

**FOOD HABITS OF TIGER (*Panthera tigris tigris*) IN PENCH NATIONAL PARK,
MADHYA PRADESH**

**DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
IN PARTIAL FULFILLMENT OF THE MASTER'S DEGREE
IN WILDLIFE SCIENCE
JUNE 1999**

BY

SAYANTAN BISWAS

UNDER THE SUPERVISION OF

DR. K SANKAR

DR. R.S. CHUNDAWAT

WILDLIFE INSTITUTE OF INDIA

DEHRADUN




भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE


This is to certify that Mr. Sayantan Biswas of Wildlife Institute of India has carried out an original research work titled "*Food habitats of tigers in Pench Tiger Reserve, Madhya Pradesh*" for the partial fulfilment of Master's degree in Wildlife Science of Saurashtra University. These investigations were carried out under our supervision from November 1998 to June 1999. We also certify that this research work has not been submitted for any degree to any other University.

Date: 23rd June 1999.

Dehradun.


(Dr. K. Sankar)

Faculty of Wildlife Biology


(Dr. R.S. Chundawat)

Faculty of Wildlife Biology

ABSTRACT

Food habits of tiger was studied in a dry deciduous forest area in Pench National Park, Madhya Pradesh, over a period of 6 months, from November 1998 to April 1999. Density estimation of major prey species was done to assess availability to tigers. Line transect method was used for estimating prey density. Fourteen line transects were laid in two major vegetation types, teak associated and miscellaneous forests. Each transects was walked 16 times. A total of 243.2 and 214.4 km of transects were walked in teak associated and miscellaneous forests respectively, totaling to 457.7 km of walk during the whole study. Pench National Park was found to have very high wild ungulate density (89.9 animals/ km²). Chital was the most common ungulate species, followed by sambar, whereas common langur was the most abundant primate species in the study area. Seventy two tiger scats were collected opportunistically from the study area and analysed. Scat analysis revealed that chital constituted the major part of tiger prey in terms of number (52.08%), followed by sambar (20.83%) and wild pig (15.63%). In terms of biomass both chital and sambar contributed equally (38%) to the diet of tiger. No langur remains were found in the analysed tiger scats. It was revealed that tigers were preying selectively in the study area on the available prey base. Chital was found to be less preyed upon compared to its availability, while sambar and wild pig were consumed more than their availability in the environment. Gaur and nilgai were killed in proportion to their availability. Results from this study stressed the importance of maintaining high density of medium and large sized ungulate population for effective conservation of tigers. The importance of Pench National Park as a potential area for long term tiger conservation was also discussed.

ACKNOWLEDGEMENTS

I would like to thank Madhya Pradesh Forest Department for giving me the necessary permission to work in Pench Tiger Reserve, and also for providing the basic infrastructure to stay there.

In this regard, I will take the opportunity to thank Mr. P.K. Mishra (IFS), Additional P.C.C.F. & C.W.L.W., Mr. S. Ahmed (IFS), the Conservator of Forest, Mr. L.K. Chaudhury (IFS), Deputy Director, Mr. Sharma (ACF), Mr. Dondhwey (R.O.), Mr. Tiwari, Deputy Range Officer, Karmajhari Range and all the forest officials and field staff of the park for co-operation.

I thank Dr. Sankar for being my supervisor, for the overall support and co-operation he provided to me and for keeping up the pressure on me all the time.

I am also thankful to my co-supervisor Dr. R.S. Chundawat for useful comments during the thesis writing, getting me funds for this project and my M.Sc course, and also to Dr. Y.V. Jhala for facilitating the fund raising process in the absence of the former, and to conduct the M.Sc course ably.

I also thank National Fish and Wildlife Foundation for providing "SAVE THE TIGER" fund to carry out this study.

I sincerely thank my field assistants Ramkumar and Rajkumar for making this study possible. Without them I couldn't have done my study. I also thank Guddu, Ghuran, Dilip, Biran also for overall help and sharing many cheerful moments with me.

I thank G. Areedran and Md. K.S. Pasha (researchers Gaur Ecology Project, WII) for being extremely helpful, supportive and encouraging in all possible ways during my field work and for all those enjoyable moments they shared with me during my stay at Pench. I am sure that, I would not have got any better colleagues during my fieldwork.

My special thanks to Mr. Sanjay Deshpande, Bhabiji and Shewali for their hospitality and encouragement throughout the study. I also thank Mr. Parashar, Manager, Bank of Maharashtra at Khawasa, for always being a good friend.

I sincerely thank Mr. Agarwal (Ex R.O. Karmajhari range) and his family for being a very helpful and encouraging friend throughout.

From Wildlife Institute, I also thank Mr. S.K. Mukherjee, Director, Mr. V.B. Sawarkar, Deputy Director for getting me the required permission for field work from the forest department.

I thank Mr. Qamar Qureshi for being extremely supportive in all possible ways during the thesis write up, analysis and also throughout my course. I also thank Dr. A.J.T. Johnsingh for providing literature, Dr. Ravi Chellam and Dr. Y.V.Jhala for general comments during the initial part of my dissertation and analysis respectively.

I would like to thank Dr. Renee Borges, Dr. Ullas Karanth and Dr. Rauf Ali for their useful comments during my thesis writing.

My sincere thanks to Shomita Mukherjee, Advait Edgaonkar, M.D. Madhusudan, Anindya Sinha, Mahesh Shankaran, Rashid Raza, Rajah Jayapal, Neel Gogate, Karthik Vasudevan, Bhaskar Acharya, Christy Williams for helping me in designing my study, analysis and thesis writing.

I also thank Dr. Archana Bahuguna and Mr. Rakesh Singh and all the laboratory staff, Vinod and the rest for their help and co-operation during the lab work.

I thank Mr. Rana, and Mr. Sardar librarians, W.I.I. for using the facilities of the library and especially Vermaji, Uniyalji, Shashiji, Kishenji and Virendraji for all the help they did during the literature search and xeroxing the necessary reprints.

I also thank all the computer staff and engineers, especially Mr. Dinesh Pundir for preparing the maps, for their help and co-operation.

I don't know how to thank Manu, Samraat, Cheryl, Shomen, Avanti, Tanushree, Krushnamegh, Anand for the support they provided me during the hard times and all the cheerful moments they shared with me which made these two years of my Master's course a worthwhile experience.

My very special thanks goes to Manu, Samraat, and Cheryl for those very special moments we shared together.

I also thank Jayapal, Manoj, Shomita, Ayesha, Nehan, Yogesh, Prachi, Kashmira, Sonali, Appu, Karunakaran, Anil, Reena, and all the earlier M.Sc and researchers in the Institute for a enjoyable company over last two years.

Lastly I would like to thank my parents, sister for always letting me do whatever I wanted to do, Avikda, Ranjan, Subhotosh and all my dear and near ones for their encouragement and support.

CONTENTS

ABSTRACT	
ACKNOWLEDGEMENT	
1. INTRODUCTION	1
1.1. OBJECTIVES	5
2. STUDY AREA	6
2.1. LOCATION	6
2.2. CLIMATE	6
2.3. TOPOGRAPHY	7
2.4. DRAINAGE	7
2.5. VEGETATION	7
2.6. MAMMALIAN FAUNA	9
2.7. PREY SPECIES OF TIGER	9
3. METHODOLOGY	12
3.1. ESTIMATION OF PREY AVAILABILITY	12
3.2. ESTIMATION OF TIGER DIET	13
3.3.1. COLLECTION OF SCATS	14
3.3.2. IDENTIFICATION OF SCATS	14
3.3.3. IDENTIFICATION OF PREY REMAINS FROM SCATS	15
3.3.4. INFORMATION ON KILLS	16
3.3. ESTIMATION OF THE BIOMASS OF PREY CONSUMED	16
3.4. ESTIMATION OF PREY SELECTIVITY	17
4. RESULTS	20
4.1. AVAILABILITY OF PREY SPECIES	20
4.1.1. CHITAL	21
4.1.2. SAMBAR	21
4.1.3. COMMON LANGUR	22
4.1.4. OTHER PREY SPECIES	22
4.2. COMPOSITION OF TIGER DIET	23

4.3. ESTIMATION OF PREY SELECTIVITY	23
4.4. KILL DATA	24
5. DISCUSSION	33
5.1. AVAILABILITY OF PREY SPECIES	33
5.2. PREY SELECTION BY TIGERS	36
5.3. CONSERVATION AND MANAGEMENT IMPLICATIONS	39
REFERENCES	41
APPENDIX 1	48
APPENDIX 2	50-61

LIST OF FIGURES

PAGE NO.

Figure 1. Map of the Pench Tiger Reserve, showing Pench National Park, the study area.	10
Figure 2. Minimum and Maximum temperature recorded daily in Pench National Park (Nov. 1998-Apr. 1999)	11
Figure 3. Map of study area in Pench Tiger Reserve showing the position of line transects	19
Figure 4.1 Percentage occurrence of different prey items in 72 tiger scats in Pench National Park	32
Figure 4.2 Contribution of different prey species in terms of biomass to the tiger diet in Pench National Park	32

LIST OF TABLES

PAGE NO.

Table 1. Crude density of individuals of the prey species in the overall study area Pench N.P. (December 1998 to April 1999).	25
Table 2. Crude density of groups of prey species in the overall study area Pench N.P. (December 1998 to April 1999).	26
Table 3. Ecological density of individuals of chital, sambar and common langur in teak associated forest in Pench N.P. (December 1998 to April 1999).	27
Table 4. Ecological density of groups of chital, sambar and common langur in teak associated forest in Pench N.P. (December 1998 to April 1999).	27
Table 5. Ecological density of individuals of chital, sambar and common langur in miscellaneous forest in Pench N.P. (December 1998 to April 1999).	28
Table 6. Ecological density of groups of chital, sambar and common langur in miscellaneous forest in Pench N.P. (December 1998 to April 1999).	28
Table 7. Percent occurrence of prey items in 72 tiger scats collected in Pench N. P. from Dec 1998 to Apr 1999.	29
Table 8. Contribution of different prey species in terms of biomass to tiger diet in Pench N. P. from Dec 1998 to April 1999.	29

Tab 9. Percent availability of the major prey species and their Utilization by tigers in Pench N. P. from Dec 1998 to April 1999.	30
Tab 10. Tiger kills found in Pench N.P. from December 1998- April 1999.	31

APPENDIX 1 47-48

Table 1. Crude density of individuals of prey species from grouped distance data in overall study area (P.N.P.) (December 1998 to April 1999).	48
Table 2. Crude density of groups of prey species from grouped distance data in the overall study area (P.N.P.) (December 1998 to April 1999).	48

APPENDIX 2

Table1. Crude density of individuals of sambar in the overall study area (P.N.P.) (December 1998 to April 1999).	49
Table2. Crude density of sambar groups in the overall study area (P.N.P.) (December 1998 to April 1999).	49
Table3. Crude density of individuals of chital in the overall study area (P.N.P.) (December 1998 to April 1999).	50
Table 4. Crude density of chital groups in the overall study area (P.N.P.) (December 1998 to April 1999).	50
Table 5. Crude density of individuals of common langur in the overall study area (P.N.P.) (December 1998 to April 1999).	51
Table 6. Crude density of common langur groups in the overall study area (P.N.P.) (December 1998 to April 1999).	51
Table 7. Ecological density of individuals of chital in teak associated forest (P.N.P.) (December 1998 to April 1999).	52
Table 8. Ecological density of chital groups in the teak forest (P.N.P.) (December 1998 to April 1999).	52
Table 9. Ecological density of individuals of chital in miscellaneous forests in P.N.P. (December 1998 to April 1999).	53
Table 10. Ecological density of chital groups in miscellaneous	

Forest in P.N.P. (December 1998 to April 1999).	53
Table11. Ecological density of individuals of sambar in teak Associated forest in P.N.P. (December 1998 to April 1999).	54
Table12. Ecological density of sambar groups in P.N.P. (December 1998 to April 1999).	54
Table 13. Ecological density of individuals of sambar in miscellaneous forests in P.N.P. (December 1998 to April 1999).	55
Table14. Ecological density of sambar groups in miscellaneous Forest in P.N.P. (December 1998 to April 1999).	55
Table 15. Ecological density of individuals of common langur in teak associated forest in P.N.P. (December 1998 to April 1999).	56
Table16. Ecological density of common langur groups in teak associated forest in P.N.P. (December 1998 to April 1999).	56
Table17. Ecological density of individuals of common langur in miscellaneous forests in P.N.P. (December 1998 to April 1999).	57
Table18. Ecological density of common langur groups in miscellaneous forest (December 1998 to April 1999).	57
Table19. Crude density of individuals of nilgai in the overall study area (P.N.P.) (December 1998 to April 1999).	58
Table 20. Crude density of nilgai groups in the overall study area (P.N.P.) (December 1998 to April 1999).	58
Table 21. Crude density of individuals of wild pig in the overall study area (P.N.P.) (December 1998 to April 1999).	59
Table22. Crude density of wild pig groups in the overall study area (P.N.P.) (December 1998 to April 1999).	59
Table 23. Crude density of individuals of gaur in the overall study area (P.N.P.) (December 1998 to April 1999).	60
Table24. Crude density of groups of gaur in the overall study area (P.N.P.) (December 1998 to April 1999).	60

