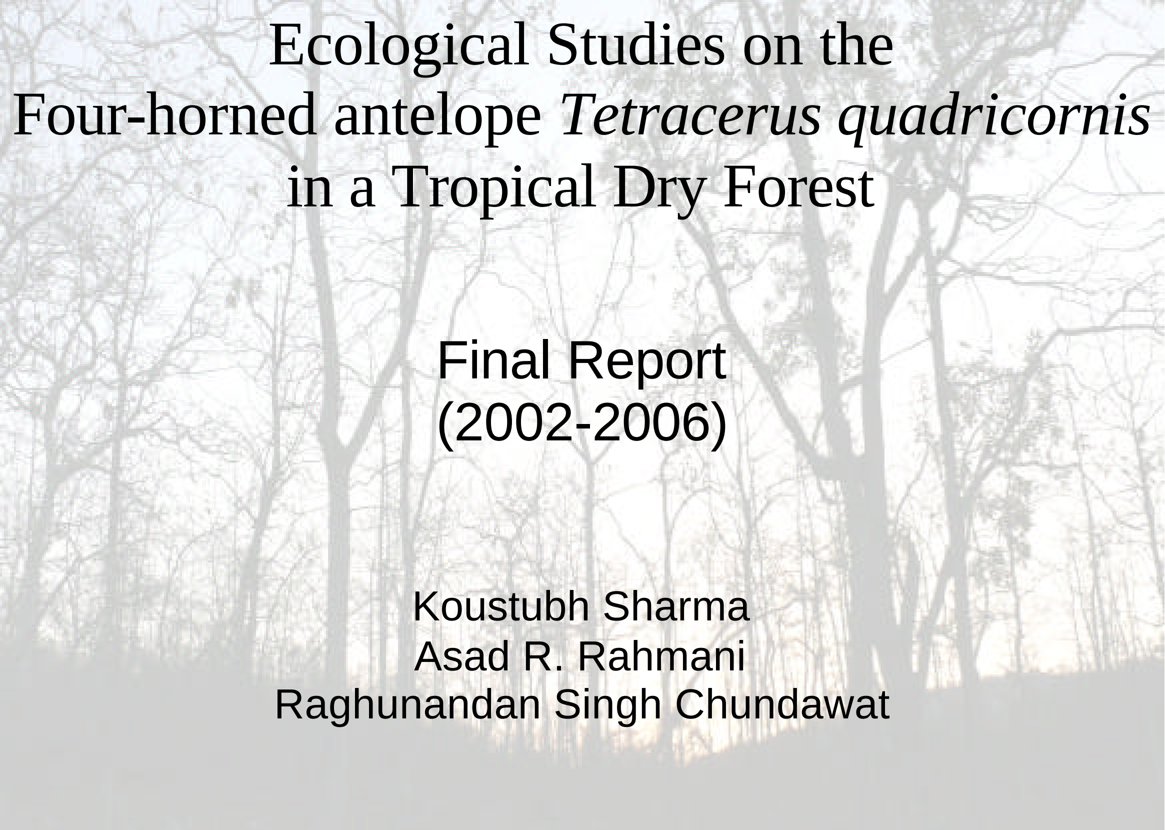

Ecological Studies on the Four-horned antelope *Tetracerus quadricornis* in a Tropical Dry Forest

Final Report
(2002-2006)

Koustubh Sharma
Asad R. Rahmani
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ECOLOGICAL STUDIES ON THE FOUR-HORNED ANTELOPE *Tetracerus quadricornis* IN A TROPICAL DRY FOREST

Final Report

(2002-2006)

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Cover photo: Left- Four-horned antelope male
Right- Four-horned antelope female

Photo credits: Koustubh Sharma

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CHAPTER I

Introduction

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INTRODUCTION

1.1 Mammals

The term mammal originates from the Latin word ‘mamma’--denoting milk glands. Mammals are a group of endothermic animals with backbones, who nurse their infants with milk. Their bodies are insulated by hair and they share a unique jaw articulation. They have a complex diversity in form and function, and individual flexibility of behaviour. There are some 5,500 species of mammals (including Humans), distributed in about 1,200 genera, 152 families and up to 46 orders, though this varies with various classification schemes.

Mammals are defined as a group of animals in which the early articular quadrate jaw joint has been superseded by a new articulation between the dentary bone of the lower jaw and the squamosal bone of the skull. About 300 million years ago during the Carboniferous period, ancestors of today’s mammals constituted a miniscule proportion when compared with the reptilian life forms. Synapsids, that can also be called as mammal-like reptiles, flourished and dominated the reptilian fauna of the Permian and early Triassic periods (280-210 million years ago). The dinosaurs usurped these synapsids during the Mesozoic Era (225-65 million years ago), but some inconspicuous mammal-like reptiles survived and evolved during the Triassic period (225-195 million years ago) into true mammals. In the late Cretaceous period, dinosaurs went into oblivion and modern mammals arose from a group called Cynodonts. These Cynodonts were mammal-like reptiles and dog-like predators, of the middle and late Triassic period. Mammals diversified into four main groups, i.e. Multituberculates (Allotherium), Monotremes, Marsupials and Placentals, during the Mesozoic Era. While Multituberculates got extinct during the Oligocene period, about 30 million years ago, the other three mammal groups are represented till date. Till lately, it was believed that the early mammals remained inconspicuously small and shrew-like throughout the Mesozoic Era and developed rapidly into larger forms only after the Cretaceous-Tertiary extinction event about 65 million years ago. Recent discoveries of about 130 and 165 million years old fossils show that there were terrestrial and aquatic mammals of the size of about a metre even in that era. Mammals took over the niches left vacant by the extinction of the dinosaurs in the Paleocene period (64-58 million years ago). While small rodent-like mammals dominated, many medium and large size mammals evolved during this period. In India, an already developed mammal fauna entered from humid tropics to oriental realm after northwards plate movements brought its north-east tip into contact with mainland Asia.

Classification of mammals is comprehensively revised recently by McKenna and Bell (1997). The McKenna/Bell hierarchical listing of all of the terms used for mammal groups above the species includes extinct mammals as well as modern groups, and introduces some fine distinctions such as legions and sublegions (ranks falling between classes and orders) that are likely to be glossed over by the layman. The class 'Mammalia' is classified into two sub-classes, i.e. Prototheria and Theriiformes. The sub-class Theriiformes is further classified into three infraclasses, of which Holotheria comprises of the live -bearing mammals and their prehistoric relatives. Of the Marsupialia and Placentalia cohorts, the Ungulata grandorder falls under the Epitharia magnorder. The Ungulata grandorder is further classified into four orders i.e. Tubulidentata, Eparctocyona, Meridiungulata and Altungulata. Members of the two orders, viz. Perissodactyla and Artiodactyla are called true ungulates and are differentiated from the subungulates i.e. Proboscidea, Sirenia and Hyracoidea orders (George, 1999). The even-toed ungulates come under the Eparctocyona mirorder, whereas the odd-toed (Perissodactyls), Elephants, Manatees and Hyraxes are classified under the mirorder Altungulata.

1.2 Phylogeny of Four-horned antelope

Ungulates comprise of several groups of mammals that use the tips of their toes to sustain their whole body weight while moving and are usually hoofed. Recent discoveries have indicated that whales and dolphins (Cetacea) are likely descendents of early artiodactyls (Sutera, 2000). In the even-toed ungulates or Artiodactyls, the third and fifth toes bear the whole body weight. About 220 Artiodactyl species are known today. The even-toed ungulates first appeared during the early Eocene (about 54 million years ago). The three major sub-orders, i.e. Suina, Tylopoda and Ruminantia developed by late Eocene (about 46 million years ago). The Ruminantia have been further classified into two infraorders, viz. Tragulina (Chevrotains) and Pecora (Moschidae, Cervidae, Giraffidae, Antilocapridae and Bovidae). All antelopes belong to the family Bovidae (Fig.1.1).

Today Bovids (Family Bovidae) are among the most widely dispersed and represented Artiodactyls with almost 140 species. They are native to all continents except Australia and Antarctica. They are mostly herbivores except few duikers, which are omnivorous (Macdonald, 1984). All bovids are known to have small cloven hoof, complex and well-developed molars that are well suited to grinding tough grasses into pulp, four-chambered stomachs and highly developed digestive system that enables them to regurgitate partly digested food, chew it again and extract the maximum benefit from it. They cannot directly digest cellulose but rely on stomach bacteria to break down cellulose by fermentation. Antelopes are a polyphyletic group of herbivores belonging to the family Bovidae, which is distinguished by a pair of hollow horns as cranial appendages and a light, elegant structure with small cloven hooves and short tails. Antelopes have no upper incisors and in order to tear grass stems and leaves, their lower incisors press

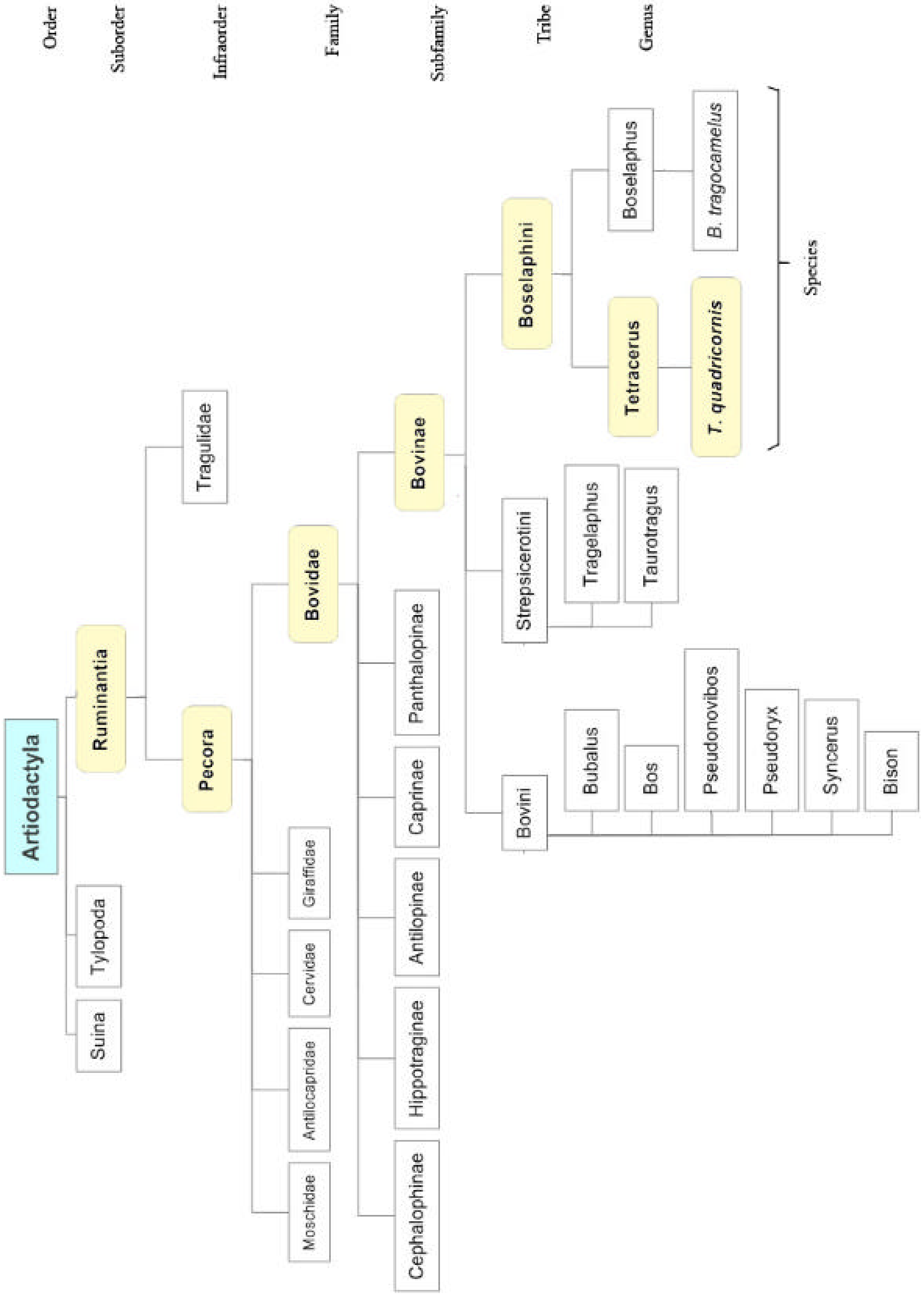


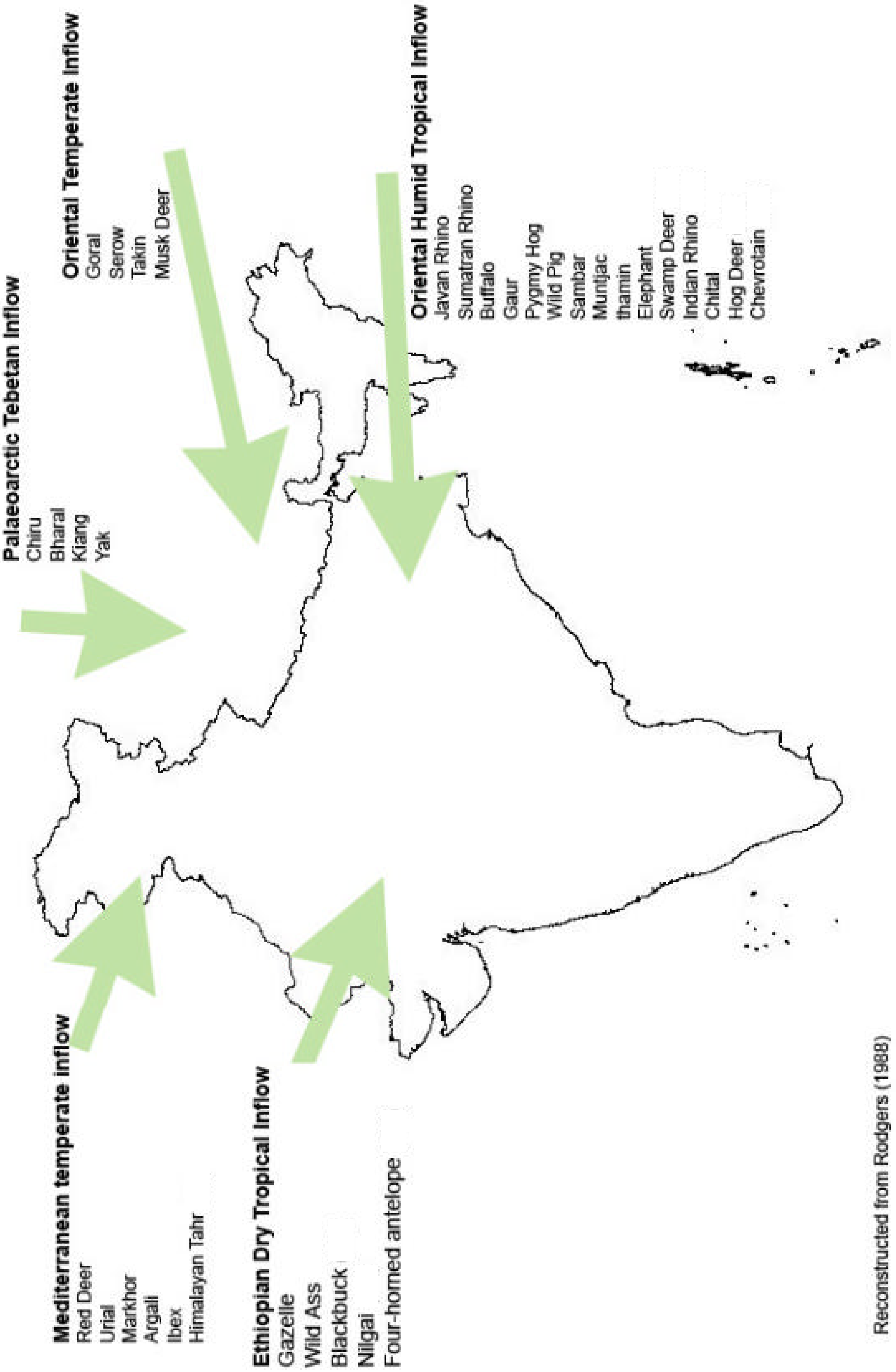
Fig. 1.1 Phylogenetic branching of Artiodactyla order up to species *Tetracerus quadricornis*

against a hard upper gum pad when they bite.

Within the family Bovidae, the subfamily Bovinae comprises of a group of about 24 species of medium-sized to large ungulates, including the domestic cattle, Bison, Water buffalo, Yak, the Four-horned antelope and the spiral-horned antelopes. Boselaphini, Bovini and Strepsicerotini are the three tribes that constitute this subfamily. Members of the Boselaphini tribe are the last survivors of a form which is very similar to that of the ancestors of the entire subfamily. Both species belonging to this tribe, i.e. the Nilgai and the Four-horned antelope, are endemic to the Indian subcontinent, have relatively primitive anatomical and behavioural characteristics, and the females are hornless. Absence of rings on horns that are keeled in front, distinguish them from the true antelopes. It is understood that cattle evolved from animals resembling the present-day Four-horned antelope and the Nilgai. Their behaviour is also what is thought to be a primitive form of social behaviour (Macdonald, 1984). The Four-horned antelope lives a solitary life, but forms small groups during some seasons. Presence of preorbital and hind foot glands indicates that these are possibly used for marking territories. Nilgai bulls on the other hand are solitary except during rut, when they establish territories and gather breeding herds, protecting them from other bulls. Defecation on middens is a trait used by both the species to possibly advertise their presence. Members of Strepsicerotini tribe comprising the spiral-horned antelopes are an African offshoot of the Boselaphine lineage but apparently differ in lacking territoriality. There are nine species belonging to this tribe such as the Elands, Nyalas, Bushbuck, Kudu, Sitatunga and Bongo out of which seven are of conservation concern (Mallon, 2003).

1.3 General Description of Four-horned antelope

Four-horned antelope is a small antelope weighing about 20-22 kg (Jerdon, 1867; Brander, 1923; Prater, 1971; Macdonald, 1984). Data from captive animals in Pune indicate that out of the six individuals weighed, none was heavier than 17 kg (Aniruddh Belsare, *pers. comm.* 2006). An adult Four-horned antelope stands about 55-60 cm tall at shoulder height and there is no diagnostic size dimorphism between the sexes. The coat of a Four-horned antelope is coarse and has rough hair. It is golden-brown in colour and darkens during the monsoon (August-January) and fades after winter (February-July). Its jaw is white below, its neck paler than the rest of its body, and its breast and underparts whitish in colour. There is no striking contrast in the pattern of colours in a Four-horned antelope, the colours diffuse into each other. This characteristic is unlike other antelopes found in India, which have more or less contrasting patterns (especially males). The Four-horned antelope has large ears that have white feathery tufts towards the inner top-edge. Two prominent black and white bands diagonally marked on the ears are diagnostic when seen in the field amidst tall grasses. The outline of its ears is more rounded than that of the Chital and is slightly more elongated than that of the Sambar. A dark band runs down its front legs but is not very prominent on all individuals. Whether it is a feature that gets darker as in other species with age (e.g. African Lions: Whitman *et. al.*, 2004), with status (e.g. African Lions:



Reconstructed from Rodgers (1988)

Fig. 1.2 Map depicting origins of the ungulate fauna of India

West and Packer, 2002) or is a variant between individuals (e.g. Tigers: Schaller, 1967; Karanth, 1995; Asiatic Lions: Jhala *et. al.*, 1999; Jaguar: Wallace *et. al.*, 2003; Leopard: Henschel & Ray, 2003; European Mink: Gonzalez-Esteban *et. al.*, 2004) is unknown. A white ring just above the hooves is diagnostic of both the Four-horned antelope as well as the Nilgai.

The Four-horned antelope has well-developed olfactory glands between the false hooves of the hind-legs (Prater, 1971) and in front of the eyes (Bourliere, 1964). The preorbital glands are regularly used for marking twigs or thorns. The glands between the false hooves could have the function of leaving scent (Roberts, 1977) at resting sites, though it is difficult to clearly indicate their purpose without substantial evidence.

The Four-horned antelope is not distinctly dimorphic other than that females are hornless. With four distinct horns, it is an important animal from the taxonomic point of view. There is a great amount of confusion in literature regarding the development of its second pair of horns. Some references quote that the front pair of horns fall off with age or that some males never get the second pair of horns (Jerdon, 1867; Brander, 1923). Observations in the field suggest that it is only under special circumstances that the second pair of horns is absent or broken in adult males. It is the young males that have only two horns, whereas the adult males have four distinct horns. The second pair of horns sprouts at an age of about 14-15 months, though this age may vary depending upon various factors. Generally the front pair of horns is smaller than the rear ones but at times may get as long as the latter. The final size that the front horns attain may also vary depending upon nutrition and habitat conditions.

Close examination of eight specimens of the Four-horned antelope (five males and three females) at BNHS collection department reveals that they have


Male Four-horned antelope


Female Four-horned antelope


Male and Female Four-horned antelope

fourteen lower and twelve upper molars. The number of lower incisors can be up to a maximum of eight whilst like other antelopes, they have no upper incisors. Four out of the five specimens had two horns each. The two-horned specimens had the same number of teeth as the four-horned or female specimens.

The Four-horned antelope is known to have a very long gestation period of about six (Blanford, 1888; Brander, 1923) to eight and a half months (Shull, 1958; Gurang and Singh, 1996). Fawns are tiny at the time of birth weighing only about 0.75 to 1.2 kg, and measuring about 42-45 cm in length and 24.5-27 cm at shoulder height (Shull, 1958; Acharjyo and Mishra, 1972; Acharjyo and Misra, 1975). The mother usually keeps her fawns hidden amidst thick vegetation and visits often to suckle the young. The fawns are extremely vulnerable at this age and can easily fall prey to a wide range of predators including large raptors. Cover is important for survival of fawns as they are completely dependent on their ability to hide, especially for the first 15-20 days after birth.

The Four-horned antelope is widely distributed in India but found nowhere in high abundance. It has always been known as a shy and elusive creature (Prater, 1971; Gurang and Singh, 1996; Menon, 2003) and is known to inhabit dry deciduous forests where it thrives in well wooded and well watered undulating or hilly country (Jerdon, 1867; Brander, 1923; Viceroy, 1936).

1.4 Definition of Problem

One of the main factors that have influenced the choice of species for field studies is 'ease of observation' (Leuthold, 1977). While a considerable body of information on ungulates living in grasslands and fairly open savannahs exists, little is known about the elusive, solitary and forest dwelling ungulates. Information on the natural history of ungulates has been studied for long. The history of studying animals can be dated back to the days when prehistoric man started depicted

Adult male Four-horned antelope skull

Adult female Four-horned antelope skull

Subadult male Four-horned antelope skull hunting shots on cave walls. Most of the animals depicted on these prehistoric paintings can still be identified, providing ample evidence that even thousands of years ago observations on animal morphology and behaviour were made. It was in the eighteenth century, that many fields of biology as science including botany, zoology and geology, began to professionalise. The history of systematic ecological studies on wild species is relatively new in India. George Schaller (1967) was among the first few scientists to have studied selective fauna in greater detail at Kanha National Park. There have been some studies conducted on most of the ungulates found in India but despite its wide distribution in the subcontinent, the Four-horned antelope has by large been the least studied antelope of India.

India has more than 350 known species of mammals out of which antelopes and gazelles constitute six (Prater, 1980). The Four-horned antelope and Nilgai belonging to the Boselaphini tribe have primitive characteristics that represents ancient lineage. Both have relatively primitive anatomical and behavioural characteristics as discussed above. The Four-horned antelope is a monotypic species of its genus and is endemic to the Indian subcontinent. Many of its physiological and behavioural attributes are similar to those of duiker species found in Africa (Brander, 1923; Newing, 2001). They are known to inhabit forest habitats, live solitary or in pairs, prefer freezing as their anti-predatory strategy when threatened, and forage mainly on fruits, flowers and fresh browse (Rodgers, 1988; Newing, 2001).

In India, scientific studies of different magnitudes have been conducted on most antelope and deer species. Scientific studies have been done on Indian antelopes such as the Blackbuck (Schaller, 1967; Nair, 1976; Ranjitsinh 1982; Rahmani 1991), Chinkara (Rahmani 1990a, b, 1997; Rahmani & Sankaran 1991; Alfred *et. al.*, 2001) and Nilgai (Qureshi, 1992; Singh, 1995).


Four-horned antelope in camouflage


Juvenile male Four-horned antelope (only two little horns)


Young male Four-horned antelope (short front pair of horns)

Among the Cervids, Chital (Schaller, 1967; Mishra, 1982; Sanker, 1994; Chundawat, 2001; Chundawat, 2006), Sambar (Schaller, 1967; Mishra, 1982; Chundawat, 2001; Sanago, 2005; Chundawat, 2006), Hog Deer (Biswas, 2002; Dhungel and O'Gara, 1991); Swamp Deer (Sawarkar, 1989; Qureshi *et. al.*, 1990; Gopal, 1995); Musk Deer (Green, 1985) and Hangul (Gee, 1965; Inayatullah, 1982; Mansoor, 1994;) are well studied, but there is little research done on the Chevrotain and Muntjack (e.g. Krishnan, 1975; Lai *et. al.*, 2002). The Four-horned antelope is widely distributed in India and some pockets of Nepal but still no detailed study has ever been conducted on it except some basic ecological observations by Berwick (1974) and Krishnan (1975), a short study by Bhaskaran (1999) and a questionnaire survey by Rice (1991). Even the status report for the International Union for Conservation of Nature (IUCN) Antelope Action Plan (Rahmani, 2001) highlights the dearth of information on its ecology and current population status. IUCN Red Data book (Rahmani, 2001; Mallon, 2003) refers to the Four-horned antelope as Vulnerable and it is included in the Schedule I list of the Wildlife Protection Act (1972, amended- 2002).

1.5 Goals and Objectives

The goal of this study was to undertake ecological research on the Four-horned antelope with emphasis on its natural history, habitat utilization, population, behaviour, distribution and an assessment of threats to this vulnerable species. The study involved six specific objectives:

1. To study the habitat utilisation by the Four-horned antelope.
2. To study its population density in relation to sympatric antelopes.
3. To study its demographic relationships and investigate the significance of four horns in its biology.
4. To study its behavioural ecology: basic behaviour, anti-predatory behaviour, and behavioural usage of different habitats to classify the niche occupied by four-horned antelope.
5. To demarcate the distribution of four-horned antelope in India
6. Based on ecological studies and distribution, investigate the biotic threats faced by the species.

Close up of an adult Four-horned antelope (male)

CHAPTER II

Study Area: Panna National Park and its Characterization

CHAPTER II

STUDY AREA: PANNA NATIONAL PARK AND ITS CHARACTERIZATION

2.1 Introduction

India, being a vast country, shows great diversity in climate, topography and geology and hence is rich in terms of biological diversity. The Indian sub-continent is characterised into 10 biogeographic zones (Rodgers & Panwar, 1988). Of these, the Trans-Himalaya, Himalaya and North-East cover the Northern and North-Eastern zones, whereas Desert and Western Ghats mark the Western limits of the country. The islands and coasts constitute two distinctly identifiable biogeographic zones. South of the Himalayas, running down westwards till almost half the length of the country is the Semi-Arid Zone, and a similar stretch towards the East, following the course of the Ganges are the Gangetic Plains. Between these two zones and running down south till the end of the peninsula is the tenth zone which is called the Deccan Peninsula (Fig. 2.1). Panna lies in the Deccan Peninsula which holds about 41% of the total landmass of the country. In the Deccan Peninsula-- Vindhya, Satpura, Maikal, Ajanta and Palkonda are the main hill ranges and the major rivers of this biogeographic zone are Yamuna, Chambal, Narmada, Mahanadi, Godavari, Krishna and Kaveri.

Since India stretches across the Tropic of Cancer, its climate is tropical. Conventionally tropical temperatures range between 15ºC and 35ºC but in India temperature regimes vary from -50ºC (e.g. Drass) in winter to 52ºC (e.g. Jaisalmer) in summer. It is suggested that the effect of altitude is much greater than that of latitude in the Indian subcontinent in determining temperature regimes (Champion & Seth, 1968).

Since in India the temperature, soil, precipitation and wind conditions vary greatly on the spatial scale, the forest types and compositions also vary accordingly. The forests of the Indian subcontinent have been divided into six major classes. These classes are further classified to constitute 16 groups, which are further segregated into 39 sub-groups (Champion & Seth, 1968). For the Deccan Peninsular Biogeographic Region, the identified forest types are classified as Tropical Dry Deciduous Forest, Tropical Moist Deciduous Forest, Tropical Thorn Forest, Tropical Dry Evergreen Forest, Tropical Semi-Evergreen Forest, and Littoral and Swamp Forest.

2.2 Panna National Park

The Panna National Park is situated between coordinates 24°15'-24°20' N and 80°00'-80°15' E towards the Northern boundary of the state of Madhya Pradesh (Fig. 2.2). It is 543 km^2 of Tropical Dry Deciduous Forest (Champion & Seth, 1968) with altitude ranging between 200

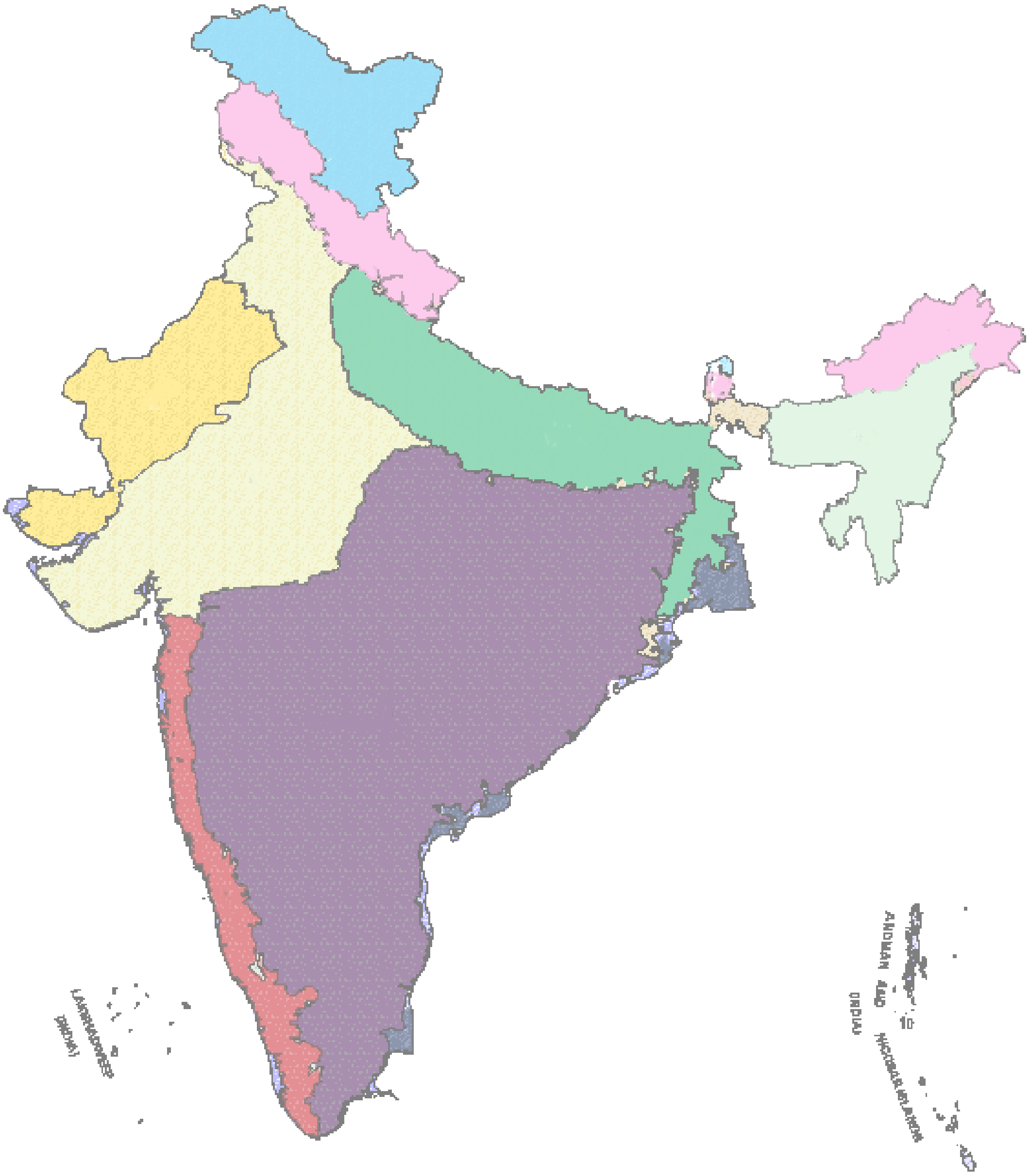


Fig. 2.1 Biogeographic zones of India

m and 550 m. Situated in the Vindhyan Hill Ranges, the terrain of Panna National Park is typified by extensive plateaux and gorges. It has a unique bench topography that discriminates the area into Hinauta (middle) and Talgaon (upper) plateaux respectively. The meandering Ken River splits the Park into valleys, steep slopes, cliffs, deep gorges and mud banks along the 54 km of its course through the Park. Along its course, the river goes beyond the National Park boundaries for about 13 km from near Gangau village and re-enters the Park near Kaneri village. The whole National Park acts as catchment to the Ken River and the area's major surface water flow is towards north and north-east. The Vindhyan sandstone provides a good medium to recharge

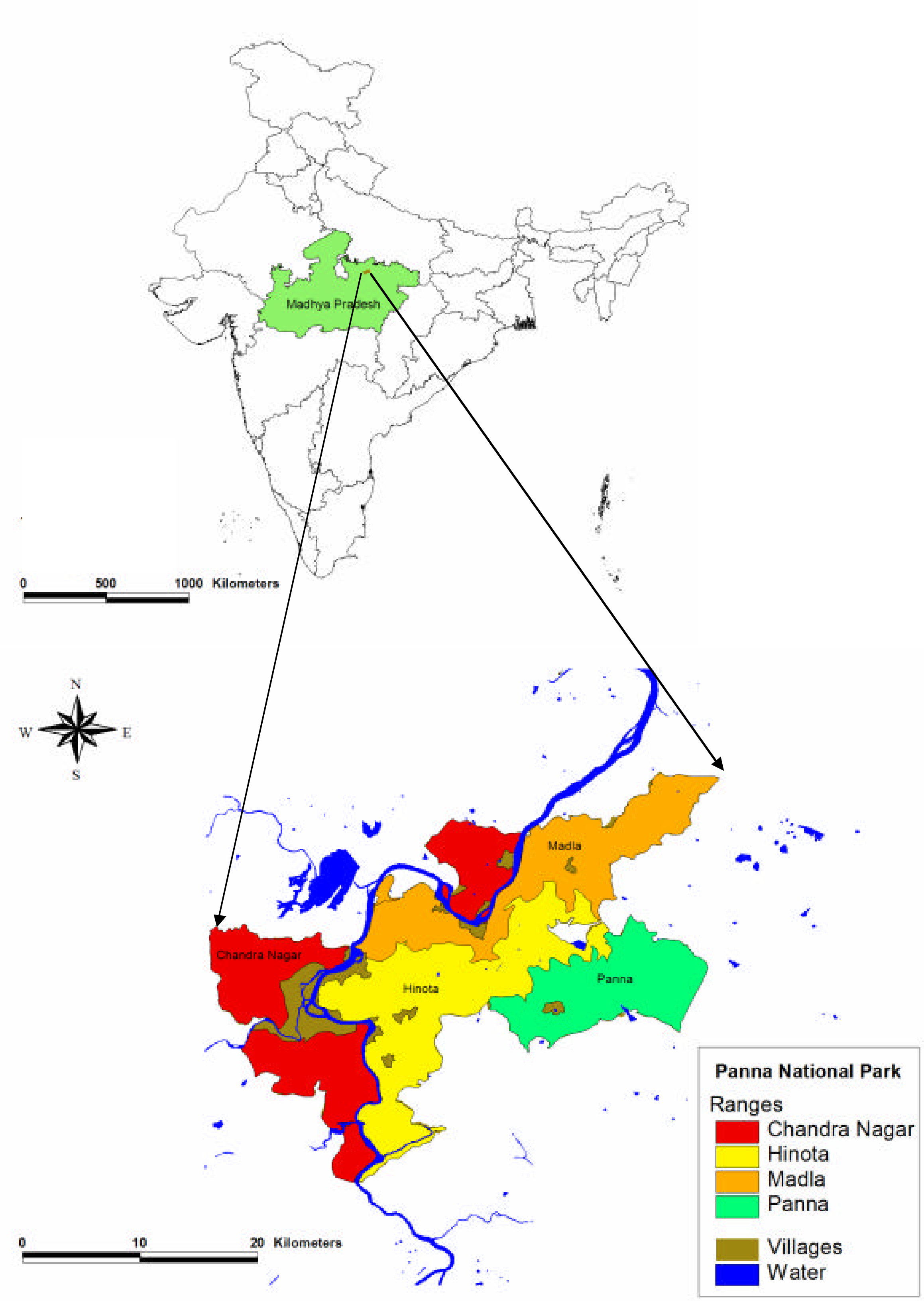


Fig. 2.2 Map depicting location of Panna National Park (and its ranges) in India.

aquifiers and at some places the water keeps trickling throughout the year from perennial springs**.**

The Gangau Wildlife Sanctuary, which is now about 78 km^2 in area, was about 478 km^2 before the declaration of Panna National Park. This Wildlife Sanctuary was established in the year 1975 covering an area of about 287 km^2 and was extended to 478 km^2 in the year 1979. It covered most of the areas that comprised sections of the protected hunting grounds of the erstwhile Rajput reign. Panna National Park was established in the year 1981 covering a large portion of the Gangau Wildlife Sanctuary (leaving out 29 compartments), Forest land of Chhatarpur district, leased out area to the Gangau dam, leased out area to the Diamond Mining Project, NMDC and all enclaved villages. The Gangau Wildlife Sanctuary is still existent towards the Eastern and the Northern boundaries of the National Park as an independent management unit. The National Park encompassed an area of about 543 km^2 and there are 13 villages comprising 15 habitations still within its peripheries. Three villages have been relocated from the Park area after payment in cash towards compensation. The entire Panna National Park came under the Project Tiger in the year 1994. Recently, an attempt is also being made to take the remaining portion (78 km^2) of the Gangau Wildlife Sanctuary under the aegis of Tiger Reserve to facilitate proper management. The area is envisaged to serve as a buffer for wildlife and help reduce pressures on the core area.

a. Geology and Soil: Broadly eight kinds of geological terrains are identified from within the boundaries of Panna National Park (fig. 2.3). Soils are mainly of three kinds. Most of the area is covered by lateritic soil. Black cotton soil can be found in some low elevation areas, mostly near water-bodies. Loamy soil, found mostly in Hinauta plateau and valley of the River Ken, is the third category.

b. Meteorology: Panna receives an average annual rainfall of about 1,100 mm, of which almost 60-70% is received between July and September. Occasional showers in late January and February are not uncommon but do not add substantially to the overall precipitation. Winters on the other hand can be characterized from November to January when temperatures may go down to as low as about -0.7°C. Frost in the grasslands is a regular feature between December and January whereas late January often experiences days with reduced visibility as a result of thick fog. Onset of summer is often slow and not as distinct as the other two seasons. Temperatures start rising around mid February and peak sometime in the month of May when the highest temperature frequently goes up to 47°C. Water is a limiting factor in summers when only a few springs and concrete waterholes (saucers) that are artificially filled are left with water, apart from the Ken River, for animals to use. Since Ken River is not accessible at points because of the presence of villages and steep gorges, the smaller waterholes become important hub of life in the Panna National Park.

c. Culture and History: Apart from its diverse natural heritage, Panna also has a rich cultural background. In many caves and rock shelters one can still see remains of paintings that can be dated to the early historic era (Erwin Neumayer, *pers. comm.*, 2003). The area

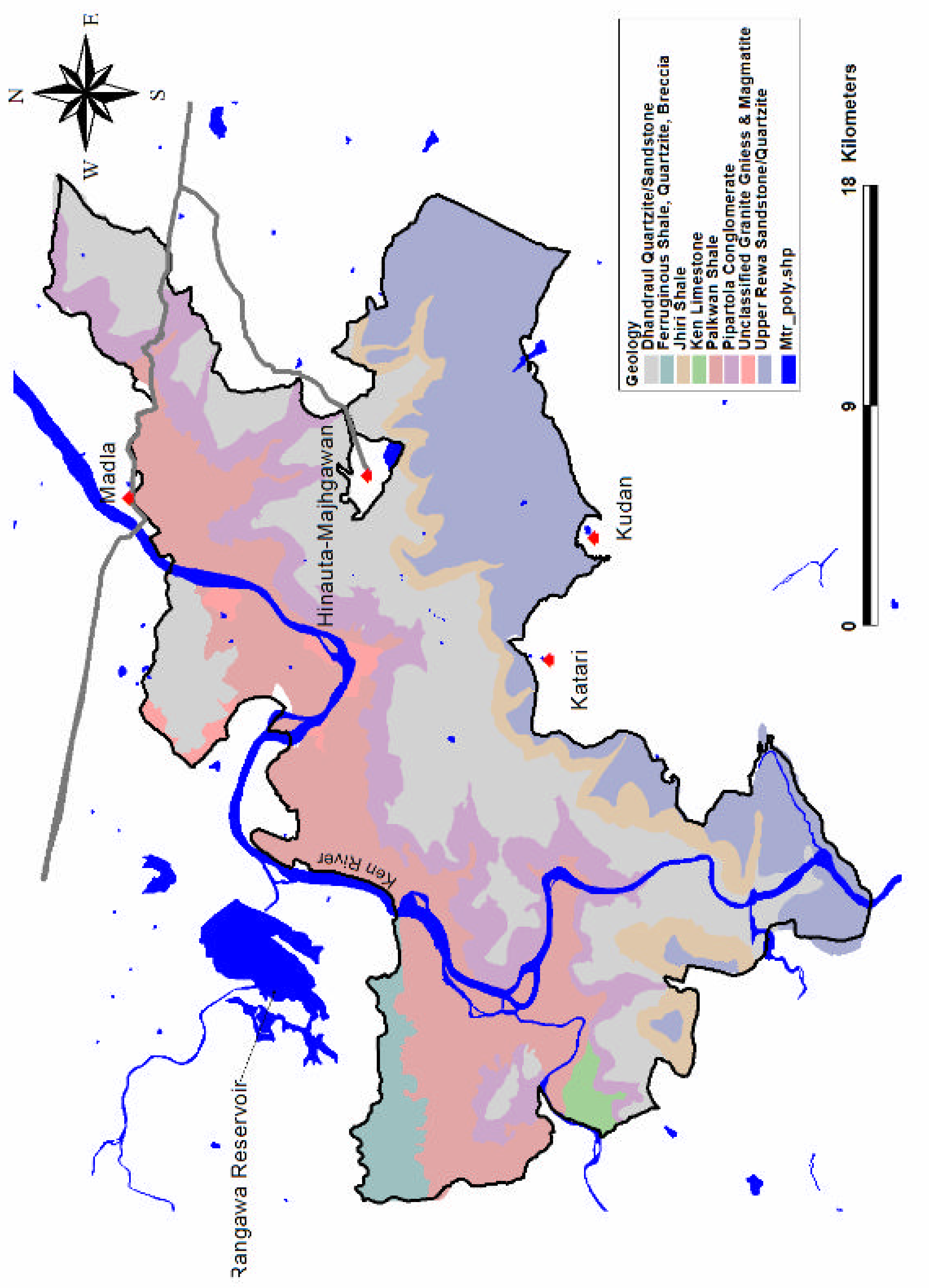


Fig. 2.3 Geology of Panna National Park
(Map courtesy: GIS cell, Panna National Park)

is known to have been ruled by Rajgonds for many years. Remains of their dynasty can be seen sporadically throughout the area. Khajuraho, a world heritage site, is only 30 km away from the Panna National Park. The magnificent temples of Khajuraho were made by the Chandel rulers who reigned there between 950 and 1050 A.D. Panna was ruled by the Rajputs for a considerable period of time. Panna State was a small but important Rajput kingdom of Central India. It was a *Sanad* state in the Bundelkhand Political Charge of the Central India Agency of the British. Some old hunting resorts and palaces are still located in and around the Park, standing witness to the fact that Panna has been rich in wildlife for quite some time. After Independence in the year 1947, along with other such kingdoms, the state of Panna was merged with the Republic of India. It was included in the present Madhya Pradesh at the time of reorganisation of states in the year 1956.

Religion has played a major role in conserving wildlife and India's natural heritage. In fact, there are numerous shrines and places of worship inside the Park. Legend has it that deities of many of these shrines are the protectors of the forests and are a reason why the areas are still rich in wildlife and forest cover. People following these deities have strong sentiments and fears associated with them, and are hence wary of damaging these forest patches.

d. Forest Type: Panna is strategically located on the forest map of the country. It is not only the northernmost frontier of natural Teak *Tectona grandis* forests, but also demarcates the eastern boundary of Kardhai *Anageossis pendula* forest (Champion & Seth, 1968; Chawdhry, 1997; Dwivedi, 2003). Panna lies in the biological classification of Zone 6E- "Deccan Peninsula-Central Highlands" (Rodgers & Panwar, 1988). The forest types (Champion & Seth, 1968) are as follows:

(i) Southern tropical dry deciduous teak forest- 5A/C1b:

The upper canopy is mostly closed but uneven and not very dense. It is formed by a mixture of deciduous trees and most of the species are also common with those found in the moist deciduous forest. The lower canopy is mostly deciduous though some patches that are covered and well sheltered may have some evergreen or sub-evergreen species. Understorey is usually adequately present, but adequate sunlight often permits good grass growth along with shrubs. With regular burning, this results in a savannah-like formation. With this sub-class, teak is present in high proportion as a result of high grazing pressure and other anthropogenic pressures.

