responsible for forming research questions, data collection and analysis, as well as the majority of the manuscript composition.

A version of Chapter 4 has been published [Koirala RK, Ji W, Aryal A, Pathak ML, Raubenheimer D. 2016]. Feeding preferences of the Asian elephant (*Elephas maximus*) in Nepal. BMC Ecology. 16:54. I was the lead investigator, responsible for all forming research questions, data collection and analysis, as well as manuscript composition. Aryal A and Pathak ML were involved in the early stages of data collection and contributed to manuscript edits. Ji W and Raubenheimer D were the supervisory authors on this project and was involved throughout the project in all aspects.

A version of Chapter 5 has been published [Koirala RK, Ji W, Aryal A, Rothman J, Raubenheimer D. 2015]. Dispersal and ranging patterns of the Asian Elephant (*Elephas maximus*) in relation to their interactions with humans in Nepal, Ethology Ecology & Evolution 28:221-31. I have conceptualised the project, reviewed literature and drafted the manuscript. Raubenheimer D, Ji W, Rothman J, was the supervisory authors on this project and was involved throughout the project in manuscript edits. Aryal A contributed in manuscript edits including figures and map preparation.

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Thesis outline

The primary aim of this thesis is to understand whether the human-wildlife conflict is driven by food preferences and nutritional needs. Such knowledge is important for conservation management of elephant populations, their habitat and mitigation of human-elephant conflict.

This thesis includes two themes: 1) Diet and nutritional ecology of Asian elephants, and 2) human-wildlife interaction. Exploration of these themes leads to recommendations for developing strategies to balance wildlife conservation and human needs.

Theme one of this thesis documents the pattern of diet preference of the wild Asian elephant (*Elephas maximus*) in the Terai region of Nepal and evaluation of nutritional values of food plants selected by captive and domestic Asian elephants. Such information is vital for understanding elephant-habitat interactions, especially in the wild. **Chapters 1-4** are included under the first theme.

Theme two covers aspects on the distribution and movement patterns of the Asian elephant (*Elephas maximus*) and the nature and status of human-elephant interactions in the Terai region of Nepal and documents the causes and extent of damage by wild elephants in central Nepal.

The aim is to understand general human-elephant conflict issues in order to more effectively manage elephant habitats and reduce human-elephant conflicts. Theme two contains **Chapters 5–7**.

Each chapter was written as a stand-alone paper for publication in a scientific journal. Chapter 4 has been published in BMC Ecology and Chapter 5 in Ethology, Ecology and Evolution. Chapter 2 and 6 are submitted to the journals. The published chapters follow respective journal format.

Below are details of each chapters.

Theme 1: Wildlife nutritional ecology and conservation strategies

Chapter 1 Understanding the aspects of elephant diet and nutrition relevant to minimising human-Asian elephant conflict.

This chapter provides an overview of relevant literature on the diet and nutritional aspects of the Asian elephant and introduces the different frameworks to explain nutritional ecology concepts. The chapter highlights the nutrient balance hypothesis that may influence food selection and the “nutritional geometry” analytical framework and its application to the foraging ecologies of elephants. I further review human-elephant conflict and its potential link to habitat loss and consequent effects on elephants’ foraging abilities.

Chapter 2 Diet composition and macronutrient prioritisation in a captive Asian elephant.

This chapter investigates the relationship between macronutrient composition of food provisioned to a captive Asian elephant and food eaten, as an approach to test for macronutrient-specific selective feeding. This study was a pilot exploration of the composition of the typical elephant diet in situations where the animal was under the care of humans.

Chapter 3 The effects of age, sex and season on the macronutrient composition of the diet of the domestic Asian elephants.

This chapter examines the effects of age, sex class and season on the nutrient composition of food intake by 16 domesticated Asian elephants. I tested whether the domestic elephants selected a diet with the similar nutritional composition to that of their wild counterparts and whether they faced constraints in reaching their nutritional goal due to qualitative or quantitative restrictions on food availability.

Chapter 4 Feeding preferences of the Asian elephant (*Elephas maximus*) in Nepal.

This chapter explores the feeding preferences and dietary requirements of wild Asian elephants based on feeding sign and dung analysis. I also investigated food availability by conducting a survey using point-centred quarter methods. This chapter has been published in BMC Ecology.

Theme 2: The status of human-elephant interactions, their causes and recommendations for management

Chapter 5 Dispersal and ranging patterns of the Asian elephant (*Elephas maximus*) in relation to their interactions with humans in Nepal.

This chapter reviews the past and present population distribution of Asian elephants in Nepal, the spatial and temporal patterns of elephant movements (migration), the history of human-elephant conflict and mitigation measures. This chapter has been published in *Ethology Ecology and Evolution*.

Chapter 6 Patterns, perceptions and spatial distribution of human-elephant (*Elephas maximus*) conflict in Nepal.

In this chapter, based on the findings of chapter 5, I evaluate local human-elephant conflict in the central region of Nepal through household surveys and secondary analysis of published data.

Chapter 7 Conclusions.

This chapter summarises findings of this research and concludes that macronutrient balance is important for the management of captive and domestic Asian elephants. Plants utilised by wild populations as important food sources should be taken into account in elephant habitat management.