1. INTRODUCTION

Tiger (*Panthera tigris*) is a highly adaptable animal occurring in a wide range of forest types and showing a remarkable tolerance to variations in altitude, temperature and rainfall regimes (Karanth 1991). Historically, tiger was distributed over a wide geographical region that extended from Russian Far East, through eastern and southern China, south-east Asia, the Indian subcontinent, and into the Indus River Valley in Pakistan (Seidensticker 1997). Isolated populations of tiger were living in and around the southern part of the Caspian Sea and associated river valleys, and on the Indonesian islands of Sumatra, Java, and Bali (Corbett & Hill, 1992; Seidensticker, 1997). In the last hundred years, three out of the eight subspecies of tiger (Caspian, Javan and Bali) have gone extinct (Seidensticker 1986, 1987, 1997). In the Indian subcontinent, it occurs in extreme habitats ranging from dry, semi-arid scrub forest to tidal mangroves on one hand and from sub Himalayan terai to rain forests on the other hand (Schaller 1967). The Indian tiger (*Panthera tigris tigris*) constitutes almost sixty percent of the present population of tigers in the wild (Seidensticker et al., 1999), but its future is not secure, in a constantly human altered environment. In spite of the initial success of Project Tiger in 1973 to conserve the subspecies, conservation efforts in the subcontinent have largely failed to check the major threats to the tiger population, namely habitat degradation and insularization, depletion of prey base and poaching of tigers for their body parts used in traditional medicine in some of the East Asian countries. The first two factors have gone hand in hand to fragment tiger habitats resulting in isolated populations, which runs high risks of extinction due to natural stochastic processes or poaching. Hence, the survival of the tiger in future lies in our in-depth understanding of its ecology, its resilience in this changing environment and our promptness to take management measures to implement these findings.

Our understanding of tiger ecology has its roots in Schaller's (1967) landmark study on tiger and its prey species in Central India. Information prior to this was confined to anecdotal natural history accounts by hunters and naturalists,

which revolved around descriptions of encounters with the animal and hunting episodes (reviewed in Perry 1964, Schaller 1967). Following the trails of Schaller (1967), the last three decades have seen a few studies conducted on tiger in the Indian subcontinent. These includes, studies on general ecology (McDougal 1977), social organization (Sunquist 1981), land tenure system (Panwar 1979, Smith *et al.*, 1987, Chundawat *et al.*, 1999), scent marking, dispersal and communication (Smith, 1987,1993), prey - predator interaction (Johnsingh, 1983, 1993, Tamang 1979, Karanth & Sunquist 1995), predatory behaviour and population ecology (Seidensticker and McDougal 1991, 1993) and ecological separation with leopards (Seidensticker, 1976).

Food habits determine a number of life history strategies like habitat selection, movement and success of reproduction (Krebs 1978). Prey selection, which ultimately determines the food habits of a predator is a complex phenomenon (Sunquist & Sunquist 1989) influenced by multiple ecological factors. This has stimulated ecologists to hypothesize the way an efficient predator should forage. This took the form of optimal foraging theory (MacArthur and Pianka 1966), which predicts that a predator should go for the most profitable prey when they are abundant in the environment. Once the availability of profitable prey in the environment goes down, it will not be beneficial for the predator to forage selectively anymore (Krebs, 1978; Sunquist & Sunquist 1989). Selective foraging refer to intake of a particular food item more than its availability in the environment (Chesson 1978). While profitable prey is the one, which when preyed upon maximizes the energy intake per unit time of searching and handling (Krebs 1978). For large felids it appears that large body sized prey, which can be handled safely, would be the most profitable to prey upon. Tiger studies in terai region of Nepal, central and southern Indian forests (Schaller 1967, Sunquist 1981, Johnsingh, 1983, 1993, Karanth & Sunquist 1995) have documented the intake of large ungulates like sambar (*Cervus unicolor*) (150-250 kg) and gaur (*Bos gaurus*) (450-1000 kg) (Schaller 1967) selectively. But profitable might be the function of a

larger set of factors than just the body size. Apart from the prey size other factors like, prey density, their social organization, habitat selection (in space and time), anti-predator strategy are some of the aspects of prey species ecology, that puts major constraints on predator's hunting success (Sunquist & Sunquist 1989). For example, though gaur was present in Chitawan terai area in Nepal, it was not found to be predated by tiger, because of the low density with which it occurred there (Sunquist, 1981). Large bovids like nilgai (*Boselaphus tragocamelus*) falls under the category of large prey (150-220kg) (Prater 1980). But this species has been found to be consumed less than its availability (Sankar et al., 1993), probably because of its preference for open habitats, which makes it less prone to tiger predation. Method of hunting also plays an important role in influencing the prey killed. Unlike the coursing predators, the tiger hunts by stalk and ambush (Schaller, 1967; Sunquist, 1981). While it is generally inferred that coursing predators remove the sick and old individuals from the population, this may not be a case for a stalk and ambush predator like tiger (Sunquist, 1981). In fact studies from central and south India (Schaller, 1967; Johnsingh, 1983, 1993; Karanth & Sunquist, 1995) have found that a majority of the individuals killed by tiger were in good physical condition. Other factors like presence of hunting cover and terrain for the predator, time of hunting, climatic condition, presence of intra- and inter specific competitors, and energetic requirements also influences the prey choice by the predator (Sunquist & Sunquist 1989). In Chitawan, once the grassland areas were burnt at the beginning of the year, cover for effective predation by tiger reduced. This was manifested in increased sambar predation in the adjoining sal (*Shorea robusta*) forest. Later, when the grassland grew back, the success rate of predation for tigers again went up in these grassland areas (Sunquist, 1981). Tigers on an average, like most other cats takes more number of prey, which are generally less than its body size (Packer, 1986; Sunquist & Sunquist, 1989), but readily consumes prey species larger than its body, when large sized prey are available in higher densities (Karanth & Sunquist, 1995). Hence prey selection of tigers in any area is ultimately the cumulative effect of these different ecological,

behavioral and habitat factors which delineates the availability and vulnerability of prey species at any particular time.

Since gathering ecological information about cats is difficult in wild, since many of them are nocturnal and elusive. Hence, addressing their food habits gives us an opportunity to accumulate the first line of evidence for understanding the prey predator interaction at any site. These studies are also time and cost efficient method, because indirect and non invasive methods (see methodology) can be used for the same. Throughout its range tiger is a part of ecosystems which vary widely in its prey species composition and abundance. Hence studying its feeding ecology would help us to understand the prey predator dynamics in any particular area, plasticity of the tiger to utilize its resources and to make valid generalizations about the animals' ecology.

Dry deciduous forest constitutes 45% of the overall tiger habitat in the Indian subcontinent (Wikramanayake et al., 1999). Most of the detailed studies on tiger till date are available from sub tropical moist deciduous and alluvial grasslands (Schaller, 1967; Sunquist, 1981; Stoen, 1994; Karanth & Sunquist, 1995; Chundawat et al., 1999). Though studies are available in dry deciduous forests also (Johnsingh, 1983), it is far less than required. This is because dry deciduous forest areas are one of the most disturbed habitats where tigers occurs and studies in these areas which has varying amount of disturbance level will give us better tool to conserve tigers in an increasingly human dominated landscapes. For the present study on food habits of tiger Pench Tiger Reserve (P.T.R.), Madhya Pradesh (M.P.) was selected.

1.1. OBJECTIVES OF THE STUDY

The present study had the primary objective to find out -

Whether tigers are preying selectively on the prey species in the study area.

The primary objective was further broken down to the following sub objectives:

1. To estimate the prey density in the intensive study area taking it as an index of prey availability to tigers.
2. To estimate the proportion of prey consumed by tiger.
3. To infer whether the tigers in the study area are feeding on the prey species in proportion to their availability or not. This was done by testing the null hypothesis that tigers do not predate selectively
4. To elucidate the ecological factors which may be influencing such occurrence of choice, if present.

2. STUDY AREA

2.1. Location:

Pench Tiger Reserve (PTR) M.P. was selected as the study area (Fig 1.). The park lies between 22°N and 78°55' E and 21°8' N and 79°35' E and covers an area of 758 sq. km. It falls under, Chindwara and Seoni districts of M.P.. The intensive study area was the 145.24 sq. km eastern block of Pench National Park (P.N.P.) in Seoni District. According to the Biogeographic classification of Rogers and Panwar (1988), Pench Tiger Reserve (Fig 1) is a part of the central Indian highlands which falls under zone E of the 6th Biogeographic provinces – the Deccan peninsula. PTR was declared as a Tiger Reserve in November 1992. Of the total area, the core and the buffer are 292 sq. km and 118 sq. km respectively. The river bisects the National Park into the 147.61 sq. km western block (in the Gumtara range of the Chindwara Forest Division) and the 145.24 sq. km Eastern block (in Karmajhiri Range of the Seoni Forest Division). The Eastern block is largely undisturbed wildlife habitat, while the Western block is more disturbed with varying levels of anthropogenic pressures (Kumar 1990).

2.2. Climate:

The area experiences four distinct seasons, summer (March to June), monsoon (July to August), post monsoon (September to October) and winter (November to February). The present study was carried out from mid November to end of April. This covered the whole winter season and the first half of summer. The mean annual rainfall in this area is 1400 mm.. Most of the rainfall is concentrated during the monsoon months. During the study period (winter & first half of summer) the area experienced occasional light showers. The temperature varied from -2 °C in winter to 49°C in summer during the study period . The daily minimum and maximum temperature in Pench (at the base camp) recorded during the study period is shown in Fig 3.

2.3. Topography :

The park is located in the southern lower reaches of the Satpuras, which forms the catchment area of the Pench River. The area is generally undulating with small ridges and hills with steep slopes. The highest point in the park is about 2054 ft above sea level (Kumar, 1990).

2.4. Drainage :

The main source of natural water inside the park is the Pench River, which flows in a north to south direction (Fig 1). A dam was built on the Pench River in the Maharashtra side of the Pench Tiger Reserve in the early nineties, the backwaters of which are on the M.P. side of the park. This has led to the submergence of 54 sq. km of prime forest of the National Park (Kumar 1990). The river is perennial, but gets drastically reduced to pools along many parts of its length during peak summer by the month of May. Towards the eastern side of the park is a big artificial water tank, called Bodanala tank which is the second largest source of water in the park. In addition to these, numerous streams of varying length and width cut across the park. Most of these streams barring very few dries up as summer advances, forcing the ungulates to restrict themselves close to these water bodies. To meet the water stringency in the park, during summer the forest department has constructed a number of hand pumps throughout the park, which start functioning by middle of March. This reduces the water crisis in the park faced by the animals in summer to a large extent.

2.5. Vegetation:

According to Champion & Seth (1968) classification, the forest type in region of the Tiger Reserve comes under the category of,

I. Tropical Dry Deciduous forests :

a. TYPE 5A/C_{1b} Dry Teak Forests,

b. TYPE 5A/C₃ Southern Dry Mixed Deciduous Forests.

II. Tropical Moist Deciduous Forests:

a. TYPE 3B/C_{1c} Slightly Moist Teak Forests.

Within the study area the forest was stratified into two major categories for the present study :

1. Teak associated (*Tectona grandis*) forests, corresponding to 5A/C_{1b} of Champion & Seth (1968)
2. Miscellaneous forests corresponding to 5A/C₃ of Champion & Seth (1968)

In the teak associated forest, teak is found in association with *Terminalia tomentosa*, *Madhuca indica*, *Lagerstromia parviflora*, *Diospyros melanoxylon*, *Buchanania lanzan*, *Ougeinia parviflora*, *Miliusa velutina* *Sterculia urens* and *Lannea coromandalica*. The miscellaneous forest on the other hand was composed of *Anogeissus latifolia*, *Boswellia serrata*, *Phyllanthus emblica*, *Madhuca indica*, *Terminalia tomentosa*, *Grewia tiliaefolia*, *Schebera swietenoides* and *Bridelia retusa* . Apart from this there were Bamboo (*Dendrocalamus strictus*) forest which occurred in association with teak. Along the perennial and seasonal streams were narrow strips of riverine forest dominated by *Terminalia arjuna*, *Syzigium cumini* and *Ixora parviflora*. Except the above two major vegetation types, the south west portion of the park had patches of an unique monospecific dominant patches of *Cleistanthus collinus*.