In the study area, this type of forest is commonly found on Talgaon plateau, near a place called Ponria and along the southern boundary of the Park, and at many places in Madla region, especially around the shrine of *Dulha babba*.

(ii) Northern tropical dry deciduous mixed forest- 5B/C2:

The upper canopy is light but mostly irregular with patches of dense and open sections. Height of trees is rarely found to be over 15 m and trees are usually much shorter. Canopy is formed almost entirely of deciduous trees that are also found in moist deciduous forests. These forests usually have thin shrubby undergrowth. During summers, these forests are almost entirely leafless whereas in the monsoon they are lush green and give an image of an opaque, closed canopy forest.

This is the most common type of forest found in the study area. Most of the Hinauta region is comprised of it, as also large sections of Talgaon plateau as well as Madla region. Despite commonality across the three sites, the species composition, age structure and number of species vary significantly across these three ranges.

(iii) Dry deciduous scrub forest- 5/DS1:

This class is typified by shrubby growth usually between 3 to 6 m in height. Thin grass occurs throughout though most of the shrubs are usually not grazed.

This category of forest can be found West of Hinauta, between Pipartola and Lalar, towards areas adjacent to settlements in Talgaon plateau and in some sections of Hinauta plateau, especially closer to the Hinauta village.

(iv) Anogeissus pendula forest- 5/E1

This type of forest is determined by the predominant presence of usually contiguous patches of Kardhai *Anogeissus pendula*, which can reach upto a height of 6 m. Its associates are mostly thorn forest species and the forest is leafless after March, till the onset of monsoon. Usually no bamboo growth is seen, but at times a thin shrub and grass undergrowth can be found.

The *Anogeissus pendula* forests are seen in many patches within Madla region and can be identified from a distance. Some smaller patches can also be seen in and around Bargadi, though larger contiguous patches can be found near Pipartola and Lalar. The understorey in these areas is minimal and so is the grass growth. Though animal sighting is not uncommon in these patches, their level of usage is still unknown.

(v) Boswellia forest- 5/E2

The typical forest category where *Boswellia* is the dominating species occurs in association with teak, which is also stunted in its growth. These forests are leafless from February till the onset of monsoon. Low grass, scanty undergrowth and regular burning classify these forests with low or almost absent regeneration.

Despite widespread presence of this species, there are no known contiguous patches of this kind of forest in the study area. Information about its regeneration status is scarce as few saplings of the species could be observed. *Boswellia* is mostly found interspersed with other forest classes rather than its presence as an individual class in the study area.

(vi) Dry bamboo brakes- 5/E9

Dense bamboo *Dendrocalamus strictus* thickets form such a forest type. Usually bamboo grows with grass, and deciduous and thorny shrub between its clusters. Scattered growth of hardier species of dry deciduous forest can also be found, though on many sites there is no such overwood present.

Most slopes and valleys have a rich bamboo growth throughout the study area. In Panna National Park, these bamboo brakes virtually constitute the vestibules between different plateaux and cover the slopes extensively. Usually there is a thick undergrowth along with some overhead canopy of various deciduous species.

In Panna National Park, 22 species of grass have been identified (Chawdhry, 1997). While the grasses in Panna do not attain great height in most areas, there are some portions of the National Park such as Bhadar, Gadiya Dol and Basai where some species may reach up to a height of almost two metres. It was observed that the grass attained maximum height every alternate year. In Panna, we recorded tallest grasses in the year 2002-2003 and 2004-2005 whereas 2003-2004 and 2005-2006 recorded a relatively shorter grass regime. Most of these grasses flower around January and February and usually wilt after that due to the load of heavy dew and sporadic rains. Early burning of plots and fire lanes in February and March allows fresh grass to sprout, which attracts grazing ungulates in large numbers.

Canopy of Panna varies greatly, not only across different habitat types, but across different seasons as well. From closed canopy dense forests and mixed forests with dense understorey, the canopy is virtually non-existent in grasslands. Isolated or cluster of trees in the open forest and savannah provide a certain level of shade to the animals in the Park. The densely forested areas look like almost close-canopy forest during and just after the monsoon due to profuse development of leaves. The same closed canopy opens up considerably during the late winters and most trees shed their leaves to regain them only by the next monsoon. Pattern of spatial usage of terrain by animals varies greatly across these areas with season (Chundawat, 2001; Sanago, 2005), and can be credited to canopy apart from availability of water and other resources.

e. Fauna: Panna National Park supports a diverse range of mammals. The carnivore population comprises of Tiger *Panthera tigris*, Leopard *Panthera pardus*, Dhole *Cuon alpinus*, Golden jackal *Canis aureus*, Striped hyaena *Hyaena hyaena* and Indian fox *Vulpes bengalensis*. Sloth bear *Melursus ursinus*, Wild pig *Sus scrofa*, Sambar *Cervus unicolor*, Chital *Axis axis*, Nilgai, Chinkara *Gazella bennettii* and Four-horned antelope are among the other conspicuous mammals of Panna.

Panna National Park is home to a large number of birds as well. More than 250 species of birds are reported from the area (Gogate & Yoganand, 2002; Sharma & Kumal, 2006). Panna is also identified as one of the Important Bird Areas of India (Islam & Rahmani, 2004). Although only five species of reptiles are listed in the checklist of Panna’s fauna (Chawdhry, 1997), it is evident that some common species such as the Monitor Lizard and at least 10 species of snakes that were seen during the course of this study were not reported. A systematic reptile survey of the area is needed.

2.3 *Characterisation of Panna using Geographical Information System (GIS)*

GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986). Over the years, analysis of spatial data has not only become an integral part of resource and land planning but has found extensive application in mammalogy, ornithology, ecology and biodiversity assessment (Johnson, 1993; Berry, 1993; Ravan & Roy, 1995; Martin *et. al.* 1998; Bawa *et. al.*, 2002). Beyond just spatial modelling and analyses (e.g. Lai *et. al.*, 2002; Lauver, *et. al.* 2002; Kushwaha, *et. al.*, 2004; Jeganathan *et. al.*, 2004), recently GIS is also being used in developing dynamic models for simulating biological populations (e.g. Ahearn *et. al.*, 2001). Information about habitat cover, dependence on natural resources (e.g. water), disturbance and elevation models along with concise data about the sampling efforts and efficiency are used in this study to analyse spatial data of Four-horned antelope's distribution and pattern of habitat use. GIS not only allows fast and efficient analyses of spatial data, it also reduces human error to a considerable extent.

2.3.1 Habitat/Land-use Layer (One layer, Fig. 2.4)

In collaboration with the Tiger Research Project, Panna, a satellite image was obtained with the help of the Indira Gandhi Conservation Monitoring Centre, WWF-India Secretariat, New Delhi, from the National Remote Sensing Institute, Hyderabad. This False Colour Composite (FCC) image with four bands (viz. 2, 3, 4 and 5), taken from IRS 1-D LISS III satellite on path 99, row 54 at 1030 hrs on 14th October 2002 was digitized for classifying different habitat types. The maps were geo-referenced with the help of digitized Survey of India toposheets and few conspicuous points were physically verified on ground before collecting habitat data on a larger scale.

Initially 100 random points were laid on the map of Panna National Park using Random Point Generator (Jenness, 2005) on Arcview 3.2. Plots of dimension 20m x 10m were demarcated on 88 of these points to identify and count tree and sapling species. Ocular estimation of canopy, terrain type, and grass cover was also done at each of these plots. The satellite image was then subjected to unsupervised classification resulting in 40 categories. It was found that 23 out of 40 classifications depicted forest habitat whereas the remaining classifications indicated fallow or settlement areas. Data from the first 88 habitat plots were used to assign certain habitat types but the information was found to be insufficient to prepare a detailed habitat map of Panna. To circumvent this problem, another set of 162 habitat evaluation were randomly laid and visited for data collection in the same way as above. Data from a minimum of three and a maximum of 18 habitat evaluation plots were collected from each of the 23 classifications. Data from a larger number of plots were collected for classes that showed high variability in the preliminary run. Less than five plots were visited for seven classes whereas data from more than 10 plots were collected for three categories of the unsupervised classification. In total, data were collected from 250 habitat evaluation plots for preparing the habitat map of Panna National Park.

Tree density, sapling density, Shannon Wiener Diversity Indices for trees and saplings (e.g. Kent & Coker, 1995), understorey and grass growth, terrain type and dominating species were extracted from the dataset using macros developed for MS Excel. Discriminant Function Analysis (DFA) was run on the habitat data from the plots to investigate classification of the predetermined 23 classes on the basis of these parameters. The remaining 17 unsupervised classes either depicted human land-use or were unclassified due to clouds and their respective shadows in the image. Unsupervised classifications in the plot (fig. 2.5a) with small Euclidian distances between group centroids were then pooled into fewer categories by comparing differences in the habitat variables. The habitat map was reclassified using tree and sapling densities, canopy cover, thorny or non-thorny character, and similarities in the

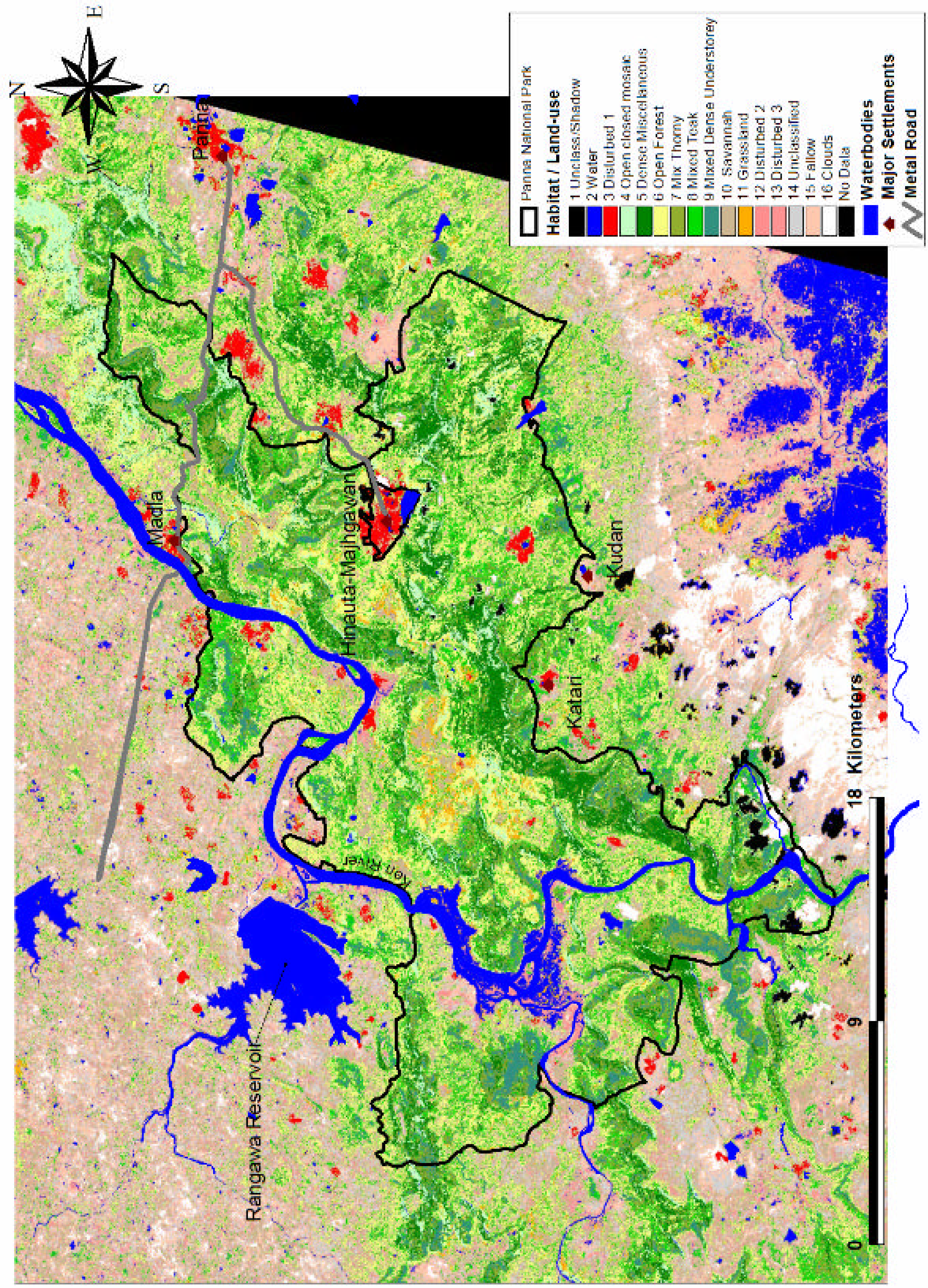


Fig. 2.4 Habitat/Land Use Map of Panna National Park and neighbouring areas.

species composition. Whenever required, Tripartite Similarity Indices (Tullos, 1997) were also used for estimating similarities between any two unsupervised classes based on their species lists.

Using the aforementioned approach, unsupervised classes were merged and subjectively classified into eight habitat classes. These eight derived habitat classes were subjected again to DFA using the existing data on four variables from the habitat evaluation plots (fig. 2.5b). Table 2.a denotes the correlation of the discriminating variables with the standardised canonical discriminant functions. Canopy and Tree density are correlated with the first function whereas sapling density and proportion of thorny trees are correlated with the second and fourth functions respectively. The classification function coefficients (Table 2.b) were used to measure the degree of success of the classification for this sample. Results show that 60% of the original grouped cases could be classified correctly with the help of classification function coefficients. Since DFA could not incorporate the subjective assessment of similarities in species composition, it is believed that the actual classification was more accurate than what was predicted using DFA.

The following eight habitat/land use categories could be classified:

a. Dense miscellaneous forest ***(17% of the Park's total land cover)*****:** This category records a forest category with tree density higher than 1,100 /ha and a high value of percentage canopy cover.

b. Cluttered open and closed mixed forest ***(6% of the Park's total land cover)*****:** Mixed vegetation with a close-knit mosaic of open areas along with clusters of thick vegetation constitutes this forest category.

Table. 2.a Structure matrix showing pooled within-groups correlation of each habitat variable with the Canonical Discriminant Function after reclassification of habitat types

	Function			
	1	**2**	**3**	**4**
Canopy	.814(*)	.153	-.312	.466
Tree Density	.749(*)	-.570	.288	.179
Sapling Density	.564	.704(*)	.424	-.081
Thorny	-.075	.145	.321	.933(*)

* Largest absolute correlation between each variable and any discriminant function

Table. 2.b Classification function coefficients for estimating classification scores for assigning data from unclassified plots into one of the revised habitat classes

	Revised Habitat classes							
	4.00	**5.00**	**6.00**	**7.00**	**8.00**	**9.00**	**10.00**	**11.00**
Canopy	.134	.176	.150	.186	.185	.233	.073	.099
Tree Density	-2.847	1.085	-2.275	-1.851	-2.842	-2.311	-3.205	-2.811
Thorny	1.674	-1.153	.478	.306	.312	-2.164	3.309	3.170
Sapling Density	-1.941	-.519	-2.122	.377	-.991	.851	-.936	-1.946
(Constant)	-6.241	-10.282	-4.678	-10.137	-7.374	-14.102	-4.807	-4.921

c. Open forest *(30% of the Park's total land cover)*: Tree density in this forest type is generally low (~250<density<550 /ha) whereas the sapling density is between 600 and 1,100/ha.

d. Mixed teak forest *(16% of the Park's total land cover)*: Lies between 'a' and 'c' categories described above in terms of vegetation density. Tree density is between 350 and 550/ha and a moderate sapling density (1500<sapling density<2,600 /ha).

e. Mixed thorny forest *(11% of the Park's total land cover)*: Similar to the above type but with thorny vegetation (*Acacia* and *Zyziphus*) as necessary components. This eventually results in a higher sapling density thereby providing a good undergrowth cover.

f. Mixed forest with dense understorey *(5% of the Park's total land cover)*: Sapling density is the most influential variable in discriminating this category from the rest. The category has a dense understorey and a closed canopy.

g. Savannah *(10% of the Park's total land cover)*: Separated from Open Forest on the basis of a slightly higher number of saplings and a lower tree density. The savannahs necessarily had a significant grass cover and the terrain was often rocky.

h. Grassland *(2% of the Park's total land cover)*: This category has very little vegetation other than vast grasslands and minimal tree cover. Sapling density did not contribute significantly in classifying this category in the map.

2.3.2 Water-bodies and Drainage Layers (Two layers, Fig. 2.6)

For demarcation of water-bodies and drainage system of Panna, both satellite images as well as digitized toposheets were used. Since the image resolution was 23.5m x 23.5m, all water-bodies larger than this size were visible on the satellite imagery. For other water-bodies, Global Positioning System (GPS) was used to take coordinates and these water-bodies were cumulatively plotted as a separate layer. Drainage system of the whole area was digitized with the help of toposheets. These drains were rated on

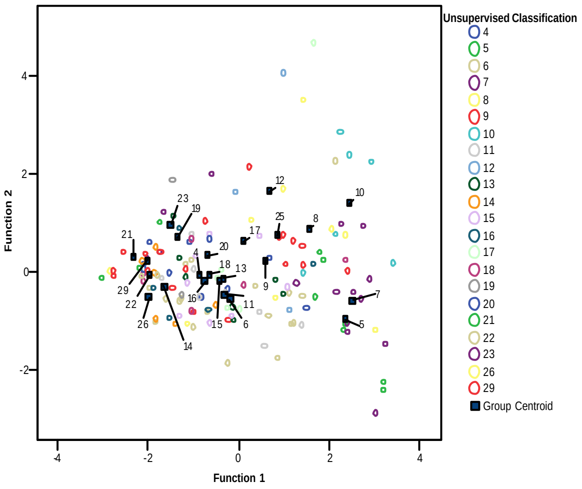


Fig. 2.5a Centroids of 23 unsupervised classes plotted in the ordination space of the canonical discriminant functions

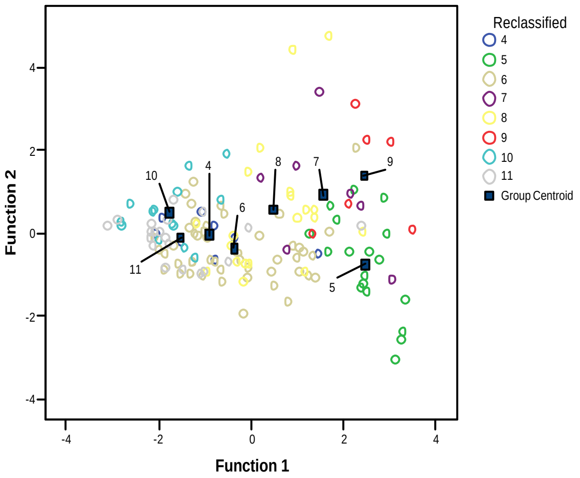


Fig. 2.5b Centroids of eight derived classes plotted in the ordination space of the canonical discriminant functions

the basis of their catchment area for further analyses if required. A specific layer of water-bodies and drainage system provides useful information for management of water, which is one of the most crucial resources for wildlife.

2.3.3 Forest Boundaries (Five layers, Fig. 2.7)

Forest boundaries of the Park were designed using maps available with the Forest Department. For range boundaries, circles, beats and compartments, the maps developed by Madhya Pradesh Council of Science and Technology were borrowed from the Forest Department and georeferenced on existing maps. Since the compartments are segregated on the basis of geographical features such as streams, escarpments and cliff edges, these serve as ecological units for analysis of data on a smaller scale.

2.3.4 Contours and Digital Elevation Model (Two layers, Fig. 2.8)

The contours were converted into surface using specialised software and a digital elevation model was prepared. The elevation model was verified by confirming course of streams from higher elevation to lower elevation, and using ground verified roads and cliffs. Panna’s typical bench topography characterised by steep cliffs, plateaux and river systems can be visualised using the digital elevation model (Fig. 2.9).

2.3.5 Settlements (One layer, Fig. 2.10)

Settlements were marked using toposheets. Other than that, three disturbance levels were also identified from the satellite imagery and ground verification. Further verification of many points mentioned in the toposheets was required, which were either relocated or abandoned. Using available records with the Forest Department, such site locations were distinguished from actual villages.

2.3.6 Metalled and Forest Road Network (Two layers, Fig. 2.11)

A map of the road network was developed initially using toposheets. It was found that since these cart roads and walkways were marked over 30 years ago (1971), they had become redundant. To collect fresh data on current road network, Garmin 12 and Etrex Ventura Global Positioning System (GPS) receivers were used. The GPS devices were attached on a moving vehicle and the tracking rate was fixed at a level where the device would mark the trail every few metres. The recorded trails were then downloaded on a computer using MapSource 6.5^{TM} and then exported in text format. The recorded trail of points was then uploaded and converted into a polyline using XTools (DeLaune, 2003). Overall, a precise and accurately marked road network of 228.5 km was mapped using this methodology. The road network inside the protected area provides a useful overview of connectivity and coverage within the National Park. For this study, since forest roads were extensively used for surveying and observing Four-horned antelopes, the road network provides a useful estimate of area sampled.

2.3.7 Tree and Sapling Species Richness Layers (2 layers, Fig. 2.12 & 2.13)

In Panna National Park most of the habitat types as classified above can be found uniformly across the two plateaux and the adjoining valleys. While their proportions may vary, the availability of these habitat types in the two plateaux indicates uniformity in the forest composition. Despite these apparent similarities, there are some stark differences that can be observed across these terrains. Even the encounter rates of Four-horned antelope differed to a great extent between these areas. It was envisaged that a map of the overall floral species richness may not only provide useful information in classifying the different habitats, but could also become important in understanding the distribution of particular species.

Apart from the 250 habitat evaluation plots (10m x 20m dimension) we collected additional data from the field to develop a new layer denoting floral species richness at two levels, viz. Tree and Sapling. Total 501 additional points were surveyed following the quadrat sampling design (Williams *et. al.* 2002) representing a tight and conservatively estimated area of about 7,150 ha. Quadrat sampling involves sub-division of an area of interest into a number of smaller sampling units for collecting species detection/non-detection data (Table 2.c). Each of these sampling sites was visited once and treated as a temporal replication at the time of analysis. The boundaries of the smaller sampling units were left open-ended and at each point a list of tree and sapling species was made along with information about its coordinates and terrain. Visibility, and hence forest type, influence the dimensions of the area within which presence of each detected species was established. This meant that, larger areas were scanned in open forests than in dense forests.

A total of 90 species of trees and 44 herb/ shrub are reported from Panna (Chawdhry, 1997). On the basis of 751 points from where vegetation data were collected, a total 91 plant species could be identified during this study (***Annexure A***: Checklist of flora found in Panna National Park). The sampling effort for estimating the floral species list fairly represented the study area (fig. 2.14). Using the previously discussed capture-recapture modelling, the highest tree species richness of a particular site in Panna National Park is estimated to be 79.8 (Std. Error = ±17.02) and that of the saplings is 52 (Std. Error = ±29.01). Information about the flowering and fruiting phenology of plants, especially trees, was also collected. *Annexure B* details the phenology of trees in Panna National Park. It is found that in all seasons other than the late monsoon months there are more than two species with ripe fruits. Similarly, mature flowers are also avidly taken by ungulates and it is only in the early winter that their availability goes down. On combining the two, it is evident that there is a regular availability of fruits and flowers throughout the year (Fig. 2.15).


Savannah grassland in Panna National Park

Table. 2.c Estimates of tree and sapling species richness at various sites demarcated on the basis of compartment and habitat type within the study area

SiteCode	Tree Model	Tree SR	Tree SE	Sap Model	Sap SR	Sap SE
Bargari-North9	M(h)	68.97	15.3	M(h)	24.910	5.838
Bargari-South4	M(h)	43.5816	4.097	M(h)	25.534	6.189
Bargari-South7	M(h)	42.2	6.11	M(h)	23.303	5.6687
Bharar3	M(h)	40.99	4.36	M(o)	14.000	0.564
Bharar4	M(h)	43.52	6.686	M(h)	28.030	5.106
Bharar5	M(h)	64.36	9.25	M(th)	7.000	0
Bharar7	M(h)	57.79	4.512	M(bh)	31.000	4.14
Bharar9	M(o)	11	0.79	M(o)	7.000	0.548
Bharar10	M(h)	44.538	30.108	M(h)	23.480	6.406
Hinota-North5	M(o)	19	1.046	M(o)	20.000	2.1542
Hinota-South4	M(h)	68.4356	13.367	M(h)	27.240	4.44
Hinota-South5	M(h)	40.552	4.099	M(h)	32.360	5.63
Hinota-South7	M(h)	24.306	3.028	M(h)	26.577	4.82
Hinota-West5	M(h)	49.886	4.726	M(h)	21.010	3.5507
Hinota-West7	M(h)	47.769	4.975	M(h)	35.410	5.705
Hinota-West10	M(h)	50.98	7.07	M(h)	21.010	3.5507
Jhalar5	M(h)	41.577	7.205	M(bh)	13.000	0.213
Kheraia3	M(h)	55.78	9.07	M(b)	52.000	29.083
Kheraia4	M(h)	79.799	17.015	M(h)	42.966	5.417
Kheraia5	M(h)	55.96	3.72	M(bh)	27.000	0.929
Kheraia7	M(h)	28.708	3.29	M(o)	12.000	0.5656
Madla4	M(b)	14	0.1957	M(o)	11.000	1.488
Madla5	M(h)	49.758	5.842	M(o)	31.000	1.927
Madla6	M(h)	39.41	8.099	M(bh)	15.000	0.0848
Pipartola3	M(h)	47.84	9.569	M(th)	20.000	6.426
Pipartola4	M(b)	33	0.335	M(o)	21.000	2.11
Pipartola5	M(h)	35.94	4.275	M(o)	17.000	0.472
Pipartola6	M(o)	21	2.2376	M(o)	20.000	1.24
Pipartola7	M(h)	35.658	6.504	M(o)	20.000	1.24
Pipartola8	M(h)	33.45	6.3853	M(o)	29.000	5.76
Talgaon5	M(h)	49.306	7.59	M(h)	42.077	4.86
Talgaon4	M(h)	43.556	4.296	M(h)	39.716	3.813
Talgaon7	M(h)	43.556	4.296	M(h)	39.716	3.813

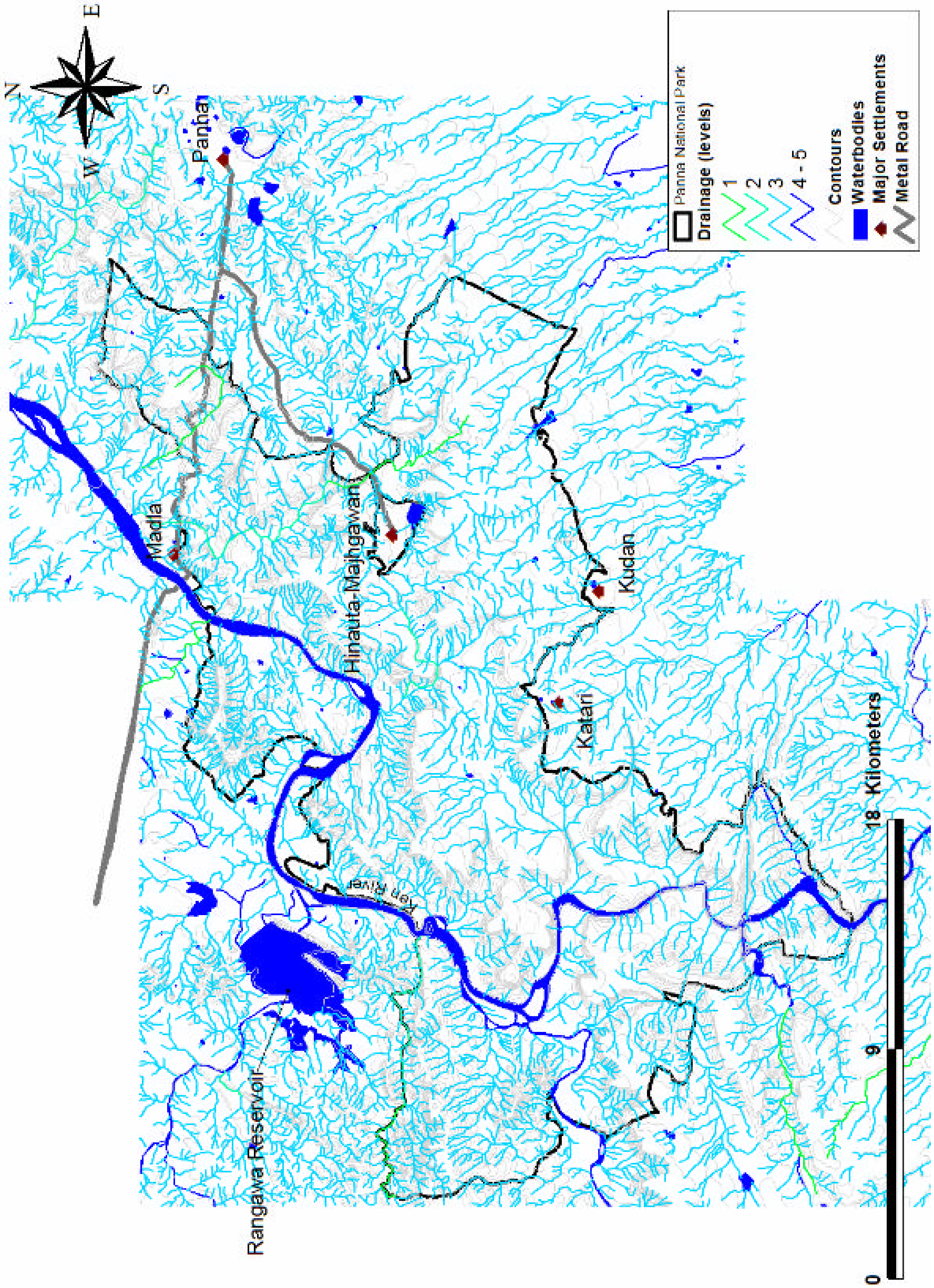


Fig. 2.6 Water-bodies and drainage system of Panna National Park and its neighbouring areas

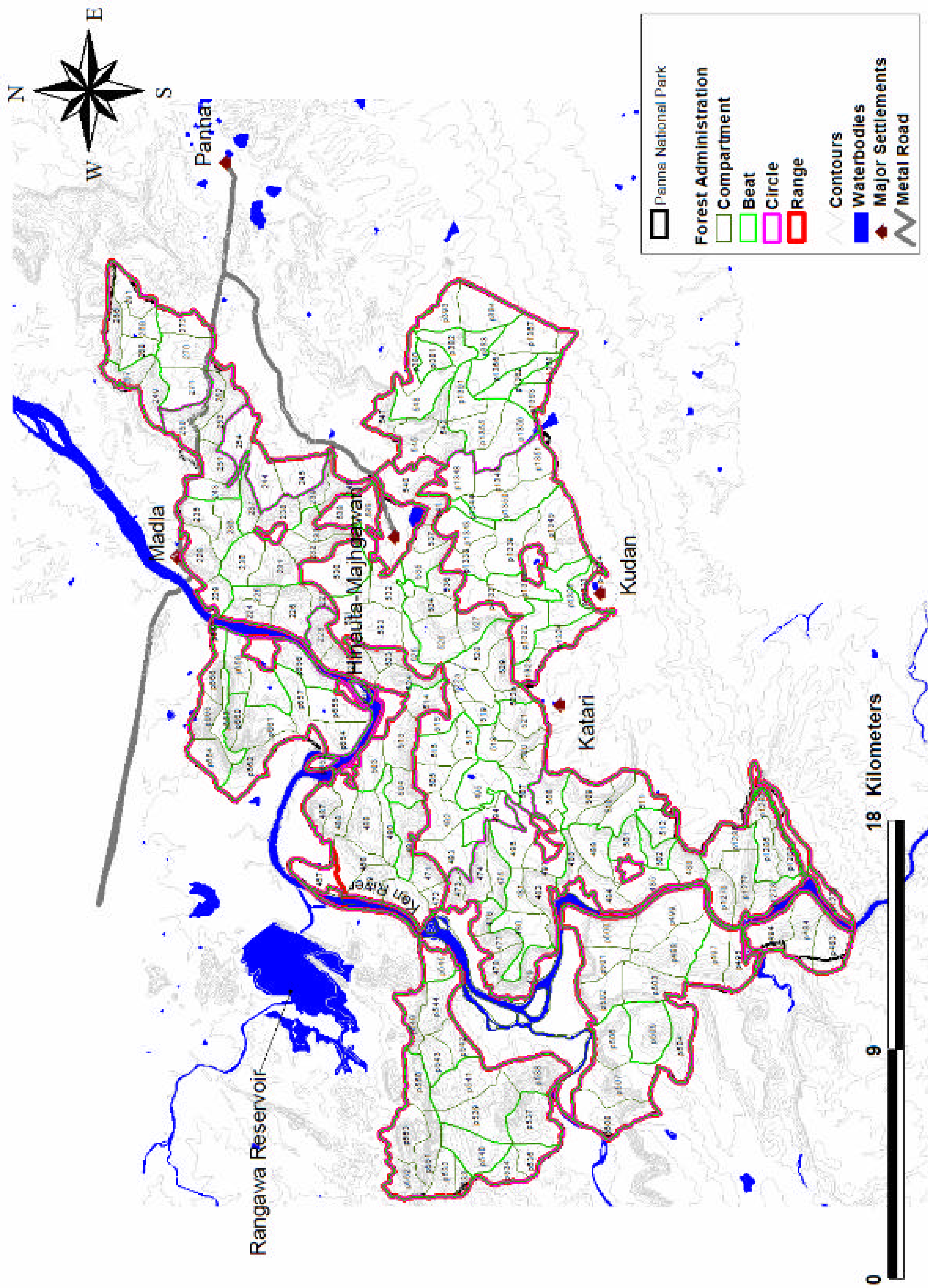


Fig. 2.7 Forest Administration Map of Panna National Park

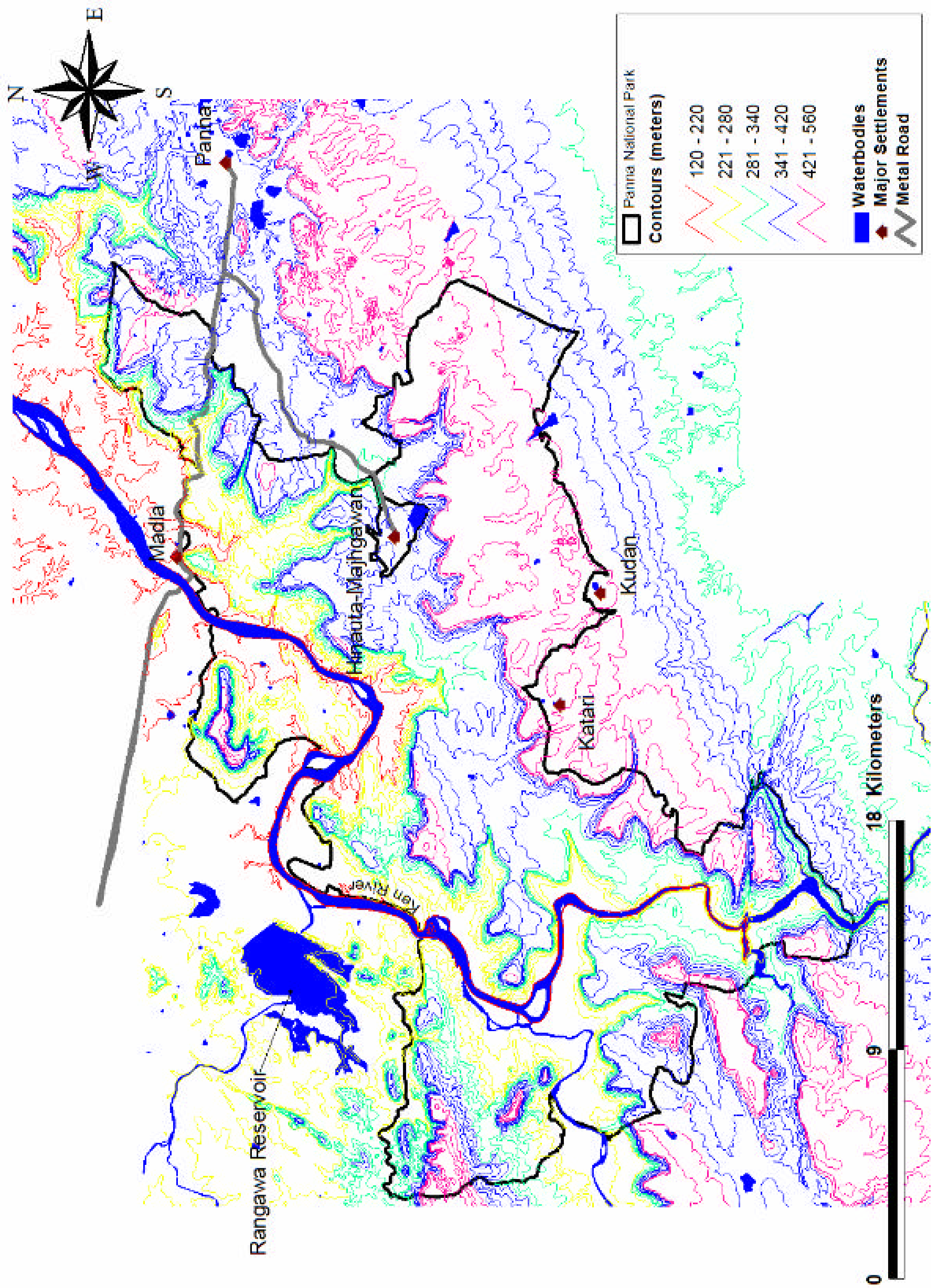


Fig. 2.8 Contour Map of Panna National Park

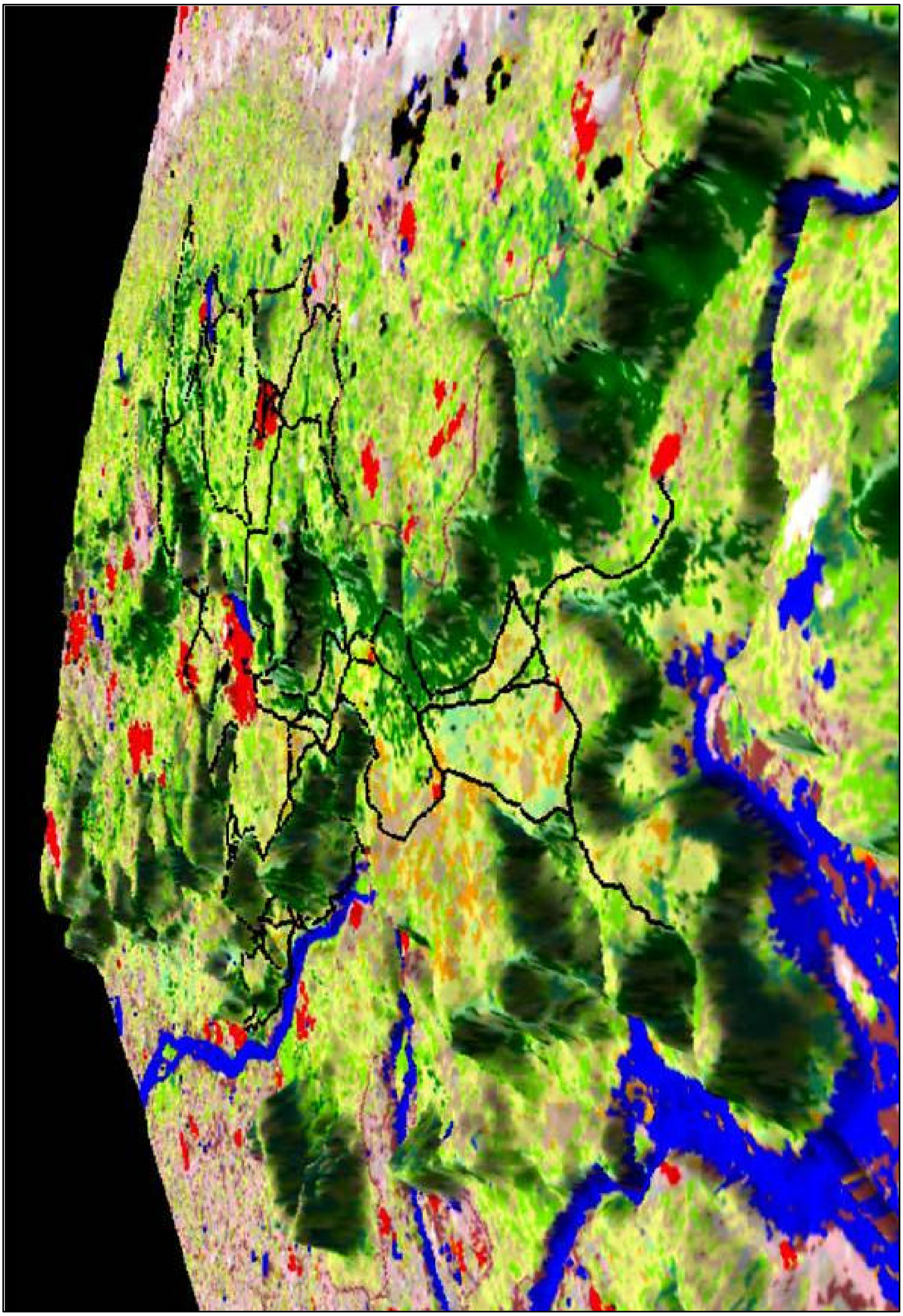


Fig. 2.9 Digital Elevation Model draped with National Park boundaries, roads and habitat/land-use Maps

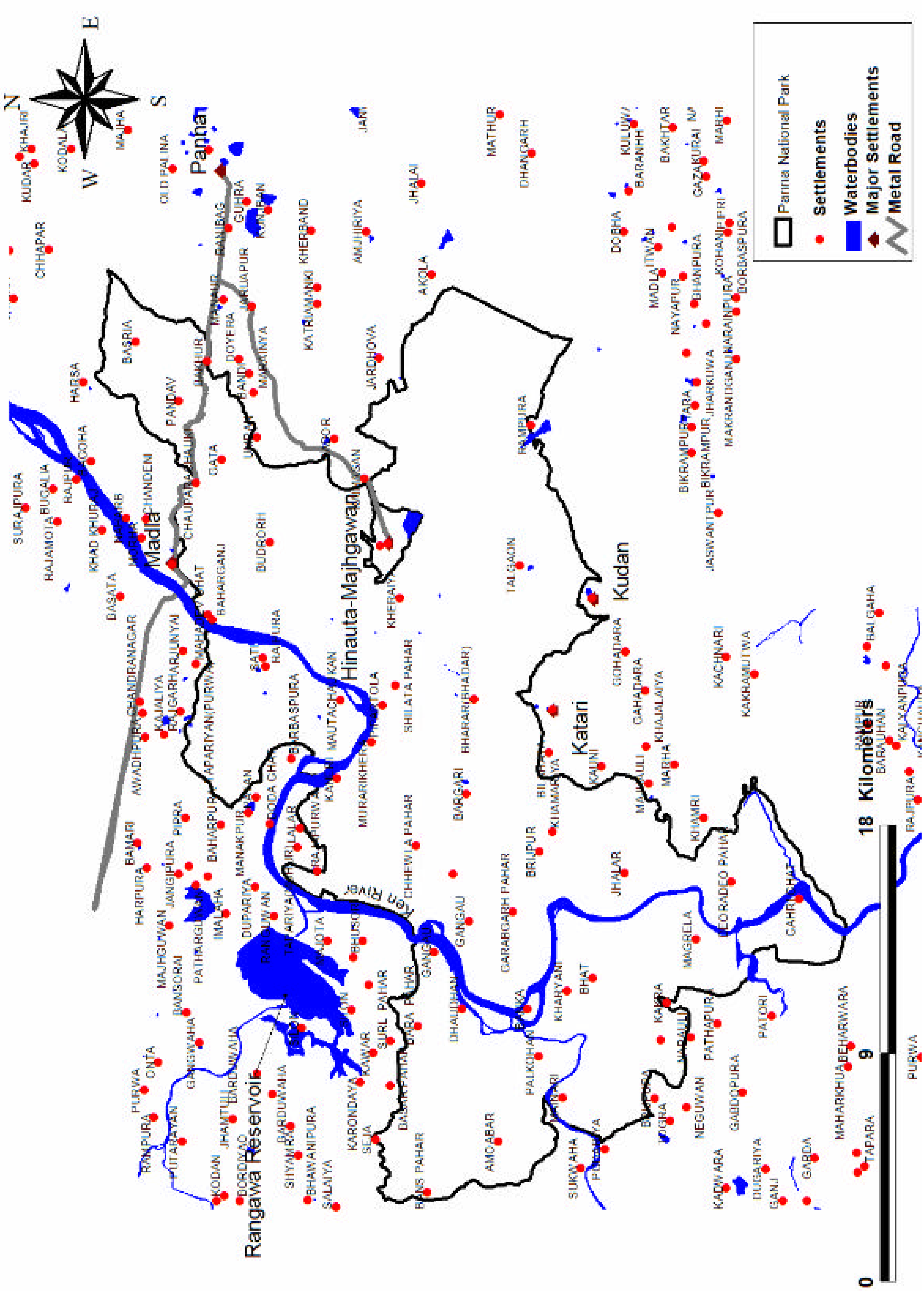


Fig. 2.10 Settlements within and around Panna National Park.

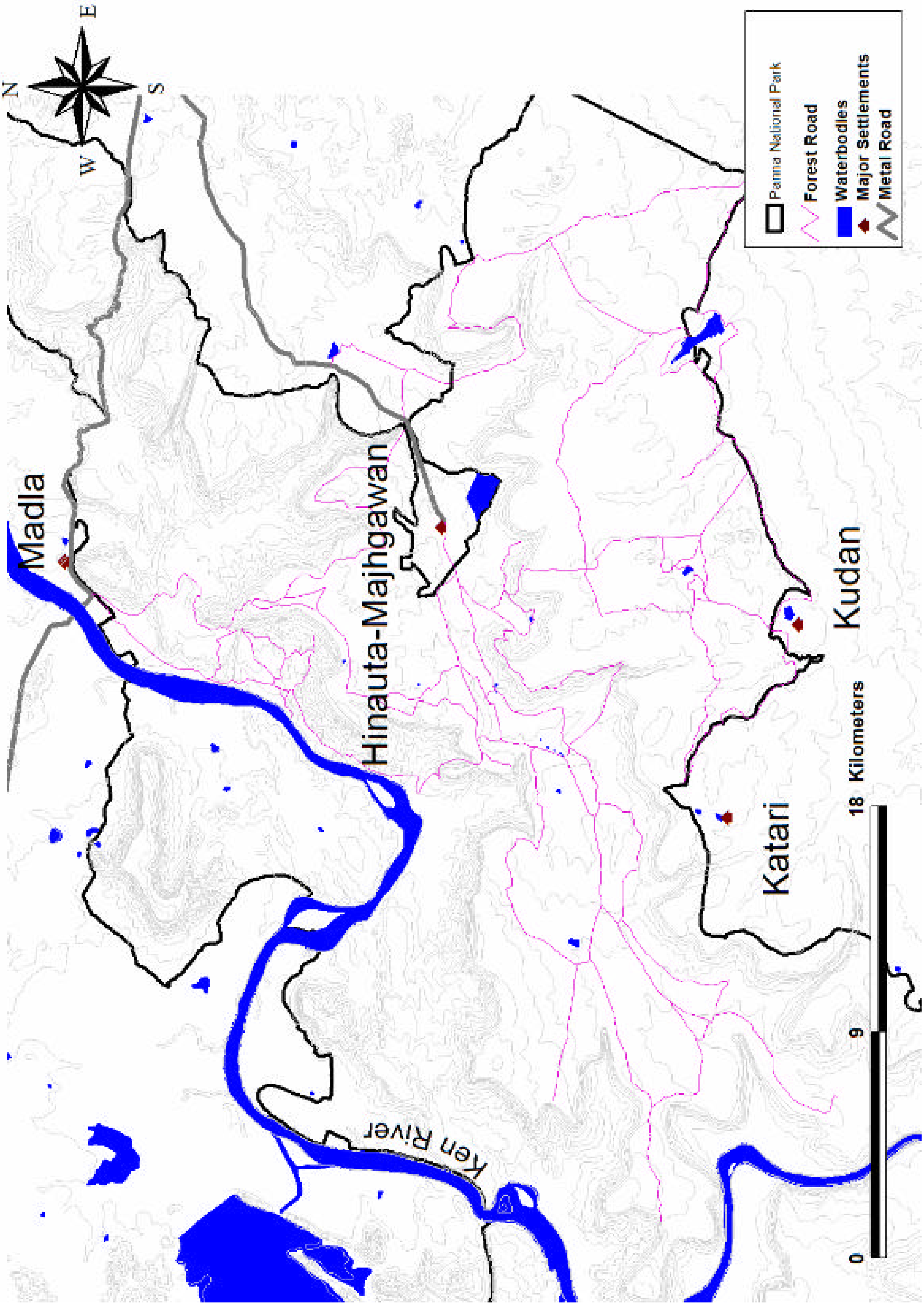


Fig. 2.11 Road Network of Study Area within Panna National Park

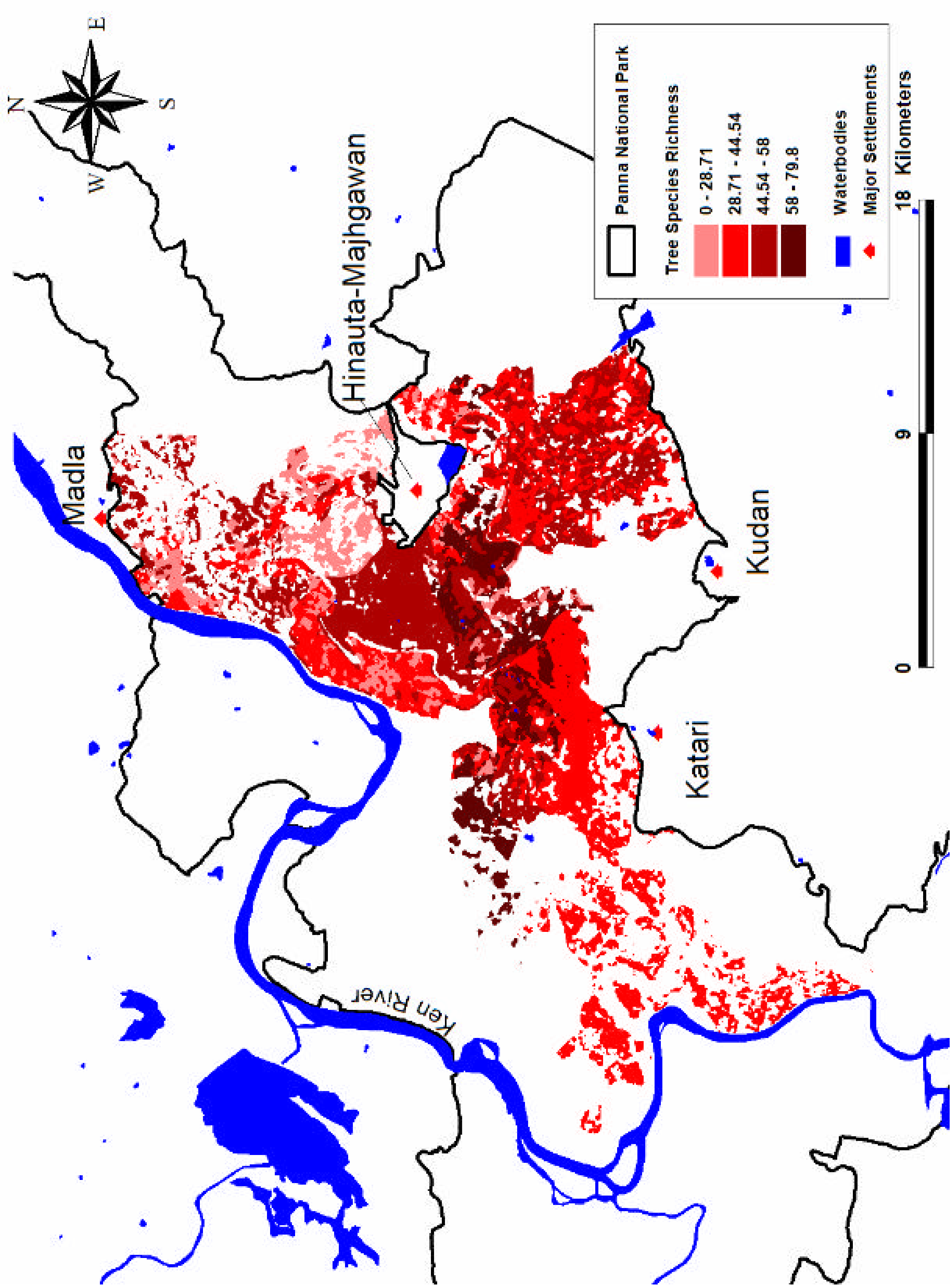


Fig. 2.12 Map of Tree Species Richness at sampled sites within Panna NP

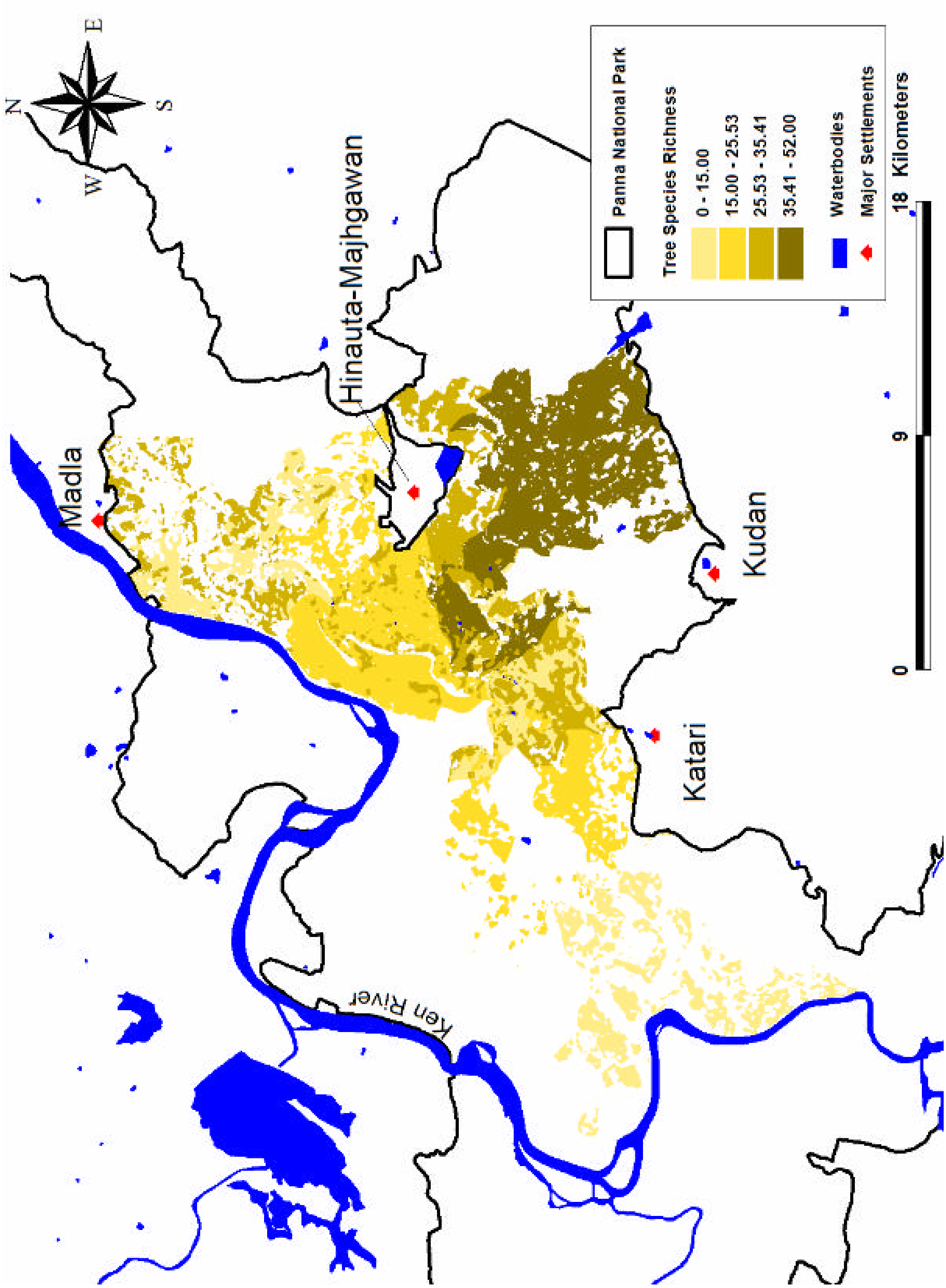


Fig. 2.13 Map of Sapling Species Richness at sampled sites within Panna NP

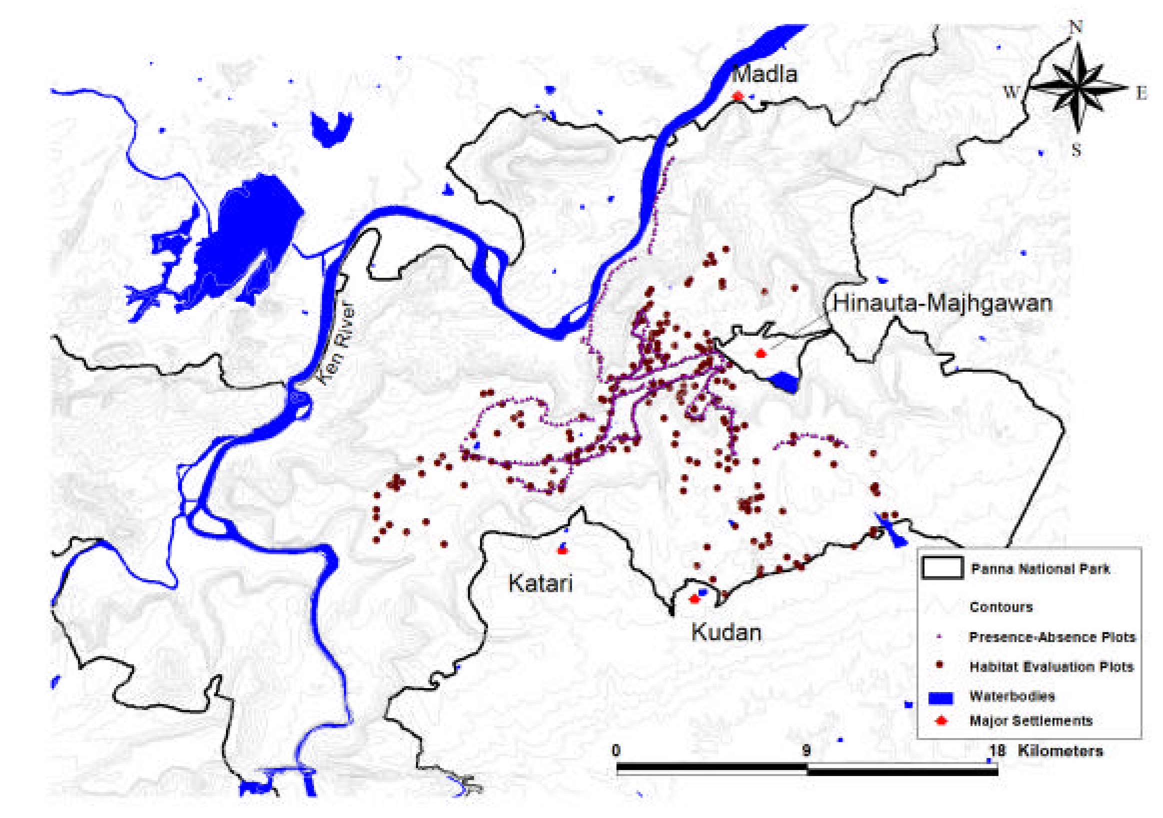


Fig. 2.14 Locations of 501 presence-absence (for species richness) and 250 habitat evaluation (for vegetation assessment) plots

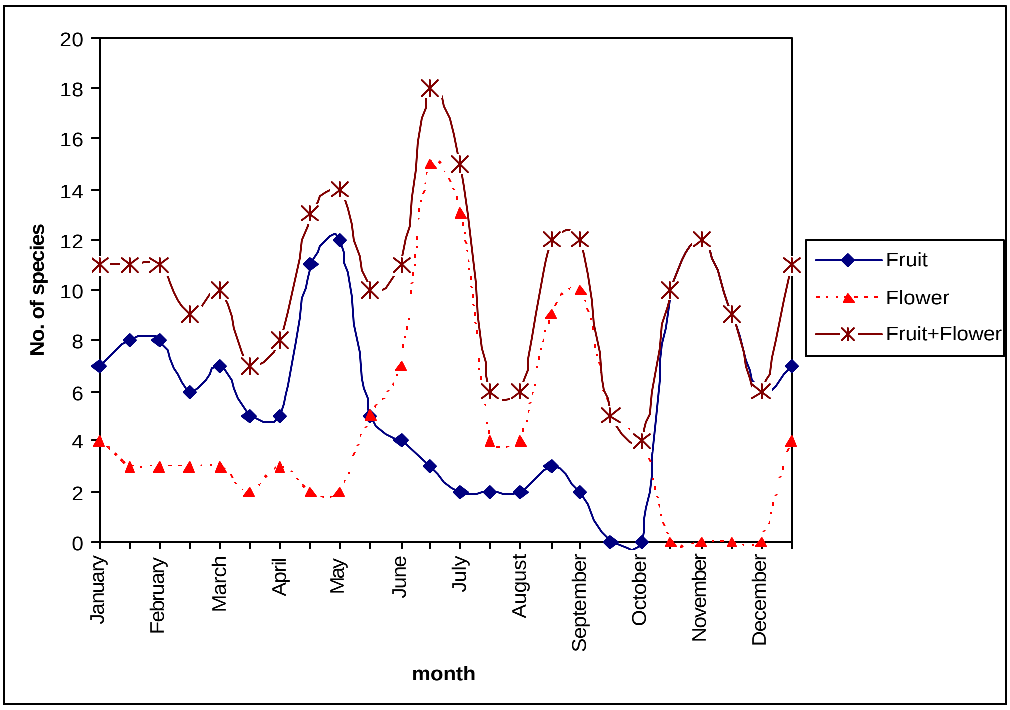


Fig. 2.15 Fortnightly availability of ripe fruits and flowers on the forest floor across the year

CHAPTER III

Habitat Use and Distribution of Four-horned antelope in Panna National Park

3.2 Methodology

CHAPTER III

HABITAT USE AND DISTRIBUTION OF FOUR-HORNED ANTELOPE IN PANNA NATIONAL PARK

3.1 Introduction

Odum (1971) defines habitat of an organism as the place where it lives. Habitat comprises of the physical conditions surrounding a population or individual representing an organism or community to live and grow (Clements & Shelford, 1939; Morrison *et. al.*, 1992; Hall *et. al.*, 1997; Krausman, 1999). It implies more than vegetation or vegetation structure, as it includes the sum total of all the environmental conditions present at a specific place occupied by an organism (Thomas, 1979; Garshelis, 2000). The resources include food, cover, water and other special factors needed by a species for survival and reproductive success (Leopold, 1933). Thus, migration and dispersal corridors, and the land that animals occupy during breeding and non-breeding seasons, also come under the definition of habitat.

Habitat use is the way an animal uses the physical and biological resources in a habitat (Krausman, 1999). It may be used for foraging, cover, nesting, escape, resting or other life history traits. While these different categories of usage are discrete, there is a significant amount of overlap between them. One or more categories may exist within the same area, but it is not necessary that the area will comprise of the same physical characteristics used for cover, resting or both. Factors other than habitat variables, such as presence of conspecifics and interspecific competitors, could also influence whether an animal stays at a particular place (Svardson, 1949). Many studies show that for some species habitat selection is influenced by conspecifics (Butler, 1980; Railsback *et. al.*, 2003), interspecific competitors (Werner & Hall, 1979), and/or predators (Hobson, 1978; Werner et. al. 1983; Lima and Dill, 1990; Rangeley & Kramer, 1998), apart from the features of the environment, directly or indirectly related to the resources needed for survival and reproduction.

Concept of habitat is a cornerstone in the management of wildlife. Knowledge of habitat preferences is critical to formulate appropriate management plans which are dependent on our understanding of the animal's habitat requirements. Five stages of wildlife management were initially identified (Leopold, 1933): laws and regulations, predator control, reservation of land and refuges, artificial replenishment, and environmental controls. Another stage, mentioned by Krausman (1999), which is widely used but not mentioned above, is habitat management and control. Leopold (1933) stated that science had accumulated more knowledge of how to distinguish one species from another than of the habits, requirements and inter-relationships of living populations. Habitat quality has long been recognized as one of the primary influences in determining animal use and abundance in a given area, with habitat selection models as the primary tool for identifying those relationships (Broomhall, *et. al.*, 2003).

Habitat quality is defined as individual fitness provided by the habitat (Garshelis, 2000). Fitness Potential is what a habitat type provides an average animal in the absence of competition. It is an intrinsic characteristic of the habitat and can be evaluated even if animals are absent. It depends on both growth potential and mortality risks presented by a habitat type. Habitat type is defined as density i.e. the number of individuals observed using a habitat type, divided by the area of the habitat of that type available to the population (Manly *et. al.* 2002). It is difficult to statistically establish relations between habitat selection and habitat variables since they are too complex to model (Railsback, *et. al.*, 2003). One of the possible causes of this complexity is that cells with very different habitat characteristics can provide equal fitness. It is understood that factors other than habitat have important effects on population response. Competition among individuals strongly affects population response, and creates complex secondary effects of habitat alteration such as negative relation between density and births. Organisms also modify local resource distribution regularly, influencing both their ecosystems and the evolution of traits whose fitness depends on such alterable sources of natural selection in environments (Laland *et. al.*, 1999).

Adaptation and specific requirements of different species define the niches that they occupy to reduce competition and maximise efficiency in utilisation of resources. Niche, means a position in space literally. An ecological niche defines all of the environmental conditions and resources that are necessary for an organism to maintain a viable population. Hutchinson (1957) proposed a separate niche dimension not only for each important environmental condition, but also for each of the resources that the organism requires. A fundamental niche describes the full range of environmental conditions under which an organism or its population can exist. Usually a species has a larger ecological niche in the absence of competitors and predators than it has in their presence. There are certain combinations of conditions and resources that can allow a species to maintain a viable population, but only if it is not being adversely affected by enemies (Begon *et. al.*, 1996). Differences between sympatric species regarding the use of trophic, temporal and spatial niches have been frequently used to describe and explain community structure (Sunquist *et. al.*, 1989; Kruuk *et. al.*, 1994; Singh *et. al.*, 2000; Newing, 2001). Segregation of these niche dimensions may permit the partitioning of resources and thus facilitate ecological coexistence of species.

While availability of food is crucial for the well being of any species, shelter ensures protection from predatory and environmental threats. Animal distribution is closely related to availability of favourable habitat (e.g. Erickson *et. al.* 1998; Mathai, 1999; Lai *et. al.* 2002; Kushwaha *et. al.* 2004; Jegannathan *et. al.*, 2004; Zarri *et. al.*

2005; Niemuth *et. al.*, 2005). Several examples exist where species distribution within an area changes once there are some alterations in the habitat they live in (e.g. Rahmani, 1989).

In case of ungulates, some habitat variables are specifically emphasized when discussing their distribution. Availability of water is one of the crucial parameters that define distribution and sustenance (e.g. Prater, 1980; Illius and O'Connor, 2000; Chundawat, 2001; Sanago, 2005; Chundawat, 2006). Ungulates of different size and metabolic rates have specific demands in terms of nutrition and hence are known to have spatial and temporal niches (e.g. Jarman, 1974; Newing, 2001). Different species use specific habitats to meet their requirement of shade through overhead canopy. Demand of overhead canopy varies for different species depending on local temperature, level of solar radiation and individual tolerance (Hoar, 1966).

For ungulates to protect themselves and their young ones from predators, they adapt specific anti-predatory strategies (Leuthold, 1977; Caro *et. al.*, 2004; Broom and Ruxton, 2005). Visibility causes serious implications on site selection by species. Grass and vegetation undergrowth are both considered to influence visibility in an area. Studies suggest that slope, soil quality and aspect affect distribution of vegetation as well as animals (e.g. Champion & Seth, 1968; Lai *et. al.* 2002; Kushwaha *et. al.* 2004; Zarri, 2005). Tolerance level to disturbance varies across species and the level of exposure to such disturbances that it has undergone over a period of time. In this study, disturbance is considered as purely anthropogenic, ranging from physical presence of human beings and cattle, and movement to environmental damage in terms of poaching, habitat destruction (lopping, grass cutting, collection, overgrazing and fire) and trampling. Disturbance levels often regulate the extent of an animal's distribution.

India has seen a steep decline in its wildlife in the last century. With an ever increasing human population pressure, the natural resources are depleting fast (Johnsingh & Negi, 2003). A network of protected areas in all states of the country was foresighted to serve as seed areas for wildlife (Rodgers & Panwar, 1988). With many variables influencing species survival within these protected areas, it is important to manage them with specific conservation goals (e.g. Halvorson, 1999; Ramakrishnan, 1999; Shipley, 1999). What is to be managed, how is it to be managed and when should it be managed set the guidelines before imparting any interventions. As discussed above, habitat is an area that is used by a species or its populations to survive in. Therefore, to implement proper management interventions it is important to understand the habitat requirements of a species. Moreover, studies on habitat use also provide insight into various other behavioural (e.g. Ruckstuhl, 1998; Shipley, 1999; Blumsetin et. al. 2002), evolutionary (Jarman, 1974; Janis, 1981; Geist 1998) and ecological (Mysterud, 2000; Harte *et. al.* 2004) aspects of the natural history of a species. These studies help understand the niche occupied and the role played by a species in the ecosystem.

Out of six antelope species found in India, only the Four-horned antelope is known as a forest antelope (Rahmani, 2001). While the Blackbuck uses open grasslands (Schaller, 1967; Nair, 1976; Ranjitsinh, 1982), Chinkara and Nilgai can be found in forests that are predominantly open in nature (Rahmani, 1990a & 1990b; Qureshi, 1992; Alfred *et. al.* 2001). Other antelopes, i.e. the Tibetan antelope and the Tibetan Gazelle are found in high altitudes (Brander, 1923; Prater, 1980; Menon, 2003) and hence have specifically different habitat requirements than those found in the lower altitudes. The Cervids on the other hand, use a variety of habitats. The Barasingha is a typical grassland dweller (Gee, 1964; Schaller, 1967; Prater, 1980; Ranjitsinh, 1982), whereas the Sambar is found mostly in dense forests (Prater, 1980; Chundawat, 2001 & 2003; Sanago, 2005). Chital utilizes a mix of grasslands and forests (Mishra, 1982; Chundawat, 2001 & 2003), whereas the Muntjac (Lai *et. al.*, 2002; Kushwaha *et. al.* 2004) and Chevrotain or Mouse Deer (Krishnan, 1975) dwell in densely forested habitats. The Hangul, Hog Deer (Dhungel and O'Gara, 1991; Biswas *et. al.* 2002), Brow-antlered Deer (Ranjitsinh, 1978) and Musk Deer (Green, 1985) have extremely confined distributions limited to their very specific habitats (Brander, 1923; Prater, 1980; Menon, 2003).

Little was known about the habitat requirement and preferences of the Four-horned antelope. Available literature suggests that it prefers well watered country and undulating terrain (Brander, 1923; Prater, 1980). Bhaskaran (1999) suggests that it uses semi open canopy while Berwick (1974) points out that it is an animal of distinct dry forest. No long term scientific research was ever conducted attempting to study its habitat use. Being a cryptic animal, the information available about its natural history was also scarce and usually based on opportunistic records.

3.2 Methodology

3.2.1 Field

The Four-horned antelope is an elusive species. Direct sighting of a Four-horned antelope is considered to be rare and a matter of chance in many areas where it is found (Berwick, 1974; Jathanna, 2003; Karanth & Sunquist, 1992). However, this is not the case in Panna. Direct sightings can be easily made in Panna Tiger Reserve, especially in the drier seasons. Considering a comfortably high encounter rate (see Chapter IV, Density Estimation), vehicular search was considered as one of the possible means to obtain data on site coordinates and other habitat parameters. Presence and absence data have been widely used for habitat use analyses (Shackelford & Conner, 1997). Apart from this, each sighting of Four-horned antelope during the line transects was recorded with the help of distance markers on the transect line. Using Distance and Azimuth Tools (Jenness, 2005) in Arcview 3.2^{TM}, the sighting points were located on a map and plotted along with points denoting direct sightings from the road or otherwise. While direct sightings certainly provide information about the physical location of an animal at the time of sighting, there are covariates such as detection probability (Burnham, 1980; Buckland, 1993; McKenzie et. al. 2002; Royle & Nichols, 2003) and systematic avoidance of roads (Thomas & Karanth, 2002; *this study*) that potentially bias the data collected using this method.

Grass height was estimated wherever a direct sighting was obtained. With the help of a bamboo stick with six sections etched on it, grass height was measured as one the following six categories: ***Very Low*** **(0< to <10 cm),** ***Low*** **(10< to <25 cm),** ***Low medium*** **(25< to <45 cm),** ***Medium*** **(45< to <70 cm),** ***Tall medium*** **(70< to <1 m)** and ***Tall*** **(>1 m)**.

Antelopes are known to defecate on middens (Schaller, 1967; Leuthold, 1977; Ranjitsinh, 1982; Brashares, 1999). Four-horned antelope also has a similar tendency where it regularly defecates on middens (Prater, 1980; Berwick, 1974; Bhaskaran, 1999; Menon, 2003). Any defecation point with signs of multiple defecations was called as a midden. The signs include presence of pellets in different decay stages, different sizes and distinguishable heaps (and not trails) of single defecation visits. These middens are usually defecated upon by not only different individuals of the same species, but also by different species (Nilgai, Chinkara and Four-horned antelope). Using the map of Panna National Park, areas with high encounter rate of Four-horned antelope were marked in Hinauta and Panna ranges, and assigned different numbers (see Fig. 3.1). Out of these, seven points were selected using random number generator in MS Excel. Plots with sizes ranging from 1.95 ha to 63.66 ha were surveyed for middens at these locations. Roads, physical barriers such as cliffs and accessibility demarcated the natural boundaries of these plots. Systematic search for middens was done on these midden plots where on each sampling occasion, a team of three surveyors combed the area thoroughly along closely spaced parallel lines. At each midden, data were collected about its coordinates, size, status and the species that have defecated on it.

3.2.2Analysis

Broadly three kinds of study designs are distinguished according to the level at which habitat availability and use are measured (Thomas & Taylor, 1990). Design-I measures availability and use at population level and individual animals are not identified (e.g. Erickson *et. al.*, 1998). Design-II measures habitat availability at population level but the use is measured for each animal after identifying some individual animals belonging to the population (e.g. Dhungel and O'Gara, 1991; Kilgo *et. al.*, 1998; Chundawat *et. al.*, 1999; Dickson *et. al.*, 2005; Sanago, 2005). With Design-III, both the availability and use of habitat are measured for each identified animal. Design-II and Design-III require monitoring of animals using radio-tracking and are the most frequent designs in literature dealing with habitat selection. Since no animal could be radio collared during this study, here we use only Design-I for analyzing habitat use.

Before analyzing the data on direct sightings, classification on the basis of grass heights and forest categories was done. Using data collected on perpendicular distance from the line of movement (road/line transect), detection functions were calculated separately for each category.

Considering that direct sightings were used for these estimations, there was a high chance of missing animals in tall grasses due to reduced visibility. Detection probabilities were systematically estimated using distance sampling to circumvent this problem. It was found that although the detection probability of Four-horned antelope varied across areas of different grass heights, there was negligible variation in

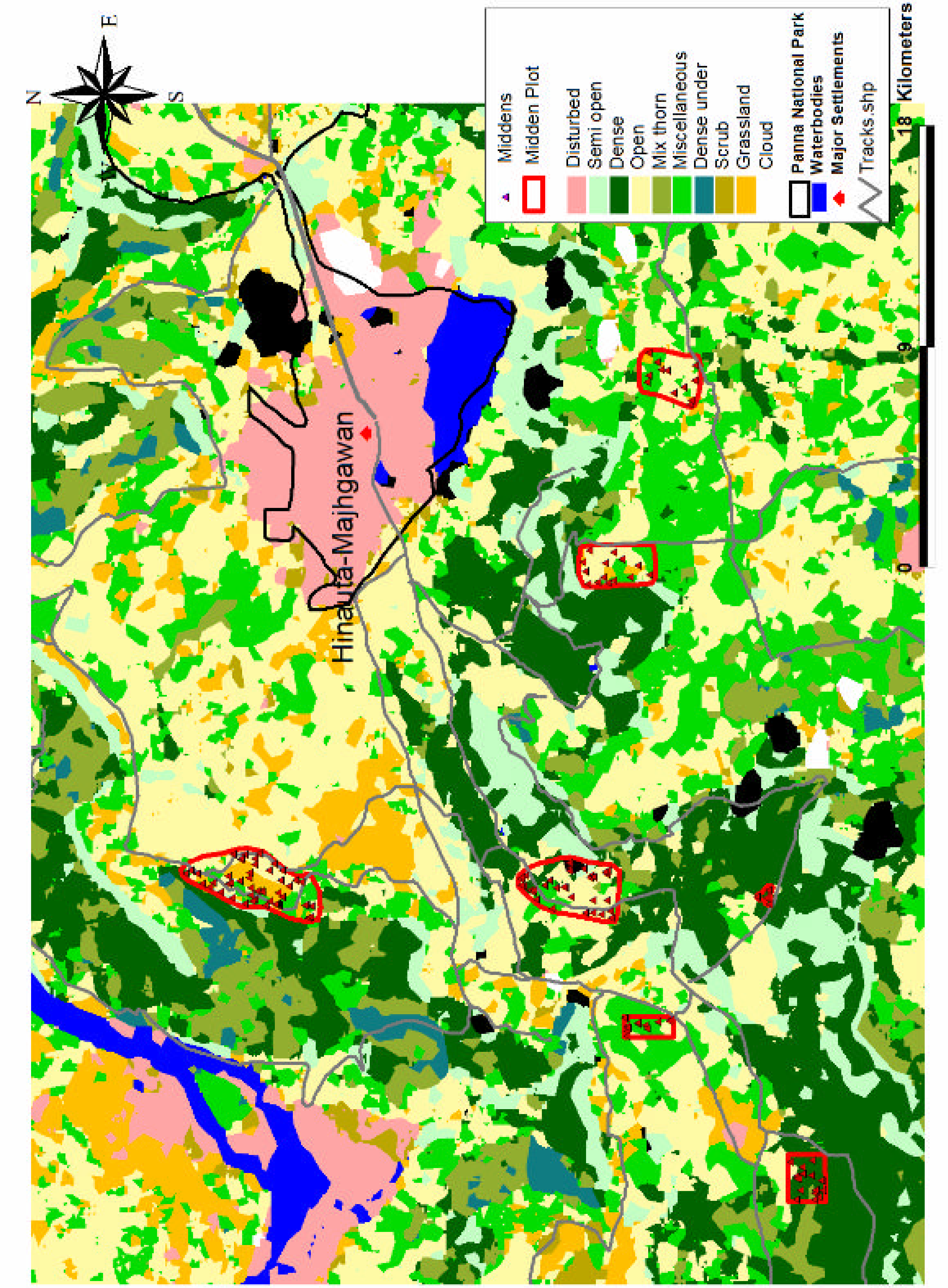


Fig. 3.1 Map depicting the seven midden plots laid in the Study Area

detection probability when compared across different forest classes. These detection probabilities were incorporated to adjust data for detectability within various forest classes and grass heights before analysis.

Points of direct sighting and middens were overlaid on different GIS layers to understand the pattern of habitat use. Neu *et. al.'s* (1974) method was used, which is known to identify habitat selection patterns consistent with known requirements of animals at all levels of habitat availability. It is recommended that availability should be defined at the study area level rather than using circular buffers (McClean *et. al.* 1998). For estimating availability of different forest classes for selection of defecation sites, boundaries of each of the seven midden plots were taken and in the case of sightings from vehicle or transect, a buffer of 100 meters was taken on both sides of the road (Fig. 3.2). The areas covered within these buffers were considered as available. Null hypothesis that there is no significant difference between the expected and observed frequency was tested using the Log-likelihood G-test (Wilks, 1935). G-test was preferred over the conventionally used Chi square test (Neu *et. al.*, 1974; Byers & Steinhorst, 1984; Broomhall *et. al.*, 2003) considering its robustness (Zar, 1999). With the help of use/availability data on forest classes, Bonferroni's Confidence Intervals (Neu *et. al.* 1974; Byers & Steinhorst, 1984) were evaluated for both direct sighting as well as midden data with the help of macros that we developed for MS Excel. Since

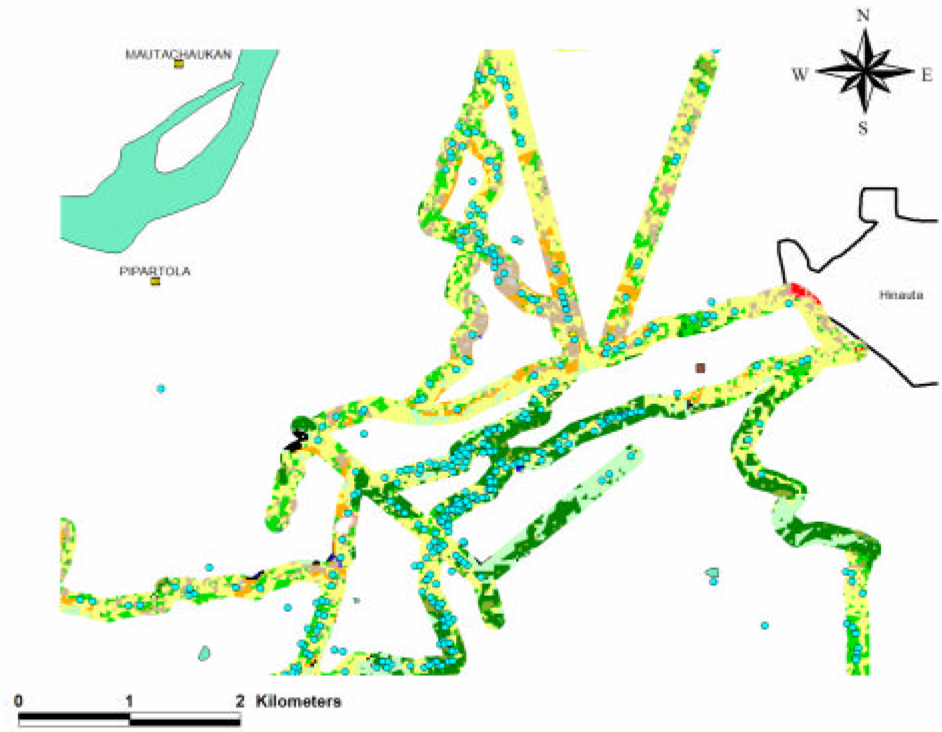


Fig. 3.2 Points of direct sightings and buffer of 100m on both sides of the road.

middens provided additional information on two other antelope species i.e. Chinkara and Nilgai, which are sympatric to the Four-horned antelope; an analyses of their habitat selection for defecation sites was also done. Using contingency tables and chi-square tests, data were subjected to association tests in order to understand the niche separation and overlap between the three species.

Middens are used extensively by antelopes for defecation (Leuthold, 1977; Prater, 1980). Overlapping usage of middens by different species was used to generate information about their niche separation. Species using a particular habitat defecate at a particular rate and dung can efficiently be used as an indicator of presence of a species (Mathai, 1999; Chundawat, 2001; Karanth & Nichols, 2002). This dataset can also be used to indicate extent of use (e.g. Mathai, 1999; Brashares, 1999; Marques, 2001; Laing, 2003; Kushwaha, 2004).

Species richness is an index denoting the total number of species found in an area (Kent and Coker, 1995). Floral species richness maps were developed using Capture-recapture framework (e.g. Williams *et. al.*, 2002) for 33 ecologically separable blocks within the study area (see Chapter 2, Study area). These maps were made for trees and saplings species richness and covered 106 km^2 of the total study area (Fig. 3.3). Species richness of trees and saplings were estimated at each point of direct sighting of the Four-horned antelope. Correlation coefficient between the species richness and the number of sightings was estimated to understand the factors governing resource selection by the Four-horned antelope.

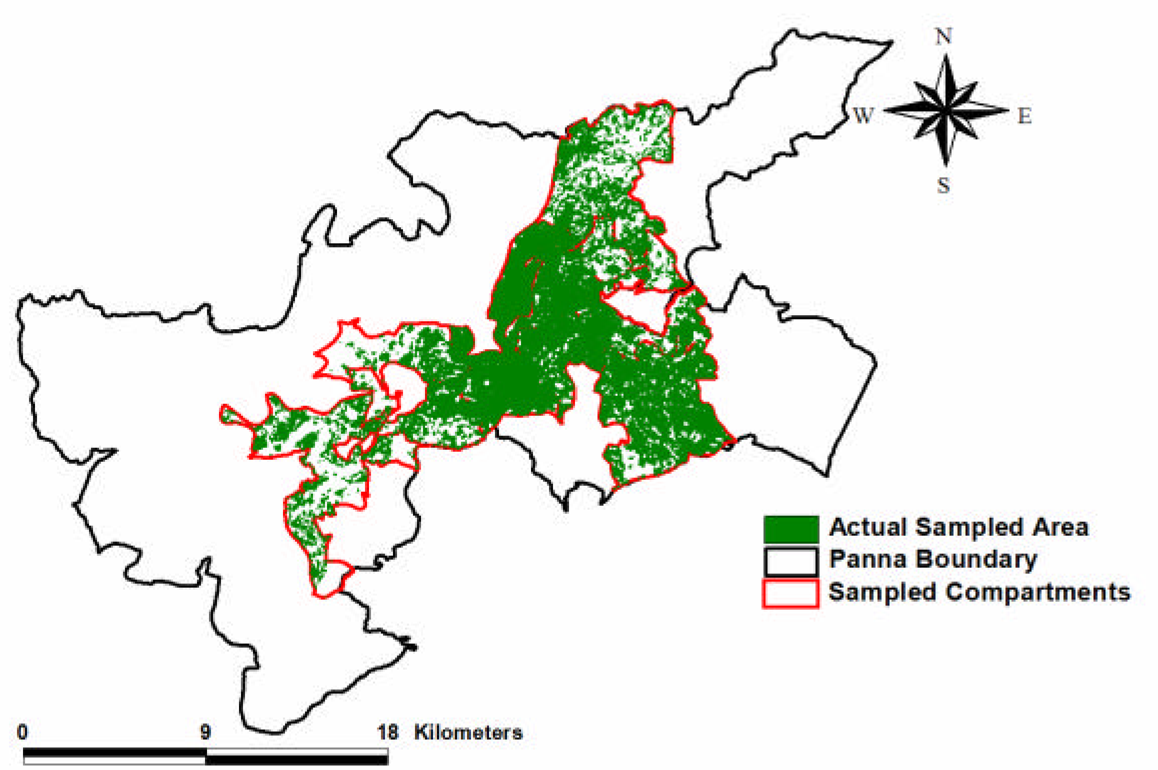


Fig. 3.3 Compartments and actual area sampled for estimation of species richness in the study area.

Buffer layers were developed with gradients at appropriate distance groups for water-bodies and disturbed areas to investigate the dependency of Four-horned antelope's distribution on these two factors (Fig. 3.4 and 3.5). Using Distance/Bearing tool (Jennesse, 2005) in Arcview, we obtained the minimum distance between these features and points of direct sightings of the Four-horned antelope.

Habitat concept is by essence multivariate, but most studies carried out on habitat selection by animals consider only one single categorical habitat variable (Calange *et. al.*, 2005). Eigen-analyses are efficient methods in revealing the main characteristics of multivariate data (Escoufier, 1987). Principal Component Analysis, Correspondence Analysis, and Canonical Correlation Analysis have been used with success in ecological studies (Manly *et. al.*, 1994). Principal Component Analysis (PCA) is a useful technique to reduce multivariate data into a usable and more understandable number of correlated variables (Pearson, 1901; Hotelling, 1933). It is widely used by researchers to investigate habitat relationships (Goodall, 1954; Orloci, 1966; Morrison et. al. 1992; Kent & Coker, 1995; Mathai, 1999; Chundawat, 2001; Kushwaha *et. al.* 2004; Zarri, 2005). PCA was used to investigate the relationship between different habitat variables, and Four-horned antelopes' response to these. It is one of the most difficult tasks to decide which explanatory variables or combination of variables should enter the mode (Boyce & McDonald, 1999; Calenge *et. al.*, 2005). Based on the natural history observations and available data, PCA was run on seven variables (Distance from water, Distance from settlements, Slope, Tree species richness, Sapling species richness, Grass height and canopy).

3.3 Results

The total number of direct sightings recorded during the three year period with coordinates is 672. Out of these sightings, 115 were made during line transect exercise conducted in the year 2003 and 2005, whereas the remaining sightings were made during road counts, behaviour study or are from random encounters made during field visits.