2.6. Mammalian Fauna :

The park was well represented by mammalian fauna characteristic of the Central Indian Highlands. Major ungulate and primate species were gaur (*Bos*

gaurus), sambar (*Cervus unicolor*), chital (*Axis axis*), nilgai (*Bosephalus tragocamelus*), wild pig (*Sus scrofa*), muntjac (*Muntiacus muntjac*), fourhorned antelope (*Tetraceros quadricornis*), chinkara (*Gazella gazella benneti*), common langur (*Presbytis entellus*) and rhesus macaque (*Macaca mulatta*). Some part of the park, adjoining the Eastern boundary had domestic livestock (domestic cattle, buffalo and goat) grazing, but, my intensive study area was free from livestock.

There were also a number of sympatric carivores present in the park along with tiger. These were leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), jungle cat (*Felis chaus*), sloth bear (*Melursus ursinus*), toddy cat (*Paradoxurus hermaphroditus*), small indian civet (*Viverricula indica*), wolf (*Canis lupus*), striped hyaena (*Hyaena hyaena*), ruddy mongoose (*Herpestes smithi*) and common mongoose (*Herpestes edwardsi*).

2.7. Prey species of tiger

Most of the small, medium and large sized mammals are vulnerable to tiger predation. From existing studies it was found that tigers generally prey on medium to large sized ungulates and primate species, namely, chital, sambar, nilgai, gaur, wild pig, muntjac and common langur (Schaller 1967, Johnsingh 1983,1993, Sunquist 1981, Karanth & Sunquist 1995). But occasionally tigers have been found to predate other carnivores like leopard, sloth bear, civets and small vertebrate like frogs (Schaller 1967). For the present study only chital, sambar, gaur, nilgai, wild pig, muntjac, chowsingha and common langur were considered as prey species of tiger and information about their density was collected.

Fig 1. PENCH TIGER RESERVE, MADHYA PRADESH

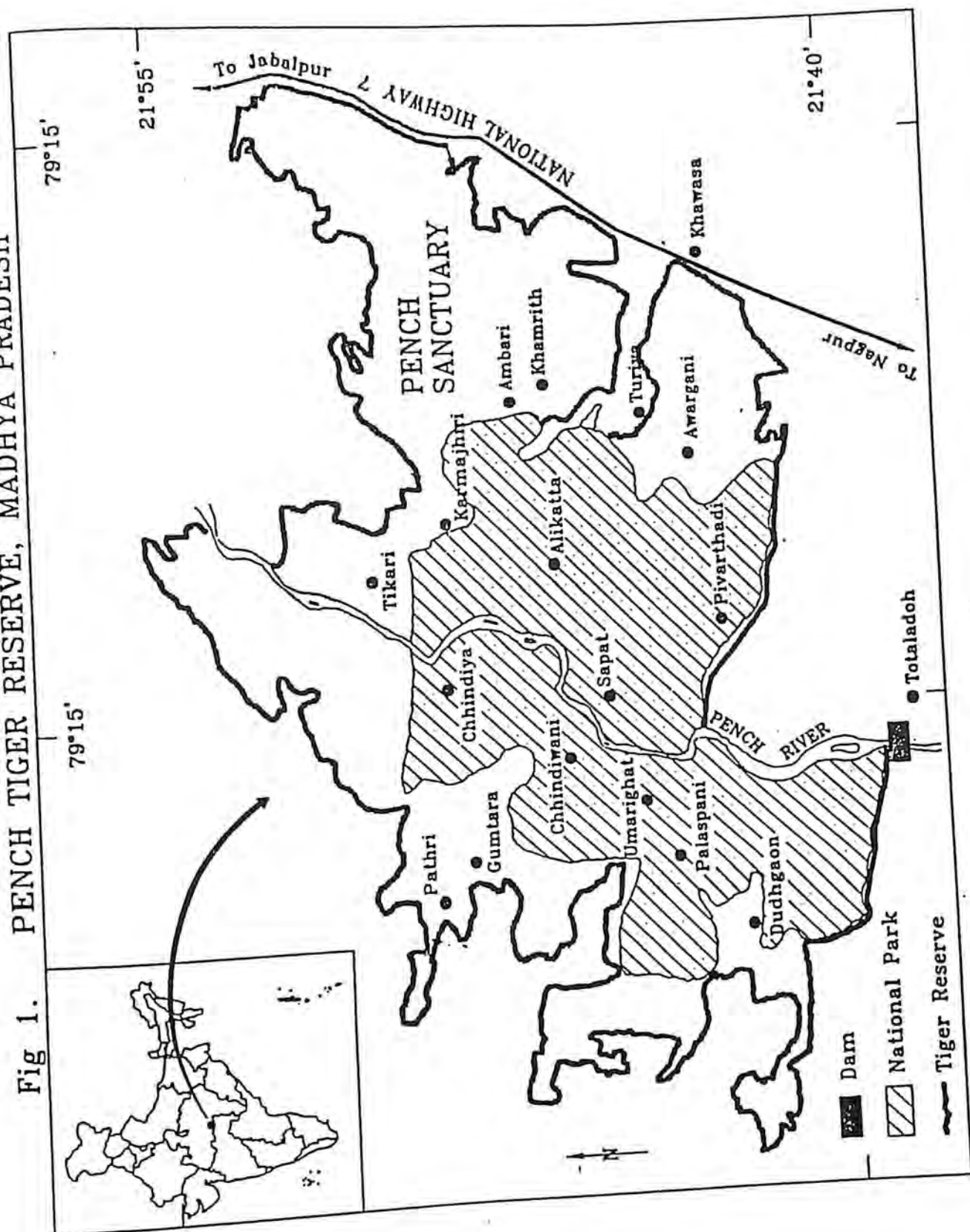
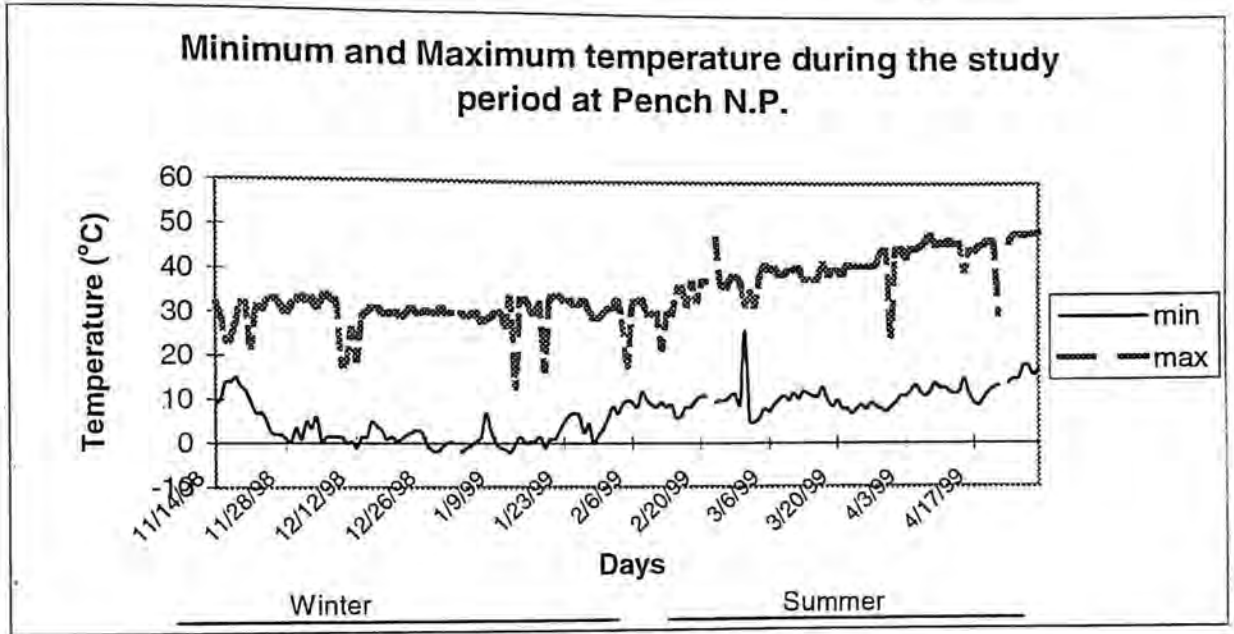


Fig 3. Minimum and Maximum Temperature recorded daily in Pench National Park (Nov 1998-Apr 1999)



3. METHODOLOGY

3.1. Estimation of prey availability:

Prey density was considered to be the indicator of prey availability to the tiger (Johnsingh 1983, 1993, Karanth & Sunquist 1995). To estimate the density of wild prey species, in the study area, line transect method was used (Eberhardt, 1968). This method was used by several workers earlier for effectively estimating ungulate density in similar tropical conditions (Eisenberg & Lochart 1972; Johnsingh 1983, Karanth & Sunquist 1992,1995; Khan et al 1996, Seidensticker 1976, Sunquist 1981, Tamang 1979, Varman & Sukumar 1995). The theory and application of line transect method is dealt in detail by Burnham et al., (1980) and Buckland et al., (1993).

The study area was stratified into two major vegetation types, teak associated forest and miscellaneous forest. Densities of wild prey species were estimated for both the major vegetation types separately and for the whole study area. The total area of the two vegetation types was not known. Hence roughly equal sampling effort was put in laying transects in each vegetation types. Fourteen transects, with a total of 28.4 km were laid in two habitats, eight in teak associated forest and six in miscellaneous forest. The transects were laid down randomly in the study area (Fig 2.). But each transect was laid in such a way that it's entire length falls in one vegetation type only. The length of individual transects varied from 1.2 km to 2.7 km. The total length of true replicates in each of the habitats was 15.2 km in teak associated forest and 13.4 km in miscellaneous forest. The riverine areas and *Cleistanthus collinus* dominant patches were not sampled because of small patch size and difficulty to reach these areas for sampling.

All the transects were walked sixteen times (by me and my assistant), eight times each during morning and evening, resulting in 457.7 km of transect walk spread over two seasons. The total length of transects walked in each vegetation type was 243.2 and 214.4 km in teak associated and miscellaneous forest respectively. The transects were walked early morning and late afternoon during first and last three hours after sunrise and before sunset respectively when the animals were most active (Schaller 1967). On the transects all the tiger prey species were counted. For each cluster of prey animals encountered on the transect, the following parameters, namely, species, sighting angle (with a compass), sighting distance (visually estimated), cluster size, sex and age class of the individuals (Schaller 1967) (whenever it was possible to classify them) were recorded.

The density of all prey species were calculated using Distance program *Version 3.5* (Laake et al., 1998). The analysis involved fitting of different models based on detection function to the observed data for the estimation of densities. A robust model is the one which can fit with a number of different observed data sets. The best estimate was then taken for the model which gave the lowest Akaike Information Criteria (AIC) values and lowest percent coefficient of variation (%CV) (Burnham et al., 1980; Buckland et al., 1993).

Since the sighting distances on transects were estimated visually, there was a chance of bias in estimation due to heaping (Buckland et al., 1993). Hence, the distance data was analysed again after grouping into different class intervals. This was then compared with the density estimates results obtained from ungrouped distance data.

3.2. Estimation of tiger diet.

Feeding ecology of carnivores are usually studied using different methods like observation in the field, stomach content analysis, identifying kills and scat analysis (Reynolds and Aebischer 1991) . But the scat analysis was found to be the most suitable method for the present situation since it is non invasive and cost and time effective method

(Schaller, 1967; Kruuk, 1972; Sunquist, 1981; Johnsingh, 1983,1993; Karanth & Sunquist, 1995). Field conditions does not allow locating all possible kills made by tiger, which ideally would have given the best estimate of the animals diet. This leads to the inherent bias in kill data by under estimating the utilization of smaller prey, since smaller prey kills will be consumed faster and are less likely to be located than that of larger ones (Sunquist 1981, Johnsingh 1983, Karanth & Sunquist 1995).

Scat analysis was used for estimating the proportion of intake of prey species by tiger. This was done in the following stages.

3.3.1 Collection of scats:

Tiger scats were collected whenever encountered in the study area. For each of the tiger scat collected the following information were recorded - date, time, location (as precise as possible w.r.t. any land mark), habitat (vegetation type), forest compartment number, approximate age of the scat (in number of days), diameter at the thickest portion (by means of vernier callipers), number of segment and dry weight of the scat. Pugmarks and any associated signs like scratching, scrapes were also recorded whenever encountered along with the scat.