Seven plots were surveyed with an objective of detecting middens and 147 middens were recorded. Out of these, 22 middens were exclusively used by Four-horned antelope, one belonged to Chinkara and 12 were defecated upon by Nilgai only. On all other middens association between two or more species was detected. Fig. 3.6 explains the association and exclusivity of middens used by the three species with the help of a Venn diagram. Treating the total area surveyed as available (e.g. Erickson, 1998), data was analyzed for preference using the Use/Availability methodology (Neu *et. al.* 1974; Byers & Steinhorst, 1984). It was found that only Chinkara has a significant habitat preference ($G = 55.51$, $p = 0.00$) whereas Nilgai and Four-horned antelope use the terrain in proportion of availability ($G_{\text{Nilgai}} = 6.77$, $p = 0.34$; $G_{\text{Four-horned antelope}} = 9.46$, $p = 0.15$) and had no significant preference or avoidance of any particular habitat. Using Bonferroni Confidence Intervals (Neu *et. al.* 1974; Byers & Steinhorst, 1984) it was found that Chinkara preferred savannah and avoided the wooded areas (Fig. 3.7). No indications of any such preference or avoidance of a

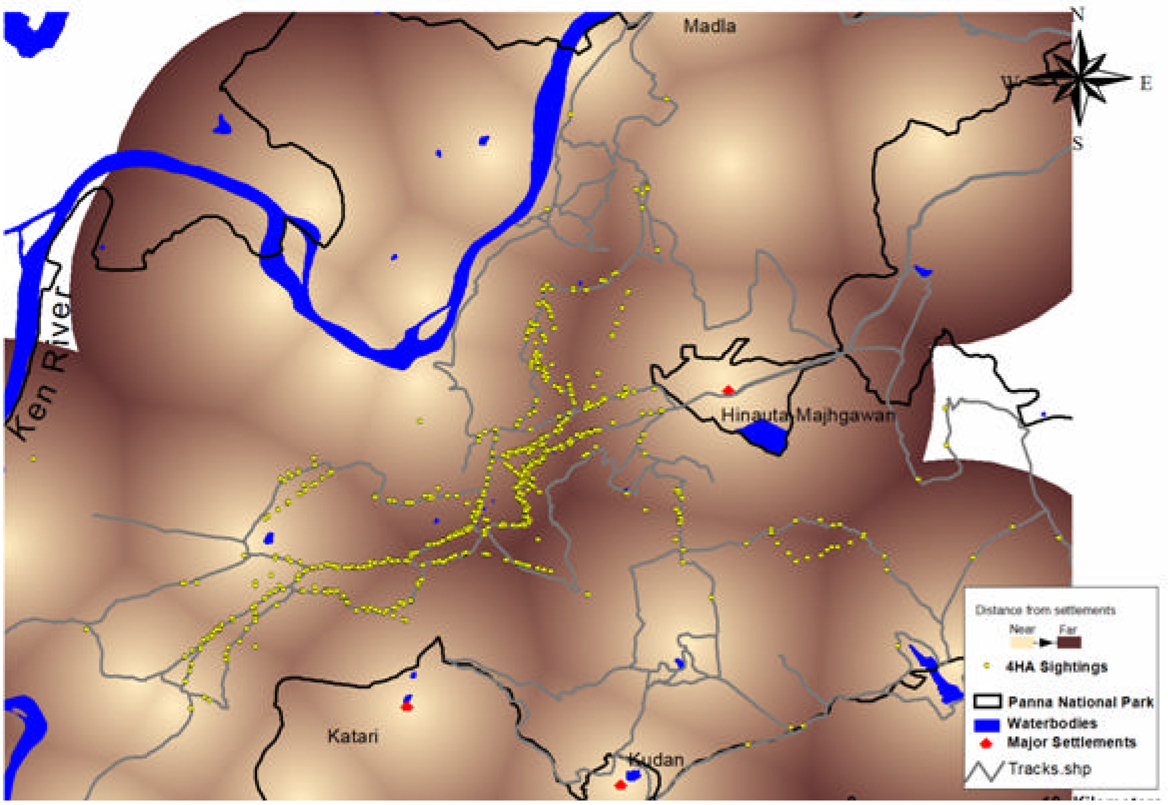


Fig. 3.4 Gradient buffer of settlements and points of direct sighting

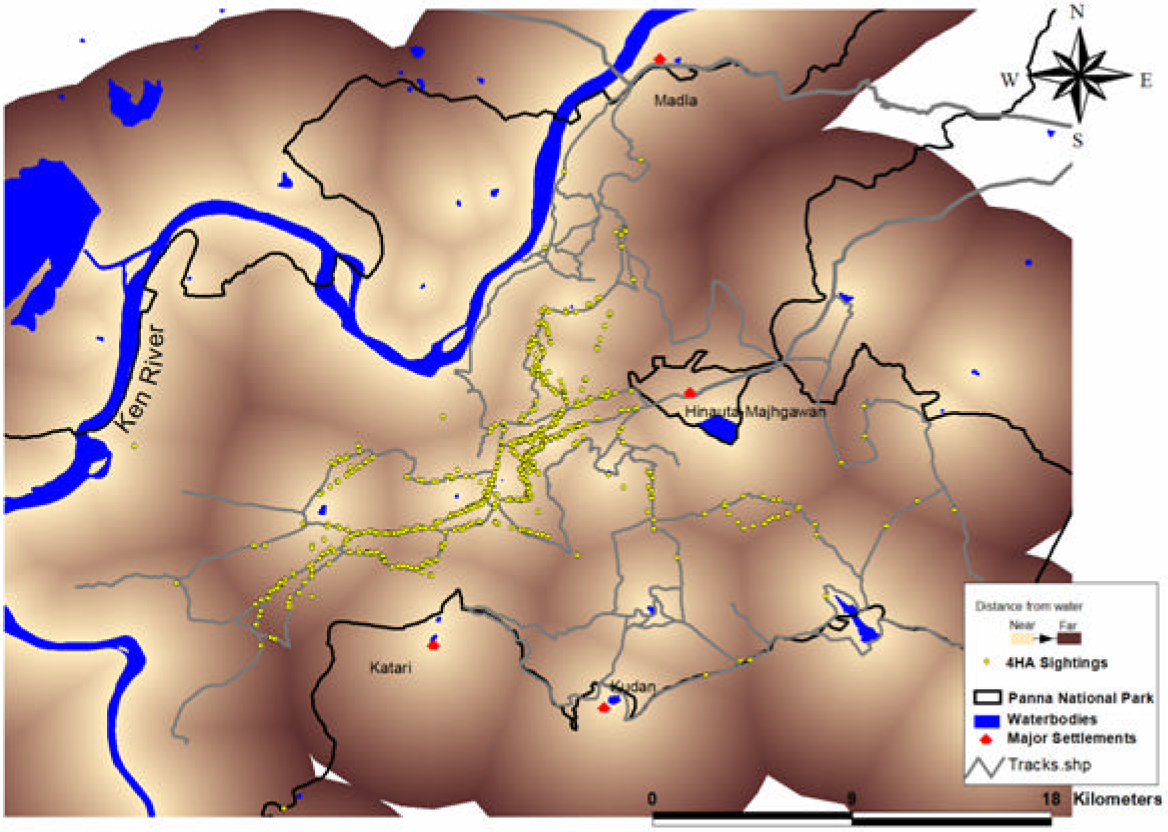


Fig. 3.5 Gradient buffer of water-bodies and points of direct sighting

particular habitat type could be observed in the case of Nilgai and Four-horned antelope (Fig. 3.7).

To perform similar tests on data collected from direct sightings, a buffer of 100 m was trimmed on both sides of the roads to estimate the availability. It was found that the roads are not only traversing across all habitat types within the study area, they fairly represent true proportions of different habitat classes found in the National Park (Table 3.a). Using this information, direct sightings were also used for evaluating habitat selection by Four-horned antelope within the surveyed area. Data from line transects were collected using an entirely different technique and hence, analyzed separately. Before analysis, the detection probabilities were estimated for sightings obtained from each of these habitat types using methods of distance sampling. As no significant difference was found between these detection probabilities, the data was safely used without estimating the detection probabilities, assuming that the number of animals missed in a particular habitat type is not expected to vary greatly across habitat types.

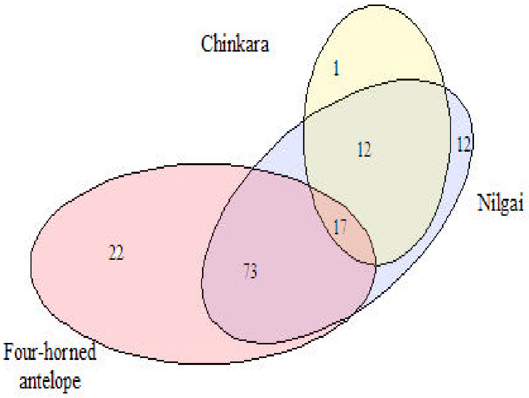


Fig. 3.6 Exclusivity and Overlap of middens of different antelopes in Panna National Park

Table. 3.a Proportion of available Habitat types: in Panna National Park and in the 100m buffer clipped on both sides of the road.

Habitat	Road (%)	Actual (%)
Dense	16.7	15.8
Miscellaneous Disturbed	0.9	2.4
Fallow	0.1	0.7
Grassland	3.1	2.3
Mixed Teak	18.5	16.2
Mixed Thorn	6.7	11.3
Mixed with dense understorey	1.2	5.4
Open Forest	37.6	29.9
Open-closed mosaic	4.8	5.7
Savannah	10.4	10.3

Data collected from the forest roads (Fig. 3.8) suggest that there were significant habitat preferences (G = 73.34, p = 0.00). Contrarily, line transect data revealed no such preferences (G = 1.41, p = 0.96) and all available habitat types were used in proportion to their availability (Fig. 3.9). Bonferroni Confidence Intervals estimated from road data indicate that the Four-horned antelope not only avoid disturbed areas, but have a preference for dense forests as well. Since only one sighting could be obtained from the category having mixed forest with dense understorey, not much could be said about Four-horned antelope's habitat usage in this habitat type. More advanced studies such as radio telemetry are required to understand the pattern of use from these habitat types.

Using contingency tables and chi-square test for association with Cochran's correction (Cochran, 1942; Haber, 1980), information on niche separation and overlap of Four-horned antelope, Nilgai and Chinkara was generated (Table 3.b).

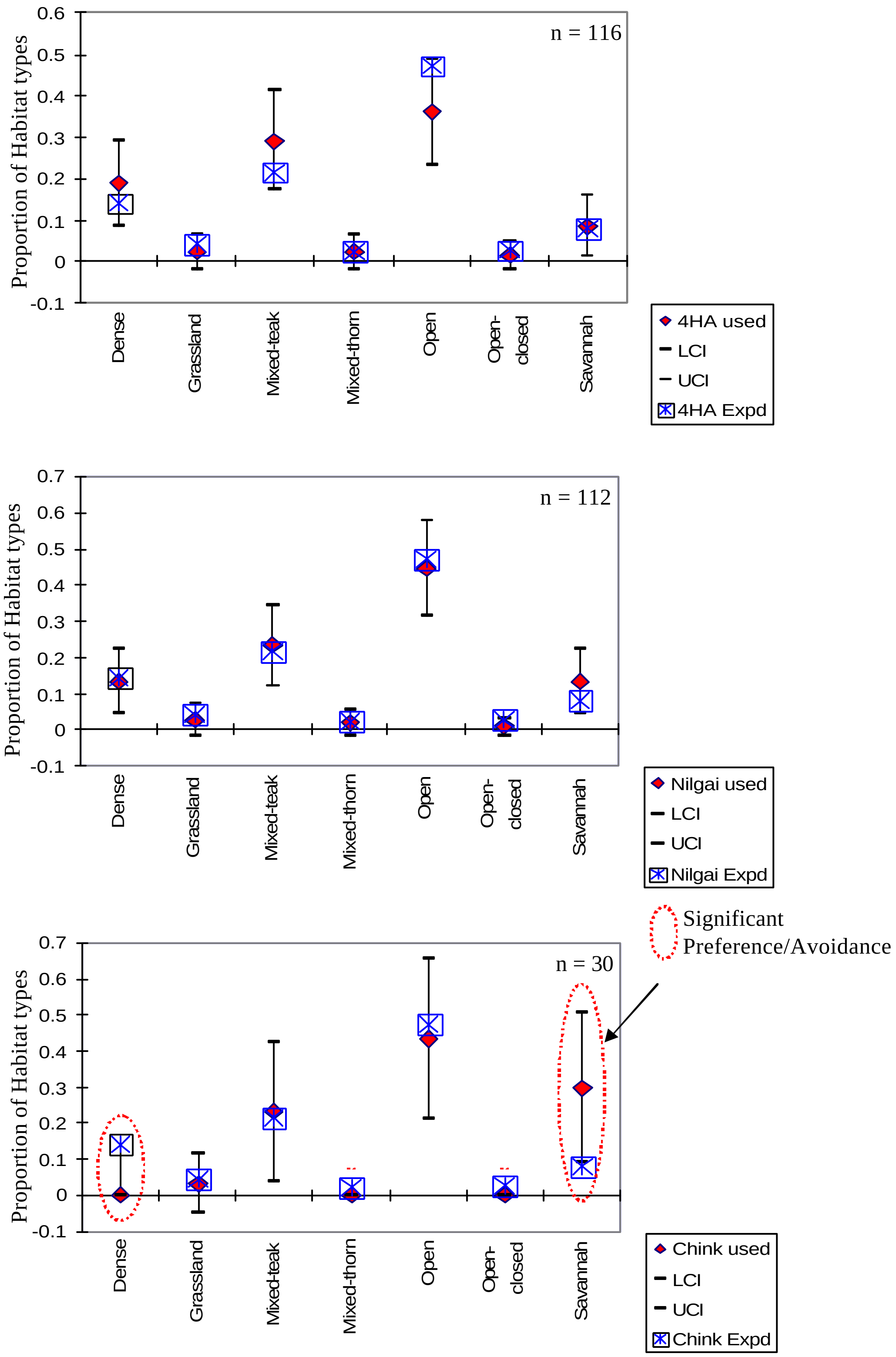


Fig. 3.7 Bonferroni Confidence Intervals depicting habitat preferences for middens by Four-horned antelope (4HA), Nilgai and Chinkara (Chink).

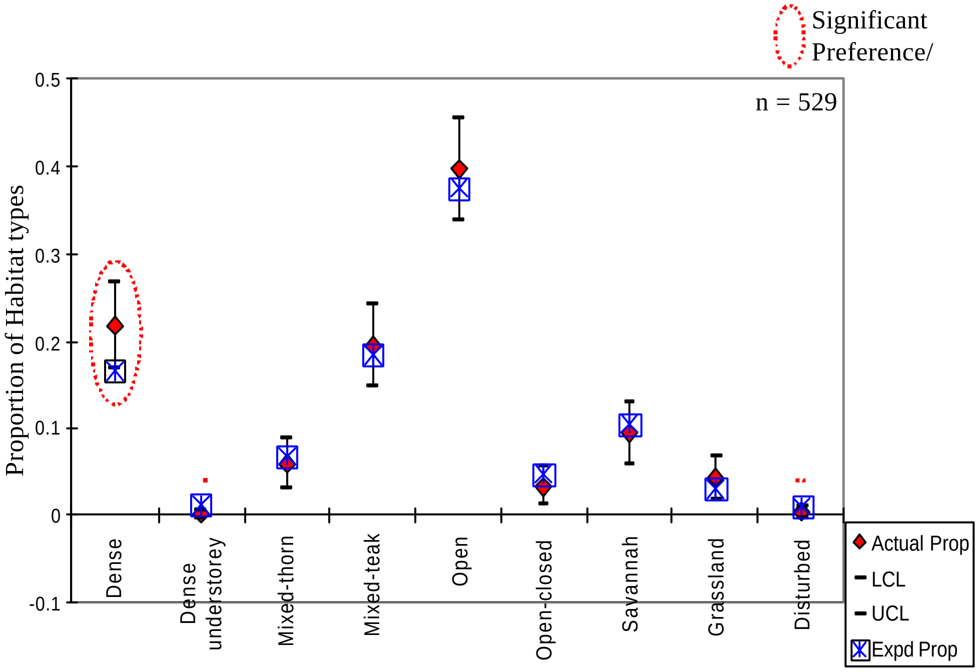


Fig. 3.8 Bonferroni Confidence Intervals depicting habitat preferences of the Four-horned antelope (based on direct sightings from forest roads)

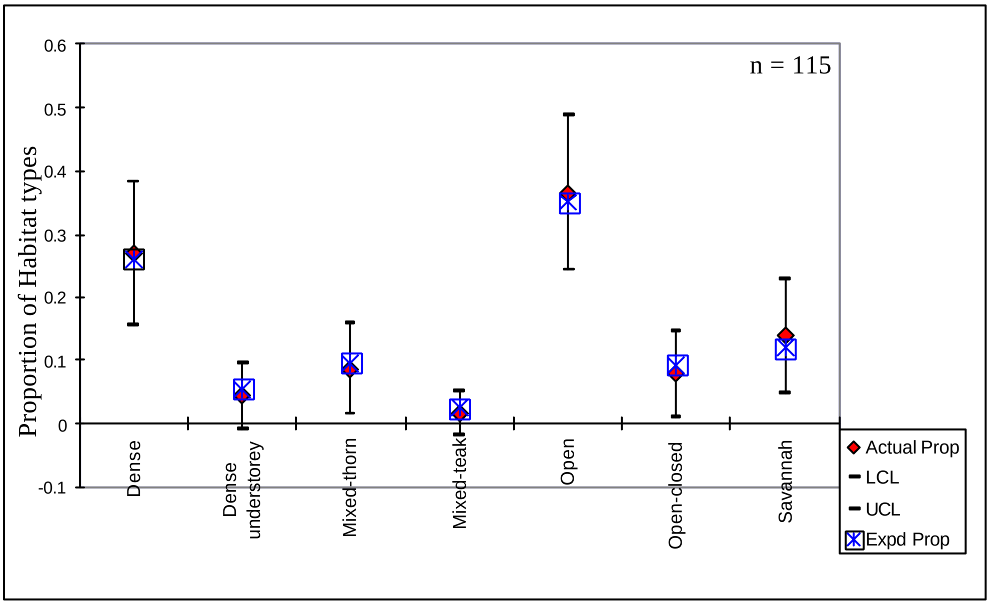


Fig. 3.9 Bonferroni Confidence Intervals depicting habitat preferences of Four-horned antelope (based on direct sightings on line transects).

Strong positive association was found between Nilgai and Chinkara ($\chi_c^2 = 7.54$, p = 0.01), whereas a slightly weaker but significant negative association was found between a Four-horned antelope and Nilgai ($\chi_c^2 = 5.56$, p = 0.02). Similarly a strong dissociation was found between Four-horned antelope and Chinkara ($\chi_c^2 = 14.89$, p = 0.00).

Principal Component Analysis was used to understand the influence and cumulative effect of seven habitat variables on presence of Four-horned antelope (see Table 3.c for details). It was also used to comprehend the distribution of Four-horned antelope across these habitat variables. After using Varimax rotation on the Principal Components, we could find that other than Grass height and Canopy cover, all the variables accounted for more than 50% extraction in the analysis (Table 3.d). The analysis explains 62% of the overall variance in the data with the help of three Principal Components contributing 29%, 16 % and 16% respectively (Table 3.e). Principal Component scores for each record were plotted across three axes. To understand the pattern of use, the plots were subject to density estimation. Zones that have a dense cloud of presence Four-horned antelope in the ordination space can be treated as those used more frequently (Fig. 3.10). The three components can be explained as follows:

PC1: Indicates an increasing richness and decreasing distance from water.

PC2: Represents distance from settlements and increasing canopy cover.

PC3: Increases with increasing slope and decreasing grass height.

Table 3.b Niche separation and overlap between Four-horned antelope, Nilgai and Chinkara using midden data

Species	c^2	**p**	**Association**
Four-horned antelope : Nilgai	5.56	0.02	Significant & negative
Four-horned antelope : Chinkara	14.89	0.00	Highly significant & negative
Nilgai : Chinkara	7.54	0.01	Highly significant & positive

Table. 3.c **Rotated Component Matrix** showing partial correlation between factors and components.

	Component		
	1	2	3
Tree_Rich	.917	-.088	.098
Sap_Rich	.817	.130	.229
Dist_wtr	-.691	.023	.216
Dist_stlm	-.004	.832	-.149
Canopy	.009	.650	.248
Slope_Cd	.196	.022	.728
Grass_ht	.108	-.049	-.638

Table. 3.d **Communalities** showing estimates of variance of each variable used in the analysis.

	Initial	Extraction
Dist_wtr	1.000	.524
Dist_stlm	1.000	.714
Slope_Cd	1.000	.569
Tree_Rich	1.000	.859
Sap_Rich	1.000	.736
Grass_ht	1.000	.421
Canopy	1.000	.484

Further tests were conducted where Species richness of trees and saplings were plotted against encounter rate of Four-horned antelope. Trees' species richness is found to be correlated positively with the encounter rate of Four-horned antelope (R = 0.55, Fig. 3.11). At the same time, Saplings' species richness is weakly correlated with the encounter rate (R = 0.24, Fig. 3.12). Similar tests on grass height were also conducted to investigate the pattern of use. The data were corrected for varying detection probability across different grass heights before plotting it against grass height. Graph (Fig. 3.13) suggests that most sightings were obtained at points with medium grass height (45-70 cm).

3.4 Discussion

Habitat studies provide crucial information about the ecological requirements of a species or community. Habitats of animals have been studied for long. From the initial days of Aristotle (344 B.C.) where man learnt about habitat use by animals due to innate curiosity to today's times when understanding ecological relationships (e.g. Merriam, 1890; Adams, 1908; Svardson, 1949; Morisson, 1992), conservation of natural resources (e.g. Soule, 1986) and management of areas with specific requirements (e.g. Fox *et. al.* 1988; Rahmani, 1989) have made it mandatory to understand habitat requirements of different species. Increasing habitat loss causes a significant increase in extinction risk among many species, especially habitat specialists (Rahmani, 1989; Birdlife International, 2001; Norris and Harper, 2003; Mallon, 2003). While it is important to assess the habitat usage, it is equally important to conduct studies addressing the pattern of usage. It is assumed that high quality resources will be selected more than low quality ones and use may change with availability when the latter is not uniform (Manly *et. al.*, 1993). This follows Garshelis (2000) who discussed the fatal flaws in habitat selection models based on use versus availability. These models rely considerably on the assumption that an animal is more likely to use a particular habitat type if more of it is available. This assumption may get violated if habitat type offers abundant or non-limiting resources (e.g. small area may suffice the requirement of habitat for resting and hiding). Another assumption is that highly selected habitat provides high fitness potential or carrying capacity. There are various problems foreseen in this assumption: Habitat types used only for short times or in small amounts may still be critical to fitness, whereas it is also possible that none of the observed habitats provide a sustainable level of fitness. If resources are abundant or non-limiting, their apparent selection is likely to be arbitrary as some animals may require a mix of habitat types. Furthermore, competition can exclude all but dominant individuals from the best habitat. Multivariate analysis provided useful information for

Table. 3.e **Eigen values and loadings** denoting the percent of variance explained by the three Principal Components

Total Variance Explained

	Initial Eigenvalues			xtraction Sums of Squared Loading			Rotation Sums of Squared Loadings		
Componen	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.080	29.714	29.714	2.080	29.714	29.714	2.035	29.070	29.070
2	1.223	17.469	47.183	1.223	17.469	47.183	1.142	16.317	45.387
3	1.003	14.334	61.517	1.003	14.334	61.517	1.129	16.130	61.517
4	.973	13.901	75.418						
5	.805	11.506	86.924						
6	.714	10.206	97.130						
7	.201	2.870	100.000						

Extraction Method: Principal Component Analysis.

habitat usage of the Four-horned antelope.

Unoccupied habitat with low selection cannot be assumed to provide low fitness potential. Although effect of habitat cover, landscape structure and spatial variables on abundance of birds has been reported (Heikkinen *et. al.*, 2004), fitness potential of habitat cannot be assumed to vary with habitat selection and a gradient in observed density does not necessarily indicate a gradient in habitat quality (Hobbs & Hanley, 1990). Similarly, population response cannot be assumed to vary positively with availability of selected habitat for animals that are subject to strong competition for habitat. It is important that habitat selection studies be supplemented with mechanistic approaches to understanding the fitness value of habitat. Learning how key fitness elements like growth, survival and reproductive success depend on habitat characteristics seems more likely to produce general and reliable results than is habitat selection modelling alone (Railsback, *et. al.*, 2003).

When using direct sightings or evidence of presence of animals in a particular area, one has to remember that they might be using a particular habitat just for transit between two optimal habitat types (Boitani & Fuller, 2000). It is equally important for habitat studies to circumvent the problem of obtaining spurious inferences due to insufficient information about the pattern of use. The three approaches used in this study for collecting data on habitat use reduced chances of collecting insufficient or biased data., but still fail to provide comprehensive information about the pattern of use. While direct sightings (e.g. homing in telemetry studies) have

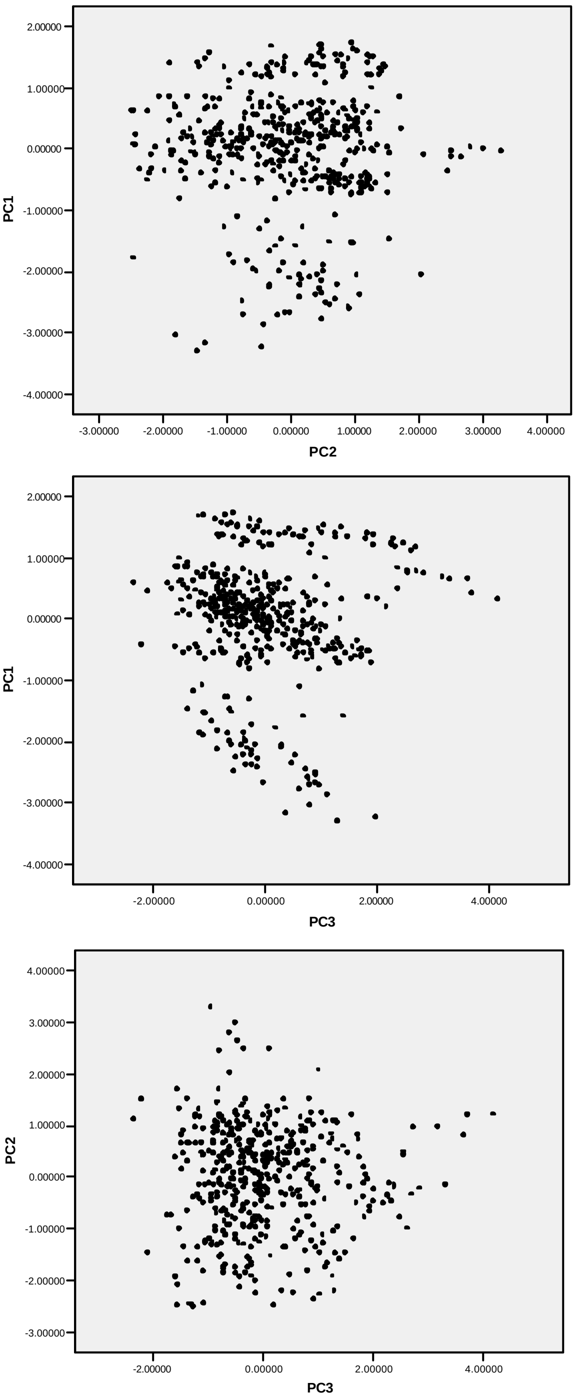


Fig. 3.10 Points denoting sighting locations of the Four-horned antelope within the ordination space of the Principal Components (PC1, PC2 and PC3)

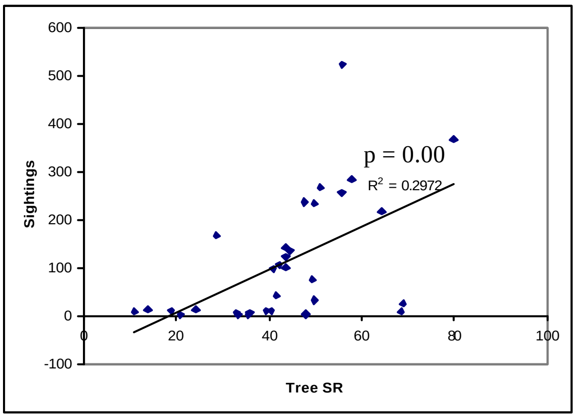


Fig. 3.11 Correlation of Species richness of trees with sightings of the Four-horned antelope

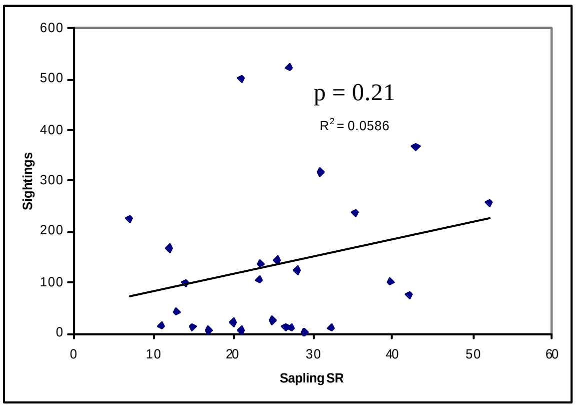


Fig. 3.12 Correlation of species richness of saplings with sightings of the Four-horned antelope

their own limitations of being biased by detectability and accessibility, they provide data on presence as well as animal activity. This information can be further used for assessment of habitat-use pattern in a particular area.

Animals, especially ungulates defecate at a particular rate, which varies between species, but is usually constant within species (Marques *et. al.*, 2001; Laing, 2003). Using them as indirect evidences of presence have their understandable strengths, but at the same time there are some fatal caveats in the method. Although the issue of detectability is reduced greatly when areas were combed thoroughly for faecal matter, the issues of disintegration rate and site selection pose a serious concern of biasing results.

In this study, no preference was found for a particular habitat when line transects and midden data were used. The only case where a preference for dense forests is observed against systematic avoidance of disturbed areas is when the data were analyzed on the basis of direct sightings from the road. It can be concluded that on a smaller scale, the Four-horned antelope does not show any specific preference of any habitat type, but when looking at a larger scale, there seems to be some preference of well wooded terrain.

The GIS map of the Panna National Park suggests that about 16% of the area inside the Park boundaries is dense forest (see Chapter 2, Study Area). Overall, the terrain has a uniform mosaic of different habitat types. Since Four-horned antelope showed no specific preference or avoidance for any habitat type, it was important to understand other aspects of the habitat that regulate its distribution in the Park. Encounter rates from different zones suggested that the Four-horned antelope had a low density in the Madla range. Madla in itself has 21.2 km^2 of dense forest and a mosaic of all other forest types that are found in Hinauta region (Chapter 2, Study Area). It is therefore inferred that beyond just forest type, its composition and possibly other features such as availability of water, distance from disturbed areas, canopy cover, grass height and slope affect the distribution of Four-horned antelope.

Prima facie, PCA suggested no distinct preference of any particular habitat variables. But when examined closely, the distribution of Four-horned antelopes in a three dimensional ordination space suggested that most sightings are from areas that have moderately high species diversity and were within a specified distance from water. On studying the three axes, it is clear that maximum sightings of Four-horned antelope are around those values where these variables take a mid value. There is a thicker cloud along the axis denoting species richness and proximity to water, whereas the other two variables are more or less evenly scattered. Similarly it is inferred that Four-horned antelopes seem to use areas with moderately tall grass and gradual to no slope in the terrain. On the other hand, we found weak relationship between sites used by the Four-horned antelope, and their canopy and distance from settlements.

Effect of tree species richness was found to be most significant on the distribution of Four-horned antelope in Panna National Park. It was found that while the tree diversity is positively correlated with the presence of Four-horned antelope, there is a weak correlation between its presence and sapling diversity. Such positive correlation indicates that in a snapshot of time, Four-horned antelopes are thriving in areas that have species rich stands of trees. Their distribution seems to be less influenced by the species richness of saplings.

Four-horned antelopes are small antelopes and like other similar-size ungulates, have high metabolic requirements (Kleiber, 1961; Jarman, 1974; Brashares *et. al.*, 2000). Since their food intake capacity is limited, unlike large ungulates, Four-horned antelopes can not take coarse and fibrous food material in large quantities. They require high protein diet and are therefore largely dependant on fruits, flowers, pods and fresh browse (see Chapter VI, Behavioural Ecology). Available habitats fluctuate over diel and seasonal periods, which can influence distribution and abundance of species (Yu & Peters, 2002). Phenology of vegetation in Panna indicates that except for the monsoon, there is a continuous availability of fruits, flowers and pods for animals rest of the year (see Chapter II, Study Area; and *Annexure B*). For such continuous availability of high protein diet, it is important to have a high diversity of

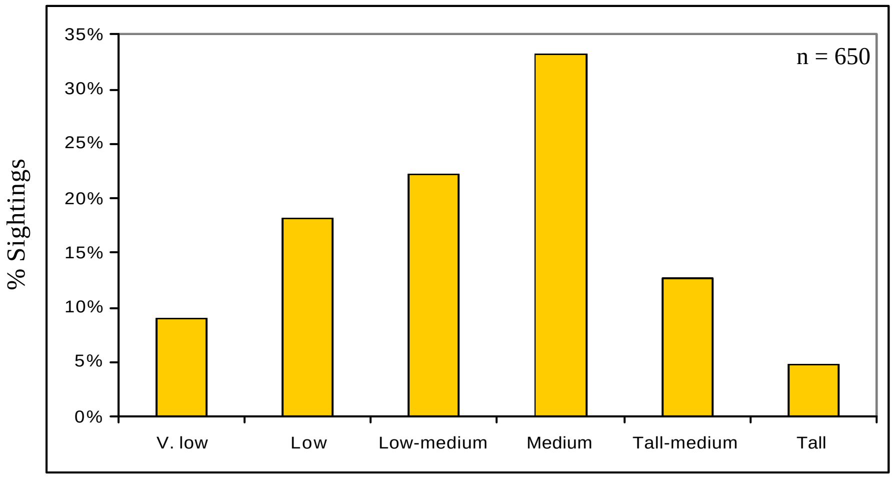


Fig. 3.13 Percent sightings (corrected) of Four-horned antelope within various grass heights

fruiting vegetation in the area. PCA and correlation of encounter rate with species richness indicate that despite having a similar mosaic of all habitat types, the floral diversity of fruiting vegetation provides haven to the Four-horned antelope and ensures food availability throughout the year. The only season when little or no such food is available to the Four-horned antelope is the monsoon, but fresh nutritive browse is available in abundance to meet its food requirements.

Predation has an important influence on the spatial distribution of animals through its effects on avoidance behaviour of prey. Formation of herds and flocks is a common response to predation risk by animals occupying open habitats (Hobson, 1978). Alternatively, animals can disperse in highly structured habitats that reduce the capacity of predators to detect or pursue their prey (Lima & Dill, 1990). Further analysis of data on grass height reveals that Four-horned antelopes use areas with medium (45-70 cm) to tall-medium (70-100 cm) grasses. An increasing trend of use towards taller grasses was observed up to medium grass height. The Four-horned antelope was rarely found in tall-medium and tall (>100 cm) grasses. This pattern can be explained with the help of its anti-predatory and vigilance behaviour. Four-horned antelopes have a distinct anti-predatory strategy where they freeze and keep an eye at the threat rather than taking to evasive action (see Chapter VI, Behavioural Ecology) and use vegetation cover to hide from potential predators. Since the average height of a Four-horned antelope is 55 to 60 cm, it is difficult for it to see through grass taller than 1 m. It is understood that with low grass height, the visibility increases considerably and the Four-horned antelope's anti-predatory strategies are compromised (see section 6, Behavioural Ecology). Similarly in grasses that are too tall, it must be difficult for the Four-horned antelope to keep an eye at the threat. It is possibly because of these reasons that the Four-horned antelopes thrive well in areas of moderate grass height.

Tree canopy cover is an important feature that may influence an animal's habitat preference as it has direct relationship with the energy costs incurred by thermal radiation (DeVos & Mosby, 1971). Trends suggest that shaded canopy was used more in comparison to open. Little is known about the tolerance of the Four-horned antelope to heat. It is also likely that since they forage extensively on fruits and flowers dropping from the trees, most of their sightings were made when they were dwelling under a tree.

Habitat qualities such as food supply or access to sites of refuge often influence home-range size of animals. Such qualitative differences usually lead to intra as well as inter-specific competition over space, which can be an important factor in determining distribution of individuals within populations (Spong, 2002). Usually a species has a larger ecological niche in the absence of competitors and predators than it has in their presence (Begon *et. al.*, 1996).

Habitat use and niche separation of the three antelopes was understood with the help of midden usage and its spatial location. Nilgai and Four-horned antelope, both show no specific habitat preference when evaluated using the surveyed plot area as available, but Chinkara shows a distinct preference of savannahs and avoidance of forest stands.

It is clearly understood that Chinkara is an open terrain animal (Rahmani, 1990; Alfred *et. al.* 2001) and does not respond well to increasing vegetation cover. On the other hand, absence of evidence of habitat preference for Nilgai and Four-horned antelope suggests that these two species utilize areas in proportion to availability. A close examination of niche separation between the three species points to an interesting fact that the Four-horned antelope's niche overlaps to a certain extent with that of the Nilgai. Similarly the niche of the Nilgai and that of the Chinkara overlap to a significant level indicating similarity of use of terrain. Four-horned antelope and Chinkara also have a distinctly exclusive niche where the niche occupied by the Chinkara is excluded by that of the Four-horned antelope and vice versa.

With the information generated on habitat use by the Four-horned antelope and its sympatric antelope species, it can be concluded that it thrives in areas with high floral diversity, that in turn ensure annual food security. It is a species which is relatively more forest oriented than the other two, and occupies a distinct niche within the antelope community in Panna National Park.

Four-horned antelope (Female) in dense forest

CHAPTER IV

Density Estimation of Four-horned antelope, Nilgai and Chinkara

4.3 Methodology

CHAPTER IV

DENSITY ESTIMATION OF FOUR-HORNED ANTELOPE, NILGAI AND CHINKARA

4.1 Introduction

Population is defined as a group of organisms of the same species occupying a particular area at a particular time (Krebs, 1972) with a potential to breed with each other (Williams *et. al.*, 2002). In India, almost all good populations of wildlife are surviving in managed protected areas. With managed populations it is often necessary to assess the success or failure of interventions. Due to their cost effectiveness, indirect population indices are widely used for estimating population trends, but chances of these trends providing spurious information are high as they usually fail to address issues of Detection (Moore & Kendall, 2004) and Identification (Evans, 2006) bias. Population estimations hence provide useful information about the response of animals to specific management interventions. At times, interventions addressed towards a specific species affect other species which are not directly of interest to the management regime. In such situations it is important to assess populations of other species that may not be of great importance to the target species/group of species directly, but might be playing an important ecological role. Abundance estimations of wildlife populations also provide vital benchmarks for future management actions, if and when required. These benchmarks help taking decisions regarding the need and extent of managerial interventions in the future. Another important purpose of population estimation is to develop empirical knowledge that would help in predicting situations in the future (Caughly, 1977).

Use of density estimates for assessing abundance is a common practice since it provides measurable estimates from a small sample that may, if need be, extrapolated to the whole region. Density estimates of different species can also be used to assess their associations and relationships within the habitat sampled. Changes in ecological conditions may favour one species at the cost of another. Long term population monitoring helps in understanding these issues. Moreover, ecological and genetic viability of a particular population can be modelled with the help of abundance estimates.

The Four-horned antelope is known to be a solitary, forest dwelling antelope (Prater, 1980; Rahmani, 2001). Information on population size, its structure and dynamics are important for ecological studies as they give an insight about spatial utilization patterns of a particular species. These estimates can also be used to predict distribution of the species on the basis of habitat suitability modelling.

It is almost impossible to count each and every individual in a wild population spread across a large landscape, and that too with varying levels of vegetation cover and undulations. Various methods have been developed to estimate animal populations e.g. block count; strip count; dung count; capture-recapture by physical capture or photographic capture, DNA analysis; band-recovery count, double-observer counts, and distance sampling using road counts, aerial counts, line transects or point counts (Overton, 1972; Williams, 2002). Feasibility and other constraints associated with these techniques were explored and assessed before zeroing down on a specific methodology.

4.2 Development of Distance Sampling Theory

Till the early 1930s, strip count was a widely used methodology for estimating animal populations in the wild (e.g. Anderson & Pospahala, 1970). The basic assumption of strip count is that everything is counted within the sampled strip. While the same may stand true for a narrow strip with no vegetation or terrain related undulations, one has to consider the fact that despite all efforts, detection probability (given presence, probability that an animal/object of interest is seen within the sampled area) is seldom equal to one. Observer skills, terrain, vegetation, fatigue, distance from observer and animal behaviour influence the chances of missing out an animal despite its presence. To cater to this problem, detection probability was defined as a function of distance from the observer. It was assumed that anything within a short distance from the observer will have a detection probability of 1, i.e. will be detected with certainty, but this probability reduces gradually with distance. R. T. King identified the problem of non-detection of all individuals for the first time in 1930s. He attempted to use the average distance from the line of movement in line transects as the effective strip width (Leopold, 1933). The actual width of the surveyed strip was replaced by this effective strip width while estimating density using all sightings. Effective strip width was explained properly by Gates (1979) who suggested that it is that width where the number of animals seen beyond is equal to the number of animals missed within this width.

Hayne (1949) used sighting distances but the method did not perform well when tested against sighting angles. It was found that this method worked only when average sighting angle was equal to 32.7^o. As a result its use was discontinued following the lack of robustness.

Gates *et. al.* (1968) and Eberhardt (1968) provided the first conceptual approaches towards line transects. While Gates *et. al.*'s approach was restrictive and possibly inappropriate in terms of estimation of detection function on many occasions, Eberhardt's explanation was fairly more general where detection probability decreased with increasing perpendicular distance. Eberhardt suggested that the shape of the detection function varied from survey to survey, and that there was little information on the appropriate shape. To model the detection function, he proposed use of family of curves like the power series and the modified logistic.

Burnham & Anderson (1976) developed the general formulation of line transect sampling and provided baseline for general construction of line transect estimators: general formula— $D = n \, . \, f(0)/2L$, was developed. The key problem was that of modelling $g(x)$ or $f(x)$, and estimation of $f(0)$. Burnham *et. al.*'s (1980) monograph on theory of distance sampling discussed the theory and applications in greater detail (see Analysis section, for detailed discussion and terminology used).

Distance sampling provides reliable results with little bias if data is collected from a random sample of primary sampling units (Cassey and Mcardle, 1999; Buckland *et. al.*, 2004). Line transect method is widely and reliably used in various studies in the tropical forests (Qureshi, 1992; Karanth and Sunquist, 1995; Verman & Sukumar, 1995; Khan *et. al.*, 1996; Chundawat, 2001, 2003; Biswas & Sankar, 2002; Jathanna *et. al.* 2002; Bagchi *et. al.*, 2003; Karanth & Kumar, 2003). This method is used reliably not only on mammals, but on birds (e.g. Thompson, 2002; Javed & Kaul, 2002; Nichols, 2004; Zarri, 2005; Sundar, 2005), reptiles (e.g. Hayes and Carter, 2000), insects (e.g. Longcore *et. al.*, 2004; McIntyre, 1995), and cetaceans (Palka & Hammond, 2001; Hedley & Buckland, 2004; Thomas *et. al.*, *in prep.*) alike. Line transects are usually conducted on foot, but is equally effective when conducted through boat, submarine, airplane, helicopter, and vehicle. It is important to note that at least 60-80 sightings are needed to model the detection function properly (Buckland *et. al.*, 1993).

The basic assumption of Distance sampling is that as distance from the observer increases, there is a monotonous decrease in probability of detecting the target animals. Conventional Distance Sampling theory assumes that perpendicular distance from the observer is the only factor affecting probability of detection (Buckland *et. al.*, 1993, 2001). The distribution of animals is assumed to remain constant while traversing the line and at the same time no significant change in the detection probability within each sampling bout is expected. In reality, though, there are possibilities of factors other than perpendicular distance influencing the detection probability. These factors could be season, time of the day, observer, group-size or some other parameter. A recent development (Buckland *et. al.*, 2004; Thomas *et. al.*, 2005) into the Distance Sampling design is that of Multiple Covariate Distance Sampling (MCDS). MCDS takes into account other covariates that possibly affect the detection of animals when moving on a line and accordingly estimates detection probability empirically.

Depending on the distribution, encounter rate and behaviour of the species, mode of traversing transects can be decided. It is also important to consider that existing paths and roads, water-bodies, and geographical structures such as cliffs and valleys may affect distribution of animals. This biased distribution along the transect line can thereby bias the results as well. While road transects are logistically less expensive and faster, their alignment along geographical structures, lack of randomness in their layout and their individual effects on animal behaviour may cause the data to be biased.

4.3 Methodology

4.3.1 Field work

Distance sampling techniques were used for assessment of animal abundances. A preliminary survey was conducted between November 2002 and January 2003 to thoroughly assess the study area. The basic objectives of this survey were to get a rough idea about the expected encounter rate of Four-horned antelope and other sympatric antelope species in Panna National Park. Survey included traversing forest tracts on foot and on jeep. Existing transect-lines that were laid by the Tiger Ecology Study and Forest Department were surveyed to investigate feasibility of using the technique on Four-horned antelope. Previous studies from different areas had revealed that encounter rates of Four-horned antelope were generally too low to use distance sampling with confidence (Karanth & Sunquist, 1992; Khan *et. al.,* 1996; Bhaskaran, 1999; Jathanna *et. al.*, 2002; Biswas & Sanker, 2002; Gangadharan, 2005). While the encounter rates on roads could be different than on transects conducted on foot, the exercise gives useful baseline information to design the study and zero down on a methodology for doing the count. An encounter rate can be defined as the rate at which an animal is seen after traversing a distance of one unit length (taken as km in this study). The survey was also used to obtain *prima facie* information about the distribution of Four-horned antelope in the Park. Areas with different levels of anthropogenic activities were surveyed, and locals were also interviewed to generate information on areas that have high and low encounter rates.

While considering the objective of estimating population of Four-horned antelope in Panna National Park, an assessment of different techniques available to estimate animal density was done. Techniques such as block count (e.g. Bhaskaran, 1999), capture/mark-recapture (Otis *et. al.*, 1978; Pollock *et. al.*, 1990, Williams *et. al.*, 2002), line transects (Buckland *et. al.*, 1993), road transects (Shah, 1994; Prakash *et. al.*, 2003; Sundar, 2005) and strip counts (Anderson & Posphala, 1970; Karanth & Nichols, 2002) were compared for efficiency and reliability within the premises of the logistical constraints of our study.

Four-horned antelope is a shy animal, and this trait makes it difficult to capture the animal for marking and then attempt a recapture. Trap shyness and other constraints were expected to influence the results (Wegge *et. al.*, 2004). Use of camera traps (Karanth, 1995) was a possible option but since these animals do not have any distinct morphological patterns to distinguish between individuals, as is in the case of the Tiger (Karanth, 1995; Karanth & Nichols, 1998; Karanth, 1995; Carbone *et. al.,* 2001; O'Brien *et. al.*, 2003), Leopard (Henschel & Ray, 2003), Snow Leopard (Chundawat, *unpublished data*), Lions *Panthera leo* (Jhala *et. al.*, 1999), Jaguars *Panthera onca* (Wallace *et. al.*, 2003; Silver *et. al.*, 2004), European Minks *Mustela lutreola* (Gonzalez-Esteban *et. al.*, 2004) or Chital (Milind Pariwakam, *pers. comm.*); feasibility of using this method on Four-horned antelope was doubtful. Moreover, there is little evidence that the Four-horned antelopes use fixed tracks (roads, trails). Instead they were observed using a closely knit network of walkways with no fixed pattern of movement. Although their tendency of defecating on middens could have been exploited for setting up camera traps, there were other constraints that were considered to decide against using this method for population estimation of the Four-horned antelope.

The other technique assessed was that of using block counts. This technique was used on Four-horned antelopes in Mudumalai (Bhaskaran, 1999), but its results could not be validated for accuracy and bias when dealing with an intensive census. It was primarily because the technique provides only minimum population estimates. Secondly, block counts need a large number of observers combing the sampled block. Being quite an invasive method, it could have failed in a long term study design on a shy species, which may predict observer movements on later attempts and evacuate the area temporarily. Using signs and indirect evidences was also a potential prospect for estimating animal abundance (Neff, 1968; Marques *et. al.* 2001; Laing *et. al.*, 2003; Campbell *et. al.*, 2004), but no reliable references could be obtained that related abundance of indirect signs of Four-horned antelope with actual animal abundance. Pellet count technique needs an estimation of defecation or decay rate (Neff, 1968; Marques *et. al.*, 2001; Laing *et. al.*, 2003; Campbell *et. al.*, 2004). The Four-horned antelope defecates on middens. Factors responsible for an animal to defecate on middens may range from olfactory signals (Leuthold, 1977; this study) to visual signages (Schaller, 1968; Ranjitsinh, 1982). Middens are randomly placed within the area of usage (see Chapter III, Habitat Use) and are defecated upon as and whenever encountered (Chapter VI, Behavioural Ecology). Removal of pellets from middens could have affected future defecation probability on the site, resulting in bias. Decay rate was also difficult to estimate since decay of faecal pellets depends on midden size, composition (number of species defecating on a particular midden), weather and terrain. These factors made it difficult to use pellet count methodology for estimating abundance of Four-horned antelope.

Based on logistical and practical considerations, methodology of fixed length line transects (Burnham *et. al.*, 1980; Buckland *et. al.* 1993; Thomas & Karanth, 2002, Thomas *et. al.*, 2002, Verman & Sukumar, 1995) was selected for estimation of density. This methodology was used successfully in the years 2003 and 2005 to estimate ungulate populations. In the year 2004, logistic problems restricted us and our field assistants from conducting line transects and an alternative exercise was done using existing forest roads as transects. The data generated from the two different methods are comparable, but debatable in terms of meeting basic assumptions of distance sampling (Buckland, *et. al.* 1993; Thomas *et. al.*, 2002; Karanth *et. al.* 2002; Boitani & Fuller, 2000). While the road count method is just an extension of the line transect method, there are issues such as disturbance, openness of habitat and coverage of the sampling that may influx a significant bias in the population data.

Preliminary surveys and available literature (Chundawat, 2001) on Panna suggested that the methods of using direct sightings in line/road transects would have been appropriate and feasible as the encounter rate of Four-horned antelope was sufficiently high (~0.17 encounters/km). Within the scope of distance sampling, we used the two different techniques of line and road transects to test the difference between them for providing density estimates of different species. Since Nilgai and Chinkara are sympatric with the Four-horned antelope in Panna National Park, data on these species were also collected.

Nine independent transect lines (Fig. 4.1) were used for estimating densities and population of the target species in the year 2003 and 11 transect lines were used in the year 2005. The line transects covered in the exercise represent a smaller region (about 200 km^2) and since they

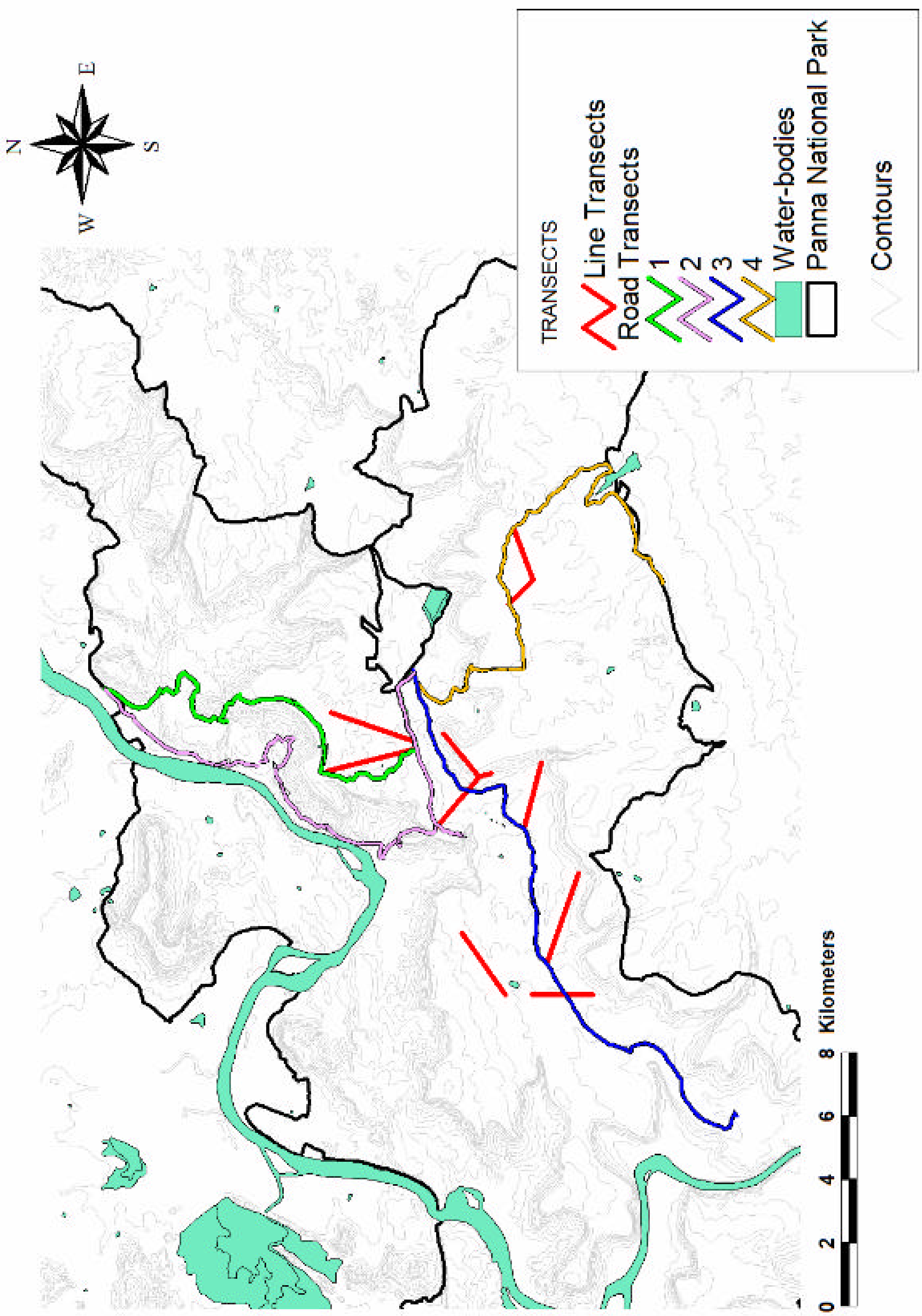


Fig. 4.1 Nine Line transects and Four Road transects demarcated for density estimation of ungulates in the Study Area.

were laid only in the Upper and Lower Plateaus (Fig. 4.1), the results cannot be extrapolated for the whole National Park (543 km^2). These lines were initially laid by the project team working on 'Tiger Conservation in Dry Tropical Forests of India' under the supervision of Dr. R. S. Chundawat. One of the objectives of the aforementioned study was to assess prey abundance and prey availability to the Tiger in Panna National Park. As the two studies shared a common objective of counting ungulate communities that were also the prey base for Tigers, we collaborated for conducting counts on the line transects. The length of these transects varied between 1.8 km and 2.8 km, and they were randomly laid across various habitat types. Trees or rocks were permanently marked with distance markers on all of these lines at visible distance to avoid observers straying from the actual transect line. All lines were marginally trimmed of excess vegetation to allow survey personnel along the lines quietly while causing minimum disturbance to wildlife. Over-clearing on the transect line was avoided as it may cause an improved visibility along the line when compared with sightings towards either sides of the line (Karanth *et. al.*, 2002). This causes a brusque spike in the detection function which is difficult to model (Buckland *et. al.* 1993, 2001). Creating openings on the transect line may also attract or repel animals (Karanth *et. al.*, 2002), therefore proper care was taken not to create a peculiar habitat by over-clearing. Analyses of data from line transect exercise in Panna suggests that changing weather, vegetation cover and other such parameters affect detection probability across seasons (Chundawat & Sharma, *in prep*). To minimize the effect of such temporal, weather related changes, transects were traversed in a short window of time, (45 days in 2003 and 26 days in 2005).

Each field day comprised of two visits, one in the morning and one in the evening as ungulate activity is known to be the maximum in the these periods of the day (Schaller, 1968; Chundawat, 2001; Karanth *et. al.*, 2002; Chundawat 2003; Sanago, 2005). Three teams comprising of two to three persons each would traverse one transect at a time. In the year 2003, the transects traversed in the morning session were repeated on the same evening. Different set of three transects were traversed on the next day and the same transects were repeated every fourth day. It was observed that when a team of observers repeated transects within a short period of time, there was a significant difference seen in the density estimates of morning and evening data. To minimize this problem, the survey design was changed during the exercise conducted in the year 2005 when no transects were repeated on the same day, and maximum possible gap of time was provided to each transect between repeat surveys. Assuming an average speed of about one to two km per hour including time spent in taking notes, each transect walk took about two hours each. Observers started walking transects after about 5 to 10 minutes after sunrise and about two hours before sunset. As a result transects walk was finished as soon as the hotter periods of the day started in the morning, and just before it got too dark to see animals in the evening. This was done in an attempt to maximize the effort in the field.

On sighting an individual or group of animals of interest, an array of parameters was recorded. Time of sighting, radial distance from point of observation to the animal, bearing of sighting from observer to animal, and group size were essentially recorded whereas age-class, sex, activity and point location within the transect (using nearest transect markers) were noted whenever possible. We tested skills of the field staff in estimating distances accurately. It was found that generally the data of ocular distance estimates consists of high variability across observers. Moreover variability in estimation of distance estimators may vary greatly for the same observer when estimating in different kinds of habitats. Although distance sampling works well with distance intervals (e.g. 10-20m, 20-30m and so on), it is always advisable to obtain accurate distance estimates in order to facilitate redrawing of the detection function (Thomas & Karanth, 2002). To circumvent this problem, laser rangefinders (Yardage Pro™) were used by each team traversing the line transects. For measuring the angle of sighting, sighting compass (Suunto™) was used.

Radial distance and angle of sighting of the animal from first point of observation on the line were used to estimate perpendicular distance of the animal(s) from the line of movement using the trigonometric relationship:

$$\text{Sin}\ \theta = p / h$$

$$p = h\ \text{Sin}\ \theta$$

Here, p = perpendicular distance of point of interest from transect line

h = radial distance from first point of sighting to the animal(s)

θ = Angle of sighting.

For estimating θ, the following relationship was used on the whole dataset:

$$\theta = \alpha - \tau$$

Here, α = Compass bearing at which transect is laid

τ = Compass bearing of the animal (s) seen from the transect

In the year 2004, due to logistic problems, line transect exercise could not be conducted. Instead, four different road paths were chosen to conduct animal counts (see Fig. 4.1). These roads run across different habitats and each of the selected path was about 18-20 km long. These paths were selected from a wider network of roads that were otherwise being used regularly to collect data on encounter rate, population structure, habitat use, demography and spatial distribution of the Four-horned antelope. An open-hooded vehicle was used to traverse the roads at speeds less than 20 km hr^{-1}. Each sighting of the Four-horned antelope and other ungulates were recorded as discussed above for line transects, only distances were measured differently. Roads in the forest are never straight and have many turns and twists, thus it is not possible to use trigonometric relationship on curving roads. To address this problem, at each sighting, the shortest distance was recorded with the help of a rangefinder between the road and the point where the group of animals was, when first seen. This distance was used as perpendicular distance at the time of analysis. Road counts were done throughout the year, but as visibility in a tropical dry deciduous forest changes with seasons, it is expected to affect detection probability. Detection function was tested for significant differences across different months to eliminate the risk of unaccountable variance. A group of months with high encounter rate was selected posteriori to have a sufficient data size. Group of months (season) was chosen in a way that detection function did not change significantly across months. This data was then used to estimate density of different species, but with appropriate use of covariates.

Using roads as transects is generally not recommended for estimation of density because roads themselves represent a specific microhabitat. Some animals may use roads as tracks while others may avoid them due to disturbance. Specific behaviour of different species to these roads may bias results as an actual gradient in density with distance from the road may get confounded with the gradient in detectability with distance (e.g. Karanth & Nichols, 2002). Roads are also made usually to pass through an easy–to-manoeuvre path and may not always represent the sampled area sufficiently.

4.3.2 Analyses

Distance 5.0$^{\text{Beta4}}$ (Thomas *et. al.*, 2005) was used to analyze the data and estimate density of the three species (Four-horned antelope, Chinkara and Nilgai).

Line transects are an extension of the conventional strip transects. A particular width (Strip Width) across the line transect is considered within which detection of animals is sought while walking on the line. A detection function is developed which helps in estimating the probability with which animals are seen within the Strip Width. The curve, under normal circumstances and random distribution of animals across the sampled area, takes a monotonous shape denoting a decreasing detection with an increase in the distance from the line of movement. Assuming a random distribution of animals across the sampled strata, if there is no loss of detectability with distance from the transect line, one can expect a uniform detection function, as depicted in Fig. 4.2a. The shaded region denotes the empirical estimate of the number of animals that were supposedly present but not detected. Using the detection curve, an effective strip width (ESW) is estimated, within which the number of animals missed from detection is expected to be equal to the number of animals seen beyond (Fig. 4.2b). ESW is that width, within which the probability of detection of all sightings (within the actual strip width) can be estimated as 1.

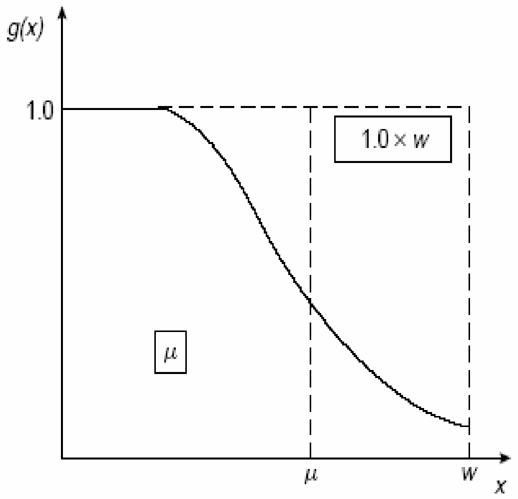


Fig. 4.2a Uniform detection function (dotted) and monotonously decreasing detection function across width w

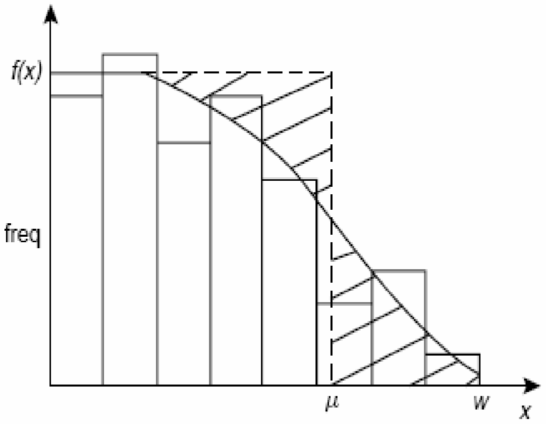


Fig. 4.2b Effective Strip Width where number of animals seen beyond m equal those missed before m

It is understood that group size of the animals affects detection. To address this potential bias in the data, instead of estimating average group size as simple mean, log of individual group sizes was regressed against detection probability, which is a function of distance from the transect line. If the regression was not found significant at an alpha level of 0.15 (85% confidence interval), a simple mean of all group sizes was estimated as the average group size.

For estimating detection probability, software Distance provides an option to choose from various mathematical models available. Akaike's Information Criterion (Akaike, 1975; Burnham and Anderson, 1998) is used to select the best model fit. Best fit was selected out of the three standard models, viz. Half-normal, Hazard Rate and Uniform key. Negative exponential model was not tested at all as its shape did not match at all with that of the actual detection function obtained. Moreover, literature suggests against using this model unless inevitable (Buckland *et. al.*, 1993, Buckland *et. al.*, 2001; Thomas *et. al.*, 2005). To understand the distribution of detections across the strip width, analysis was first done without any truncation. In the second stage of analysis, 5 to 8% of the data with largest perpendicular distance were truncated (right truncation) to avoid the need of constraining the data for monotonicity at the time of analysis (e.g. Fig. 4.3). Even though slight evasive movement was observed in the case of Four-horned antelopes, the model fit the empirical data well.

Best fit for the detection curves on predefined models were tested using Kolmogorov-Smirnov (K-S) and Chi-square tests. Density estimates from the two methodologies (Line and Road transects) were compared with help of encounter rate and detection function. While the K-S test can be used only when continuous distance data is available, Chi-square tests work well even when the data is categorized in intervals.

DISTANCE software estimates density using the following equations and modelling procedures (Thomas *et. al.*, 2002):

The canonical estimator for estimation of density is:

$D = (C/A)/p$

Where D stands for density,
C for the count of animals seen during the survey,
p is the detection probability, and
A is the area surveyed.

Let k lines of lengths $l_1, l_2 \ldots l_k$ be positioned in some randomized scheme. If number of animals seen beyond a particular distance w from the line are not recorded or truncated after the survey, then the surveyed area is estimated as:

$A = 2wL$, where 2w denotes the width of the strip estimated on both sides of the transect line

$L = l_1 + l_2 + \ldots l_k$

Considering P_a as the probability of detecting a randomly chosen animal in the surveyed area, animal density D is estimated by the equation:

$$D = n / (2wLP_a)$$

To estimate P_a, a detection function g(x) needs to be defined as the probability that an object at a distance x from the line is detected where x may take any value between 0 and w. One of the primary assumptions of distance sampling is $g(0) = 1$. This infers that all animals on the transect line are detected with certainty.

A variable, μ = integration g(x) dx is defined such that $P_a = \mu/w$. This variable μ is called the effective strip width. Thus,

$D = n/(aP_a) = n / (2\ w\ L\ \mu/w) = n/2\mu L$

Now to estimate μ, the probability density function (pdf) of perpendicular distances to detected objects is rescaled so that it now denotes the detection function $g(x)$ and integrates to unity. For this, $f(x) = g(x)/\mu$. Since $g(0) = 1$, $f(0) = 1/\mu$.

Therefore the density equation can be rewritten as:

$$\boxed{D = n / (2\mu L) = [n \cdot f(0)] / (2L)}$$

To model pdf of perpendicular distances and evaluate the fitted function at $x = 0$, DISTANCE software uses parametric key functions, polynomial and/or cosine series adjustments until the fit is judged to be satisfactory by one or more criteria.

4.4 Results

In the year 2003, the transect exercise was conducted between 10 Feb 2003 and 24 March 2003. Rains and forest fire occasionally forced the study team to stop the exercise for a few days. It took 34 field days spread across a window of 45

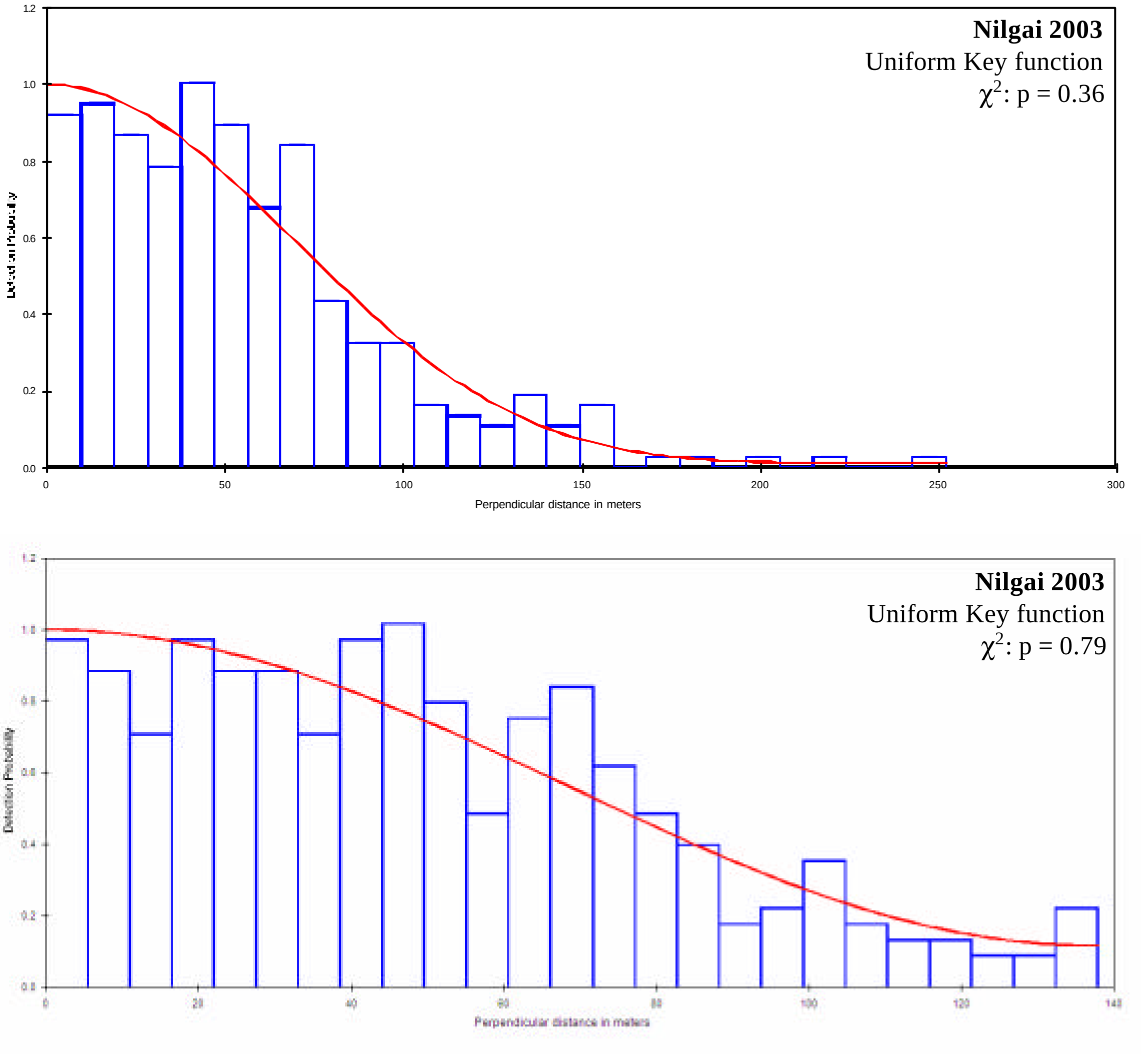


Fig. 4.3 Untruncated (?) vs. truncated (?) plots of detection function (smooth line) superimposed on frequency of counts (histograms).

days to conduct the exercise with three teams traversing one transect each, every morning and evening. The study team walked a distance of 466 km and obtained 82 direct sightings of the Four-horned antelope, 316 of the Nilgai and 81 sightings of Chinkara. The same transects were repeated in the year 2005 when line transect exercise was conducted between February 26, 2005 and March 23, 2005. Due to technical reasons the exercise could not be continued further. As a result, a total distance of 214.6 km could be traversed in a shorter window of 26 days comprising of 20 field days. While 29 sightings of Four-horned antelope were marginally sufficient to develop a detection function and fit it to one of the predetermined models, only 12 sightings were obtained for Chinkara, hence making it impossible to plot a detection curve. For Nilgai, a total of 117 sightings were obtained, which was sufficient to empirically plot the detection curve.

In the year 2004-2005, due to logistical constraints, line transect could not be conducted. Instead, road transects were conducted throughout the year. A total of 921 km was traversed by road. Line transects covered Hinauta and Panna ranges, whereas road transects covered Madla region as well (see Fig. 4.1). Data from tracks covering Madla region were excluded from analysis to keep the results comparable, although they were still used in other habitat and demographic analyses. After scrapping off data from seasons with relatively low encounter rate, we could obtain data from 422 km covered between the months of March and May. This selection of shorter distance was based on high encounter rate, low variation in detection function across month groups, and a relatively even distribution of resources like water and forage. Seventy direct sightings of Four-horned were made within these three months were used for distance sampling. Nilgai and Chinkara were sighted 241 and 71 times respectively.

Nilgai consistently had the highest encounter rate and even the largest group size in comparison to the other two species (Table 4.a). The encounter rates of Chinkara and Four-horned antelope were similar in the year 2003, but that of the Chinkara was considerably low in the year 2005. Mean group size of Four-horned antelope was observed to be slightly smaller than that of the Chinkara. Only the Four-horned antelope’s count of 2004 showed significant (alpha level = 0.15) regression of log of group size with detection function (Fig. 4.4). On all other instances, average cluster size was used.

Fig. 4.5 to 4.7 denote the detection functions and best model fits that were selected on the basis of minimum value of Akaike’s Information Criterion (AIC) for different species in different years. As the number of total sightings of Chinkara was too low in the year 2005, detection function could only be plotted for year 2003 and 2004. Detection of Four-horned antelope generated smallest ESWs of all the species throughout the study period.

Density estimates of the three species across three years are presented in Table 4.a. While no significant difference between density estimates of the Four-horned antelope were observed in the years 2003 and 2005, results from 2004 showed much lower density estimate than those obtained otherwise. Using the detection probability estimated from the exercise done in the year 2003, density of Chinkara was estimated to be about 0.55 (CV = 74%).

Table. 4.a Density Estimates of the three antelope species (2000-2005) from Panna National Park.
Road transect
* source: Chundawat and Sharma, *in prep.*

Species	**Year**	**N**	**D**	**D CV %**	**95% CL**		**Encnt. Rate**	**Cluster size**	**Dg**	**Dg CV%**
					LCL	**UCL**				
Nilgai	* 2000	107	11.37	29.1	6.14	21.07	0.44	3.14	3.63	26
	* 2001	126	6.30	37.2	2.84	13.99	0.6	2.72	2.67	37
	2003	333	13.11	26	7.45	23.09	0.68	2.98	4.40	24.5
	# 2004	241	9.91	16.63	7.03	13.97	0.57	2.81	3.52	15.05
	2005	117	10.38	21.85	6.56	16.40	0.55	2.60	3.99	20.23
Four-horned Antelope	* 2000	31	2.98	31.9	1.55	5.71	0.13	1.61	1.85	29.5
	* 2001	96	3.95	19.2	2.62	5.96	0.21	1.23	3.33	19
	2003	82	2.70	20.6	1.74	4.20	0.17	1.22	2.22	20.2
	# 2004	70	1.53	19.6	1.01	2.30	0.17	1.24	1.23	19.16
	2005	29	2.22	24.67	1.34	3.68	0.14	1.31	1.70	23.44
Chinkara	* 2000	25	2.30	50.3	0.76	6.94	0.1	1.88	1.23	49.4
	* 2001	44	0.91	42.1	0.38	2.19	0.1	1.62	0.72	41.6
	2003	85	1.98	45.5	0.735	5.32	0.17	1.81	1.09	45.1
	# 2004	71	2.60	38.03	1.18	5.71	0.17	1.87	1.39	37.25
	2005	12	*Insufficient data*				0.06	1.58	0.26	73.35

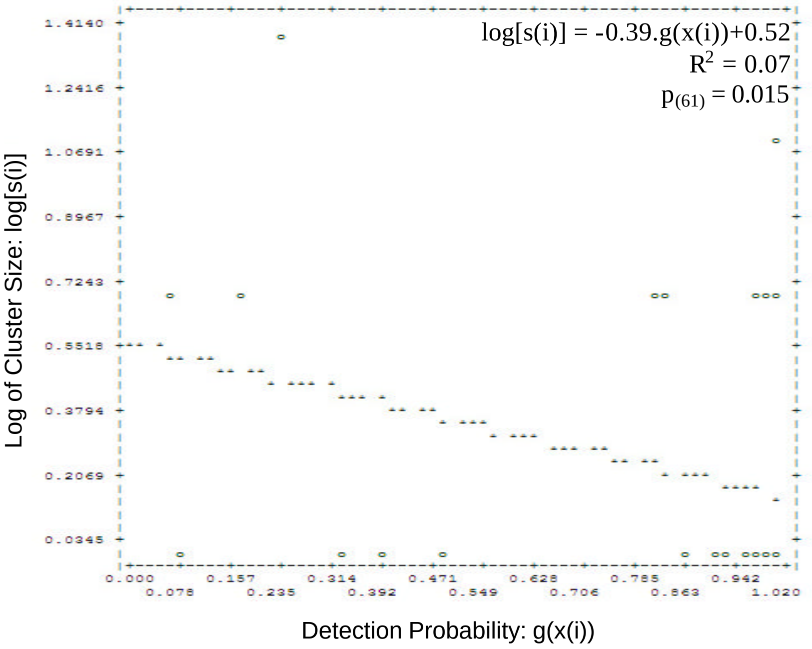


Fig. 4.4 Regression of log of group size with detection function for Four-horned antelope

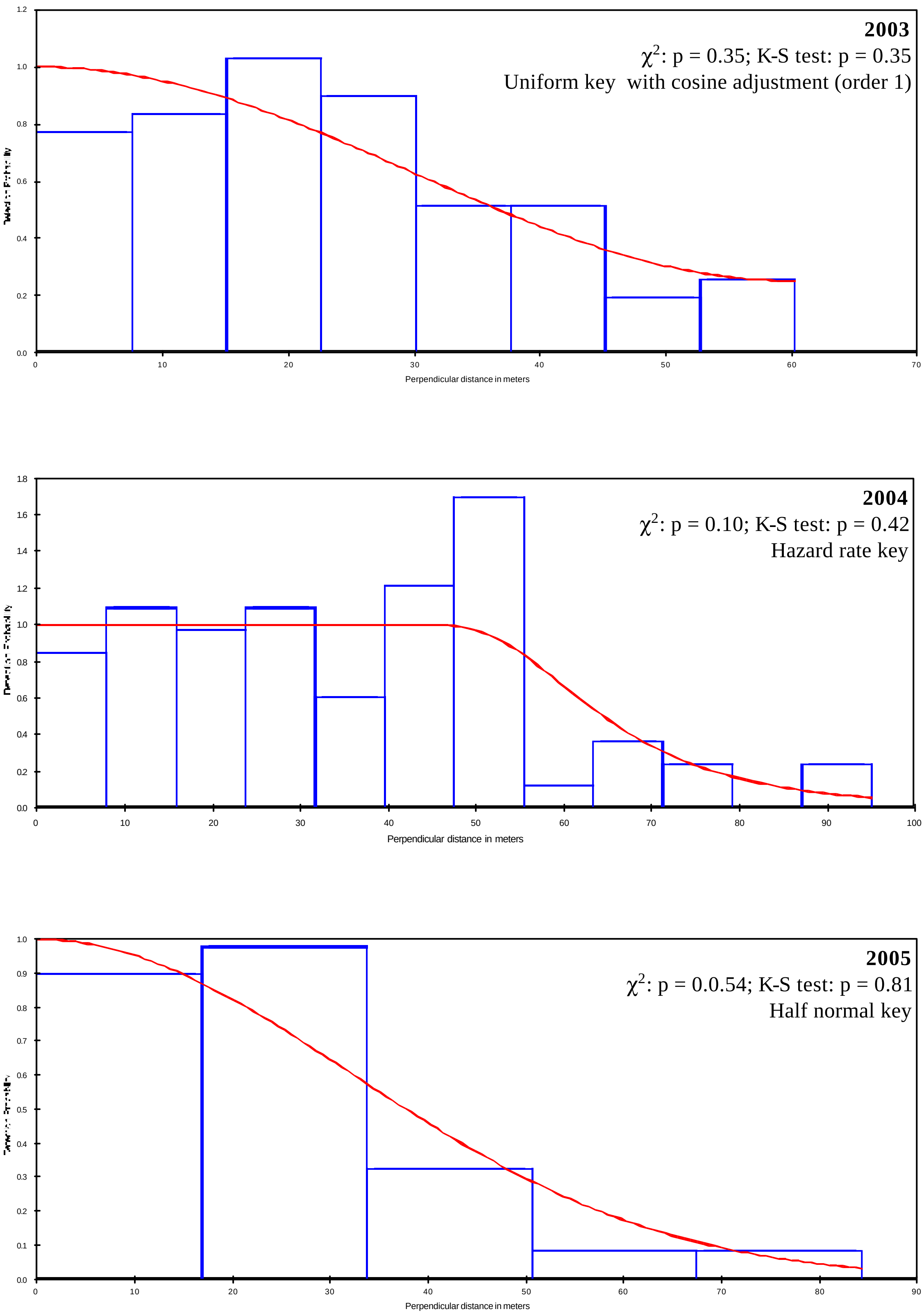


Fig. 4.5 Detection Function and Histogram of frequency of counts of Four-horned antelope

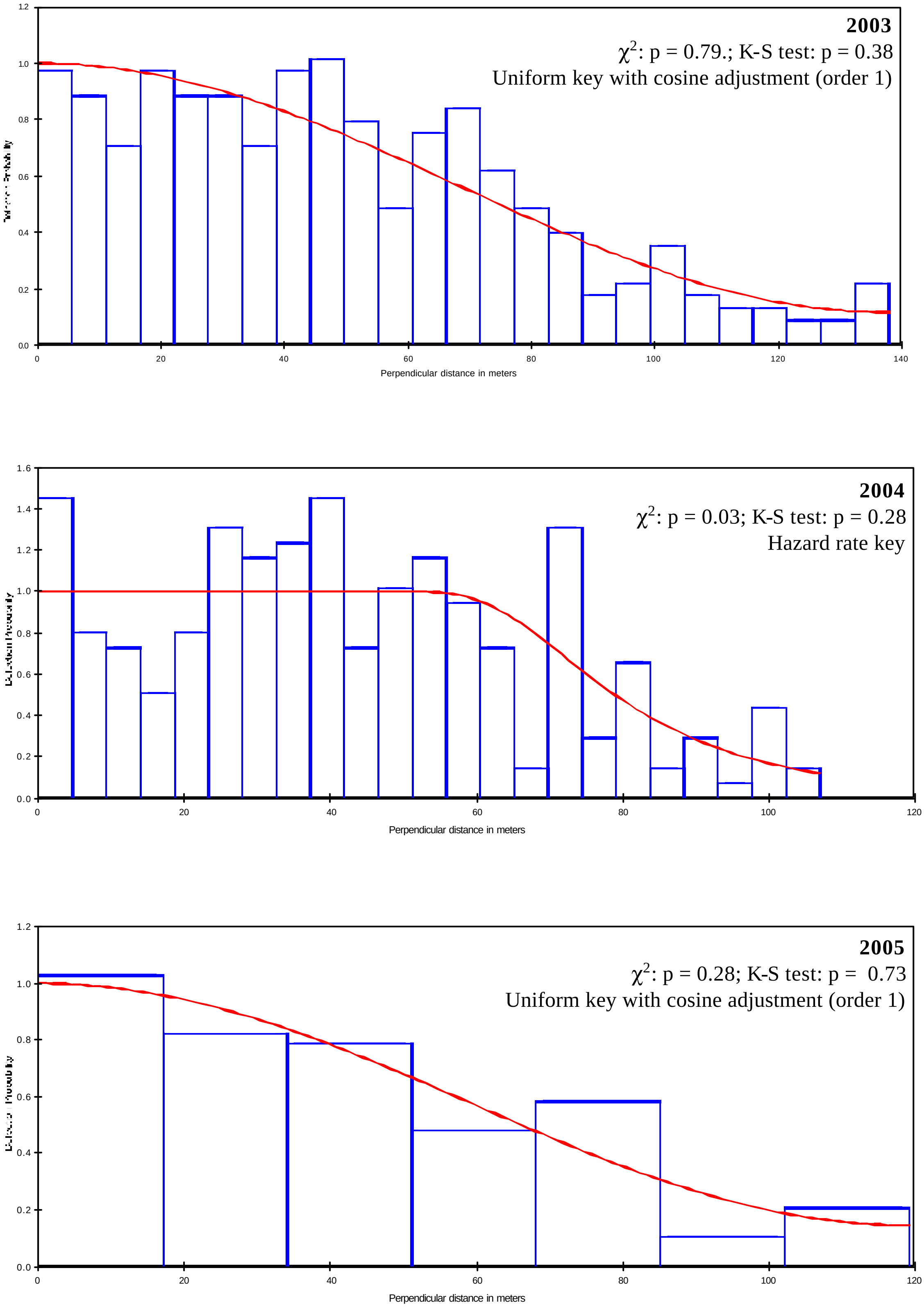


Fig. 4.6 Detection Function and Histogram of frequency of counts of Nilgai

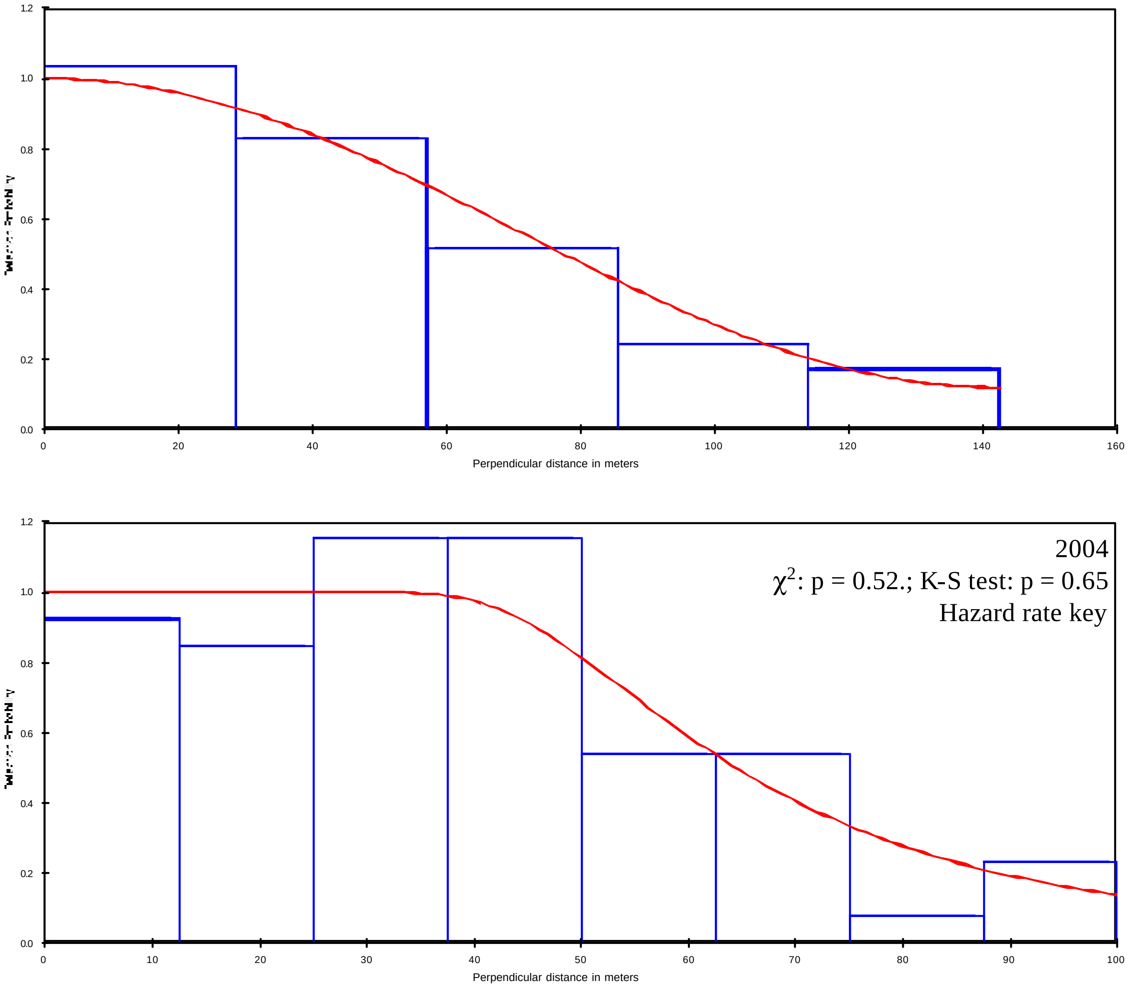


Fig. 4.7 Detection Function and Histogram of frequency of counts of Chinkara

In the course of sampling for density estimates, repeat visits were made on each transect line twice a day. This is a general practice employed to maximize the effort within a limited amount of time (Thomas & Karanth, 2002). In the year 2003, the line transects traversed in the morning were repeated on the same evening. Density estimates from morning and evening were significantly different for some species including Nilgai (F = 16.66, p = 0.00) and Four-horned antelope (F = 16.83, p = 0.00), whereas no significant differences were observed in the case of Chinkara (F = 0.13, p = 0.72). The detection functions (Fig. 4.8 to Fig. 4.10) of evening data also showed clear 'evasive movement' (see Buckland *et. al.*, 1993, 2001; Thomas & Karanth, 2002) when compared with those obtained with the morning data. While conducting line transect exercise in 2005, the repetition schedule was slightly modified so that a transect line monitored in the morning was not visited the same evening. Instead it was visited upon next time with a gap of at least one day. Results show that the encounter rates of Nilgai for morning and evening transects are different, although the density estimates are not significantly different (F = 3.37, p = 0.08). The effect

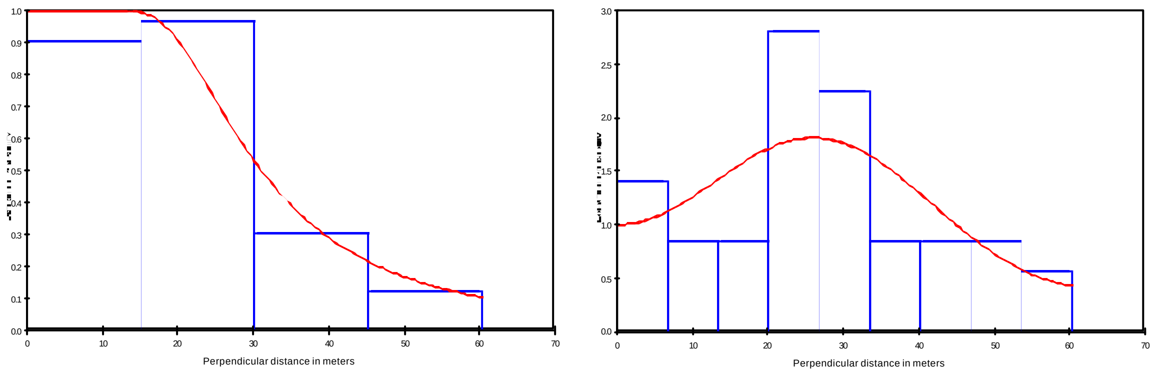


Fig. 4.8 Morning & Evening Detection Functions of Four-horned antelope (2003)

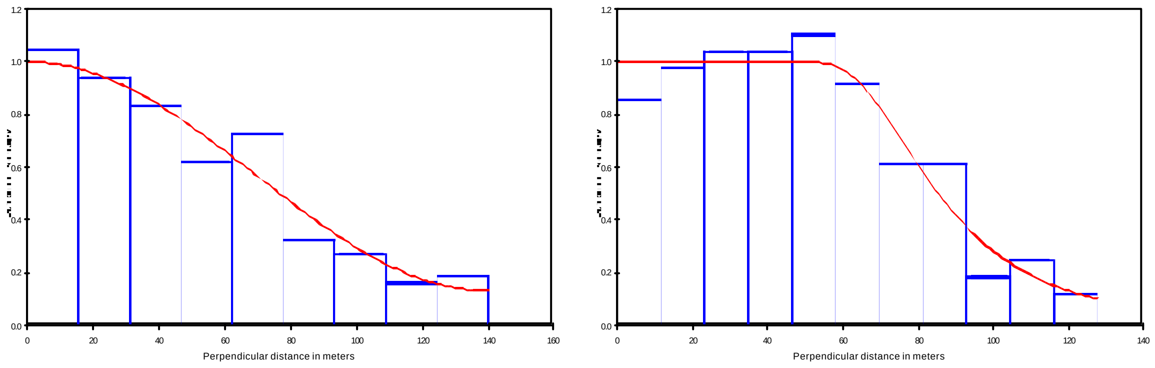


Fig. 4.9 Morning & Evening Detection Functions of Nilgai (2003)

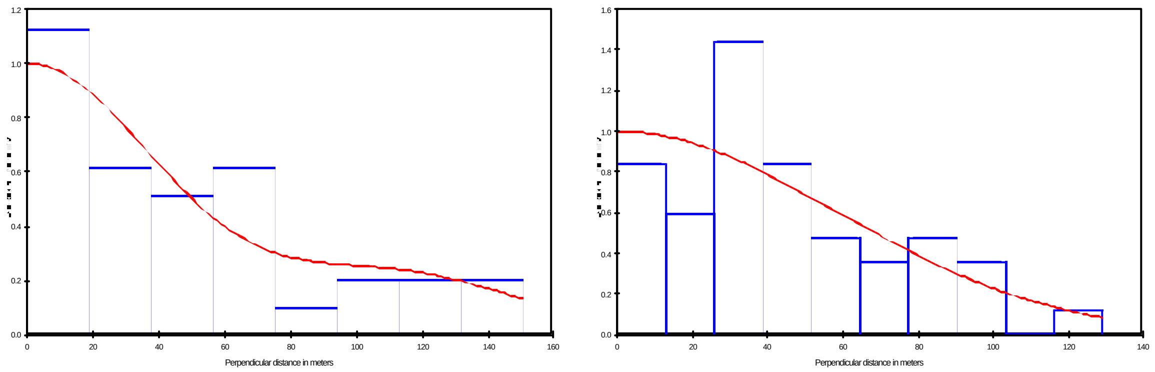


Fig. 4.10 Morning & Evening Detection Functions of Chinkara (2003)

of evasive movement is also diluted when transects are allowed some time so that the normal animal distribution is restored (Fig. 4.11). Similar results were obtained for Chital and Sambar (Table 4.b). Due to reduced effort and hence a small number of sightings of Four-horned antelope and Chinkara in the year 2005, similar tests could not be performed for these species.