Scats were then washed with water, holding over sieve. Any remains of bones, quills, teeth or other undigested body parts of the prey species were separated and the information was recorded. Washed hair were then sun dried and kept in ziplock bags with naphthalene for further analysis.

3.3.2 Identification of scats:

Tiger scats were identified from other predators especially leopard by the size of the scat and by the presence of associated evidences like pugmarks and size of the scrape (Johnsingh, 1983; Sunquist, 1981; Karanth & Sunquist 1995). Tiger scat was found to be less coiled and having larger distance between two

successive constrictions within a single piece of scat, when compared to leopard which were mostly coiled and have smaller distance between constrictions (personal observation). Though evidence of tiger tracks were found on very few occasion along with the scats, but whenever found these conditions also seem to hold. Tiger and leopard scat were mostly found deposited in one place on the side or middle of the road on grass strips, while that of wild dogs were mostly deposited on the bare soil of the road (Johnsingh, 1983; Sunquist, 1981; Karanth & Sunquist, 1995). Scats, which couldn't be accorded definitely to tiger, were excluded from the analysis.

3.3.3 Identification of prey remains from scats:

Hair from scats were used for identification of prey remains, because it passes undigested through the gut and can be used for species identification (Sunquist, 1981; Karanth & Sunquist, 1995; Mukherjee *et al.*, 1994a, 1994b). Hair from each of the washed scat was mixed up thoroughly and then 20 hair were picked up randomly for analysis. These were washed in xylene and then mounted in DPX to make permanent slides. These slides once dried were then examined under a binocular compound microscope. The hair of the prey species were compared with the reference slides maintained in the Wildlife Institute of India laboratory based on the following structural features described by Mukherjee *et al.*, (1994b).

1. Hair width,
2. Medullary structure,
3. Medullary width/ hair width ratio.

Quantification of the diet was done based on the scat analysis by calculating percent occurrence i.e., number of times a specific item was found as percentage of all the item found (Ackerman *et al.*, 1984; Floyd *et al.*, 1978).

3.3.4. Information on kills

Information on kills were collected during the period of study. Kills were located using odor, call and flight patterns of jungle crows (vulture activities were found to be very low in the study area). Whenever a kill was encountered information was collected on the following aspects: species, sex and age class, freshness of the kill (from the presence of flies, maggots), method of killing (whenever the kill was fresh), feeding method of predator, carcass utilization (%), presence of any symptoms of disease or injuries before the kill was made, bone marrow condition, both color and texture (Riney 1982). The identification of the predator killing the prey was deduced from the presence of tracks, scrape, scats, feeding method, prey size and caching behavior (Karanth & Sunquist 1995). The lower jaw of killed prey species were collected whenever possible and later aged according to the criteria listed by Schaller (1967).

3.4. Estimation of biomass and number of prey consumed by tiger from scat analysis, using a correction factor

Frequencies of the identifiable prey remains in the scat don't tell us about the actual proportion of prey type eaten. This is more so when the prey types varies in size to a considerable degree. Smaller prey species, having more amount of undigested material (i.e., hair) due to higher body surface to mass ratio. Hence, intake of smaller body sized prey induces relatively more amount of scats production per unit mass of prey consumed leading to an over estimation of smaller prey species in the diet studies of carnivores (Ackerman *et al.*, 1984; Floyd *et al.*, 1978).

Correction factor developed by Ackerman *et al.* (1984), from feeding studies on cougar (*Felis concolor concolor*) was used to estimate the relative proportion of biomass of prey consumed by tigers. Application of this regression equation for tigers involves assuming similar carcass utilization and comparable digestive system of cougars with Tigers (Karanth & Sunquist 1995).

The regression equation developed on cougars is :

$$Y = 1.980 + 0.035 X,$$

where Y = kg of prey consumed per field collectible scat; X = Average weight of an individual of a particular prey type (Ackerman *et al.*, 1984). The equation was used as follows:

1. The average weight (X) of individuals of each prey type was collected from available literature Karanth & Sunquist (1995) and Khan *et al.*, (1995)
1. Solving the equation for Y gave the number of kg of prey per collectible scat for each prey type.
2. Multiplying each Y by the number of scats found for each species from the total no. of scats analyzed gave the weight of each type of prey fed on.
3. This was then computed for percentage contribution of different prey to tiger diet in terms of biomass.

3.5. Estimation of prey selectivity

Prey selectivity by tigers was estimated for each prey species by comparing their availability and utilization data. The expected proportion of scats in the environment (i.e. availability) was calculated using the following equation (Karanth & Sunquist 1995)

$$f_i = \{ (d_i / d_t) * \lambda_i \} / \Sigma \{ (d_i / d_t) * \lambda_i \}, \text{ where}$$

f_i = the expected scat proportion in the environment,

d_i = density of the i th species,

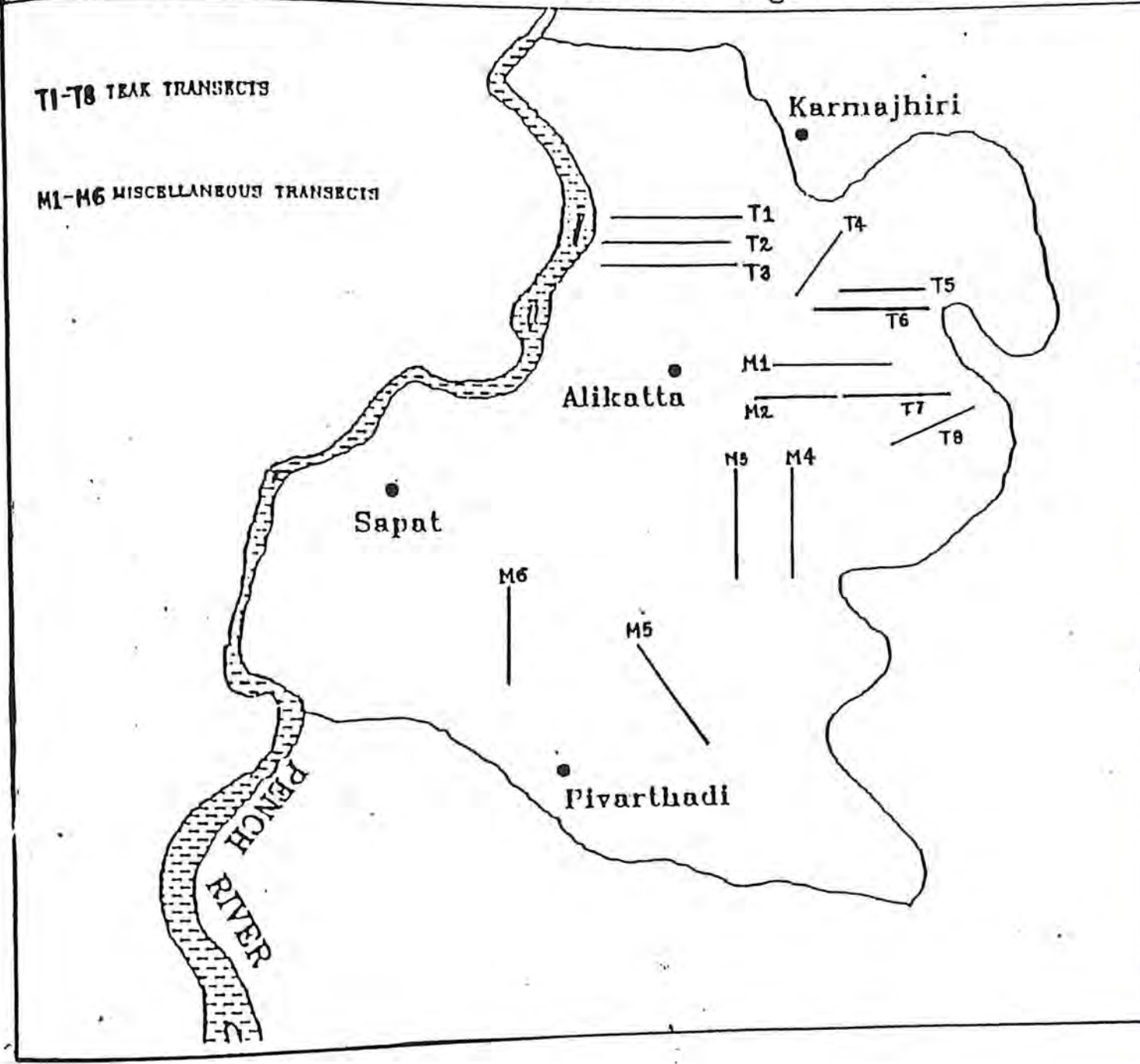
$$d_t = \Sigma d_i,$$

$\lambda_i = X/Y$ = the average number of collectible scats produced by tiger from an individual of /
th prey species.

For the full form of X and Y, refer to the previous section 3.4.

The utilization data was obtained from the results of scat analysis. The availability and utilization data was then compared by G test (Zar 1984). Once a significant difference was found Bonferroni's confidence interval was calculated (Byers & Steinhorst 1984). This was to find out which of the prey species were utilized more or less than it's availability.

Fig 2. Intensive study area (eastern block) showing location of transects in Pench Tiger Reserve



4. RESULTS

4.1. Availability of prey species:

The prey density was estimated for chital, sambar, common langur, wildpig, nilgai and gaur (Table 1 to 6). For the first three species the number of sightings of group and individuals recorded were enough for satisfying the minimum sample size criteria of distance sampling (Buckland et al., 1993); chital (groups=975 & individuals=3349), sambar (groups=140 & individuals=239) and common langur (groups=454 & individuals=2718). Sightings of groups and individuals in case of wild pig, nilgai and gaur were very low ; wild pig (groups=24 & individuals=101) nilgai (groups=11 & individuals=21) and gaur (groups=4 & individuals=21).

All the density estimates were done after 10% truncation of the farthest sighting data from line transect. This was done as suggested by Buckland et al., (1993) for distance estimation. Since this helps in better density calculation by omitting the outliers and also helps in better model fit.

While estimating density of prey species for the study area, uniform key function with cosine adjustment gave best fit for all the species, except chital. For chital it was negative exponential key function with cosine adjustment which was the best fit. For group densities of these species, negative exponential with hermite polynomial was the best fit for chital and uniform with cosine adjustment for the rest.

Along with estimating prey density in the overall study area, density estimates were done separately for chital, sambar and common langur in teak associated and miscellaneous forests. This revealed that chital, sambar and common langur had higher densities in miscellaneous forest than teak associated forests. Uniform with cosine adjustment gave the best estimate for chital in both the vegetation types and for common langur in teak associated forest. The same was achieved for common langur in miscellaneous forests by half-normal with cosine adjustment. For sambar negative exponential adjusted for hermite polynomial and cosine gave the lowest AIC

value for teak associated and miscellaneous forests respectively. The details of density estimate by other models are summarized in the Appendix.

Density estimation of prey species after grouping the observations into distance classes didn't give any considerable difference in terms of better density estimate or model fit except for some improvement in case of nilgai and gaur (See Table 1 and 2 in Appendix 1). Hence, the results of ungrouped data were used for subsequent analysis.

4.1.1. Chital :

Chital was found to be the most abundant prey species in the study area with a density of 80.75 animals/ km² (%C.V.= 8.61) and the group density was 27.35 groups / km² (%C.V.= 8.42). The average group or cluster size was found to be 3.44 animals. Chital individual and group densities were of the order 54.12 animals/km² (% C.V.=9.04) and 18.26 groups/km² (% C.V.=7.77) in the teak forests, while 94.27 animals/km² (% C.V.=8.53) and 30.08 groups/km² (%C.V. =7.48) in miscellaneous forests. The average group size of chital in both the forest types was similar, being 3.25 and 3.54 animals for teak and miscellaneous forests respectively.

4.1.2. Sambar :

Sambar density for the study area was estimated to be 6.09 animals/km² (% C.V =9.57) with the group density of 3.5 groups/km² (% C.V =8.42). The estimated mean group size of sambar was 1.7 animals. Sambar also showed higher density in miscellaneous forest than teak associated forests. For teak associated forests and miscellaneous forests sambar densities were 5.49 animals/km² (% C.V. =14.65) and 9.24 animals/km² (% C.V.=18.79) respectively. While the group densities were 1.65 groups/km² (% C.V. =12.77) and 5.1 groups/km² (% C.V. =17.83) in teak associated forest and miscellaneous forests respectively. The average group size of sambar

didn't vary between habitats with 1.65 and 1.73 groups/km² in teak and miscellaneous forests respectively.