4.5 Discussion

Annual abundance estimates of populations provide vital information about the

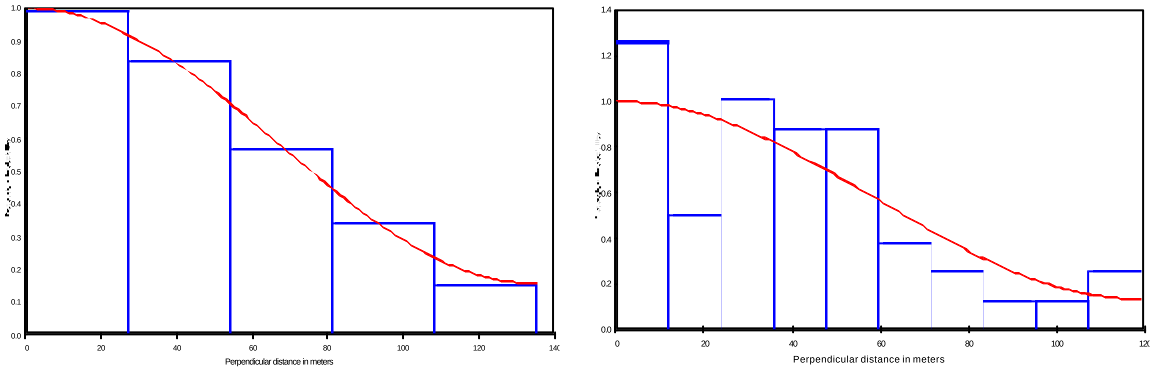


Fig. 4.11 Morning & Evening Detection Functions of Nilgai (2005)

status of the communities of interest and their response to management interventions (Karanth *et. al.* 2002; Williams *et. al.*, 2002). Abundance is not expected to change within a seasonal cycle unless there has been a natural or induced calamity. In most forest habitats and especially in dry deciduous habitats such as Panna National Park, visibility changes dramatically across seasons. Also, animal populations are dependent on availability of resources including water, forage and shelter. Since summers are marked with clumping of resources, distribution of animal populations is also expected to get clumped around waterholes and better foraging grounds. Data from different seasons suggest that there is a significant variation in the encounter rate when classified across seasons. While the density does not vary across seasons within a year, low encounter rate is concurred with low detection probability and hence a thinner Effective Strip Width. For distance sampling to provide useful results, it is important to have at least 60 to 80 sightings of the target species (Buckland *et. al.*, 1993; 2003). Low detection probability (and hence low encounter rate) would suggest that one has to traverse longer distance to obtain that minimum number of sightings. At the same time, if animal populations are clumped, the number of transect lines required to explain actual population size with low CVs goes up (Buckland *et. al.*, 2004). The months of February and March are therefore among the best seasons to con-

Table. 4.b Independent density estimates with morning and evening data for the year 2003 (visited every day) and 2005 (visited on alternate days)

Species	**Period**	**2003**		**2005**	
		D	**SE**	**D**	**SE**
Nilgai	Morning	15.58	4.42	11.27	3.11
	Evening	8.75	2.38	8.8	2.58
Four-horned antelope	Morning	2.86	0.78		
	Evening	1.4	0.58	*Data insufficient to analyse separately*	
Chinkara	Morning	2.34	1.2		
	Evening	2.54	1.13		
Sambar	Morning	10.81	3.79	12.51	4.48
	Evening	9.08	3.41	10.77	4.4
Chital	Morning	18.25	8.04	28.33	12.68
	Evening	15.13	6.08	29.61	16.87

duct line transect exercise in the tropical dry deciduous forests such as those of Panna (also see Chundawat and Sharma, *in prep.*). It is important to note that encounter rates may not always be the true indicators of actual abundance as they are estimated without considering probability of detection. This detection probability may change across seasons, landscapes and observers, thereby influencing the density estimates.

Temporal replication of transects is often done, mostly to increase number of sightings. For distance sampling to estimate detection function and hence detection probability, while at least 25 to 40 sightings of groups of animals of interest are needed to plot the probability detection function, literature suggests that at least 60-80 sightings must be obtained to do it reliably (Buckland *et. al.*, 1993). It is adviced that these temporal replications should not be used as independent samples in the analyses as they represent pseudo-replication (Hurlbert, 1984; Johnson, 2002; Buckland *et. al.*, 2001). A common practice is to sum the total length walked on a particular transect and present it as the transect length at the time of analysis. This disables the distance sampling engine from estimating variance empirically, and a default Poisson's variance is estimated instead.

We tested the impact of temporal replication on density estimates by comparing morning and evening counts and treating them as independent. Many studies use this field design of repeating transects every morning and evening to maximize the effort per unit time. Although this design allows for a larger survey effort within a small window of time, thereby reducing the seasonal effect discussed above, it biases the density estimates of different species depending on their individual behavioural ecology. Morning and evening estimates suggest that for Nilgai and Four-horned antelope, the evening estimates are significantly low. The same was not true for Chinkara, whose morning and evening estimates did not show any distinct variations, though the overall variability of Chinkara density was too high to use this comparison with confidence (see Table 4.b). Transect exercise requires observers to physically traverse the lines, stopping and recording different parameters at each sighting instance. This causes some disturbance despite all efforts by the field staff to be as quiet and inconspicuous as possible. As a result, animals tend to move away from the line. This induces a temporary change in the distribution of animals along the transect lines, leaving fewer animals near the transect. Histograms of the three species show that animals had moved away from the transect line, thereby biasing the results (see Fig. 4.8 to 4.10). In case of the Chinkara, the sampled strip is wide. Moreover since Chinkara preferably use open habitats with greater visibility (see Chapter III, Habitat Use), changes in their distribution along the line are negligible when compared to the overall strip width. It can be inferred that Four-horned antelope and Nilgai move away considerably when disturbed during the transect walk, and take some time to restore their usual distribution along the line. As a result of this, when transects are run on the same morning and evening, even though the encounter rates might be similar, the density estimates get biased due to the skewed animal distribution.

Following the results in Chapter III (Habitat Use) and Chapter VI (Behavioural Ecology), it can be said that Four-horned antelopes use forested habitats and are more cryptic in nature. On the other hand, Chinkara prefers using open habitats where visibility is high. Nilgai, being a large bodied animal can usually be seen from a greater distance, but since it uses open as well as forested habitats, there are chances that it may have lower detection probability than the Chinkara. The results are also in compliance of the above theory as the ESW of Chinkara was found to be higher than that of the Nilgai during line transects. Only while conducting the road transects, Chinkara had a thinner ESW, which suggests that there are unknown covariates affecting the data collected while using roads.

In the year 2005, the sampling design was changed slightly and transects were run in a way that the time between two walks on the same transect line was maximized. This helped in damping the impact of disturbance, which is caused when the transect is walked. For Nilgai, the density estimates of 2005 showed no significant difference between morning and evening. Similarly for other species such as Chital and Sambar, the results show an effect of disturbance in 2003 but none in 2005 (Table 4.b). It was not possible to segregate the data on Four-horned antelope and Chinkara into morning and evening classes and estimate the detection probabilities independently. Despite this, results clearly indicate that it is advisable to allow some time to the transects after each walk to replenish themselves with the normal distribution of animals along the transect line.

Road and line transect exercises conducted for population estimation of the three antelope species reveal interesting facts about the usability of these two methods with respect to different species. Their encounter rates did not change much between the two methods, but the density estimates were significantly different for Four-horned antelope and Chinkara. Density of Nilgai, when estimated using road transects, is comparable to that obtained using line transects.

The Detection Probability plotted against perpendicular distance of sightings indicates that on many occasions during the line transect exercise, the animals were too shy to be detected actively (i.e. observer detects animal before it detects observer). In the case of road transects, this evasion was even more obvious (Fig 4.5 to 4.7). Apart from evasive movement, general avoidance or preference of roads by different species due to their openness added to the problem. Collectively, inability to device a proper detection function resulted in discarding of the dataset of 2004 for population estimation of Four-horned antelope. It was observed that the encounter rates did not change significantly, but because of a wider effective strip width (ESW_{2003}=37 m; ESW_{2004}=65.1 m) the density estimates of Four-horned antelope were lower in 2004. More animals seen between 30 and 50m mark than on the road made it difficult to fit the detection curve to any of the predefined models. Inbuilt feature of Kolmogorov-Smirnov test was used to test goodness of fit and it was found that the detection function was less problematic in case of line transects (D_n = 0.106, p = 0.35) than in road transects (D_n = 0.135, p = 0.24).

In case of the Four-horned antelope, graphical output of the detection function and its visual interpretation suggest that during road count, the probability of detection up to about 60m from the road was equal to 1, i.e. no animals were being missed within this distance range from the road. This is in contrast with the detection functions of line transect exercise in 2003 and 2005 that fitted with Uniform key and Half-normal key respectively. These functions show a steady decline in detectability with distance, from as close as about 20 m. Four-horned antelope is a small animal with preference for thickets and clusters of vegetation (see Chapter III, Habitat Use and Distributon), and does not take evasive action until inevitable (see Chapter VI, Behavioural Ecology). Given these behavioural traits, detection function obtained in 2004 made little ecological sense. The road and abutting clearing up to about 30m on both sides could act as a microhabitat for the Four-horned antelope. Typically a forest dweller, the Four-horned antelope avoids open clearings and roads following their anti-predatory behaviour (for details see Chapter VI, Behavioural Ecology). As a result, the distribution and hence density of these animals along the roads used as samples is expected to be rarefied when compared with their actual density. Using left truncation to account for this problem was attempted but it did not yield reliable results as large amount of data points were lost in doing so.

When dealing with data on Chinkara, it was observed that their density estimates were higher in 2004 against a significantly low population estimated in 2005. While the encounter rate remained constant in 2003 and 2004, a higher detection in a thinner strip was responsible for this unexplainable raise in the density estimates. Again, the fact that roads and their adjoining clearing act as microhabitats resulting in an uneven usage around roads explains the phenomenon. Chinkara, unlike the Four-horned antelope have a preference for open terrain with greater visibility. Since their anti-predatory strategies require them to stay in open and take evasive action from a greater distance, they tend to aggregate around the roads. In fact on many occasions, Chinkara were observed resting either on the road or on the clearing on either side.

Density estimates from road transects were different from those of the line transects for the two small species, viz. Four-horned antelope and Chinkara, but were similar for Nilgai. While encounter rates had not changed, detection functions of small animals (e.g. Four-horned antelope and Chinkara) estimated separately exhibit problems related to study design in case of the road transect. This is not the case when using the same method for large bodied animals such as the Nilgai, Sambar and Chital. In the year 2004, minimum AIC (Akaike's Information Criterion) was obtained for Hazard Rate model (AIC = 458.5) when estimating the detection probability of the Four-horned antelope. Visual interpretation of the Hazard Rate model fit for the road transect exercise suggests that detection probability was equal to 1 till about 50m on both sides of the line of movement. This would mean that according to the model, no animals were missed from being detected in the 100 m wide strip on both sides of the road. Considering the size and cryptic behaviour of the animal, it is unlikely to have such high detection probability up to 50 meters from the line of movement. Sighting lanes are one meter wide strips running parallel to the roads at a distance of 30 m on both sides. It is also possible that these 'sighting lanes' are used by the Four-horned antelopes for usual movement as walkways, thereby causing a high concentration of animals around the 40-60 m mark.

It is possibly because of the distribution of Four-horned antelopes, which was not random on either sides of the road. In case of Nilgai, which is a large bodied animal and can be detected more easily than the Four-horned antelope, estimates were comparable and did not vary greatly across the three years. It was only in the case of Chinkara, that the encounter rate reduced to less than three times when line transects are compared. It is likely that there is an actual decline in Chinkara populations over the years, though it is worth noting here that the Coefficient of Variation for estimates of Chinkara are very high to deduce such fluctuations reliably.

Line transects are suitable for population estimation of Four-horned antelope wherever a good encounter rate of the species can be obtained. If designed properly, random sampling can be achieved resulting in reliable estimates using this technique. This method is usually free from microhabitat and accessibility bias and can be used to cover most of the available habitat types unless there is a cliff or some other completely inaccessible terrain. The only problems with line transects are that they are expensive to run, take time and need careful marking in the forest while avoiding over-clearing along the transect path.

Using road transects for small animals like the Four-horned antelope is not recommended because they pose a potential problem in obtaining an unexplainable probability distribution function and consequently provide underestimates of densities. But the Road Transects can be used for obtaining other related information, such as the population structure, group size and basic habitat use because such parameters are usually not influenced by detection probability directly. Another benefit of to this technique is its efficiency, which is certainly higher than the line transect because it allows coverage of a larger area within a short period

Table. 4.c. Four-horned antelope densities from Panna National Park and other sites.

Site	**Density (km^{-2})**	**Reference**
Panna National Park, Madhya Pradesh	2.9 2.7	Chundawat *et. al.*, 2001; Chundawat *et. al.*, 2006 This study
Pench National Park, Madhya Pradesh	0.29 1.1	Biswas and Sanker, 2002 Karanth and Kumar, 2003
Gir Wildlife Sanctuary, Gujarat	0.75	Khan *et. al.*, 1996
Mudumalai Wildlife Sanctuary, Tamilnadu	0.88	Bhaskaran, 2002
Dhaknakolkaz Wildlife Sanctuary, Maharashtra	1.28	Rice, 1991
Nagarhole National Park, Karnataka	0.8	
Melghat Tiger Reserve	0.5	Karanth and Kumar, 2003
Tadoba Andhari Tiger Reserve	0.5	Karanth and Kumar, 2003

of time, that too at a lower logistical cost (manpower, fuel, equipments and time).

The Four-horned antelope is evenly distributed throughout the study area of 200 km^2. Low CVs indicating precise estimates despite small sample size of nine transects, indicate its uniform distribution in the whole sampled area.

Density estimates of Four-horned antelope from other known sites are presented in Table 4.c. It is noted that Four-horned antelope is usually found in low density at all sites. The estimated density of 2.7 animals per square kilometer in 2003, 2.2 in 2005 and even a much lower value of 1.56 in 2004 is among the highest of the known populations in India (Rice, 1991; Khan *et. al.*, 1996; Berwick, 1974; Biswas & Sankar, 2002; Karanth & Sunquist, 1992; Bhaskaran, 1999). Habitat suitability and other factors like proportion of other species in the overall ungulate community possibly support this high density of Four-horned antelope in Panna National Park. Panna provides an ideal habitat of dry deciduous forest with high floral diversity to the Four-horned antelope (for details see Chapter III, Habitat Use). In Panna, Protection and minimal anthropogenic pressures along with controlled Chital abundance possibly help the Four-horned antelope attain a relatively high density.

Comparison of recent density estimates of the Four-horned antelope with previous study in Panna (Chundawat, 2001) using the same methodology suggests that there is possibly a slow decline in the population of Four-horned antelope in Panna National Park (see Fig. 4.12). A steady increase in the Chital populations is also reported from the study area. It is envisaged that proliferation in population of a particular hardy and generalist prey species usually results in the decline of specialist species. Factors such as habitat

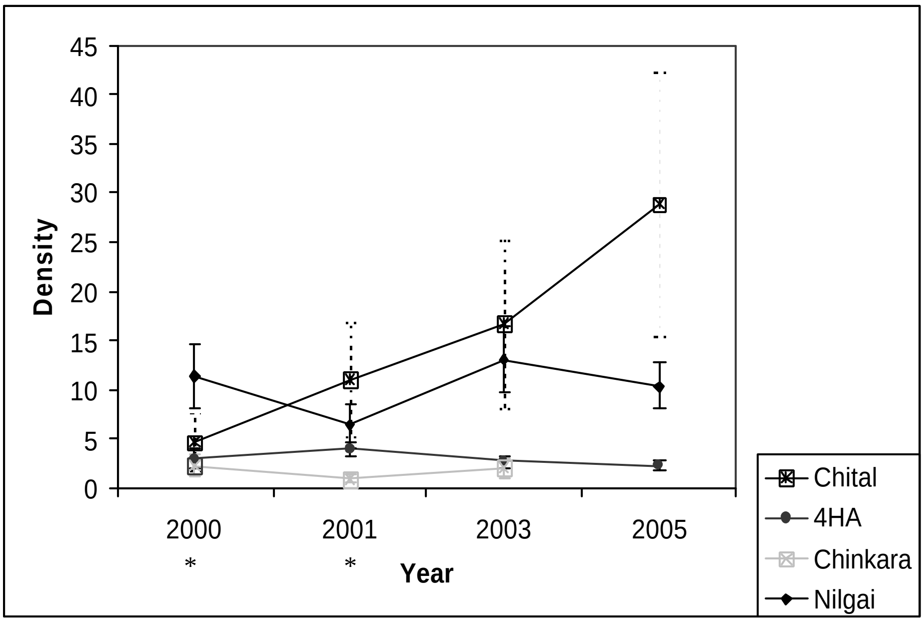


Fig. 4.12 Population trends of Chital and the three antelopes in Panna National Park
(*source: Chundawat and Sharma, *in prep.*)

alteration favouring Chital can possibly be the reason behind this slow decline.

Chinkara populations are highly clumped in Panna National Park. Out of nine transects Chinkara was seen on five in the year 2003, and only on three in the year 2005. Since it prefers open habitats for survival, transects laid in forest habitats produced no sightings. This results in high CVs, making the results largely unusable for monitoring minor fluctuations in the populations. It is recommended that for estimating Chinkara density with higher precision, a stratified design be made with more number of transects in each stratum. Despite high CVs obtained for Chinkara's density estimates, there is a steep decline in the year 2005 when compared with data from 2001 and 2003. In absence of sufficient number of observations, it was not possible to estimate density in the year 2005, but the low encounter rate suggests that their populations may have declined over the last few years. Chinkara is known to inhabit open habitats. In absence of climax grasslands (Champion & Seth, 1968), there is a continuous need to maintain open areas through management interventions. Due to a complete prohibition on grazing and anthropogenic pressures in areas within the National Park, it is possible that the Chinkara populations may have declined, though much focussed research is still needed.

Nilgai is believed to prefer open forests. Though in Panna, they are seen in the open areas as well as in dense forests. Study shows that the niche occupied by Nilgai partially overlaps that of the Four-horned antelope as well as that of the Chinkara (see Chapter III, Habitat Use). A gradual decline can be observed over the years in the Nilgai populations as well (see Fig. 4.12). The reasons for this decline are unknown and need further investigation.

It is intriguing to note that population of all the three antelopes in Panna are declining, some slowly, while others steeply. Comparing these population estimates with data on Chital (Chundawat and Sharma, *in prep.*) suggests that there is a sharp increase in their population over the past few years. Whether the increase is at the cost of other species needs further investigation. The issue is dealt with in greater detail in Chapter VII (Conservation and Distribution).

Transect exercise being conducted in the field

Four-horned antelope sighting on a transect

CHAPTER V

Demography of Four-horned antelope and Significance of Four Horns

CHAPTER V

DEMOGRAPHY OF FOUR-HORNED ANTELOPE AND SIGNIFICANCE OF FOUR HORNS

5.1 Introduction

Food, reproduction and protection are the basic needs that influence behaviour and ecology of ungulates. These factors also influence their grouping behaviour, demography and pattern of habitat use. Different ungulate species have different grouping preferences addressing their requirements with respect to various ecological and behavioural factors.

Population of a community comprises of individuals and their characteristics, which are shaped by natural selection (Williams *et. al.* 2001). Characteristics that are associated with high survival or reproductive rates are favoured by natural selection. The organisms possessing such favourable traits tend to be represented by more descendants in future generations. This potential of breeding and producing more offsprings is also represented by the overall fitness of the species. Despite being separate sections of the biological studies, fitness and population growth are closely related. Growth rate or sustenance of a geographically closed population is determined by survival and reproductive rates, while in case of an open population, migration adds up as an additional variable. At the same time, fitness of individuals is determined by the probabilities that they will survive from year to year and produce offsprings in each reproductive season. Due to this interrelationship between population status and individual fitness, it is important to study demography and social structure and obtain additional information on evolutionary ecology.

Members of different age/sex categories within the same populations commonly show different degrees of gregariousness (Leuthold, 1977). In many species, due to their social and reproductive status, fully adult males tend to become solitary, whereas females often tend to be slightly more gregarious. One may also get this impression erroneously since females are often accompanied by their offspring, which is not usually the case in males. There is a slight difference between grouping and aggregations. This difference has been dealt in this chapter and also in Chapter III (Habitat Use). The basic difference between the two is that the grouping constitutes of coherent social entities whereas the latter does not. Aggregations are often a response to some external factor such as favourable foraging conditions, water availability or temporary threat from predators. On the other hand, groups or herds are more cohesive, long lasting, and most importantly, show social bonding between members of a group. Although it is often difficult to determine whether a given grouping is a social entity or merely an aggregation, some knowledge about the species' usual tendencies help in making this decision.

The group size and social structure of ungulates depend upon their ecological needs (Jarman, 1974; Brashares, 2000). Mating, fawning, resource partitioning and protection are the parameters that govern the social structure of ungulates (Leuthold, 1977). The Four-horned antelope is documented as a solitary animal which can often be seen in pairs or small groups consisting of male, female and fawns (Jerdon, 1867; Brander, 1923; Prater, 1967; Gurung & Singh, 1996; Menon, 2003).

5.2 Methodology

5.2.1 *Field Work*

To collect data on demography and social structure, the study site was intensively surveyed across different seasons. Each direct sighting of Four-horned antelope was recorded along with a battery of other important parameters including date and time, number of individuals, age/sex class, basic habitat parameters, behaviour, distance from the observers' line of movement, animal's post detection reaction and site coordinates. For obtaining data on demography and social structure, individuals were categorised into identifiable age/sex classes. The female was categorized into Adult and Sub-adult, although in due course of time it was realized that it is very difficult to classify a female into the above classes, as there are no diagnostic differences between the two other than body size. Even estimation of body size was prone to ambiguity in the field in the absence of a comparable reference. This caused inappropriate classification for solitary females into the aforementioned classes. As a result of the discrepancy in identification, most sub-adult females reported in our dataset are identified and recorded in a group of two or more. As a result of this bias, the data may not be a true representative of the actual proportion of female sub-classes.

Horns in male Four-horned antelopes continue to grow for a long time, possibly life long (*pers. obs.*). Schaller (1967) suggested an age classification in Chital and Sambar. According to him, adult Chital males grow antlers of different sizes when in different phases of their life. While a young male would have small spikes protruding on its skull, an adult and healthy male would have fully developed antlers with tines. Size of these antlers may vary depending on the nutrition intake of the individual and may in return indicate its health and even social status within a herd. we used similar methods to classify males into different age groups. Against four classes suggested by Schaller, we used three classes, i.e. Class-2, Class-3 and Class-4. Unlike large antlers of Chital or Sambar, the Four-horned antelope has small horns. It is therefore difficult to put adult males in various age-classes. Nevertheless, as this species has four horns, we classed individuals on the basis of presence of frontal pair of horns and their length with respect to the rear horns (which are longer). Since young males have only two horns, we could not classify them into the Class-1 (Cl1) and Class-2 (Cl2) age classes. Instead, all such individuals were identified as either fawns or juveniles depending on their size with respect to an adult Four-horned antelope. Class-2 (Cl-2) was assigned to the individuals that have almost attained the size of an adult, but have only two horns (Fig. 5.1). Class-3 (Cl-3) were the individuals with smaller front horns, less than or equal to 1/3rd of the size of the rear horns (Fig. 5.2). Class-4 (Cl-4) was assigned to males having front horns longer than 1/3rd of the size of rear horns (Fig. 5.3).

Young males start developing their rear horns at an early age of about two to three months. Regular record taken from a captive Four-horned antelope in Van Vihar National Park and Zoo, Bhopal suggests that once a male fawn is about 10-14 months old, the front-horns sprout on his forehead, initially as swollen knobs, slowly taking shape into tiny button like horns within a few months' time. One individual in Van Vihar which was already adult when brought into captivity, had small but well developed front-horns (FH/RH = 1/3). In two years' time, its front-horns grew to more than double the previous size. Three years being almost one third of their estimated captive age of eight to nine years (L.N. Acharjyo *pers. comm.*, 2006), this indicates that these horns could either be termed as indicators of their age, or of the nutrition the animal gets during the growing stage, and that these front-horns continue to grow slowly for a long period of time.

Classification of males into one of the three aforementioned categories was attempted during each sighting. Whenever possible, the length of the front horns was also estimated in proportion to that of the rear horns with the help of close up photographs or binoculars. The longest observed front horn length in field was almost as big as the size of the rear horn (10-15 cm), while most males (76%, n = 153) had front horns of length proportions between 1/4 and 2/3 of the rear horn.

It is often difficult to get a proper glimpse of young Four-horned antelopes in the wild, as they are generally wary of humans and predators alike (see Chapter VI, Behavioural Ecology). Fawns are kept hidden till about two to three weeks after which they start following their mother. It was not possible to locate fawns of this age (In three and a half years we managed only two sightings of fawns of this age), and hence, whatever information we have, is based on fawns between the age of about a month to a year. To simplify data collection from the field, the fawns and juveniles were classified into one category only. In routine sightings, a fawn was classified as an individual smaller than 2/3rd of the body size of an adult. Any antelope bigger than this was either classified as a sub-adult (only if there was an adult nearby for size reference) or as an adult. One can safely assume that fawns smaller than this size would not venture on their own. Even if they did, their size and anatomy was generally too diagnostic to be confused with an adult.

5.2.2. *Analyses*

Data from three years was analysed to estimate different parameters of the social structure and demography of the Four-horned antelope in Panna Tiger Reserve. A collective analysis of datasets collected differently (line transects and random vehicular sightings) was done. Although different observers walked and collected data during transect exercise, we assume that chances of different observers misidentifying sex or estimating group sizes wrongly were negligible. Since male classification needs prolonged and thorough sighting, the data of male Four-horned antelope from transects were not used due to chances of human error and observer variability. Data from three years of fieldwork were compared for differences, and in absence of significant difference in results, pooled to have a bigger sample size.

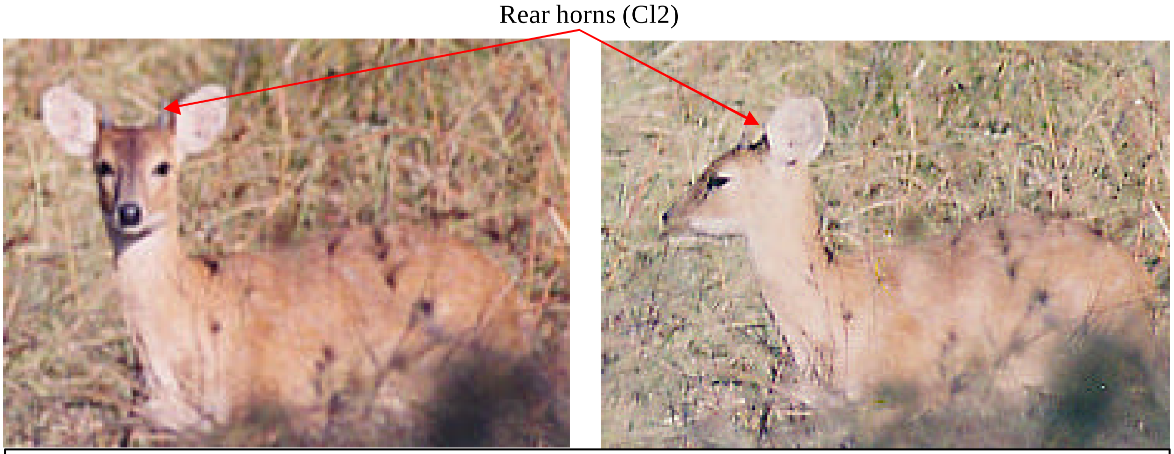


Fig. 5.1 Class 2 (Cl2) male: Four-horned antelope

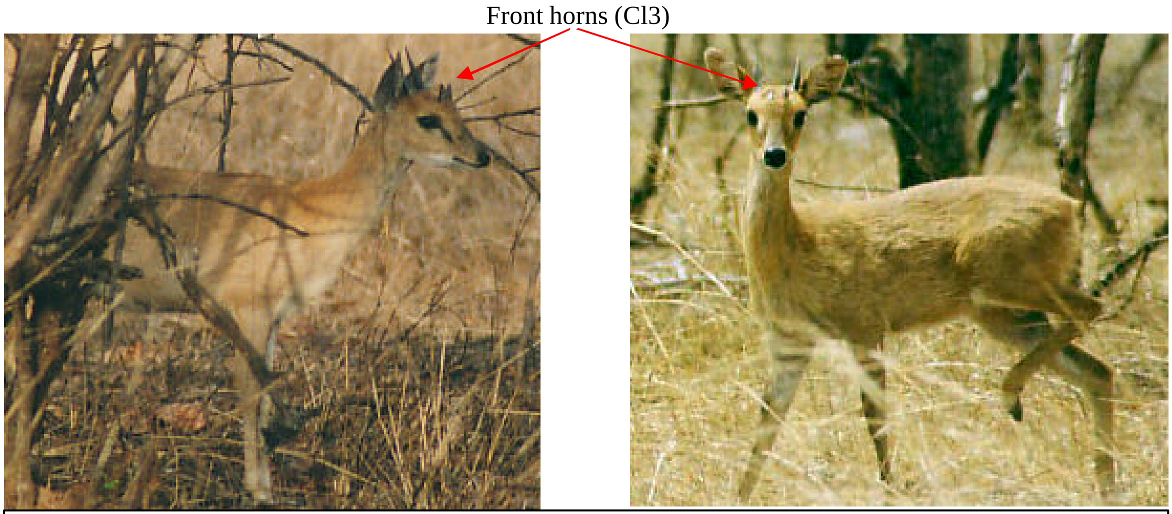


Fig. 5.2 Class 3 (Cl3) male: Four-horned antelope

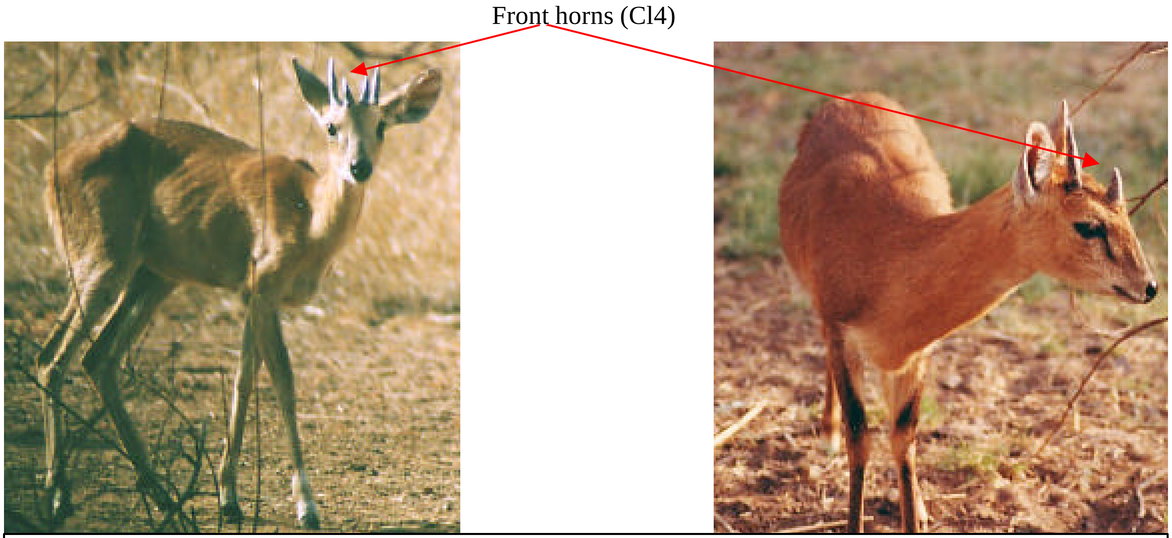


Fig. 5.3 Class 4 (Cl4) male: Four-horned antelope

An early analysis of demography data suggested that it is possible that males, females, fawns and sub-adults may have different detection probabilities, given their priorities in antipredatory, foraging and reproductive strategies. To address this possible discrepancy in detection of different age/sex classes, a systematic estimation of detection probability was done using theory of distance sampling (Burnham & Andreson, 1976; Buckland *et. al.*, 1993; Buckland *et. al.*, 2004). As mentioned above, minimum distance between observer's line of movement and animal was estimated using a rangefinder whenever possible. This distance was used as the perpendicular distance from the line of movement to animal while analysing using software Distance 5.0 (Thomas *et. al.*, 2005). Since data were collected round the year, it is expected that detection probability changed across seasons (Chundawat and Sharma, *in prep*). One has to identify that in a dry deciduous forest, visibility changes greatly from wet to dry season due to vegetation. Animal behaviour is also expected to change with seasons as their priorities change. Grouping tendencies are expected to influence detection probability, and so is expected from the observer's mode of travel of (bike, foot, jeep).

For analysing demography as proportion of different age/sex classes in the overall population, we analysed the data using Multiple Covariate Distance Sampling Engine (MCDS: Buckland *et. al.* 2004; Thomas *et. al.*, 2005) available in Distance 5.0 software. It is expected here that detection probability is not only a function of distance from the line of movement, but parameters like season, mode of travel and group size are also potential covariates affecting the scale of the detection function.

To model the detection function, the MCDS engine uses a (key function + series expansion) formulation. It differs from the conventional distance sampling in incorporation of covariates in addition to distance into the key function. So,

g(x, z) = key(x, z)[1 + series(x)]

where **g(x, z)** is the probability of detecting an object at distance x and covariates z, **key(x, z)** is the key function, and **series(x)** is the series expansion.

The covariates are assumed to affect the scale parameter of the key function, ó, which controls the width of the detection function:

Half-normal key function,

$$\exp \{-x^{2} / 2\, \text{ó}(z)^{2}\}$$

Hazard rate key function,

$$1 - \exp \{- [x / \text{ó}(z)]^{-b}\}$$

The scale parameter is modeled as an exponential function of the covariates:

$$\text{ó}(z) = \exp(\hat{a}_o + \hat{a}_1 z_1 + \hat{a}_2 z_2 + K\, \hat{a}_q z_q)$$

{q = no. of covariate parameters}

Factor covariates classify the data into more than one distinct category or level.

For factor covariates, the actual covariate values are not important, since a separate parameter is defined for each factor level. The last factor level is incorporated into the intercept. The model for the scale parameter will be:

$$\text{ó}(z) = \exp(\hat{a}_o + \hat{a}_1 z_1)$$

{ $\hat{a}_o$ = intercept and $\hat{a}_o$ = the slope}

For estimation of average group size, a linear model was used to test whether there was an effect of group size on detectability. It is possible that large group of animals is detectable at greater distances than is a small group. This can induce an upward bias in the cluster size if estimated as simple average. To address this issue, expected group size was estimated by regressing **ln (s_i)** on **g (x_i)**, and then testing the significance of the regression. If p value was estimated to be greater than the significance level of 85% (alpha = 0.15), average group size was used assuming no effect of group size on detection probability, otherwise regression method for estimation of group size was used. Univariate Analysis of Variance was used to test effect of month and year on data. Annual phenology of group size of Four-horned antelope based on two years' data was analyzed since it is important for understanding the cost effectiveness of grouping in terms of predatory threats and benefits of reproductive success (Ruckstuhl, 1998; Ruckstuhl & Neuhaus, 2000; Ruckstuhl & Neuhaus, 2002). Univariate Multifactor Analysis of Variance (Uni-MANOVA) was used to investigate the effect of interaction between the two factors, viz. month and year. Since there is a possibility that as a result of overall changes in climatic conditions within different months, seasonal effects may have changed within the two years, Uni-MANOVA was selected over One-factor ANOVA. The upside of selecting Uni-MANOVA is that it treats each year's data spread across different months separately. This approach also guards against indiscriminate pooling of data where different months may represent different environmental conditions across different years.

Tests were also conducted on data from individual age classes of males to investigate if there were any significant differences in their detection probabilities. Male-female grouping tendencies and patterns were estimated using the corrected proportions of individuals (by dividing detection probability to the observed count) into different age classes rather than using naïve estimates (which assumes an equal detection probability for all age/sex classes).

An equation was also developed to estimate the survival rate of fawns based on empirical data on proportion of individuals in a particular age class, available literature on proportion of male to female and twins at the time of birth, and the overall proportion of adult individuals. The main assumptions here are:

- $K_{Fwn\text{-}SAd} \sim K_{MFwn\text{-}Cl2}$
  i.e. the survival rate of fawns to Sub-adulthood is independent of their sex.
- Every adult female breeds
- Proportion of adults to sub-adults is the same in both the sexes.

$K_{MFwn\text{-}Cl2} = P_{Cl2} / P_{MFwn}$

$P_{MFwn} = (P_{TotFwn} \text{ x } R_{MFwn})$

$P_{TotFwn} = P_{Female} \,.\, R_{AdultF} \text{ x } [(R_{twins} \text{ x } 2) + (R_{single} \text{ x } 1)\}$

$R_{AdultF} = P_{Female} \text{ x } (P_{AdultM} / (P_{Cl2} + P_{AdultM})$

Therefore,

$$\boxed{K_{Fwn\text{-}SAd} = \frac{(P_{Males} \text{ x } R_{Cl2})}{[\, R_{MFwn} \text{ x } P_{Female} \,.\, \{P_{AdultM} / (P_{SAdM} + P_{AdultM})\} \text{ x } \{(R_{twins} \,.\, 2\,) + (R_{single} \,.\, 1)\}]}}$$

$K_{Fwn\text{-}Sad}$ = Survival rate of fawn to Sub-adult
$K_{MFwn\text{-}Cl2}$ = Survival rate of male fawn to Class 2
P_{MFwn} = Population proportion of male fawns

P_{TotFwn} = Population proportion of total fawns

P_{Cl2} = Population proportion of Class 2 males

P_{Female} = Population proportion of Females

P_{AdultM} = Population proportion of Adult Males

P_{AdultF} = Population proportion of Adult females

R_{twins} = Birth ratio of twin fawns vs. single fawns

R_{single} = Birth ratio of single fawns vs. twin fawns

R_{AdultF} = Ratio of Adult Females vs. Sub Adult Females

5.3 Results & Discussion

Four-horned antelopes were seen on 819 occasions either solitary or in groups between November 2002 and June 2005. This includes 114 sightings obtained while conducting foot transects. Since data was analysed using distance sampling considering possible effect of covariates, it is safely pooled across all modes of observation, seasons, and group size. Out of 309 male sightings in the field, 279 could be assigned one of the three classes. Ordination of 202 males based on their horn lengths' proportions (*horn prop* = *len* FH / *len* RH) could be done using close observations, photographs or video recordings from the field.

Out of 405 sightings of females, on 260 occasions we could differentiate between adult and sub-adult females. Out of 977 Four-horned antelope sightings recorded in the field, 855 were identified for their sex/age. Remaining 122 individuals had to be discarded as unidentified in absence of confirmatory identification. 141 fawns were recorded out of which only 30 could be given a proper size reference in relation to the adult.

5.3.1 *Group size*

Sightings data was processed using distance sampling methods to estimate the mean group size across twelve months after pooling the data for three years. Since effect of this variability across three years was taken care of using covariates, it was safe to use pooled information. Data from line transects are used in addition to the data collected using other modes for this analysis. This was done after mode of observation was assigned as a covariate.

Mean group size was estimated as 1.34 (CV = 1.58%). Analysis suggests that there was a significant regression between detection probability and group size (p = 0.08; Fig. 5.4). This regression indicates that in average group size, a positive bias is expected. We also tested group size data for each individual month for its effect on detectability, but only in three months (December, January, June) such influence could be noticed.

Fig. 5.5 depicts monthly variation in mean group-sizes. Using Univariate Multifactor Analysis of Variance, we tested the hypothesis that there is no change in the mean group size across years and months, and that there is no interaction between the two variables (year and month). The average group size did not change significantly across the years (F = 0.989, sig. = 0.372) and neither was any significant interaction found between the factors, viz. year and month (F = 1.412, sig. = 0.141). Significant variation (F = 2.125, sig. = 0.026) in the mean group size was found across different months. This indicates that the overall grouping tendencies were not changing across the years; and there was no noteworthy combined effect of years and months on the

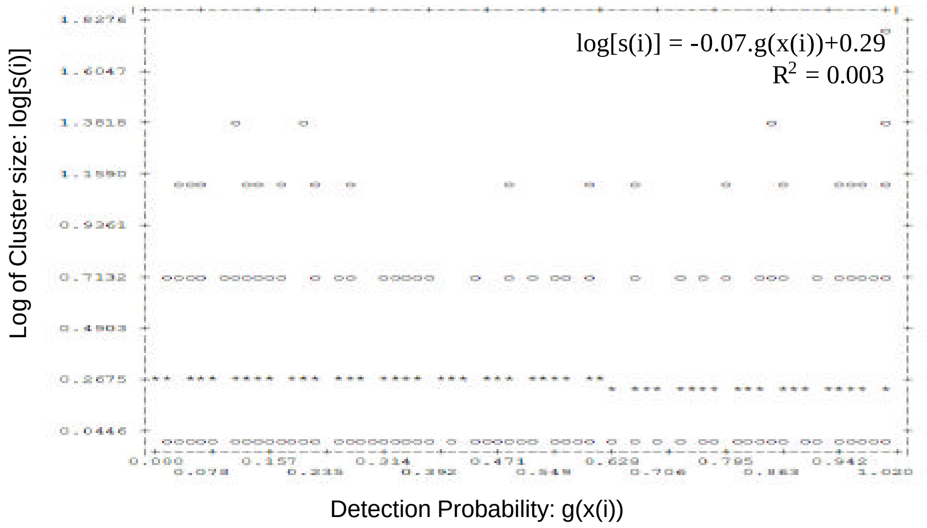


Fig. 5.4 Group size: Regression of log of cluster size [log(s(i))] on detection function [g(x(i))]

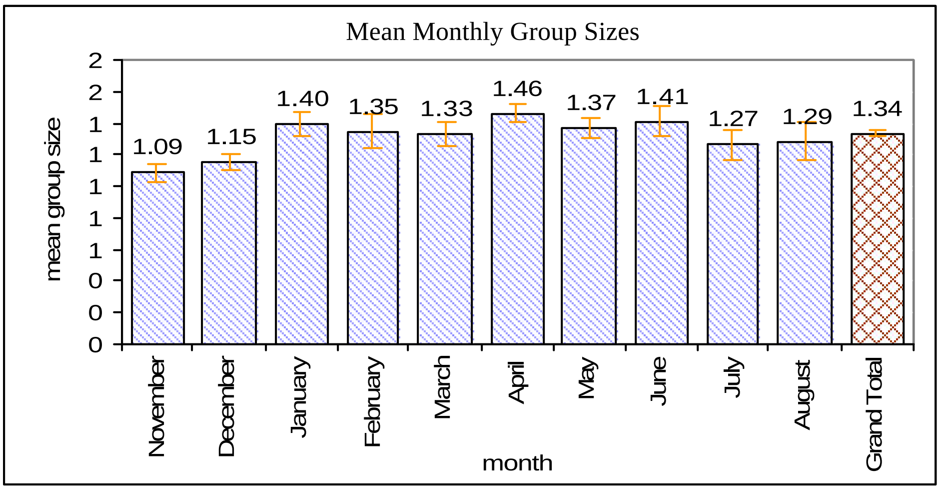


Fig. 5.5 Monthly variation in Mean Group sizes of the Four-horned antelope

data collected as well. This test also checks against possible biases incurred during observations made across three years. A significant change in mean group sizes across years would have suggested human errors.

Visual interpretation of group size data from three years suggests that mean group size increases sometime around the end of winter and remains so till the onset of monsoon. While this rise in group size can be accredited to many causes, an attempt is made to understand the stimuli behind such grouping tendencies of the Four-horned antelope.

An understanding of the seasonal group compositions discussed in the next section addresses the stimuli behind such grouping tendencies by species that are otherwise solitary. In the next section we try to elaborate on fawning, courting and other stimuli for grouping with the help of group composition data. On 69% occasions it was found solitary, followed by

24% times when it was in a group of two. Larger groups were rare and mostly comprised of fawns and/or juveniles (Table 5.a). Graphical interpretation (Fig. 5.6) of their group frequencies leaves little room for doubt in determining that the Four-horned antelope is preferably a solitary dwelling species, getting in larger groups only when the benefits of doing so exceed cost (e.g. Jarman, 1974; Zahavi & Zahavi, 1997; Brashares, 2000; Caro *et. al.*, 2004). In the chapter on behavioural ecology the grouping tendencies are discussed again for costs, benefits and risks using the handicap principle (Zahavi & Zahavi, 1997).

5.3.2 *Demography*

It was found that detection probabilities of different age/sex classes of Four-horned antelope were a function of distance, observers' mode of movement, season and group size. Demographic proportions of the population are expressed as densities of individual age/sex classes per unit area. These densities per unit area are estimated using distance sampling techniques through MCDS engine available in Distance 5.0 (Thomas *et. al.*, 2005). Different age/sex classes were analysed separately for estimating their detection probabilities in this design of open width line transect (Buckland *et. al.*, 1993). Detection probability of male Four-horned antelopes, irrespective of age class was estimated as 0.67 across a width of 68 m (Fig. 5.7). Similarly, detection probability of females was estimated as 0.53 in a strip of width 75 m (Fig. 5.8). For estimation of detection function of fawns, it was assumed that they followed an adult on most occasions. An adult with a fawn would invariably mean a larger group size when compared with other solitary individuals. The overall group size was used as a covariate using Multiple Covariate Distance Sampling (MCDS) engine, which was then used to calculate detection function and proportion of fawns in the overall population. We estimated a detection probability of 0.49 in a strip width of 69 m for fawns (Fig. 5.9). The results suggest that sighting of fawns was high around January, April, May and August (Fig. 5.10). Sufficient data were not available from the months of September and October due to thick vegetation cover causing impaired visibility.

Males were classified into different classes and proportions in population es-

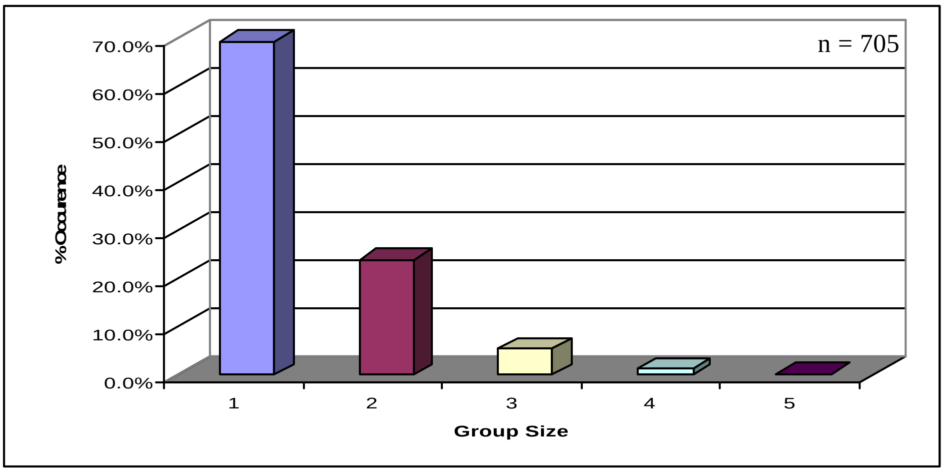


Fig. 5.6 Percent group size frequencies of the Four-horned antelope

timated after integrating detection probability into the estimates. Detection probabilities of Class-2, Class-3 and Class-4 were estimated separately. Detection probability of Class-2 individuals in a 90m wide strip was 0.45 (Fig. 5.11). That of Class-3 individuals across a 100m wide strip was 0.37 (Fig. 5.12) and for Class-4 animals the detection probability was 0.53 (Fig. 5.13) in a strip width of 91m. This suggests that Class-3 individuals were the most shy of all and that Class-4 males would often be easily detected and redetected. Since Class-2 and Class-3 represent slightly young individuals, they are expected to be shyer than the Class-4 males due to their greater wariness of potential threats. The possible reason for Class-2 having a slightly higher detection probability is that most young males less than one year usually remain with their mother. This, and other related behaviour are discussed in the next section of male biology and significance of horns.

Further analyses reveal that probability of seeing male-female groups increases rap-

Table 5.a Group compositions of Four-horned antelope in different group sizes

Group Size	Sightings	Percentage	Combination
1 **(n=490)**	199	41%	Female
	215	44%	Male
	6	1%	Fawn
	70	14%	Unidentified
2 **(n=169)**	18	11%	2 Females
	62	37%	1 Female, 1 Fawn
	10	6%	2 Fawn
	39	23%	1 Female, 1Male
	16	9%	2 Male
	7	4%	1 Female, 1 Unidentified
	7	4%	1 Male, 1Unidentified
	10	6%	2 Unidentified
3 **(n=37)**	1	3%	3 Females
	5	14%	2 Females, 1 Fawn
	12	32%	1 Female, 2 Fawn
	2	5%	2 Females, 1 Male
	6	16%	1 Female, 1 Unidentified, 1Young
	2	5%	2 Females, 1 Unidentified
	6	16%	1 Male, 1 Female, 1 Fawn
	1	3%	1 Male, 2 Unidentified
	1	3%	2 Male, 1 Unidentified
	1	3%	2 Unidentified
4 **(n=8)**	1	13%	2 Females, 1 Male, 1 Fawn
	2	25%	1 Female, 1 Male, 2 Fawn
	2	25%	1 Female, 1 Unidentified, 2 Fawn
	1	13%	4 Females
	1	13%	1 Female, 1 Male, 1 Fawn, 1 Unidentified
	1	13%	3 Female, 1 Male
6 **(n=1)**	1	n/a	2 Female, 2 Fawn, 2 Unidentified

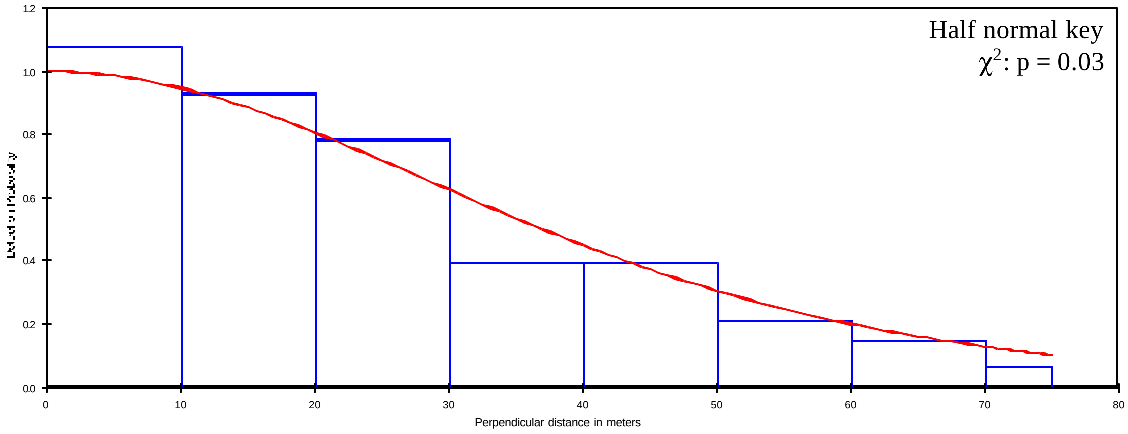


Fig. 5.7 Detection Function and histogram of Four-horned antelope: Female

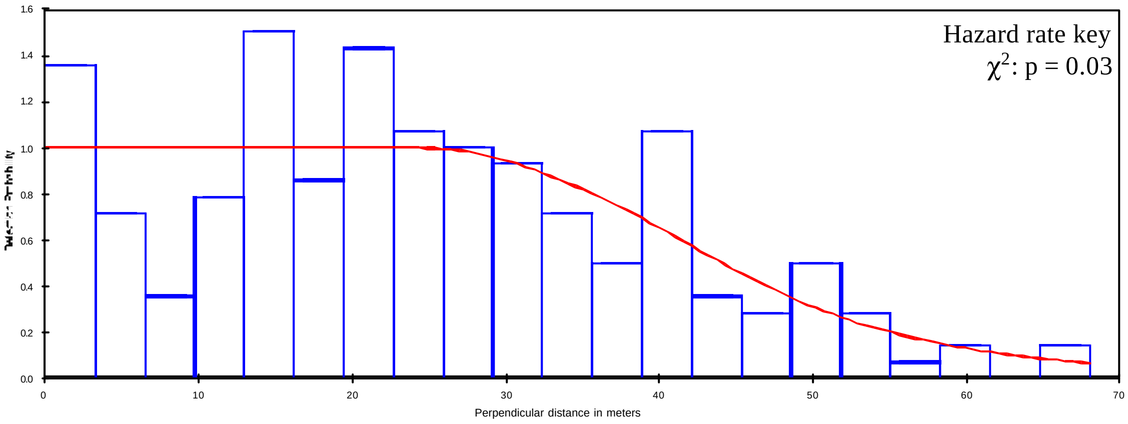


Fig. 5.8 Detection Function and histogram of Four-horned antelope: Male

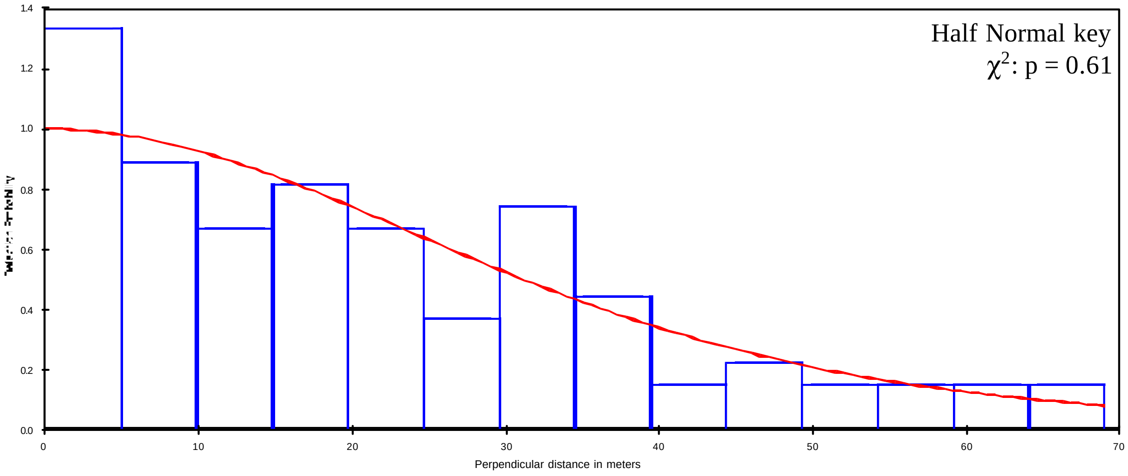


Fig. 5.9 Detection Function and histogram of Four-horned antelope: Fawns

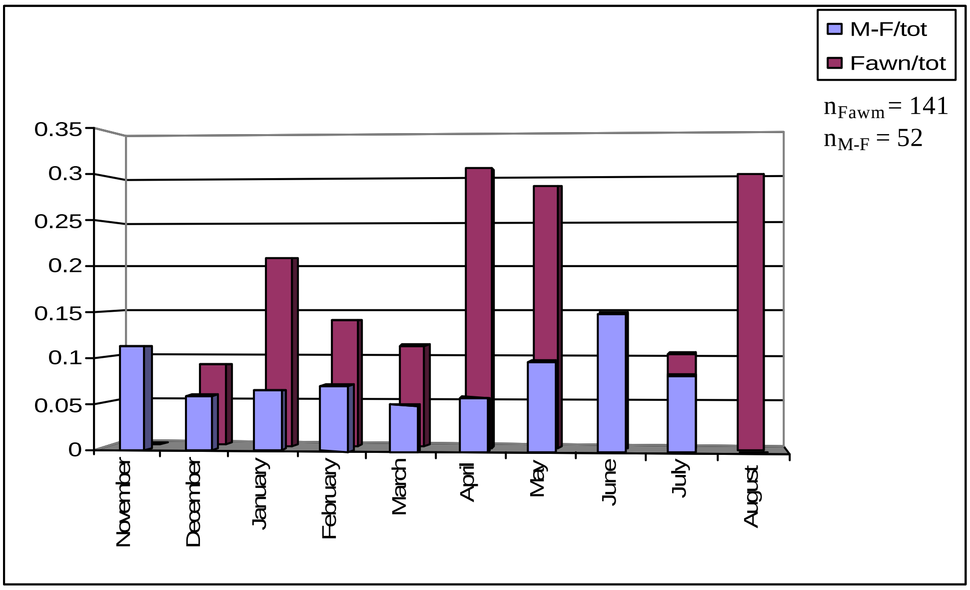


Fig. 5.10 Seasonal variation in corrected number of sightings of fawns and Male-Female groups

idly after the month of March, peaking in June (Fig. 5.10). The Four-horned antelope was seen in groups on 215 occasions. All adults' groups were recorded on 107 sightings that comprised of Male-Female, Male-Male or Female-Female groups, whereas during 108 sightings, the group comprised of one or more fawns. Out of these, unidentified adult individuals were recorded on 29 occasions. Even when the gender and age-class could not be identified, the data was still useful for understanding grouping stimuli.

Sightings with greater number of females within a group rise in the months of March, April and May where they reach a distinct peak. Grouping between males is rare and was recorded only on 12 occasions. Even during these sightings, it was clearly observed that Class-4 males were never seen with another male. Whenever males were in a group of two or more, it was found to be a group of young Class-2 males. At times an association between Class-2 and Class-3 was also observed. It is more likely that these are not bachelor groups as known from other species (Schaller, 1967; Leuthold, 1977; Isvaran, 2005) but rather twins associating with each other after dispersing from their mother. This follows the theory that bachelor groups are more commonly seen with lekking or herding species rather than solitary ones (Leuthold, 1977). The fact that no fully grown adult males were ever seen associating with other males leads to this understanding as we discuss the significance of four horns in the subsequent section. Interestingly, sighting of male-male and female-female groups peaked simultaneously, conforming to the hypotheses that these are more likely to be recently dispersed young individuals than bachelor groups. Moreover, while two females were at times seen with one male, we could never observe an association between more than one male with females. This supports the hypothesis that males avoid rivals at all costs and keep them away (discussed in greater detail in the next section: Significance of Four Horns).

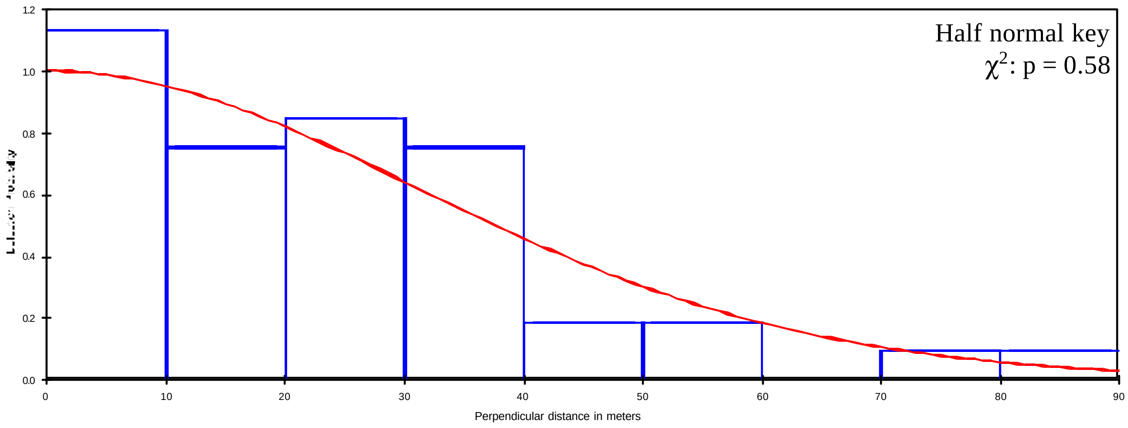


Fig. 5.11 Detection Function of Class-2 male Four-horned antelope

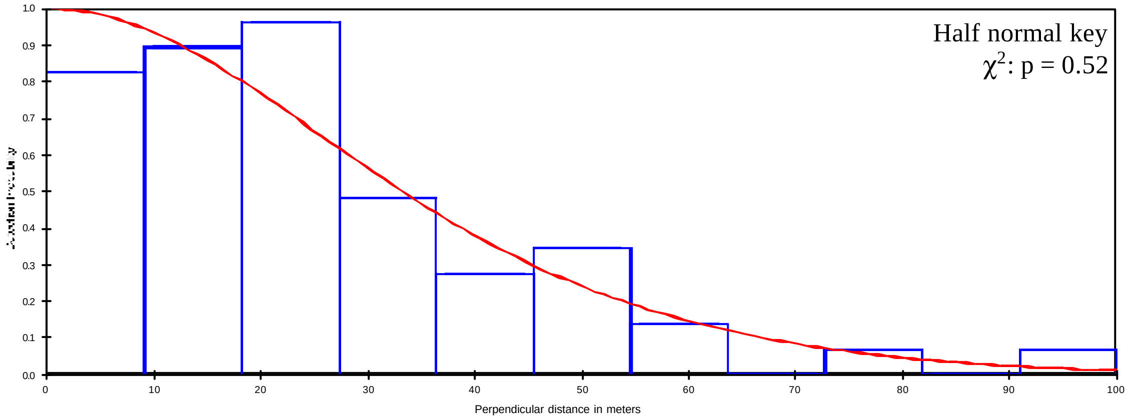


Fig. 5.12 Detection Function of Class-3 male Four-horned antelope

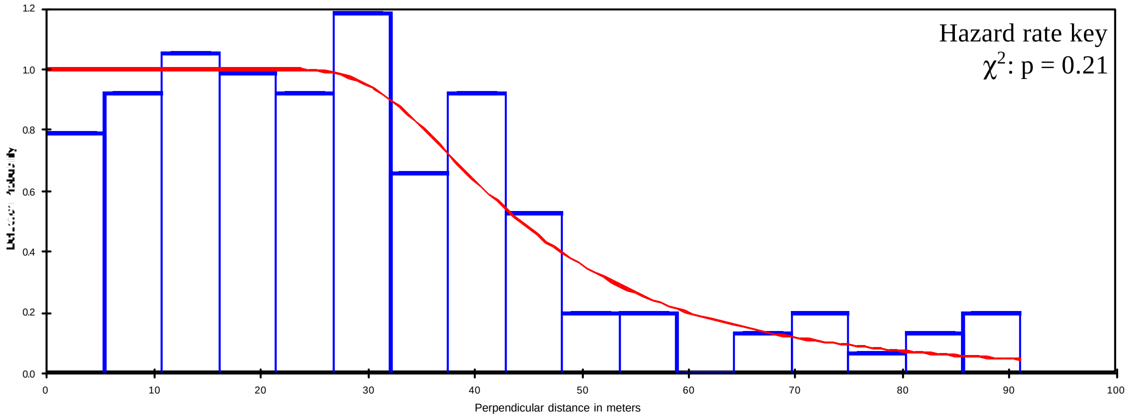


Fig. 5.13 Detection Function of Class-4 male Four-horned antelope

Fawns of Four-horned antelopes were seen throughout the year even though probability of sighting fawns peaked in January, April-May and August. While this data is not suggestive enough to estimate precise period of fawning, it suggests that there are possibly two fawning peaks in a year. There is lack of uniformity in the literature regarding gestation period of a Four-horned antelope. Published records by Shull (1958) and Prater (1980) suggest a gestation period of about eight and a half months whereas Asdell (1964) reports it to be six months. The exact period of fawning is also difficult to estimate as newborn fawns are reported in the months of October, November, January and even March (R. S. Chundawat, *pers. comm.* 2003; this study). Observations on fawning behaviour of Four-horned antelope suggest that they need good cover for a few days immediately after birth (see Chapter VI, Behavioural Ecology). Fawns lie down hidden amidst thick cover and do not move until almost tripped upon. They seem to depend more on their ability to hide than take evasive action and follow their mother. Given the requirements, it seems that post winter could be the most suitable season for fawning. This is the time when there is ample undergrowth and cover for the fawns to survive, and abundance of forage for the mother. It is important to note here that Four-horned antelopes need high quality food throughout the year as they are constrained by their small body size and hence high metabolism (Kleiber, 1961; Jarman, 1974). Since fawns are hidden till they have grown enough to follow the mother, it is less likely to see these fawns at a very young age. This behaviour is documented for all species that prefer hiding (Fisher *et. al.,* 2002). Mothers spend most of their time at a safe distance from the site where fawns are concealed and return intermittently to suckle them. The data suggests that there was a peak in sighting of fawns in January, which could be the time when fawns born in November or December would start following their mother and escape predators. Second peak in sighting of fawns was observed in the months of April and May. This can be credited to second fawning peak similar to the one observed in Chital and other ungulates (Schaller, 1967). Considering that there was a possibility that changing visibility may have caused this increase in sighting of fawns, we modelled sightings with the help of perpendicular distance from the line of movement of observer using software Distance 5.0. Using estimates that were corrected for detection probability, the fawn sighting rates were recalculated and trends were found to be similar to the uncorrected ones. Fawn sighting peaks in the months of January, April and July respectively with the highest peak being observed in the month of August (Fig. 5.10). This, in fact, conforms to the hypothesis that fawns are born at time when there is a good cover available. Since few sightings could be obtained in the months between September and November, it is difficult to suggest anything about the fawning status during these months. Other smaller peaks in January and April may denote erratic or secondary fawning cycle within a year.

Population structure of Four-horned antelope was found to be biased towards females (Fig. 5.14). The overall population structure based on analyses after incorporating detection probabilities comes to about 69 males per 100 females. The proportions are slightly different when estimated without incorporating detection probability (76 males per 100 females).

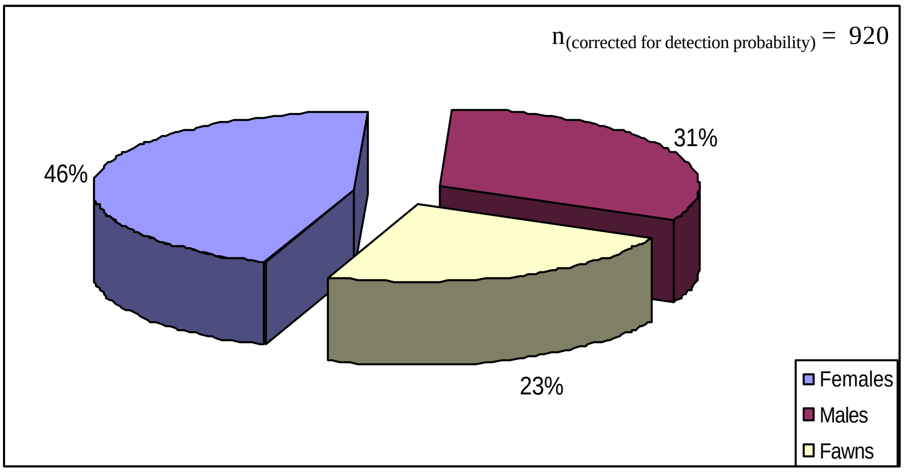


Fig. 5.14 **Female : Male : Fawn** ratio in the Four-horned antelope population in the study area

We segregated this data into seasons rather than months, since temperature and environmental data were different for the same month when compared across different years. This convolution resulted in loss of some resolution of the data, but at the same time helped in estimation of detection probability reliably as we had more sightings within each season to estimate detection probability. Since Distance Sampling was used for estimating detection probability, it was important to have large number of sightings when modelling the detection function (Buckland *et. al.*, 1993). Analysis indicates that the data is free from observer biases and population proportions are constant across seasons. The same was not true when naïve estimates (without accounting for detection probability) of population structure were made and compared. A significant variation in population structure across months was observed and there was no justifiable explanation to this variability in population structure across months within a year. Near constant population proportions after incorporation of detection function in the analysis confirm that the detection probability changes across seasons, and unless proper analytical measures are taken, estimates of population proportions can lead to spurious inferences.

The Four-horned antelopes are solitary animals, although it is not uncommon to see them in small groups. It was mostly seen solitary (70%, n_{total} = 705) and in pair comprising male, female or fawns (24%). Groups consisting of more than two animals were extremely rare and seldom seen (6%). Body size, anti-predatory behaviour and high metabolic requirements of small antelopes influence preference towards small groups (Jarman, 1974; Brashares, 2000). It was observed that Four-horned antelope had a specific anti-predatory behaviour where it preferred to hide rather than flee on seeing a predator. A prerequisite for such behaviour is inconspicuousness. By advertising presence, large herds compromise on an animal's ability to hide from predators (see Chapter VI, Behavioural Ecology). Given their body size, Four-horned antelopes are expected to have high metabolic requirements (Martin & Palumbi, 1993) and need high quality food. Such food is never abundant, and there is often stiff competition for access to such high nutrition food. Given their food requirements, Four-horned antelopes possibly also avoid competition from conspecifics similar to duikers and other small sized antelopes (e.g. Jarman, 1974).

Nilgai, which is closest relative of the Four-horned antelope, usually gives birth to two fawns. When born, fawns are 0.75 to 1.2 kg in weight and about 42-45 cm in length. Phylogenetically, Nilgai is also the closest relative to the Four-horned antelope (Hassanin & Douzery, 1999). Others, like Blackbuck, Chiru, Chinkara and Tibetan Gazelle usually have a litter size of one, though at times litter size of two or three are also recorded. Most sightings of newborn fawns in the field comprised of twins (71%, $n_{total} = 7$). Even in captivity at Nandankanan Biological Pak, Orissa, 83% (n = 6) of births of Four-horned antelope were reported to be twins (Acharjyo & Misra, 1975). But, other than few sightings when two sub-adult males or females were seen together, generally only one sub-adult accompanied mother. This suggests that on most occasions probably only one fawn survives till adulthood. This could be an evolutionary strategy where the animal ensures survival of fawns by increasing their number at the cost of nutritive inputs during pregnancy (Hayssen, 1992). As is observed in Antilocapra by Geist, 1974; the long gestation period of the Four-horned antelope possibly permits them to rut in early summer when there is high forage availability (see Chapter II, Study Area) and give birth at a time when there is a thick cover of undergrowth and grasses.

Information from studies of other ungulates indicates that it is in situations where populations are under stress, that the proportion of males and females gets distorted (Flueck, 2001; Sheldon & West, 2004; Kruger, *et. al.*, 2005). Acharjyo & Misra (1975) report male to female ratio of 1:1.75 at birth in captive Four-horned antelopes. Populations of Four-horned antelopes might suffer varied levels of stress including interspecific competition from generalist foragers like the Chital, shortage of water and food, and changing pressures by predators. An assumption regarding birth rate is made based on existing research on other solitary antelopes (Newing, 2001), which suggest that on an average, every adult female gives birth at least once a year. Considering this annual fawning cycle, and the fact that on 83% occasions Four-horned antelopes give birth to twins, an initial fawn population is estimated to be 83% of the total adult population including males and females. Considering the various factors when estimating proportion of fawns in the population, we used the proportion of sub-adults to estimate the number of fawns that survive and reach this age. Here, it is assumed that the survival rates of male and female fawns are similar, as it is expected that only after reaching adulthood, their ecology and behaviour change. Data indicates that only 30.5% of the fawns survive to the sub-adulthood (using Class-2 males' data as a surrogate for the females). Part of this population gets upgraded to adulthood, whereas most of the mortalities also take place during this age when animals are making the transition from sub-adults to adults. Mortalities may occur due to dispersion of maturing individuals in sub-optimal areas, inexperience in dealing with predators, and conflict with existing territory holders (Gaillard *et. al.*, 2000). Transient males are potentially more prone to mortality than territorial males and resident females. Since females are more resource oriented in terms of food, water and shelter, ones with sufficient availability of food may still allow their offsprings growing to adulthood to move with mother till they become totally independent. On the other hand, for males, access to females is the resource that they look forward to (Macdonald, 1984). This may result in young males posing as threat to existing adult male as soon as they reach maturity. While *prima facie* it seems that young males are more prone to mortality in the early days of dispersion, data also suggests that within a year, one gets to see more of these young males around the months of November, December April and July (Fig. 5.15). This is roughly the period when fawns born in the previous fawning season would be expected to attain near maturity. Considering that females reach maturity at an age of about one year (Acharjyo & Misra, 1975), it can easily be assumed that males, which start growing the second pair of horns at an age of about 14 months, attain maturity and wean at about this age. Although not matching with the data accurately, one can relate this with the peaks seen in sighting of fawns. Further, it seems that females are slightly more tolerant to competition than males as on a few occasions, groups with two or more females were seen. We hypothesize that in the given set of resource demand, females may have slightly smaller home ranges than males. Males would be dispersed more widely than females and as a result may have to face higher pressures for survival. The fact that there are almost 0.7 times fewer males than females indicates that either their survival rates differ or that there is a difference in the proportion of males and females at the time of birth. Four-horned antelopes possibly do not make lasting pairs, but instead get together in a particular season for mating and then live separately. This allows males to pair with more females within a season. It also helps them avoid predators and access food by moving solitarily for as long as possible. Although it is worth noting that at times males are also seen in a family group comprising of female and fawns, but that is an exception than a rule.

5.3.3 Male biology and significance of horns

Species survival is directly dependent on access to resources. While food is the main resource for a species, different age

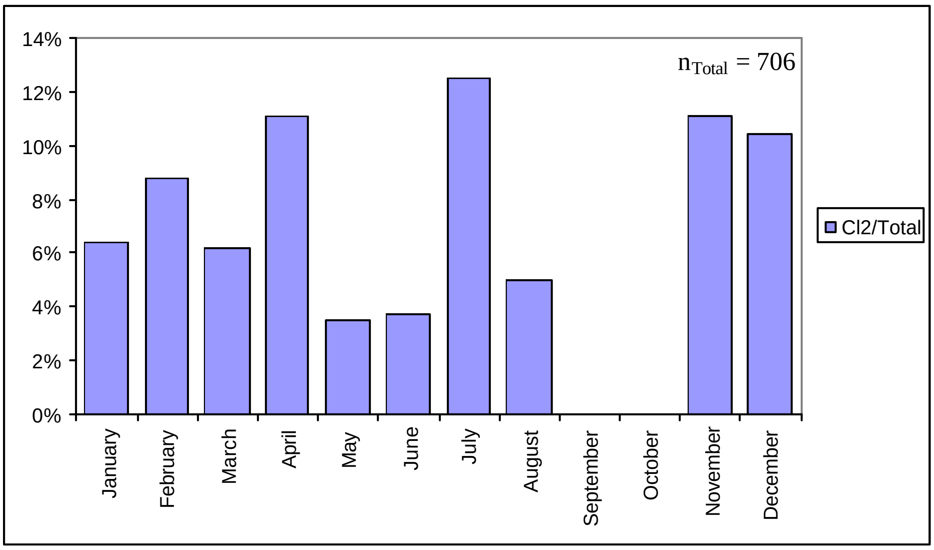


Fig. 5.15 Monthly variation in the sighting (corrected) of Class-2 males of Four-horned antelope

and sex classes of a single species may have priorities regarding resources available to them. It is understood that females are resource oriented and have forage as their primary resource. On the other hand for males, access to females is their primary resource (Janis, 1981; Macdonald, 1984). Different species have evolved armaments and distinct body structures to tackle interspecific as well as intraspecific confrontations.

While some species have distinct morphological features like body size and colour distinguishing between sexes (e.g. Nilgai), others have prominent features like horns, antlers or tushes/tusks (e.g. Chital, Barasingha, Wild pig). Costs of maintenance and subsequent trade offs of avoiding conflict regulate the factors that possibly decide development of such characteristics (Zahavi & Zahavi, 1997).

Predominant ungulates during the Miocene epoch were all hornless, with Tylopod Artiodactyls (camelids and oreodonts) and Equids forming most of the fauna. In the Old World, bony horns evolved in the majority of the ruminant artiodactyls, but only one family in North America possessed such structures. Habitat changes, resulting in more widely spaced trees may have altered the distribution of feeding types in the Tertiary faunas. Today, the most abundant and widespread infraorder of the ungulate orders are the Pecoras. Pecoras comprise of Bovid, Cervid, Giraffid and Antilocaprid Artiodactyls of the suborder Ruminantia. Most of the members of this infraorder have males possessing horns whereas in some both male and female possess horns or horn-like organs. Fossil records show that horns and pronounced sexual dimorphism turned out to be a specialised feature of Eupecoran Artiodactyls (Janis, 1981).

Mammals first appeared about 200 million years ago at the end of the Triassic. These were mainly small and mostly insectivorous or omnivorous. Diversification of mammals and evolution of large-bodied herbivores is dated back to the Tertiary period that commenced about 65 million years ago (Romer, 1966). To survive at the same latitudes, changing global climate forced animals to change their feeding strategies, and hence both their social behaviour as well as morphology (Janis, 1981). Geist (1966) suggests that horns are found only in animals above a certain body size of say 5 kg. He suggested that small animals fight by a combination of striking with limbs and biting, and that in the light of size-scaling effects such fights are too dangerous for ungulates of larger size, although his argument does not explain absence of horns in large animals such as large bodied Equids and Camelids. Jarman (1974) put forward that the degree of dimorphism in the possession or relative size of horns is correlated with the social behaviour and reproductive strategy. These are in turn closely related to the structure of the habitat and availability of food. Cranial appendages evolved differently in parallel evolution across different continents. Janis (1981) suggests that different environmental and habitat conditions affected this evolution, thereby resulting in specific requirements of each species. The main purpose of developing cranial appendages was to fight off enemies (Janis, 1981; Janis 1990). Evolution of horns in males occurred independently in a number of lineages of ruminant artiodactyls at a critical body weight of 15-20 kg (Janis, 1981). Horned ruminants first appeared in the fossil record in the late

Oligocene of North America, about 27 million years ago, in the Tylopod family Protecaratidae. *Protoceras* was the first genus to possess horns, and also the first genus in this lineage to attain a body size of this critical value (Patton & Taylor, 1973).

Few species use their cranial appendages as deterrents against predators, whereas most use them to counter conspecifics. These horns or antlers are also used as display organs to exhibit sexual and physical fitness and thereby avoid direct fights (Schaller, 1967; Janis, 1982, 1990; Geist, 1998). It is evident from information available on many species with cranial appendages (Schaller, 1967; Kruuk, 2002; Kotiaho, 2002) that bigger cranial appendages reflect physical fitness and hence better access to females, but in that case an animal may end up in a situation with super sized horns or antlers. Limiting factors for size of horns can also determined by using certain physical laws like Kleiber's Law (1961). He relates metabolic rate to the body size and determines absolute limitations on the possible physiologies and morphologies of animals. Certainly there are associated costs attached to development these organs that limit their size. Large horns may act as hindrance to animals living in thickets and dense vegetation. In contrast to this, small horns may not serve their purpose for animals living in open terrain since they use visible signals and messages to forewarn competitors of their strength and fitness.

Fighting is associated with significant energy and predation costs for animals (Riechert, 1988; Jakobsson, *et. al.*, 1995) and development of secondary display organs is a common strategy to avoid or minimize conflicts (e.g. Mane colour in lions: West & Pecker, 2002). Development of cranial appendages on males of some species and none on females is also a classic example of how evolution has ensured that there is little waste of energy and optimum budgeting while considering specific requirements. Males need to maintain territorial boundaries and dominance hierarchies. These determine access to females thereby ensuring passing of the gene (Geist, 1966). With polygamous species, mostly the males have horns and are generally larger in size. It is because males have to fight off competitors and protect females from sneaking intruders. At the same time, with monogamous species, there are known cases where both the male as well as the female possess cranial appendages. Without being too generalistic, it is believed that this is due to the fact that with monogamous arrangement, the female also needs to defend resources in a way a male would. Another theory suggests that in few species, especially large bovids (e.g. Bison), possession of cranial appendages is considered as a strategy to provide equal access to the predator that may otherwise have a preference towards easy to catch females (Janis, 1981, 1990). Females are armed with horns as males, when a pair defends a resource territory or when females have to stand up to the male competition and harassment (Geist, 1998).

Eotragus is known as the first true Bovid (with horn core). It was found in Europe (Ginsberg & Heintz, 1968) and Africa (Hamilton, 1973) at the end of early Miocene (20 million years ago). It is understood that primitively Bovidae have had only males possessing horns. This is inferred from the fact that both, horned as well as hornless skills of this genus have been found (Thomas, 1977). Bovid horns developed from dermal ossifications that later fuse to the frontal bones.

Overall 309 male Four-horned antelopes were recorded in the field out of which 279 could be classified into one of the three categories, viz. Cl2, Cl3 and Cl43. Whenever possible, an estimation of the size of front horns in relation to the rear horns was done. This was done in an attempt to increase the resolution of the data and de-convolute the three classes further for age estimation.

Three males, each of different age, were monitored in captivity in Van Vihar. Prolonged observations suggest that once the front horns start developing, there is little or negligible growth in the rear horns. It was also observed that the front horns of a Four-horned antelope continue to grow till at least a few years of age. Though the exact age up to which these horns grow is not known, using the information obtained from the observations discussed above, every time a male Four-horned antelope provided a very clear view or a close up picture in the field, an estimate of the relative size of its horns was taken. The size of front-horns with respect to the rear horns was estimated as a proportion and recorded. To record this proportion, eight broad categories were made on the basis of distinguishable proportions of the horn lengths.

Young males with no visible front horns were put into the category Zero. In the broad classification discussed in the previous section, these were called Class-2 males. Class-3 was split into three categories, viz. 1/5, 1/4 and 1/3 respectively denoting the proportion of length of front horns with respect to the rear horns. Similarly, Class-4 was split into four categories, 1/2, 2/3, 3/4 and 1, where 1 denotes male with rear horns equal in size to the front horns. Out of 282 sightings of males, while classification into the three categories was possible on 256 individuals, such detailed ordination into one of the eight classes was possible only on 215 males.

Proportion of males in each of the aforementioned category was estimated after incorporating the detection probability in the actual count (Fig. 5.16). Visual inter-

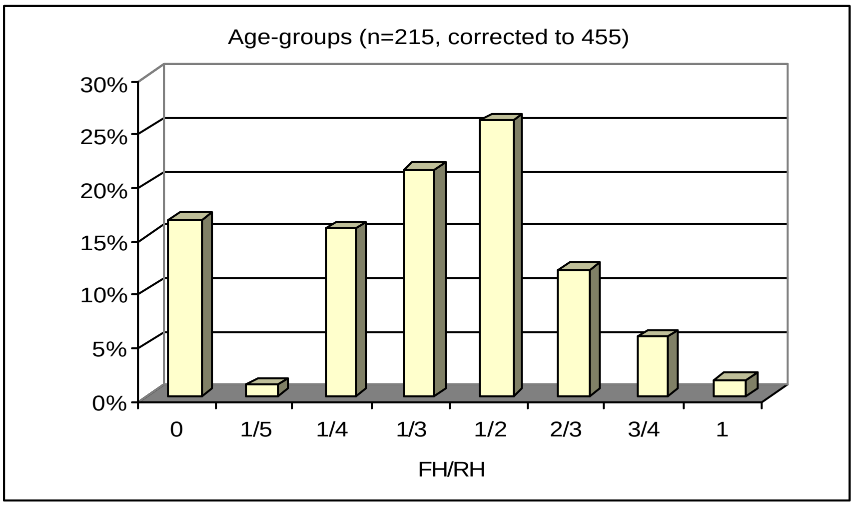


Fig. 5.16 Proportion of males with different horn sizes in the Four-horned antelope population

pretation of the number of males with various front horn lengths reveals an interesting distribution of the population. It seems that while most males are with front horns half as long as the rear horns, the remaining male categories seemed to be normally distributed around this mean. Using test of normality confirms that the population is normally distributed around mean, which is the number of males with front horn half the size of the rear horn. Only younger males with no front pair of horns were in fairly large number as compared to those belonging to their neighbouring classes. This population distribution can be used to hypothesize that front pair of horns can be used as indicators of age or fitness of male Four-horned antelopes. Based on relatively high abundance of males with just two horns, it is likely that these young males (Class-2) are allowed to use their parents' home ranges till they become a threat to the male's dominance. Absence of front pair of horns probably determines that the young male is not a threat. Data suggest that the second pair of horns (front horns) is an indicator of the sexual maturity of the Four-horned antelope. It seems that as soon as the second pair of horns sprouts, these young males, which were allowed the privilege of roaming inside their parents' home range are forced to disperse. A similar forceful dispersion is also seen in other species (e.g. Herlugson, 1981; Nunn & Pereira, 2000; Muller & Thalmann, 2000; Vangen *et. al.*, 2001). Around this time, there is a possibility that young individuals are pushed into sub-optimal habitats with limited food and cover. These situations may make them more vulnerable to predation and other threats. The reason why Class-3 males constitute such a small proportion of the population could be that these individuals are under additional stress and hence are more prone to mortality.

Male and female Four-horned antelopes were seen in a group of two or more on 52 occasions. The males in these groups could be classified into one of the three classes during 45 sightings. Although on 256 occasions the male could be classified in one of the three classes, only on 215 instances length of its front horn could be estimated with respect to the rear horns. Since the group size effect on detection function is assumed to be constant, only distance function is used to estimate the probability of detection of pairing Four-horned antelopes. On an average, chances of seeing a male of Class-4 with a female are highest (Fig. 5.17). Though rare, pairing of females with Class-2 and Class-3 could never be ruled out. Log-likelihood G-test (Wilks, 1938) and Bonferroni confidence intervals (Neu *et. al.*, 1974; Byers & Steinhorst, 1984) are used to confirm that females prefer Class-4 males over other two classes. Since data suggest that Class-4 males outnumber the other two classes, it is important to test preference in a situation that provides equal availability. Failing to do so may lead to biases resulting from over-representation in the populations. To use the tests in a situation that provides an equal opportunity to all the three classes, an equal proportion transformation was done with the data using simple multipliers. This approach generates a situation which is far from reality, but by compromising on the real population structures, an imaginary situation of equal availability can be generated, hence making tests of preference simple. Total sightings of individuals of all of the three classes were transformed into equal proportions and then the number of males pairing with females was calculated by multiplying the real number of male-female pairs with the multiplier. Expected numbers of class-wise male-female pairing were calculated by the new transformed total number of pairing individuals. The results are highly significant (G-statistic = 15.27, DF = 2, sig. = 0.000) and confirm the hypothesis that males of higher classes get a better chance of pairing with females. Bonferroni Confidence Intervals suggest that pairing between female and Class-4 male was the norm, but female pairing with Class-2 was less than expected. Probability of males pairing with a female was also plotted against different orders of horn length proportions. A strong correlation (R = 0.95) was observed between the length of the front-horns of a male and its chances of being seen with a female (Fig. 5.18).

Janis (1981) provides an explanation of development of horns in artiodactyls by correlating it with the change in dominant vegetation type, which, in turn suggests a correlation of change in morphology with change in ecology and behaviour. Jarman's (1974) categories of ungulates based on different body weight classes are also used to explain development of present day horns in antelopes. Starting with Category A (<=20 kg), these animals depend on olfactory marking for territorial marking and hide to avoid predation. Diet of these animals being limited by their small body size, they have relatively high metabolic requirements. This, in turn results in their selecting for a non-fibrous high-protein diet (e.g. fruits, berries, fresh leaves, pods etc.). This food is often available in limited quantity and widely dispersed. This would mean that such animals may have a large home range. The size of the home range is expected to be too large to maintain an exclusive feeding and breeding territory. In contrast to this, the Category B (>20 kg and <90 kg) tolerates diet of higher fibre content. Potential food resources within a given area are greatly increased. This leads to formation of smaller home ranges, for greater abundance of food will need the animal to be

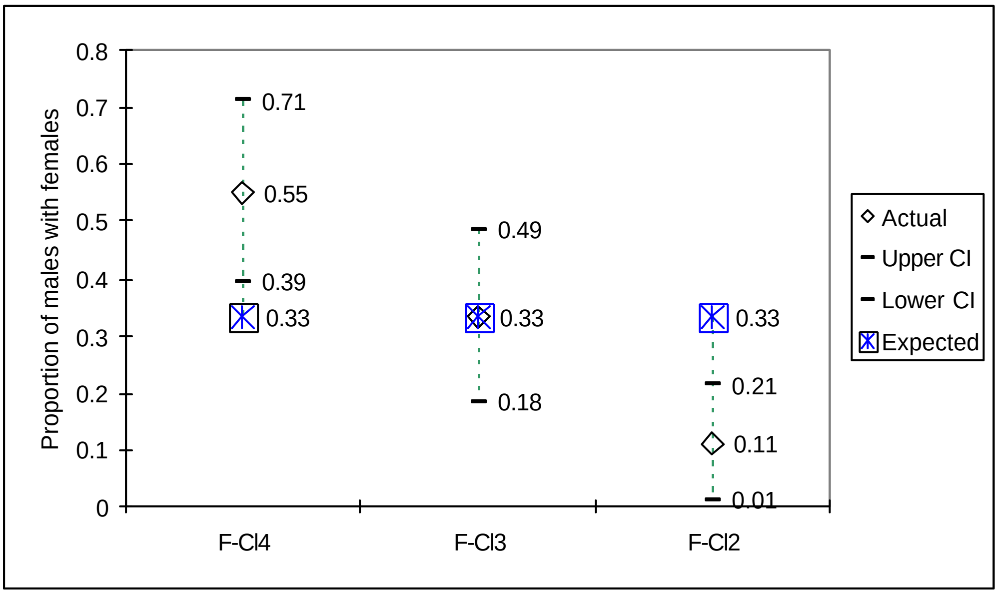


Fig. 5.17 Bonferroni Confidence Intervals showing preference of Class-4 males by females

less dispersed for foraging, even in small groups. Thus, increased body size of these animals allows for adoption of reproductive strategy by males of having exclusive territoriality. Here, effective costs of boundary patrol are expected to be less as territory perimeter is smaller. Also that the high nutrient food resources are less widely dispersed allowing females to feed together in small groups, resulting in a polygamous behaviour of males with fixed territorial base.