4.1.3. Common langur :

Common langur came next to chital in terms of abundance, with individual and group density of 77.16 animals/km² (% C.V.= 8.42) and 12.25 groups/km² (% C.V.=6.83) respectively. The mean group size was 6.12. Common langur numbers like chital increased drastically from teak associated to miscellaneous forests. It was 59.07 animals/km² (% C.V. = 11.74) in teak associated forests and 90.95 animals/km² (% C.V. =11.81) in miscellaneous forests. The group densities were similar, being 12.77 groups/km² (% C.V. =12.84) and 12.5 groups/km² (% C.V. =9.61) in teak and miscellaneous forests. The average group size ranged from 5.56 in teak associated to 6.66 animals in miscellaneous forests.

4.1.4. Other prey species :

Density estimate for the rest of the animals showed very low individual and group densities. In case of densities of nilgai, wild pig and gaur they were 0.22 (% C.V.= 22.51), 2.59 (% C.V.= 25.92), and 0.34 animals /km² (% C.V.= 38.12) respectively. Group densities for the above three species in the same order were 0.12 (%C.V.=4.67), 0.7 (% C.V.= 17.73) and 0.07 groups/km² (% C.V.=4.67) respectively. The average group size was 1.75 for nilgai, 2.3 for wild pig and 4.75 animals for gaur.

4.2. Composition of the tiger diet

The results of the tiger scat analysis was interpreted in terms of percent occurrence (number of times a specific item was found as percentage of all item found) (Ackerman et al., 1984). All together 96 prey items were found in 72 tiger scats samples. Scat analysis data showed a high preponderance of medium to large sized ungulates in the diet of the tiger. Chital, sambar and wild pig together constituted 88.5 % of the prey taken by tiger. Out of this chital constituted 52.08%,

followed by sambar and wild pig with 20.83% and 15.63% respectively. Where as nilgai, gaur, muntjac constituted 5.2%, 12.1% and 1.04% respectively. 3.13% of the items could not be identified (Tab 7, See Fig. 4.1). Out of 72 scat analyzed one-third of them had more than one prey items (n=24). Common langur remains was not found in tiger scats.

Biomass contribution of different prey species to the diet of tiger as described by Ackerman et al., (1984). The average weight of prey species required for biomass estimation was taken from Karanth & Sunquist (1995) & Khan et al., (1995). This showed that though in terms of number, chital (52.08%) contributes two and half times more than sambar (20.83%) to the tiger diet, interms of biomass contribution both contributes equally (38%). Together these two species contributed to 78.7% of the tiger prey biomass. (See Tab 8. Fig 4.2)

4.3. Estimation of prey selectivity

When a G test (Zar 1984) was done to compare between the expected and observed frequency of scats it was found that tigers were preying selectively in the study area ($G = 63.14_{,0.05 \text{ df } 4}$, $P < 0.001$). Subsequent calculation of Bonferroni confidence intervals showed that chital were preyed upon significantly less when compared to their availability while sambar and wild pig were preyed upon more often than expected. Gaur and nilgai were consumed in proportion to their availability (table 9)

4.4. Kill data

Very few kills were located (n= 8) during the study period (table 10). High vegetation cover, very low scavenger activity and time and mobility constraints made it difficult to locate kills in the study area. Available kill data was not sufficient enough to comment reliably about the predation pattern of tigers in the study area (See table 10).

Out of the eight kills found six of them were of chital and the rest two were of sambar. Of the six chital kills found one was a yearling (sex not known), one adult female and the rest were adult males. Both the sambar kills were adult males. Four kills each were located in miscellaneous and teak associated forests. Kill findings were also found to be biased towards the larger sized prey individuals.

Table1. Crude density of individuals of the prey species in the overall study area Pench N.P. (December 1998 to April 1999).

Species	No. of Observation	Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF
Sambar	239	Uniform-Cosine	1014.8	6.09	4.9	7.4	9.57	0.796	17
Chital	3349	Negative Exponential-Cosine	7124.8	80.75	66.8	97.6	8.61	0.772	11
Common langur	2718	Uniform-Cosine	3166.4	77.16	63.9	93.0	8.42	0.43	10
Nilgai	21	Uniform-Cosine	100.87	0.22	0.14	0.34	22.51	0.132	11
Wild Pig	101	Uniform-Cosine	172.67	2.59	1.5	4.3	25.92	0.524	41
Gaur	21	Uniform-Cosine	32.954	0.34	0.10	1.08	38.12	1	3

* Only the results of the best-fit models are summarized. ** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively. See Appendix 2 for details.

Table2. Crude density of groups of the prey species in the overall study area
Pench N.P. (December 1998 to April 1999).

Species	No. of Obs.	Model*	AIC	DC /km ²	LCL	UCL	M.C.S	% CV	P**	DF
Sambar	140	Uniform-Cosine	1014.8	3.5	2.9	4.23	1.7	8.42	0.796	10
Chital	975	Negative Exponential Hermite Polynomial	7124.8	27.35	22.8	32.8	3.44	8.04	0.772	9
Common langur	454	Uniform-Cosine	3166.4	12.25	10.3	14.6	6.12	6.83	0.43	5
Nilgai	11	Uniform-Cosine	100.87	0.12	0.22	0.07	1.75	4.67	0.132	1
Wild pig	24	Uniform-Cosine	172.67	0.70	0.48	1.01	4.23	17.73	0.524	22
Gaur	4	Uniform-Cosine	32.954	0.071	0.04	0.13	4.75	4.67	1	1

* Only the results of the best-fit models are summarized. ** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DC = Density of groups. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively. M.C.S. = Mean cluster size. See Appendix 2 for details.

Table 3. Ecological density of individuals of chital, sambar and common langur in teak associated forest in Pench N.P. (December 1998 to April 1999).

Species	No. of obs.	Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF
Chital	1275	Uniform-Cosine	2821.5	54.12	42.14	69.52	9.04	0.175	4
Sambar	114	Uniform-Cosine	478.53	5.49	4.066	7.43	14.65	0.154	23
Common langur	1240	Hazard Rate-Cosine	1559.9	59.07	45.66	76.43	11.74	0.057	11

* Only the results of the best-fit models are summarized. ** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively. See Appendix 2 for details.

Table 4. Ecological density of groups of chital, sambar and common langur in teak associated forest in Pench N.P. (December 1998 to April 1999).

Species	No. of obs.	Model*	AIC	DC /km ²	LCL	UCL	M.C.S.	% CV	P**	DF
Chital	390	Uniform-Cosine	2821.5	18.26	25.5	13.1	3.25	7.77	0.175	2
Sambar	67	Uniform-Cosine	478.53	3.21	2.44	4.22	1.65	12.77	0.154	14
Common langur	225	Negative Exponential-Cosine	1560.8	12.77	9.72	16.8	5.56	12.84	0.036	15

Only the results of the best-fit models are summarized. ** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DC = Density of groups. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively. M.C.S. = Mean cluster size. See Appendix 2 for details.

Table 5. Ecological density of individuals of chital, sambar and common langur in miscellaneous forest in Pench N.P. (December 1998 to April 1999).

Species	No. of obs.	Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF
Chital	2074	Uniform-Cosine	4316.3	94.27	65.35	136	8.53	0.372	2
Sambar	125	Negative Exponential-Cosine	539.68	9.24	6.34	13.47	18.79	0.805	37
Common langur	1478	Half normal-Cosine	1602.7	90.95	69.69	118.69	11.81	0.416	9

* Only the results of the best-fit models are summarized below. ** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively. See Appendix 2 for details.

Table 6. Ecological density of groups of chital, sambar and langur in miscellaneous forest in Pench N.P. (December 1998 to April 1999).

Species	No. of obs.	Model*	AIC	DC /km ²	LCL	UCL	M.C.S.	% CV	P**	DF
Chital	585	Uniform-Cosine	4316.3	30.08	11.65	77.71	3.54	7.48	0.372	1
Sambar	73	Negative Exponential-Cosine	539.68	5.10	3.56	7.32	1.73	17.83	0.805	31
Common langur	229	Half normal-Cosine	1602.7	12.5	9.58	16.31	6.66	9.61	0.416	4

* Only the results of the best-fit models are summarized. ** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DC= Density of groups of animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively. M.C.S. = Mean cluster size. See Appendix 2 for details.

Table 7. Percent occurrence of prey items in 72 tiger scats collected in Pench N. P. from Dec 1998 to Apr 1999.

Species	Frequency of occurrence	
	No. of scats	Percentage
Chital	50	52.08
Sambar	20	20.83
Wild pig	15	15.63
Nilgai	5	5.21
Gaur	2	2.1
Muntjac	1	1.04
Unknown	3	3.13

Table 8. Contribution of different prey species in terms of biomass to the tiger diet in Pench N. P. from Dec 1998 to April 1999.

Species	Avg. wt (kg)	No. of scats	Percentage of prey biomass
Chital	55	50	38.5
Sambar	212	20	38.2
Wild pig	38	15	9.8
Nilgai	184	5	8.3
Gaur	287	2	4.74
Muntjac	20	1	0.53

Tab 9. Percent availability of the major prey species and their utilization by tigers in Pench N. P. from Dec 1998 to April 1999.

Species	Availability	Utilization	LCL*	UCL*	Remarks
Chital	88.11	56.85	44.1	69.6	Utilized less than availability
Sambar	10.68	21.58	11.0	32.2	Utilized more than availability
Wild pig	2.31	14.38	5.3	23.4	Utilized more than availability
Nilgai	0.37	4.31	0.0	9.6	Utilized in proportion to availability
Gaur	0.62	2.87	0.0	7.2	Utilized in proportion to availability

$G_{(0.05, df 4)} = 63.14$, $P < 0.001$. * LCL & UCL = Bonferroni's lower and upper confidence.

Tab 10. Tiger kills (n=8), found in Pench N.P. from December 1998-April 1999.

Date	Vegetation type	Terrain	Species	Sex	Age class (*)	Physical condition
30.12.98	Teak dominant, bamboo	Hill slope	Sambar	M	Adult, c3 H (IV)	Good
15.1.99.	Miscellaneous	Hill slope	Chital	M	Adult, c3 V	Good
14.2.99.	Miscellaneous	Stream slope	Sambar	M	Adult, c3 H	Na
21.2.99.	Teak dominant	Flat	Chital	M	Adult, c2 V (VI)	Na
18.3.99.	Miscellaneous	Flat	Chital	M	Adult, c3 H (VII)	Good
8.4.99.	Miscellaneous	Flat	Chital	Na	Yearling (II)	Na
10.4.99.	Teak dominant	Flat	Chital	M	Adult, c3 H (VIII)	Na
11.4.99.	Teak dominant	Flat	Chital	F	Adult, (IX)	Na

Na – information not available. H= hard antler, V= antler in velvet, M= male, F= female. (*) the age class as determined from lower jaw (Schaller, 1967).

Figure 4.1. Percentage occurrence of different prey items in 72 tiger scats in Pench N.P.

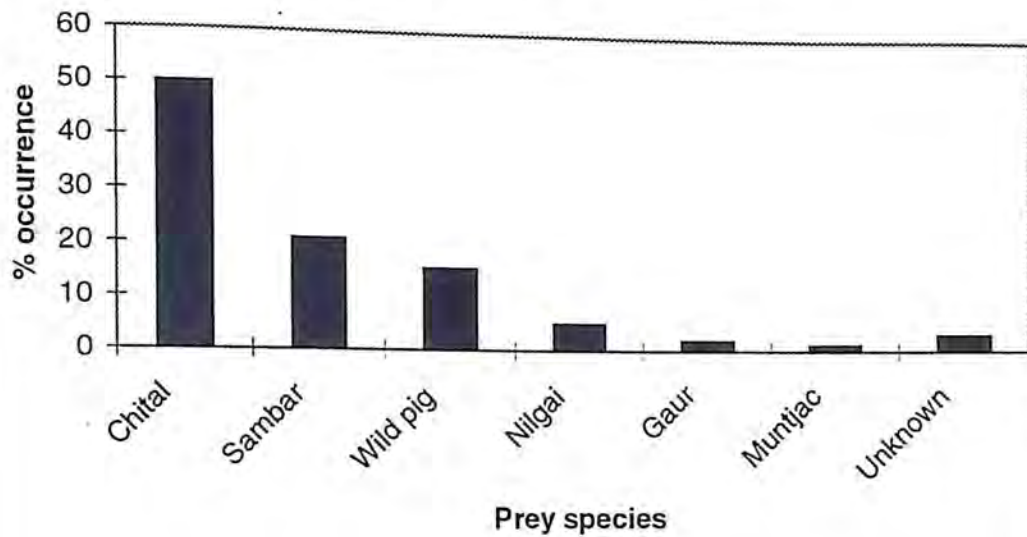
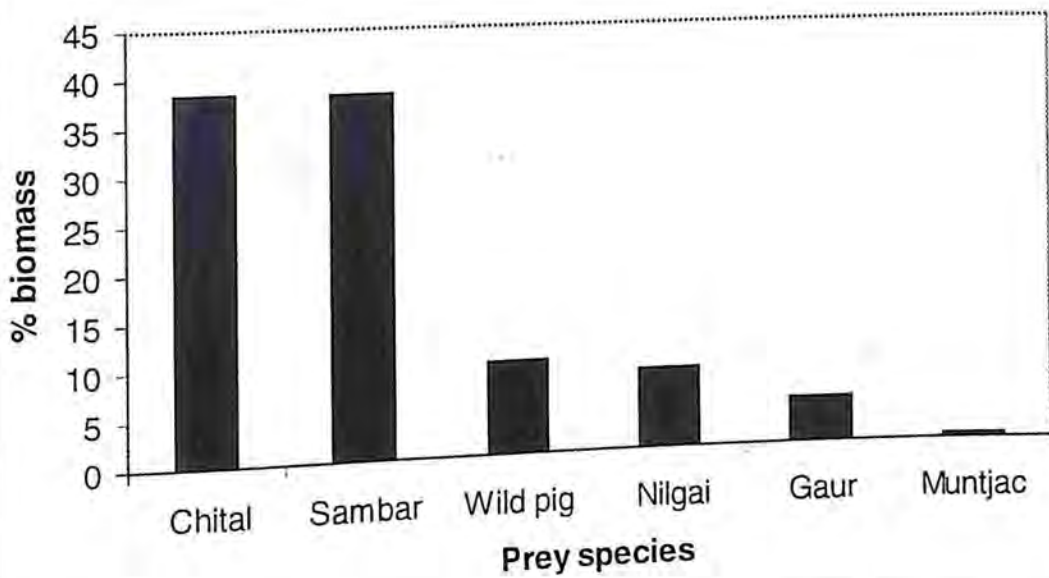


Figure 4.2. Contribution of different prey species in terms of biomass to the tiger diet in Pench N.P.



5. DISCUSSION

5.1. Availability of prey species

Chital was the most abundant wild ungulate species in Pench. When chital crude density estimate from Pench National Park was compared with other areas like Nagarahole (Karanth & Sunquist, 1995), Bandipur (Johnsingh 1983) and Chitawan (Seidensticker 1976), it was found to have much higher densities than these areas. But comparing ecological density of chital with the above mentioned area showed similar pattern in densities. In Pench the ecological densities estimated for chital ranged from 54.12 animals/km² in teak associated forest to 94.27 animals/km² in miscellaneous forest. Some of the areas with similar range of ecological densities were Gir - 43.7 to 133.9 animals/km² (Khan et al., 1996), Royal Bardia National Park, Nepal – 27.5 to 803 animals/km² (Stoen 1994), Nagarahole 38 to 76 animals/km² (Karanth 1993). Pench was a mosaic of woodland forest of different ages with small open grassy patches. These were spread over the entire park from low areas to higher ones. This kind of interspersion of habitats was very much utilized by chital, an ecotone species and utilizes both forest and grassy patches (Schaller 1967, Eisenberg & Seidensticker 1976). During the summer months chital herds, often in high numbers were sighted close to the Pench River. In teak associated forest presence of moist nallahs, which though didn't have water but provided forage for them. Miscellaneous forest on the other hand, had higher densities of chital, probably due to high forage availability in overall. Chital in the park used hilly terrains less frequently.

Sambar densities were higher in Pench. When compared to other areas like Chitwan (2.9 sambar/km²) (Seidensticker 1976), Nagarahole (4.2 sambar/km²) (Karanth & Sunquist 1995) and Gir (2.0 sambar/km²) (Khan *etal.*, 1996). But comparison with areas like Bandipur (8-9 sambar /km²) (Johnsingh 1983) and

Mudumalai (6.61sambar/km²) (Varman & Sukumar, 1995) shows comparable densities of sambar. Sambar is the largest deer of Asia (Eisenberg & Seidensticker 1976) and is distributed over a wide range of forest, rainfall and altitudinal conditions (Eisenberg & Lockhart 1972). The difference in the sambar density in similar dry deciduous habitats like Gir might be explained by annual rainfall pattern in Gir and Pench (Khan *et al.*, 1995). The annual rainfall in the above two areas in the same order were 1000mm and 1400mm respectively. Eisenberg & Seidensticker (1976) proposed that with other factors remaining similar, ungulate biomass increases with an increase in rainfall regime due to higher plant productivity. Bandipur and Mudumalai with similar sambar densities is probably because of similar or higher rainfall patterns, similar forest composition. Sambar is predominantly a browser and has evolved in forest environment (Eisenberg & Lockhart 1972). Its abundance in any particular area probably is limited by the dispersion of the shrub species in the forest and the phenophase they are under going at any particular time. In Pench most of the teak associated forest had reasonably good understorey due to the availability other tree species. While the miscellaneous forests with a much opener canopy probably has higher shrub productivity than teak associated forest. This might be a factor leading to the higher observed densities of sambar in miscellaneous forest.

Nilgai occur in the study area in low densities. Nilgai, because of choice for open habitats were rarely sighted on transects walks. This had probably resulted to underestimation of nilgai density in the area. During the winter they were more sighted in the open areas, close to roads and in areas where a village was recently relocated. In summer, nilgai were more often sighted inside forest.

Gaur, the largest of the wild cattle is more of a forest dwelling species, but also needs open grassy patches for foraging (Schaller 1967, Eisenberg & Seidensticker 1976). During the study gaur was mostly sighted in the teak associated forests and bamboo patches. In Pench National Park, teak associated forest were very important to gaur population especially, in summer they extensively debarked teak trees. The bark of the tree in summer is reported to be rich in different in essential mineral contents and moisture (Gaur Ecology Project, WII-Unpubl Report). The gaur population of the park mostly used my intensive study area during summer (mid February to April). In the park they used areas very selectively and mostly centered around water bodies during the summer, which probably led to low sightings on transects and consequently to lower density estimation for this species.

Wild pigs were found in both teak associated and miscellaneous forests. Though in winter there were very few sightings, wild pig activity increased drastically as summer approached, which the breeding time for this species (Prater 1980).

Common langur densities were higher in miscellaneous habitat because, these areas had more diverse tree associations and probably this provided various food resources to this folivorous primate.

Pench, thus offered a mosaic of ecological and habitat conditions, which effectively contributed to the maintenance of a rich assemblage of ungulates and primates in high numbers. Two more studies are available from Pench National Park, the same part of the park where I conducted my study (Acharya 1997, Karanth & Nichols 1998). These studies also support the general conclusion of my findings of high ungulate density in the park, though the individual estimates of wild ungulate densities vary.

5.2. Prey selection by tigers:

Predation is an ecological factor which pervades all levels of ecology, and understanding of it, increases considerably to our knowledge of habits and structure of animals (Curio, 1976). Predation includes searching, locating, pursuing and overcoming the prey by the predator (Dunstone & Gorman 1993). Cats are specialized predators, and enjoy much in common in terms of their morphology, physiology and behavior. (Sunquist & Sunquist 1989). Different factors like abundance of the prey species, temporal and spatial distribution, size, defenses, and anti-predator tactics in different ways constitute the ecological constraints on the predator (Sunquist & Sunquist, 1989). In addition, the distribution and abundance of hunting cover, climatic conditions, and the presence and abundance of congeners and other potential predators can also act as limiting factors .

For tigers in the Indian subcontinent, chital and sambar constitutes the main prey base wherever they occur in considerable numbers (Schaller 1967, Tamang 1979, Sunquist 1981, Johnsingh 1983, 1993, Johnsingh et al., 1993, Sankar et al., 1993, Stoen 1994, Karanth & Sunquist 1995). Apart from these two species, other species like wild pig, langur, gaur and nilgai are the other common prey species frequently preyed upon by tiger in this subcontinent.

From the present study it evident was chital and sambar constitutes the major prey species of tiger in the study area. Though numerically chital was the most preyed upon species they were still less utilized than their availability in the environment. Other studies from different parts of the subcontinent also support this findings (Schaller 1967, Johnsingh 1983, Stoen 1994, Karanth & Sunquist 1995). Chital gregariousness probably helps it to avoid predation, since group living species with their combined vigil are better at locating any approaching predator (Taylor 1976). The species liking of open flat areas also probably reduces the predation risk on the animal. Tiger probably like a typical ambush and stalk use the habitat

characteristics like horizontal cover and terrain as an important tool for stalking. In Chitawan once the grasslands were burnt, tiger's hunting success in these areas reduced drastically. This continued to be low until grasses went up again allowing successful stalking by tiger (Sunquist and Mishra Unpub). In lions in Africa, it was found that low grass height and featureless terrain effectively deterred them from successfully killing prey (Schaller 1972, Stander & Albon 1993). The teak associated forest in Pench had low grass growth and probably was not a favorite place for tiger to hunt. I could locate two adult male chital kills in teak habitat. But the cover around the place where kill was made was sparse. Probably in areas of dry deciduous forest like Pench, tigers carry out more successful predation in forested habitats during night (Stander & Albon 1993).

Another factor which might have reduced the chance of tiger predation on chital is because of their frequent association with common langurs. Though sambar and nilgai both were observed in association with langur, the number of times chital associated with langurs were far more higher than any other species. Langurs act in an effective way by keeping a strong vigilance on the surrounding area (Newton 1987).

Sambar in my area was preyed upon by tiger two and half times less than chital but it's contribution to the biomass of tiger prey species was equal to chital. Sambar occurs in much lower densities, when compared to chital and often is consumed more than their availability (Schaller 1967, Johnsingh 1983, Karanth & Sunquist 1995). In the study area, sambar were sighted more in miscellaneous than in teak associated forest. Sambar were also seen quite often in undulating tracks of the park. Thus sambar's preference of forested areas, undulating tracks and solitary mode of living probably increases its chance of encounter with tiger. This might have contributed to the observed increased predation by tiger.

Wild pig was found to be the third major prey in the study area and only second to sambar in terms of preference in tiger diet. They occur as an important prey item, after the larger deer species in most habitats where they occur with tiger. The sounders in the study area were on an average 5 to 10 animals. In the study area it was observed that females were generally in groups, while males were sighted alone more often. But more information is required to know how this grouping tendency affects the predation pattern of tiger on them

On other hand, gaur and nilgai were the two large bovids in the study area which were utilized in proportion to their availability by tigers.. Gaur has been found to be a preferred species in areas like Nagarahole (Karanth & Sunquist, 1995), where it occurs in much higher densities. Compared to Nagarahole, population of gaur in Pench is quite low and seasonally migrating within the forest in and around the park (Gaur Ecology Project, WII-Unpubl. Report). Apart from the density factor gaur constitutes a class size of prey which is difficult for a tiger to handle compared to the other medium to large sized ungulates.

Tracing back the evolutionary history, it reveals that the earlier divergence of the *tigris* line from the *Panthera* stock during the Pliocene radiation has occurred following the evolution of larger bodied forest/grassland ungulates (e.g., *Axis*, *Rusa*, *Cervus*, *Bos* and *Sus*) in southeast Asia (Flerov 1960, Geist 1971). We are unaware of tiger co-evolution as a predator with these ungulates in the evolutionary past. Hence at this stage it's difficult to say how much the evolutionary history tiger affects its predatory ability with respect to different prey species. Another important aspect of tiger predation, where our understanding still lacks is the estimation of actual prey availability from tigers point of view (Sunquist & Sunquist 1989). At any particular time the actual availability of a prey to the predator is a result of dynamic interaction of different ecological, behavioural and habitat factors (Sunquist & Sunquist 1989). Now with our present understanding we take prey density in a particular area as the

measure of availability. This does not give us an idea of actual prey availability at the time when the act of predation takes place, since different other ecological (excluding prey density), behavioural and habitat factors are not taken into account. Once these information becomes available our understanding of tiger predation dynamics will increase to a considerable extent.

In the study common langur predation by tigers were not documented. However in other areas common langur remains are reported from tiger scats (Schaller 1967, Johnsingh 1983, Sankar et al., 1993 Karanth & Sunquist 1995). Though no where common langurs are taken in terms of their proportionality. This total absence of predation on common langur needs to be further investigated. Domestic livestock in the study area were almost negligible in numbers and were not represented in the tiger scats from Pench.

5.3. Conservation and management importance:

Recent studies have proved beyond any doubt (Karanth & Sunquist 1995) that prey biomass is probably the most important prerequisite for a viable tiger population. With this context in mind Pench N.P. proves to be a very potential area for tiger conservation. Though my study a few comments can still be made regarding the usefulness of tiger conservation in Pench National Park.

1. Pench National Park has a very high biomass of tiger prey species as found by this study and two other earlier studies (Acharya 1997, Karanth & Nichols 1998).
2. The study showed high use of the area by tigers as inferred from their calls, scrape, pugmarks and scats.
3. The level of anthropogenic disturbance in the National Park was very low.

Thus Pench National Park can be considered as a potential area for tiger conservation. Continued conservation measures in this area by the Park authorities should be encouraged further. A long term project on tiger ecology in Pench Tiger Reserve is proposed to get a more detailed understanding of the prey-predator relationship and effective long term management of tigers.

REFERENCES

- ACHARYA, B.B. 1997. Habitat occupancy by wild ungulates in Pench Tiger Reserve, Madhya Pradesh. M.Sc. Dissertation. Saurashtra University, Rajkot (India).
- ACKERMAN, B.B., F.G LINDZEY. AND T.P. HERNKER. 1984. Cougar food habits in southern Utah. *J. Wildl. Manage.* 48 : 147-155.
- BUCKLAND, S.T., D.R., ANDERSON, K.P. BURNHAM, AND J.L. LAAKE. 1993. Distance Sampling: Estimating abundance of biological populations. Chapman and Hall, London.
- BURNHAM, K.P., D.R. ANDERSON, AND J.L. LAAKE, 1980. Estimation of density from line transect sampling of biological populations. *Wildlife Monographs.* 72.
- BYERS, C.R. AND R.K. STEINHORST. 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manage.* 48 : 3 : 1050-1053.
- CHAMPION, H. G. AND S.K. SETH. 1968. The Forest Types of India. Delhi: The Government of India press.
- CHESSON, J. 1978. Measuring preference in selective predation. *Ecology.* 59 : 211-215.
- CHUNDAWAT, R.S., N. GOGATE AND A.J.T. JOHNSINGH. 1999. Tigers in Panna : Preliminary results from an Indian tropical dry forest. Pgs 123-129. In J. Seidensticker, S. Christie and P. Jackson (eds). *Riding the tiger : Tiger conservation in human dominated landscapes.* Cambridge.
- CORBETT, G.B. AND J.E. HILL. 1992. The mammals of the Indo-Malayan region. Oxford Univ. Press, Oxford, England.
- ✓ CURIO, E. 1970. The ethology of predation. *Zoophysiology and Ecology.* Vol .7 Springer-

Verlag.

DUNSTONE, N AND M.L. GORMAN (EDS). 1993. Mammals as predators. Symposia of the Zoological Society of London. No. 65.

EBERHARDT, L.. L.. 1968. A preliminary appraisal of line transect. J. Wildl. Manage : 32: 82-88.

EISENBERG, J.F. AND J. SEIDENSTICKER 1976. Ungulates in Southern Asia : A consideration of biomass estimates for selected habitats. Biol. Conserv : 10 : 293-307.

EISENBERG, J.F. AND M. LOCHKART 1972. An ecological reconnaissance of Wilpattu National Park, Ceylon. Smithsonian Contribution to Zoology, 101: 1-118.

FLEROV, K.K. 1960. Fauna of U.S.S.R. Mammals: Musk Deer and Deer. Washington, D.C. : Israel Program for Scientific Translations.

FLOYD, T.J., L.D. MECH, AND P.J. JORDAN 1978. Relating wolf scat contents to prey consumed. J. Wildl. Manage. 42 : 528-532.

GAUR ECOLOGY PROJECT IN PENCH TIGER RESERVE, MADHYA PRADESH .
Progress Report : September 1997-July 1998. Wildlife Institute of India.

GEIST, V. 1971. The relation of Social Evolution and Dispersal in Ungulates during the Pleistocene, with emphasis on the Old World Deer and genus *Bison*. Quaternary Research. 1: 283-315.

GOGATE, N., AND R.S. CHUNDAWAT. 1997. Ecology of tigers to enable realistic projection of the requirement needed to maintain a demographically viable population in India. 2nd progress report . Wildlife Institute of India, Dehradun.

- JOHNSINGH, A.J.T. 1983. Large mammalian prey-predator in Bandipur. J. Bombay Nat. Hist. Soc: 80 :1-57.
- JOHNSINGH, A.J.T., S.P GOYAL,, G.S. RAWAT, , S. MUKHERJEE. 1993. Food habits of Tiger and Leopard in Rajaji National Park, North West India. Abstract presented at the International Tiger Symposium on the Tiger, 22nd to 24th February 1993 Delhi,.
- KARANTH, K.U. 1991. Ecology and management of tigers in Tropical Asia. Pg-156-159. In N. Maruyama, B. Bobek, Y. Ono, W. Regelin, L. Bartos and R.Ratcliffe (ed). Wildlife Conservation: Present trends and perspectives for the 21st Century. Japan Wildlife Research Center, Tokyo.
- KARANTH, K.U. 1993. Predator-Prey relationships among the large mammals of Nagarahole National park (India). Ph.D. Thesis. Mangalore University.
- KARANTH, K.U. AND J.D. Nichols. 1998. Estimation of Tiger densities in India using photographic captures and recaptures. Ecology, 79 : 8 : 2852-2862.
- KARANTH, K.U. AND M.E SUNQUIST,. 1992. Population structure, density and biomass of large herbivores in the tropical forests of Nagarahole (India). J. Trop. Ecol, 8 : 21-35.
- KARANTH, K.U. AND M.E. SUNQUIST. 1996. Prey selection by tiger, leopard and dhole in tropical forests. J. Anim. Ecol, 64 : 439-450.
- KHAN, J.A . R. CHELLAM, W.A. RODGERS AND A . J. T. JOHNSINGH. 1995. Ungulate densities and biomass in the tropical dry deciduous forests of Gir, Gujrat, India. J. Trop. Ecol : 12 : 149-162.
- KREBS, J.R. 1978. Optimal Foraging : Decision rules for predators. Pgs 23-63 In

- Behavioural Ecology (ed) J.R. Krebs and N.B. Davies. Sinauer Associates.
Sundeland.
- KUMAR, S. 1990. Management plan of Pench Tiger Reserve, Madhya Pradesh
1990-1995.
- LAAKE, J.L., BUCKLAND, S.T., ANDERSON, D.R. AND BURNHAM, K.P. 1994.
DISTANCE: User's guide. Colorado State University. Fort Collins
- MACARTHUR, R.H. AND E.R. PIANKA. 1966. On the optimal use of a patchy
environment. Am. Nat: 100: 603-609.
- MCDUGAL, C. 1977. The face of the tiger. Rivington Books, London.
- MUKHERJEE, S. S.P. GOYAL, AND R. CHELLAM. 1994a. Refined techniques for the
analysis of Asiatic Lion *Panthera leo persica* scats, Acta Theriologica. 39:4:425-430.
- MUKHERJEE, S., S.P. GOYAL, AND R. CHELLAM. 1994b. Standardization of scat
analysis techniques for leopard (*Panthera pardus*) in Gir National Park, Western
India. Mammalia, t.58. n 0 1: 139-143.
- NEU, C.W, C.R. BYERS. AND J.M. PEEK .1974. A technique for analysis of utilization-
availability data. J. Wildl. Manage. 38 : 3 : 542-545.
- NEWTON, P. 1987. The social organisation of forest hanuman langurs (*Presbytis
entellus*). Intl. J. Primatology. 8 : 199-232.
- # PACKER, C. 1986. The ecology of sociality in felids. In D.I. Rubenstein & R.W.
Wrangham, (eds). Ecological aspects of social evolution, Pgs.429-451. Princeton :
Princeton Univ. Press.
- PANWAR, H.S. 1979. Population dynamics and land tenures of tigers in Kanha National

- Park, Indian Forester (Special Issue) 18-36.
- # PERRY, R. 1964. The world of the tiger. London.
- PRATER, S. H. 1980. The Book of Indian animals . Bombay Natural. History. Society, Bombay.
- REYNOLDS, J.C. AND AEBISCHER, N.J. 1991. Comparison and quantification of carnivore diet by faecal analysis: a critique, with recommendations, based on the study of the Fox *Vulpes vulpes*. Mammal Review : 21: 97-122.
- RINEY, T. 1982. Study and management of large mammals. John Wiley & Sons Ltd, New York.
- RODGERS, W.A . AND H.S. PANWAR. 1988. Planning a Wildlife protected area Network in India (Vol I and II). Wildlife Institute of India.
- SANKAR, K., S.P. GOYAL, A.J.T.JOHN SINGH. 1993. Feeding ecology of tiger and leopard in Sariska Tiger Reserve. Abstracts presented at the International symposium of the Tiger, New Delhi, India.
- SCHALLER, G.B. 1967. The deer and the tiger : A study of Wildlife in India. University of Chicago Press, Chicago.
- SCHALLER, G.B. 1972. The Serengeti Lion : A Study of Predator-Prey Relations. Chicago: Univ. Chicago Press.
- SEIDENSTICKER, J. 1976. On the Ecological separation between tigers and leopards. Biotropica. 8 : 225-234.
- SEIDENSTICKER, J. 1976. Ungulate populations in Chitawan Valley, Nepal. Biol. Conserv. 10 : 183-209.

- SEIDENSTICKER, J. 1986. Large carnivores and the consequences of habitat insularization: ecology and conservation of tigers in Indonesia and Bangladesh. Pgs 1-41 in S.D. Miller and D.D. Everett, eds. Cats of the world: biology conservation and management. Natl. Wildl. Fed., Washington, D.C.
- SEIDENSTICKER, J. 1987. Bearing witness: observations on the extinctions of *Panthera tigris balica* and *Panthera tigris sondaica*. Pgs 1-8 in R.L. Tilson and U.S. seal, (eds).Tigers of the world: biology , biopolitics, management and conservation of an endangered species. Noyes Publ., Park Ridge N.J.
- SEIDENSTICKER, J. 1997. Saving the Tiger .Wildlife Society Bulletin. 25: 1 : 6-17.
- SEIDENSTICKER,J. AND C. MCDUGAL. 1993. Tiger predatory behaviour, ecology and conservation. Symp. Zool. Soc. Lond. 65 : 105-125.
- SEIDENSTICKER, J., S. CHRISTIE AND P. JACKSON (EDS).1999. Preface. Pgs - xv-xix. In Riding the tiger : Tiger conservation in human dominated landscapes. Cambridge.
- ✓SMITH, J. L.D. 1993. The role of dispersal in structuring the Chitawan tiger population. Behaviour: 124 : 165-195.
- SMITH, J.L. D., C. MCDUGAL AND M.E SUNQUIST. 1987. Female land tenure system in tigers. Pg 97- 109. In Ronald L. Tilson and Ulysses S. Seal (ed). Tigers of the World : TheBiology, Biopolitics, Management ,and conservation of an endangered species. Noyes Pub. New Jersey.

- STANDER, P.E. AND S.D. ALBON. 1993. Hunting success of lions in a semi-arid environment. Symp. Zool. Soc. Lond. 65 : 127-144
- STOEN, O. 1994. The status and food habit of the tigers (*Panthera tigris*) population in Kamal floodplain of Royal Bardia National Park, Nepal. M.Sc thesis. Agricultural University, Norway.
- SUNQUIST, M.E. 1981. The Social Organisation of tigers (*Panthera tigris*) in Royal Chitawan National Park. Smithsonian Contribution to Zoology, 336, 1-98.
- ✓ SUNQUIST, M.E. AND SUNQUIST, F. 1989. Ecological constraints on predation by large felids. Pg 283-301. In J.L.Gittleman (ed). Carnivore behaviour, ecology and evolution. Cornell University press, Ithaca, New York.
- SUNQUIST, M.E. AND H.R. MISHRA. (Unpub.) Habitat utilization and movement patterns of tigers and their prey: Implication for management and reserve design.
- SUNQUIST, M.E, K.U. KARANTH AND F. SUNQUIST 1999. Ecology, behaviour and resilience of the tiger and it's conservation needs. Pgs 5-18. In J. Seidensticker, S. Christie and P.Jackson (eds). Riding the tiger : Tiger conservation in human dominated landscapes. Cambridge.
- TAMANG, K.M. 1979. Population characteristics of the tiger and its prey. 23 pages. Unpublished paper presented at the International symposium of the Tiger, New Delhi, India.
- ✓ TAYLOR, R.J. 1976. Value of clumping to prey and the evolutionary response of ambush Predators. Am. Nat. 110 : 13-29.

VARMAN, K.S. AND R. SUKUMAR. 1995. The line transect method for estimating densities of large mammals in a tropical deciduous forest: An evaluation of models and field experiment. *J.Biosci*,20, 273-287.

WIKRAMANAYAKE, E., D. E. DINERSTEIN, J. G. ROBINSON, K.U. KARANTH, A. RABINOWITZ, D. OLSON, T. MATTEWS, P. HEDAO, M. CONNOR, G. HEMLEY, AND D. BOLZE. 1999. People, Tiger habitat availability, and linkages for the tiger's future. Pgs- 255-272. In J. Seidensticker, S. Christie and P. Jackson (eds). *Riding the tiger : Tiger conservation in human dominated landscapes*. Cambridge.

ZAR, J.H. 1984. *Biostatistical analysis*. 2nd Ed. Prentice-Hall, N.J.

Originals not seen.

APPENDIX 1

Table 1. Crude density of individuals of the prey species from grouped distance data in the overall study area (P.N.P.) (December 1998 to April 1999).

Species	No. of observations	Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF
Sambar*	239	Negative Exponential - Cosine	577.6	6.4	4.7	8.6	15	0.68	69
Chital *	3349	Negative Exponential - Simple Polynomial	3960.8	84.74	70.6	101.6	7.1	0.26	5
Common langur *	2718	Half-Normal - Cosine	1702.2	79.3	66.2	95.0	7.4	0.44	6
# Nilgai	21	Negative Exponential -Cosine	38.56	0.43	0.18	1.03	44	0.94	19
Wild pig *	101	Negative Exponential - Cosine	84.29	2.74	1.39	5.39	34.9	0.86	39
+ Gaur	21	Uniform-Cosine	14.88	0.18	0.07	0.48	39.5	0.5	4

* Only the results of the best-fit models are summarized. ** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively. See Appendix I for details.

* Distance class intervals used for sambar, chital, common langur and wild pig density estimate were all equal, 10m each.

Distance class intervals used for nilgai density estimate were 0, 21, 45, 75, 110, 155 m.

+ Distance class intervals used for gaur density estimate were 0, 21, 50, 85, 125 m.

APPENDIX 2

Table 1. Crude density of individuals of sambar in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	1015.8	5.91	4.7912	7.2819	10.06	0.552	20	
Uniform-Cosine	1014.8	6.09	4.9756	7.444	9.57	0.796	17	✓
Hazard Rate-Cosine	1017	6.47	4.5194	9.2654	18.23	0.765	45	
Negative Exponential-Cosine	1015.2	7.24	5.4461	9.627	14.32	0.826	61	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 2. Crude density of sambar groups in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	1015.8	3.41	4.1355	2.8089	8.97	0.552	13	
Uniform-Cosine	1014.8	3.5	4.2271	2.907	8.42	0.796	10	✓
Hazard Rate-Cosine	1017	3.76	5.3235	2.6527	17.65	0.765	84	
Negative Exponential-Cosine	1015.2	4.23	5.5474	3.2248	13.56	0.826	49	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 3. Crude density of individuals of chital in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Hermite Polynomial	7125.1	77.19	63.132	94.381	6.32	0.703	3	
Uniform-Simple Polynomial	7126.6	73.65	60.587	89.548	6.14	0.524	3	
Hazard Rate-Cosine	7127.3	77.25	63.665	93.738	8.97	0.61	13	
Negative Exponential-Cosine	7124.8	80.75	66.838	97.565	8.61	0.772	11	✓

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 4. Crude density of chital groups in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Simple Polynomial	7125.1	25.63	20.205	32.501	5.53	0.703	2	
Uniform-Cosine	7126.6	23.91	19.021	30.057	5.32	0.524	2	
Hazard Rate-Simple Polynomial	7127.3	25.52	21.206	30.714	8.43	0.61	11	
Negative Exponential-Hermite Polynomial	7124.8	27.35	22.806	32.794	8.04	0.772	9	✓

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 7. Ecological density of individuals of chital in teak forests (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Simple Polynomial	2821.7	56.32	43.632	72.698	9.21	0.223	4	
Uniform-Cosine	2821.5	54.12	42.138	69.521	9.04	0.175	4	
Hazard Rate-Cosine	2822.2	58.17	44.01	76.891	13.34	0.212	18	
Negative Exponential-Cosine	2819.5	61.87	48.102	79.595	10.95	0.319	8	✓

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 8. Ecological density of chital groups in the teak forests (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Simple Polynomial	2821.7	19.47	27.432	13.821	7.98	0.223	2	
Uniform-Cosine	2821.5	18.26	25.498	13.077	7.77	0.175	2	
Hazard Rate-Cosine	2822.2	20.11	26.276	15.392	12.52	0.212	14	
Negative Exponential-Cosine	2819.5	22.03	28.069	17.285	9.93	0.319	6	✓

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 9. Ecological density of individuals of chital in miscellaneous forests in P.N.P. (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	4317.6	98.53	75.833	128.01	10.21	0.405	5	
Uniform-Cosine	4316.3	94.27	65.351	136	8.53	0.372	2	✓
Hazard Rate-Hermite Polynomial	4319.5	98.64	76.041	127.94	10.66	0.246	6	
Negative Exponential-Cosine	4317.2	110.08	85.117	142.35	10.03	0.376	5	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 10. Ecological density of chital groups in miscellaneous forest in P.N.P. (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	4317.6	32.05	23.818	43.128	9.35	0.405	3	
Uniform-Cosine	4316.3	30.08	11.647	77.713	7.48	0.372	1	✓
Hazard Rate-Hermite Polynomial	4319.5	31.77	24.196	41.731	9.84	0.246	4	
Negative Exponential-Cosine	4317.2	38.02	28.432	50.829	9.15	0.376	3	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 11. Ecological density of individuals of sambar in teak forests in P.N.P. (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best fit
Half normal-Cosine	479.39	5.20	3.8366	7.0681	14.92	0.133	25	
Uniform-Cosine	478.53	5.49	4.066	7.4304	14.65	0.154	23	✓
Hazard Rate-Cosine	481.4	5.37	3.1321	9.2275	27.52	0.052	61	
Negative Exponential-Cosine	479.85	5.99	3.8734	9.2724	22.04	0.083	55	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 12. Ecological density of sambar groups in P.N.P. (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best fit
Half normal-Cosine	479.39	3.0451	2.3064	4.0204	13.09	0.133	15	
Uniform-Cosine	478.53	3.2103	2.4437	4.2174	12.77	0.154	14	✓
HazardRate-Cosine	481.4	3.1809	1.8848	5.3683	26.55	0.052	54	
Negative Exponential-Cosine	479.85	3.5599	2.3521	5.3878	20.78	0.083	44	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 13. Ecological density of individuals of sambar in miscellaneous forests in P.N.P. (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	540.54	6.93	5.1992	9.2577	13.51	0.7572	14	
Uniform-Cosine	540.6	6.95	5.3117	9.0995	12.12	0.7151	10	
Hazard Rate-Cosine	542.05	8.10	4.9953	13.16	24.54	0.5153	56	
Negative Exponential-Cosine	539.68	9.24	6.3361	13.477	18.79	0.8054	37	✓

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 14. Ecological density of sambar groups in miscellaneous forests in P.N.P. (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best fit
Half normal-Cosine	540.54	3.84	2.9192	5.0598	12.2	0.7572	9	
Uniform-Cosine	540.6	3.86	2.975	5.0014	10.64	0.7151	6	
Hazard Rate-Cosine	542.05	4.52	2.8169	7.2408	23.83	0.5153	50	
Negative Exponential-Cosine	539.68	5.10	3.5567	7.3192	17.83	0.8054	31	✓

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 15. Ecological density of individuals of common langur in teak forests in P.N.P. (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	1558.8	61.47	47.598	79.388	11.66	0.0713	11	✓
Uniform-Cosine	1559	61.46	47.493	79.545	11.76	0.0522	11	
Hazard Rate-Cosine	1559.9	59.07	45.66	76.429	11.74	0.0576	11	
Negative Exponential-Cosine	1560.8	64.89	48.102	87.539	14.64	0.036	26	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 16. Ecological density of common langur groups in teak forests P.N.P. (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best fit
Half normal-Cosine	1558.8	11.26	8.7013	14.584	9.32	0.0713	4	✓
Uniform-Cosine	1559	11.77	9.2358	14.997	9.45	0.0522	5	
Hazard Rate-Cosine	1559.9	10.48	8.226	13.344	9.43	0.0576	5	
Negative Exponential-Cosine	1560.8	12.77	9.725	16.774	12.84	0.036	15	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively..

Table 17. Ecological density of individuals of common langurs in miscellaneous forests in P.N.P. (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	1602.7	90.95	69.695	118.69	11.81	0.416	9	✓
Uniform-Simple Polynomial	1602.8	86.62	66.822	112.29	11.01	0.399	7	
Hazard Rate-Cosine	1605.3	96.98	69.787	134.78	16.22	0.277	30	
Negative Exponential-Cosine	1603.6	115.6	85.482	156.37	14.55	0.339	20	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 18. Ecological density of common langur groups in miscellaneous forest (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	1602.7	12.5	9.577	16.314	9.61	0.416	4	✓
Uniform-Simple Polynomial	1602.8	12.14	9.2319	15.956	8.61	0.399	3	
Hazard Rate-Cosine	1605.3	12.85	9.4691	17.43	14.7	0.277	20	
Negative Exponential-Cosine	1603.6	14.25	10.788	18.828	12.83	0.339	12	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 19. Crude density of individuals of nilgai in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best fit
Half normal-Cosine	101.74	0.294	0.15327	0.56484	32.04	0.183	20	
Uniform-Cosine	100.87	0.222	0.13635	0.36286	22.51	0.132	11	✓
Hazard Rate-Cosine	102.85	0.366	0.08002	1.6726	78.17	0.380	11	
Negative Exponential-Cosine	101.4	0.362	0.13833	0.94969	48.14	0.278	17	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 20. Crude density of nilgai groups in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	101.74	0.17	0.10419	0.28105	22.83	0.183	11	
Uniform-Cosine	100.87	0.12	0.06757	0.22149	4.67	0.132	1	✓
Hazard Rate-Cosine	102.85	0.21	0.04665	0.9438	74.53	0.380	9	
Negative Exponential-Cosine	101.4	0.22	0.09056	0.52475	41.01	0.278	10	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 21. Crude density of individuals of wild pig in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	173.09	2.54	1.503	4.3041	26.52	0.498	42	
Uniform-Cosine	172.67	2.59	1.5518	4.3471	25.92	0.524	41	✓
Hazard Rate-Cosine	174.63	2.79	1.1033	7.1022	47.9	0.565	28	
Negative Exponential-Cosine	172.68	2.82	1.3991	5.7211	35.83	0.432	37	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 22. Crude density of wild pig groups in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best fit
Half normal-Cosine	173.09	0.67	0.45734	0.98218	18.59	0.498	22	
Uniform-Cosine	172.67	0.70	0.4878	1.0119	17.73	0.524	22	✓
Hazard Rate-Cosine	174.63	0.82	0.34075	1.9645	43.91	0.565	20	
Negative Exponential-Cosine	172.68	0.84	0.46019	1.5494	29.91	0.432	22	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 23. Crude density of individuals of gaur in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DI /km ²	LCL	UCL	% CV	P**	DF	Best Fit
Half normal-Cosine	34.954	0.34	0.09227	1.2289	56.83		6	
Uniform-Cosine	32.954	0.34	0.10427	1.0872	38.12	1	3	✓
Hazard Rate-Cosine	36.954	0.34	0.10427	1.0872	38.12		3	
Negative Exponential-Cosine	34.954	0.34	0.05459	2.0767	80.63		5	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.

Table 24. Crude density of groups of gaur in the overall study area (P.N.P.) (December 1998 to April 1999).

Model*	AIC	DC /km ²	LCL	UCL	% CV	P**	DF	Best fit
Half normal-Cosine	34.954	0.071	0.01943	0.25865	42.41		3	
Uniform-Cosine	32.954	0.071	0.03915	0.12833	4.67	1	1	✓
Hazard Rate-Cosine	36.954	0.071	0.03915	0.12833	4.67		1	
Negative Exponential-Cosine	34.954	0.071	0.00923	0.54418	71.21		3	

** Chi-square goodness of fit p-value for model fit. AIC = Akaike Information Criteria. DI = Density of individual animals. DF = Degrees of freedom. LCL & UCL = 95 % Lower and upper confidence limit of density estimate respectively.