The Four-horned antelope seemingly fits between the Category A and B described by Jarman (1971). The change from a monogamous to a polygamous mating system results in a difference in the pattern of sexual dimorphism (Janis, 1990). The body size at which horns appear in evolution mark the transition between living antelopes in Category A and B. Evolution of horns is apparently also correlated with the evolution of boundary patrol by territorial males and their food and habitat requirements. Another ruminant that is close to Four-horned antelope in weight and body size is the Muntjac. Barrette (1977) explains its fighting behaviour as primitive where horns are originally arisen and used as organs of defence. Increase in male-male encounters would result from territorial maintenance in early ruminants thereby acting as strong selective force for the development of such defensive organs. Horns subsequently became elaborated into weapons that reflect the growth stage and physical condition of the animal, and hence displaying the growth stage and physical condition of the animal. This would reduce the number of actual encounters as ruminants generally engage in fights with individuals that are similar in age and physical condition (Geist, 1971). The potential mating enhancement factor (Owen-Smith, 1977) of reproductive strategies of territorial and non-territorial ungulates suggests that it is greater for males in those species that maintain a system involving a rank-dominance hierarchy than for those that are territorial.

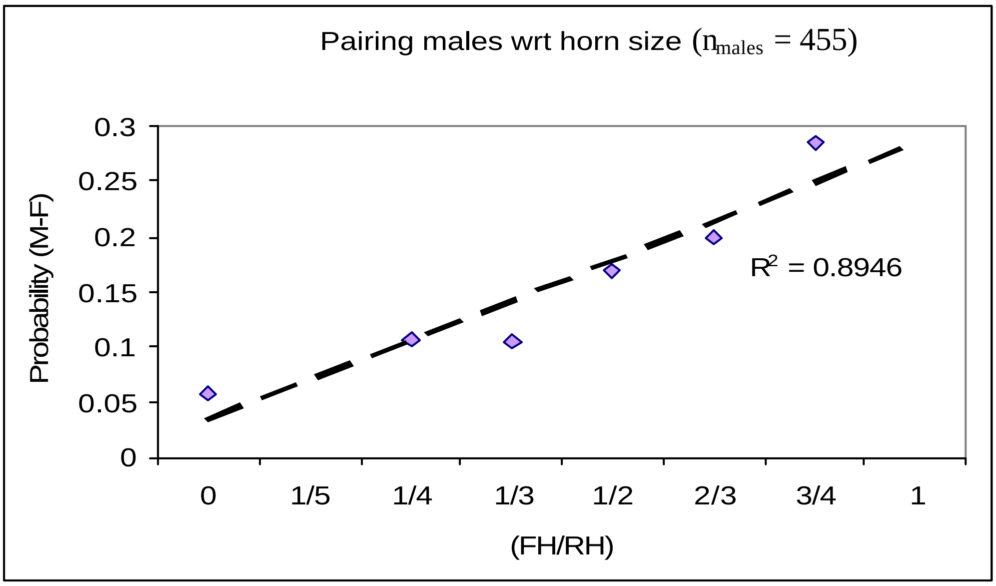


Fig. 5.18 Correlation between Probability of male-female pairing and different lengths of front-horns

Four-horned antelope is a small antelope that thrives in microhabitats comprised of thickets and stands of vegetation even within open and dry patches (see Chapter III: Habitat Use). As part of this research work, it is found that they need high quality food and avoid predators by hiding inconspicuously (see Chapter VI, Behavioural Ecology). There is a direct relationship between size and shape of horns in ungulates, and their body size and habitat related parameters (Preston *et. al.*, 2002; Caro *et. al.* 2003). It is known that through the process of natural selection, features that are too audacious and compromising for the survival of a species, are gotten rid of over a period of time (Darwin, 1979). At the same time, the very purpose of these structures is to act as secondary sexual characters. Their inconspicuousness below a certain level may eventually be of no practical purpose thereby negating the benefits which would rate below the energy costs of having them.

Four-horned antelopes fight by locking their horns for short periods similar to Blackbucks (L. N. Acharjyo, *pers. comm.*, 2006). Adult males viciously attack intruders when in enclosures (Shull, 1958; L. N. Acharjyo, *pers. comm.*; this study). It is likely that these horns are used as weapons of a material resource defender to lacerate, puncture, or bruise the opponent's body surface, yet permit quick withdrawal (e.g. Geist, 1998). It is evident from the data that presence of second pair of horns works as secondary sexual characters for the Four-horned antelope. Young males minus the front horns enjoy the privileges of using optimal habitats along with their mother. Once adult, which is supposedly displayed by growth of second pair of horns, they are forced to disperse. This possibly leads to a high mortality in this particular age group. Moreover, males with longer front pair of horns were seen having a better opportunity to mate than those with smaller horns. One gets a clear picture that these two sets of horns are display organs exhibiting an animal's sexual fitness. The most important question is that why an additional set of horns is needed. It is clear from research on other ungulates that large audacious horns and antlers actually act as secondary sexual characters. It is possible for species like the Chinkara and Blackbuck to possess large horns that can be displayed daringly since they use open habitats and their large structures would not interfere or cut short their chances of survival. The same is not true for a Four-horned antelope. While a large pair of horns would surely exhibit its sexual fitness, it, at the same time would also threaten its very survival greatly. Audacious structures can compromise the hiding skills of a cryptic animal which, instead of fleeing, prefers to evade predators by hiding and being as inconspicuous as possible. These preferences and constraints possibly restricted the development of their horns into audacious structures. On the other hand, in case of the Nilgai, evolution has possibly taken a slightly different direction when dealing with the component of attaining secondary sexual characters. Nilgai is the closest relative of the Four-horned antelope and thrives in open to closed habitats alike (see Chapter III, Habitat Use). While a Nilgai male sports small horns, it is the shades of its body and overall size that distinguish dominant ones from lower class males. Here the colour and size are used as secondary sexual characters to facilitate access to females, seek their attention with ease, and avoid direct conflicts with intruding males. The question rises that even though a Nilgai has small horns, it thrives without the need of evolving an additional set. The Four-horned antelope cannot afford such distinct morphological variations because they may compromise its anti-predatory strategies. Therefore, it is suggested as a concluding remark that this secondary set of horns was developed as secondary sexual characters while avoiding the risk of increased predatory threats and at the same time advertising the fitness by a male.

Four-horned antelopes (Female & Male)

CHAPTER VI

Behavioural Ecology of Four-horned antelope

CHAPTER VI

BEHAVIOURAL ECOLOGY OF FOUR-HORNED ANTELOPE

6.1 Introduction

Behaviour of animals in the wild state provides useful input for management of wildlife (Leuthold, 1977; Kilgo *et. al.* 1998). Habitats are used by animals in different proportions of availability. The pattern of usage differs greatly with different activities of animals. For many species, animal behaviour changes to a great extent with different levels of anthropogenic pressures (Kilgo *et. al.*, 1998; Bolhuis & Giraldeau, 2005; Rabin, 2003; this study). Almost all census methodologies rely on some basic understanding of animal behaviour. While the capture-recapture methodology for tigers assumes that tigers use roads and major walkways with a specified average home range size, the distance sampling technique has its assumptions of animal behaviour in response to the selection of lines and human movement on them. Therefore selection of appropriate census technique depends to a great extent on a-priori knowledge about animal behaviour.

Reaction of animals to environmental conditions, degree of adaptability to different circumstances, and conflict with humans can be best understood only by gaining an in-depth knowledge about their behaviour.

Research on evolution too has a close relationship with animal behaviour. Behavioural traits of living species provide useful information about their evolution (e.g. Janis, 1981, 1990), and about other closely related or sympatric species that have gone extinct. Behavioural ecology provides an insight into a species' relationship with other ecological and evolutionary features such as morphology, grouping tendencies and niche occupancy.

The Four-horned antelope was known as one of the most elusive antelopes of India. Its preference towards forested and undulating terrain (Prater, 1980) and solitary living earned it a reputation of being very shy. There was little information about its behaviour and ecology other than those based on some observations made by Berwick (1974) in Gir ,and by Bhaskaran (1999) and Kannan (1999) in Mudumalai. Apart from these, there are only a few historic records that mention its distribution and behaviour in greater detail (Jerdon, 1867; Blanfold, 1888; Brander, 1923; Prater, 1980).

Four-horned antelope is different in behaviour and its habitat preferences from the other four species of antelopes found in India. It is known to take some grass in the early monsoon and has more specialised foraging preferences in other seasons (Rodgers, 1988). It is found in forest habitat, whereas Nilgai uses forested as well as open habitats alike. Chinkara and

Blackbuck are restricted to open habitats (Schaller, 1967; Ranjitsinh, 1982; Rahmani, 1990; Rahmani and Sankaran, 1991; Isvaran, 2005; Alfred, *et. al.*, 2001), and the Chiru and Tibetan Gazelle dwell in the Himalayan mountain ranges that are scantily vegetated (Prater, 1971; Menon, 2003). The Four-horned antelope is usually solitary with a few exceptions when it can be seen in loosely associated aggregations of 3 to 5. The other antelopes usually have larger mean group sizes with an exception of Chinkara, which is found in smaller groups. Though even in the case of Chinkara, groups as large as 17 can be seen in summer (this study).

Different species have developed different morphological traits to serve as secondary sexual characters. The Four-horned antelope is unique in having two distinct pairs of horns. The other known living species to have four horns is the domesticated Four-horned Sheep found in Britain and a Four-horned Chamois described once (Beddard, 1902). Some Pronghorns develop a split in their horns near the root giving it a feel of having four distinct horns, but since their family has recently been segregated from antelopes as Antilocapridae, there is no other known species of antelopes that regularly grows four distinct horns. It is important to study the behaviour of animals to understand the evolutionary stimuli behind development of such unique characters. The morphological features not only help animals in attracting mating partners, their development into those with super-prominence is often checked by the costs that they have to pay for it. An insight into the mating and antipredatory behaviour of the Four-horned antelope is expected to provide clues about the factors behind the development of two sets of horns in this small antelope

Animal behaviour can be classified into three major classes, i.e. foraging, reproducing and predation avoidance. These three broad behavioural classes cover most of the activities performed by an animal. Animals have to continuously seek a tradeoff in attaining fitness through these mutually conflicting behavioural stimuli (Jarman, 1974; Brashares *et. al.,* 2000). The three aforementioned categories were studied with an objective of understanding the ecology of Four-horned antelope. Its foraging and anti-predatory behaviour provide an understanding about the pattern of habitat use. Using these observations, an attempt is made to explain the possible relationships of the various behavioural traits observed in the field and link them to the ecological and evolutionary biology of the Four-horned antelope. An attempt is also made to relate its behavioural ecology with the niche that it occupies in the forest ungulate community.

6.2 Methodology

6.2.1 Opportunistic Focal Animal Sampling

Methods of focal animal sampling (Altmann, 1974) were employed for studying the behaviour of the Four-horned antelopes. Systematic behaviour study mandates prolonged observations of identified individuals. Four-horned antelopes do not have any distinct morphological patterns (e.g. stripes, spots, unique horn/antler shapes) that may help identify individuals. Since no animals were radio tagged during the study period, identification of individuals was difficult. Therefore, all opportunistic sightings were considered as independent observations. The Four-horned antelope lives solitarily or in very small groups. Random encounters of Four-horned antelopes were sought, followed by specific efforts to get the animal accustomed with the observer's presence. Once located, individuals were observed as long as the observer was tolerated by the animal.

Whenever the animal was resting or ruminating, the observation was classified as Passive. Activities were represented as frequency of occurrence within an observation period. Animals were continuously observed within a timeframe and only a change in an event state or event instance was timed and recorded.

The main activity patterns that were not of the 'undisturbed' category were further classified into active and passive states. An active state was one when the animal was on its feet whereas passive state was one when an animal was either resting or ruminating. Active state was further classified into four major subclasses:

(a) Foraging: When an individual was observed ingesting food, whether it was picking forage from the forest floor, browsing a shrub or nibbling herbs.

(b) Walking: An activity where the animal was seen moving in random or a specific direction for over 10 m.

(c) Threat response: Whenever the animal was in alert position, sprinting or taking evasive action on seeing human or predators as threat.

(d) Other activities: All other activities were put together in this category as there were only a few recorded instances of these behaviours throughout the study period. While these could not be analysed statistically, they provided an insight into the natural history of a species whose behaviour was more or less unknown to science.

Between December 2002 and June 2005, the Four-horned antelopes were observed 705 times (978 individuals). Notes on their activity and behaviour were taken from 500 independent sightings in the field. Animals recorded during the line transects are not included here since different observers collected data on the transect lines. These observers' notes would have added unnecessary distortion in the data. Also, since line transects need to be traversed within a short period of time, spending time on behaviour observations may compromise with the actual purpose of running transects. Similarly, those animals that fled immediately after being detected were also excluded from the analysis as it was difficult to adjudge their activity moments before they fled.

Between November 2002 and January 2003, a thorough survey of the study area was done and sites with high probability of sighting of Four-horned antelope were identified. These sites were intensively surveyed thereon for locating and observing individuals whenever and wherever seen. The Event Instances (frequency) and Event States (duration) of animals were recorded along with an additional variable denoting whether it was in a disturbed or undisturbed state due to the presence of observer.

In absence of colour or radio tagging, it was not possible to identify or locate individuals in the field. Thus the data admittedly provides less information than otherwise. The Four-horned antelope is shy and quite elusive in its escape tactics, therefore an individual could be observed continuously for long durations on only a few occasions. The maximum duration for which an individual was observed was about two and half hours.

Another constraint in this method of observing behaviour was that to locate an individual, it was almost necessary that the animal was in active state when first seen. This bias was inevitable as the Four-horned antelope prefers thick undergrowth and grass with very low visibility for resting (Fig. 6.1). Assuming that it was resting during the hot periods of the day, most behavioural observations could be done only between 0600-1000 hrs and 1600-1900 hrs. Occasional sightings were obtained during odd hours, i.e. 1200 hrs, 1500 hrs and 2200 hrs, but they are eventually omitted from cumulative analysis because the number of independent samples during these time slots was very low.

Preliminary analysis suggested that the data obtained from the second and third year of study were different from the first year. Too many bouts of behaviour forced by the observer's presence (e.g. alert and alarmed positions) were obtained during the second year. It was possibly due to the fact that the study team used a jeep during the first year and a motorcycle in the second. Covering the human figure in its silhouette, a jeep that does not make too much noise, allowed closer approach and longer observations of the animals, whereas motorcycles usually scared away the Four-horned antelope inadvertently as they are usually shy and wary of the conspicuous human figures. Although there is no foolproof way

Fig. 6.1 Resting sites of Four-horned antelope. a. site where flushed from, b. Four-horned antelope standing up after being disturbed, c. Fawn of Four-horned antelope hidden amidst thick grass cover

of validating the independence of observations made from a vehicle as well, those made from a motorcycle are almost certainly influenced by the presence of observers. Although we used data on anti-predatory behaviour from a motorcycle, it was is difficult to observe other behaviour from the motorcycle. Subsequently, in the third year's study less time was spent on behavioural observations as there was a greater need to conduct habitat evaluations, population estimations and study other aspects of the behavioural ecology such as anti-predatory strategies for correlating them with habitat usage. Therefore, we used only the first year's focal sampling data for behavioural observations. Only data collected on anti-predatory behaviour and midden usage during subsequent years were used for analyses. Other than these, ad-libidinal observations of behaviour were also recorded whenever possible, and are reported accordingly in this chapter.

6.2.2 Midden Mapping and Monitoring

The Four-horned antelope, like many other ungulates (Leuthold, 1977; Ranjitsinh, 1982; Acharjyo *et. al.*, 1990; Biswas *et. al.*, 2002), has a tendency to defecate on middens. It was seen that many middens are shared not only by more than one individuals, but also by different species. Nilgai, Chinkara and Four-horned antelope were often seen defecating on certain middens at different times of the day.

A systematic approach was followed to understand the purpose of making and maintaining middens (Black-Decima, 2000; Leuthold, 1977) considering the costs of doing so (Returning to the same spot regularly against energy spent and predator's threat). Middens were mapped and then monitored over a certain period of time.

Faecal pellets can be used to provide evidence of presence as well as abundance of an animal in an area (Neff, 1968; Marques *et. al.*, 2001). Seeing the elusiveness and varying encounter rate of sighting a Four-horned antelope in different seasons, the middens were monitored regularly over a period of seven to fifteen days. Areas with high encounter rate of the Four-horned antelope were marked on a map. Seven points were randomly chosen from these areas with high encounter rate and surveyed for middens. Thorough searches were done to locate and identify middens in these areas. A team of two to three observers walked along fixed paths parallel to each other, and separated by a distance of about 5-10 m, depending upon ground visibility. On reaching the edge of the demarcated area, the same routine was repeated in reverse direction starting 5-10 m from the end point. This exercise was repeated till the whole plot was searched. Physical barriers (cliffs, steep slopes, roads etc.) were considered as boundaries for these demarcated plots while mapping them.

Coordinates of each midden were noted with the help of a Global Positioning System (GPS), its size was classified from a range of four (Table 6.a), the status of the midden was estimated visually on the basis of pellet groups seen on it and the species that seemed to have been defecating on it were identified.

Once mapped, middens from a selected area were visited daily for five to seven days. The time of visit was close to noon assuming that most animals would be resting during the hotter periods of the day (e.g. Chital: Chundawat *et.al.* 2006;

Sambar: Sanago, 2005). Fresh defecations were identified and classified into two categories of 'morning' or 'previous evening', apart from the identification of species and counting the number of pellets in a single defecation group. After taking the information and collecting some fresh pellets, the fresh defecation was patted and pressed gently to flatten its heap. This was done to identify fresh defecations with certainty on the next day's visit. Since the stimulus for the antelope revisiting the midden was unknown, precautions were taken not to disturb the fresh pellet group's density and its position on the midden as this could have affected the next visit of the antelope. It was possible to distinguish pellets defecated by different individuals on a midden within a day's span as most of the times there were some diagnostic differences in shape, size, colour and placement of the defecation on the midden.

Table 6.a Midden Classes (based on midden diameter)

Classification	**Criteria**
Order 1	<50 cm
Order 2	50 cm to 1 m
Order 3	1 m to 2 m
Order 4	>2 m

6.2.3 Cafeteria Experiment

To investigate food preferences, cafeteria experiments were conducted on a captive Four-horned antelope in Van Vihar National Park cum Zoo in Bhopal. The enclosure was about 3000 square feet in area with common grass *Cynodon dactylon* and a Babool *Acacia nilotica* tree within the premises of the enclosure as existing food base. A single male Four-horned antelope, about eighteen months old, was captive for about seven months. Five sessions of Cafeteria experiment were conducted in the enclosure in the last week of October 2002. These sessions were of two hour duration and would start early in the morning at about 0730 hrs and last till about 0930 hrs and then again between 1330 and 1530 hrs.

Ten species of different kinds of vegetation were provided to the animal in a semi circular fashion so that it had equal access to all. The species provided to the Four-horned antelope were Ber *Zyziphus mauritiana*, Khair *Acacia catechu*, Aonla *Emblica officinalis*, Renjha *Acacia leucophloea*, Babool *Acacia nilotica*, Amaltas *Cassia fistula* and grasses viz. Bamboo *Dendrocalamus strictus*, Lampa *Heteropogan contortus*, *Themeda triandra* and *Cynodon dactylon*.

6.2.4 Telemetry

Radio collaring of Four-horned antelope was attempted in May, 2005. In a collaborative effort of BNHS and Wildlife Institute of India (WII), Dehradun, attempts were made to immobilize four individuals for attaching radio-collars as per the permits given by the Ministry of Environment and Forests and Chief Wildlife Warden, Madhya Pradesh in the month of August, 2004.

Experts from WII visited Panna National Park in order to conduct the immobilization and radio collaring exercise. Dr. P.K. Malik, assisted by Dr. Parag Nigam from WII were stationed at Panna National Park in the last week of May 2005.

Teleinject® remote drug delivery system was used to immobilize the animals if and when found within close range of less than 30 m. A combination of Zalopine® (@50µg/kg of animal weight) and Ketamine was used as a tranquilizing drug. Antisedan® (@15-20 mg/animal, depending upon the body weight) was kept on standby as antidote to revive the animal from sedation. This drug is expected to revive the animal in about three to four minutes. A Yardage PRO™ rangefinder was used to estimate precise distance from the vehicle to the animal at each sighting.

The areas traversed during the three days exercise ranged between Hinauta gate of Panna National Park to Bargadi and some patches between Bhadar and Pipartola plateau. Considering the hot summer, tranquilizing exercise was attempted only till 0830 hrs in the morning. Total 19 sightings of Four-horned Antelope were obtained but only five times (Once at Bargadi, once at Bhadar and thrice between Bargadi and Bhadar) the animal was within safe range for darting. On all other occasions the animal was found at the edge of the fire lane and beyond 30m from the road. Of the five close sightings when the animal was within darting range, only on one occasion a female gave a clear view in absence of intermediate vegetation cover. Since the remaining four sightings either provided a very short period for aiming or had the animal amidst thick vegetation, therefore, immobilization was not attempted.

On 25th May a female with a sub-adult was seen between Bhadar and Bargadi (24.6083° N & 79.9496° E) towards South of the road. The female was 28m from the road and provided a clear view to Dr. P. K. Malik, who then darted her. The dart accurately hit the female Four-horned Antelope at her thigh and she ran for a few meters away from the spot where she initially stood. During thorough combing of the area a few minutes later, the animal was seen active and fully agile further up to the direction where she had run. The dart was found later and its investigation revealed that it had malfunctioned. Its pressure chamber broke during the projectile and the drug never got injected into the animal. The female Four-horned antelope was later seen by one of the field assistants about 40 minutes later attempting to cross the road at a distance of about 100 m from the darting site. On the morning of 27th May, the same female and a sub-adult following her were seen near the same site (24.6075° N & 79.9499° E) but to the other side of the road. She looked fit and agile but was out of the darting range and amidst thick vegetation, and hence darting was not attempted.

In future, it is proposed that immobilization and radio collaring exercise of Four-horned antelope should be done in a longer period of time (say more than seven days) to maximize random chances of encounter. Techniques of using hides and physical capture by specially designed, trauma-free enclosures could be used in addition to the conventional method of tranquilizing from a vehicle.

6.3 Results & Discussion

A total of 2902 minutes (approx. 48 hours) of cumulative observation of Four-horned antelopes in the field was obtained. Data were broadly classified into two categories, i.e. forced and natural behaviour. Forced behavioural bouts were those that were influenced by the presence of the observer. These were discarded for most analyses, but were used only for describing results on the threat response of the animal.

The natural behaviour observations were classified into Event States and Event Instances. This was done on the basis of the length of the bout of each of the different activities. Any behavioural bout occurring for less than a minute was considered as an Event Instance whereas an Event State was equal to or longer than a minute. A concise ethogram was prepared to enable analysis of basic behavioural patterns. ***Annexure D*** gives details of the ethogram used in explaining the behavioural patterns displayed by the Four-horned antelope.

As no animal was tagged due to delay in the necessary permits, individuals could not be located and observed with much success during all time-slots of the day. Observing identified individuals was also impossible due to the aforementioned constraints. Individuals of this species occur mostly solitary or in pairs. Thus the data remained unbiased in terms of "observing the obvious" (Boitani & Fuller, *2000*) except for the fact that an animal could be located in the field only if it was in active state, and within a limited distance from the observer. Focal sampling behavioural data was obtained whenever any Four-horned antelope was seen. This was done within the constraints of spotting an animal mostly when in active state. Observations from waterholes were also made in different seasons. Three waterholes were identified out of which one was a perennial spring (see Fig. 6.2), second was an artificial saucer (artificially created concrete waterhole, Fig. 6.3), and the third was a check dam (Fig. 6.4) with water availability till mid summer. These waterholes were monitored for three to five times in every season and observations about Four-horned antelopes visiting them were


Fig. 6.2 Four-horned antelope drinking water at a perennial waterhole


Fig. 6.3 Four-horned antelope drinking water at an artificial waterhole (saucer)


Fig. 6.4 Nilgai drinking water at an artificial checkdam

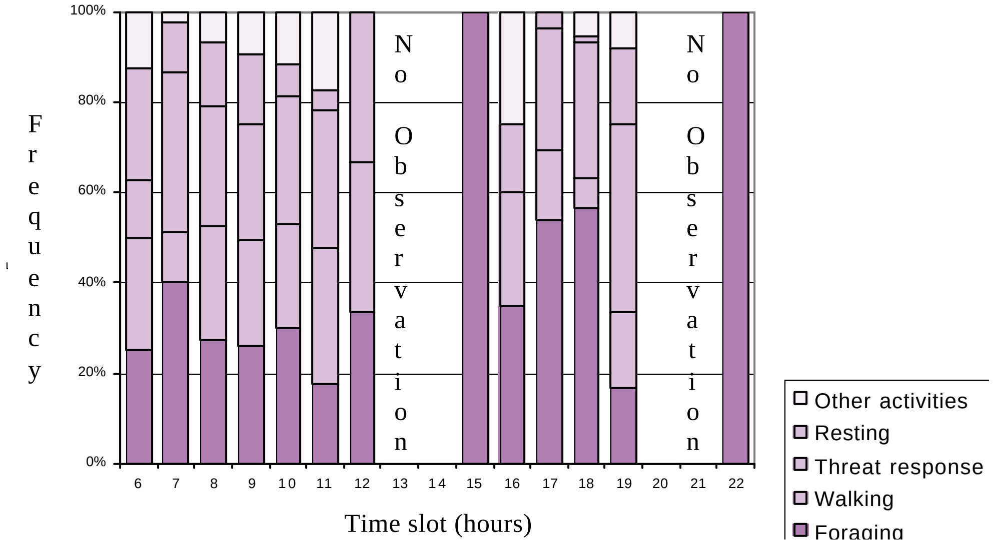


Fig. 6.5 Activity Budgeting (frequency of occurrence of events)

recorded along with their detailed behaviour.

Figure 6.5 shows the percentage of frequencies of major classifications of behaviour in different time slots. No pattern could be observed in the different behavioural categories, though time spent in foraging and threat response varied synchronously when seen across various time slots of the day. They spent approximately 20% of the observed time in foraging during all observed hours of the day.

6.3.1 Behavioural Classifications

(i) Foraging

Preliminary data on foraging preferences of Four-horned antelope were estimated using cafeteria experiment. Unfortunately only one individual was available in captivity compromising the statistical robustness of the data. Out of the ten species of vegetation provided with equal access, six were consumed by the Four-horned antelope in varying proportions (see Table 6.b). Grass species were not consumed at all, whereas Ber, Babool, Renjha and Khair were preferred in decreasing proportions respectively. Aonla and bamboo were consumed in small and insignificant proportions. Despite lower preference in terms of time spent, it is worth noting that Babool was consumed before Ber. It is only after the stock of Babool reduced that it moved towards Ber.

The Four-horned antelope was seen breaking hard twigs of Babool using molars. Ber leaves were cut into pieces or were taken one at a time using lower incisors and the upper gum. It is observed

Table 6.b Food taken by the Four-horned antelope during Cafeteria experiment

Species	**Time spent (%)**
Aonla (*Emblica officinalis)*	3%
Babool *(Acacia nilotica)*	31%
Bamboo *(Dendrocalamus strictus)*	2%
Ber *(Zizyphus mauritiana)*	43%
Khair *(Acacia catechu)*	9%
Rencha *(Acacia leucophloea)*	11%
Water	1%

that the captive Four-horned antelope was alert and cautious when foraging. It would frequently raise its head and stop all other activities for some time, and then get back to foraging. The level of alertness when foraging was much more than when it was ruminating or resting. Majority of the time during the day (noon) was spent resting and sleeping in shade. Occasional disturbances also forced the animal to wake up and start ruminating after a certain period of caution is lapsed. Since a Babool tree inside the enclosure was in bloom, the Four-horned antelope picked Babool flowers from the ground avidly. Interestingly the animal preferred leaves to flowers when both were provided artificially, but consumed flowers whenever found them on ground.

The Four-horned antelopes spent a lot of the observed time in foraging (Fig. 6.6). During the Cafeteria Experiment the Four-horned antelope showed no interest in ingesting any of the grass species other than nibbling some soft bamboo leaves on a couple of occasions.

Jarman's hypothesis (1974), re-established later statistically by Brashares *et. al.* (2000), suggests that feeding selectivity is negatively correlated with body size and group size. Due to the ***Volume : Area*** ratio, smaller species require more energy per unit weight than larger ones. Smaller antelopes have high metabolic requirements but smaller stomachs in comparison to larger ruminants. This prevents them from taking large quantities of coarse forage that is high in fibre content and low in protein. As a result, smaller antelopes are more selective in their food preferences. Since food which is high in protein content is scarce, Four-horned antelopes can not afford to thrive in large numbers. This is the reason suggested by Jarman (1974) and Rodgers (1988) behind small herbivores being mostly solitary and in low density. The Four-horned antelope seems to fit the hypothesis and tends to feed selectively. On almost all occasions when it was seen foraging, we examined the site after the animal had gone. The forage comprised mainly of fruits, flowers, pods, or fresh leaves and petals; all high in nutritive quality. The animal was never seen grazing during the study period. Cafeteria

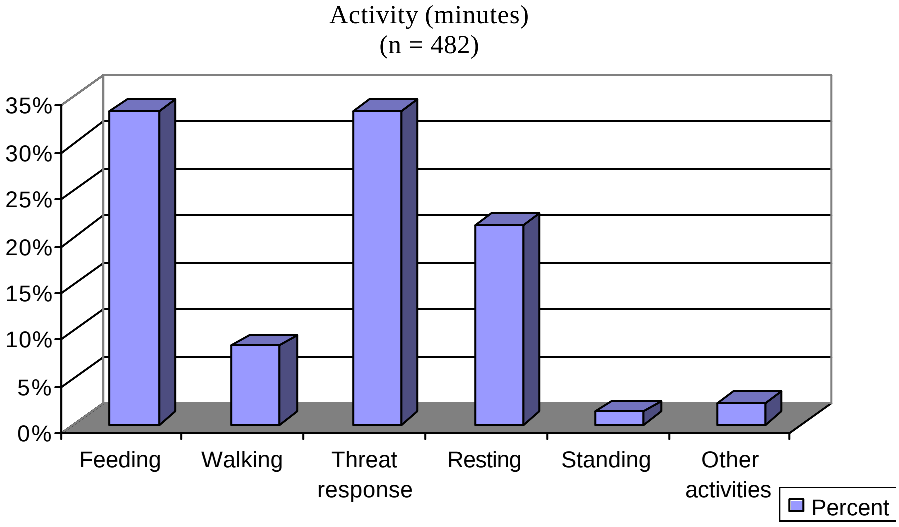


Fig. 6.6 Time spent in various activities as observed

experiments conducted on one captive Four-horned antelope in Bhopal's Van Vihar zoo helped establish the fact that it prefers to browse than graze .

When foraging, there were two distinct sets of behaviour that we could classify it in. These sets of actions were ***Foraging Move*** and ***Static Foraging***. Apart from this, there were times when the antelope was seen for a durationtoo short to determine whether it was in the state of Foraging Move or Static Foraging. These instances were termed simply as ***Foraging***.

a. Foraging Move: Whenever a Four-horned antelope would move continuously for more than five meters in an area whilst foraging, it was considered as a Foraging Move. During a Foraging Move, usually the animal would take one or two bites followed by 4-5 steps. This was again followed by a state of Down Foraging (see *Appendix F*, Ethogram). As observed during the Cafeteria Experiment as well, occasional rising of head and moments of alertness with a frozen stance would usually accompany this behavioural bout. Out of the recorded 167 foraging states in the field totalling 720 minutes of observation, on 64 times (438 minutes) the Four-horned antelope was observed to be in act of Foraging Move (Table 6.c). Out of all the occasions when Foraging Move was observed, on about 50% occasions it was complimented with momentary alertness.

b. Static Foraging: Static Foraging was the second most observed category out of the total observed foraging time. Static Foraging comprised of events of biting, chewing and looking around while either standing at a place or moving within a radius of five meters. Static Foraging was observed on 88 occasions totalling 282 minutes.

Fifteen instances were labelled as just 'Foraging' since the duration of observation was too short to classify whether the animal was in the act of Foraging Move or Static Foraging.

We found that the time spent on Foraging Move was almost 1.5 times greater than on Static Foraging. At the same time, the percentage of event states on Foraging Move was 0.7 times than that of the Static Foraging event states. This disagreement can be credited to bouts of Static Foraging, which were usually shorter than those of the Foraging Move. Mean bout length of Static Foraging was 3.18 minutes (Std. Err. ±0.4) and that of the Foraging move was 6.84 minutes (Std. Err. ±0.8).

Table 6.c Foraging States: Time spent and frequency of occurrence of events

Foraging State	Duration (minutes)	Percentage of time spent	Frequency of occurrence	Percentage of total foraging event states
Forage	*unavailable*		15	9%
Foraging Move	438	61%	64	38%
Static Foraging	282	39%	88	53%
Grand Total	720		167	

(ii) Resting

Next to Foraging and Anti-predatory behaviour, the Four-horned antelope was observed mostly when resting. It was observed that Four-horned antelopes preferred closed canopy thickets with dense undergrowth or grass cover for resting. Unlike the Chinkara, which invariably uses open terrain, forest clearings and forest roads for resting, the Four-horned antelope could never be seen resting in the open. This observation is in contradiction with the conclusions made by Bhaskaran (1999) who studied Four-horned antelopes in Mudumalai, and observed that they use forest roads for resting. While resting, the Four-horned antelopes would usually flush only when the observer was less than 15 meters away.

In a span of three years, we could observe Four-horned antelopes resting only on 28 occasions. Difficulty in detecting animals resting in thick grass or undergrowth, and their tendency to flush only as a last resort may resulted in so few observations.

Four-horned antelopes rest in the usual fashion that most ungulates also follow. They fold their front legs followed by hind legs and bundle down while occupying minimum possible space.

The state of resting was further classified into Crouching and Ruminating categories depending on the posture and activity of the animal:

a. Resting only

When resting, the Four-horned antelope puts its head either on its own body, or finds some support in the viscinity. Otherwise it simply rests its head on the ground. The Four-horned antelopes often raise their head up in semi-alert position and align their ears as radars towards the direction of slightest observable noise. Since Four-horned antelopes usually rest in thickets with very low visibility, they are probably more dependent on their sense of hearing than sight when resting.

b. Ruminating

Ruminating being an important aspect of the ecology of an ungulate, they spend significant time in this activity. Four-horned antelopes usually ruminated while resting, but there were instances we could see them chewing the cud even when on their feet. Out of the nine occasions when the Four-horned antelope was observed ruminating, four times it was standing whereas on the remaining occasions it was resting. Before ruminating, the Four-horned antelopes spent a few minutes observing and assessing their ambience. Once ambience is assessed, they twitch their stomach with a slight jerk followed by an apparent movement of the bolus through its oesophagus to its mouth. Close observations of its throat revealed the successive transitions of each bolus. Boluses were chewed for a varied number of times ranging from 10 to 28. After chewing the bolus, it was swallowed and within the next two to three seconds a new bolus was being brought to the mouth for chewing.

(iii) Interaction

The Four-horned antelope is a solitary animal. Since it is not usually seen in groups (69% solitary sightings), there were few opportunities to directly observe interactions between individuals. Detailed behavioural notes could be taken on 41 individuals when they were in a group of two or more. Rapid scanning of the two or more individuals with scan interval less than one minute was done and overall 341 behavioural bouts could be recorded. Different kinds of interaction could be identified based on field observations. Sniffing, Submission, Trailing, Mating and Agonistic were the various events of interaction and could be observed on 40 occasions. On a few occasions the Four-horned antelope was seen interacting with other species as well, allowing interspecific behaviour to be recorded.

The total sample size of interactive behaviour is too low to statistically infer much from it. Hence natural history field notes and interpretations about these behavioural bouts are described here.

a. Intra-specific interactions

a.1. Mating: A male and a female Four-horned antelope were sighted at 0916 hrs in the morning of February 7, 2003, after brief showers during the previous week. The pair moved briskly and briefly around a cluster of trees and bushes in the lower plateau of the Park, not more than 100 meters from a steep cliff, in an open miscellaneous forest with medium undergrowth. On being observed, the Four-horned antelope pair moved slightly away from the observers and then the female started eating leaves of a low height shrub. While the female was busy eating, the male approached her from behind and mounted her for about 2 seconds to which female did not react at all and continued foraging. After dismounting, the male moved again and mounted her again, this time for a shorter duration of 1 second. Then the animals moved ahead and got attentive to passing villagers on a forest road, a few meters away. At 0919 hrs, the female ran away and was followed by the male till they both disappeared in the tall grasses. On an attempt to rediscover the antelopes, the animals were found approximately 120 m from the first sighting spot resting under a Tendu *Diospyros melanoxylon* tree at 1030 hrs.time the animals did not react until the observers flushed them out from a distance of just about 10 m. The female and male ran swiftly towards different directions instantaneously but the male reunited with the female and joined her line of movement after about 70 m. Later, efforts were made to relocate the pair in the area, but due to tall grass and bushy terrain, they could not be located.

a.2 Submission: A submissive posture can be explained as one where an individual shrinks its body, lowers the head and pulls the ears back. On April 16, 2003, two individuals were observed in closed canopy area with dense miscellaneous forest in Hinauta Range. The female started foraging after a short alert while the male remained alert and frozen. On her circular movement around a cluster of bushes, the female reached close to the male and took a submissive posture while the male sniffed her rear and started foraging. After a while, both the male and female moved tenderly while foraging selectively. After foraging for about half hour, the male sat down amidst medium height grass and open-moderate canopy. Female sat down to rest after some time. It was evident that the pair was moving cohesively as we had a couple of relocations few hundred meters away from the spot of first sighting.

a.3 Kneeling Submission: This is one of the most obvious and distinct interactions between two individuals when an individual would approach another in a specific manner. Following a certain mode of communication, the other individual, not necessarily belonging to a particular sex or age group would kneel down on its front legs with its rear body still up. The approaching individual would then come close and rub its neck with the kneeling antelope or examine it closely by sniffing it. This ritual usually lasted only a few seconds after which both Four-horned antelopes retain their normal postures. The behaviour was observed between individuals of different sexes and age groups. Once two fawns behaved in this fashion on being approached by an adult female. It seems that the Four-horned antelopes either communicate dominance and submission or use it to develop a bond with conspecifics with the help of such behaviour. This distinct behaviour was observed both in captive as well as wild Four-horned antelopes. Shull (1958) also reported a kneeling 'courtship' between a male and a female Four-horned antelope, which mated later on.

a.4 Trailing: Following of an individual by another individual was categorized as "trailing". It was of the most observed behavioral bouts between any two individuals when seen together. On 46 occasions, trailing was recorded. It was mostly seen in fawn or juveniles following their mother, but occasionally observed in other age classes also, especially during the rutting season (See section 5, Social Structure).

a.5 Female-Fawn/Juvenile: The fawns seem to follow their mothers for almost a year or so. This could be established on the basis of 41 direct sightings of fawns with females spread throughout the year. As ageing was difficult in fawns, all individuals substantially smaller than the adults (less than two third the size) were considered as fawns or juvenile.

On five occasions a female was seen with a fawn and a juvenile of the size between the other two. This proves that sometimes the juvenile moves with the mother even after she had mothered another fawn. Whenever we saw a mother with a fawn or a juvenile, the latter followed the line of movement of the mother.

a.6 Nursing: One sighting of a female suckling young ones was obtained on February 10, 2003. The two fawns were initially spotted alone. On the approach of their mother, they ran hastily towards her and started suckling with one on either side of the mother and pushing persistently like the fawns of a goat.

b. Inter-specific interactions

b.1 Four-horned antelope and Langur:

Langur, being mostly arboreal frugivores usually forage on fruits and other vegetable matter on the trees. They are known to drop a mean of 4.0 kg vegetation fresh weight per day (Newton, 1989). It is also reported that for some species such as the Aonla *Emblica officinalis*, fruit fall rates without Langur are as low as 1% of the fruit crop per day compared to when these trees are perched upon by Langurs. The relationship between Chital and Langur is well known and often referred to as a classical example of symbiotic and commensal relationship. While some species like the Chital and Muntjack usually visit some fruiting tree species in small groups or pairs for short durations, in presence of Langurs on the trees their group sizes increase and they spend longer durations foraging under these trees. This association is also known to have a key role in dispersal of plant species (e.g. Prasad *et. al.*, 2004). Four-horned antelope was seen on 20 occasions associating with troops of Langurs for foraging. They were seen foraging in association with Langurs under trees of Aonla, Bel *Aegle marmalos*, Bahera *Terminalia belarica*, Ghont *Zyziphus xylopara*, Kaitha *Feronia limonia* and Semal *Bombax ceiba*.

b.2 Four-horned antelope and Chital: Four-horned antelope and Chital have an overlapping niche in a dry deciduous forest (Berwick, 1974; this study) where the former has a more widespread distribution than the latter. Chital, despite being hardier and more generalist a species than the Four-horned antelope in terms of its foraging preferences, requires ample amount of suitable habitat and availability of food for its usually larger populations. Since the Chital live in herds and the Four-horned antelopes are mostly solitary, their anti-predatory strategies are also different. Associations between two species with distinct anti-predatory behaviour and foraging preferences is rare, but was recorded occasionally by us in the study site. It was found that mostly at sites where Langur were foraging on the top canopy, Chital and Four-horned antelopes were both seen benefiting from the items that were being dropped by the Langurs. Other than this, at some sites where closed forest stands were recently converted into open forests by uprooting some trees, Four-horned antelopes were occasionally seen foraging along with herds of Chital.

***b.3 Four-horned antelope, Parasites and Treepie*:** Wild ungulates are host to ectoparasites and other insects (e.g. Wesonga *et. al.*, 2006; Miller *et. al.*, 2003; Krasnov *et. al.*, 2002). Parasites play a major role in shaping ecology and behaviour of the host species (Jog and Watwe, 2005).The seasonal distribution of some of the ungulates, including the Four-horned antelopes, changes in the monsoon possibly due to explosion in the populations of some parasites. It was observed that during the first two weeks of monsoon, most ungulates possibly moved to the rockier areas of the study area. This was evident from the reduced encounter rate of Four-horned antelopes in areas with high presence of parasites

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Treepie was the only bird which could be observed cleaning the ears of Four-horned antelopes. They would perch on the joint of head and ear of the Four-horned antelope and the antelope would gently raise its heads as if in acceptance for the act of cleaning. Treepies hang upside down while being perched on the top of the ears of Four-horned antelopes and pick ticks avidly while the animals stand almost still for getting the job done.

(iv) Threat response (Anti-predator behaviour)

An adult Four-horned antelope weighs about 17-20 kg (Berwick, 1974; Aniruddha Belsare, *pers. comm.*). According to the five social classes proposed by Jarman (1976), the Four-horned antelope fits under the A category, though there are attributes that may suit the B category at the same time. These classifications have been defined on the basis of relationship between body size, group size, feeding style and anti-predatory strategies of different antelopes of Africa. Based on its size, weight and group size, the Four-horned antelope seems to fit the description of the Class A. According to Jarman’s classification, antelopes from this category are known to feed selectively on a wide range of plant species, use particular plant parts only, remain in a restricted vegetation type, and have small home range. Its feeding style is further explained as exclusive where it feeds usually on single plant parts. These parts are not gradually reduced by repeated bites of feeding, but are removed wholly from the site. If animals comprising of the Class A feeders in a group are covering ground already fed upon by forerunners, they will have little to nibble upon as their forerunners would have taken either all of the acceptable items or would have at least consumed the more obvious or accessible ones. This is possibly one of the reasons why antelopes belonging to this class are solitary. As far as their anti-predatory behaviour is concerned, they depend largely on making themselves inconspicuous. In the presence of predators they would freeze, lie down and freeze, or run to cover and freeze. The animals belonging to Class B also resort to similar tactics when it comes to dealing with a predator. They would be frozen until a predator is almost over them, and then take a short sprint to take themselves clear of the predator. Once at a safe distance, they hide again.

Four-horned antelope evades detection and prefers hiding and freezing rather than fleeing instantaneously as it encounters a threat. It has a short flight distance, and only when it is invaded, causes it to burst into a sprint. The elusiveness and lack of studies on Four-horned antelope for so many years can possibly be credited to its anti-predatory behaviour.

We analysed the threat response of the Four-horned antelope with an objective of finding how well it fits to Jarman's classification based on body size and anti-predatory behaviour. Of the 354 occasions when attempts were made to rediscover the animal within a small radius around the point of its first sighting, 277 (78%) times the animal was rediscovered between a range of 1 to 350m. The mean radial distance of conspicuous evasion was estimated as 41.79 m (95% Confidence Interval = ± 3.77 m).

We also attempted to correlate its anti-predatory behaviour with respect to grass height. At each sighting in the field, notes were taken about the escape mechanism employed by the Four-horned antelope. It was observed that on different occasions, different strategies were employed to evade potential threats. We reclassified these 10 different escape strategies into three, viz. Quiet, Clumsy & Short, and Sprinting . Whenever the animal did not take any evasive action, quietly moved, trotted, walked with stiff legs or just quickly vanished into thick vegetation, it was classified as minimum distress. In situations when the animal took clumsy leaps with or without curiosity or resorted to taking short sprint, they were ranked as short evasive manoeuvres. Whenever the animal reacted nervously to threats and took to sprinting, it was termed as hyper evasion. Probabilities of each of these three modes being employed by the Four-horned antelope across each of the six different grass heights (see Chapter III, Habitat Use) were evaluated. Principal Component Analysis (PCA) was used to reduce the three variables, viz. quiet, short and hyper modes of evasion into one. The Principal Axis PC1 explains more than 70% of the total data variation and was plotted against grass height. Nervousness, denoted by PC1 (Principal Component 1) regressed negatively ($R^2=0.80$) against grass height (Fig. 6.7).

Further analysis was done where fleeting distance was plotted against grass height. It is expected that the antelopes would usually take shorter sprints in taller grass as compared to low grass. Figure 6.8 shows that a significant power regression

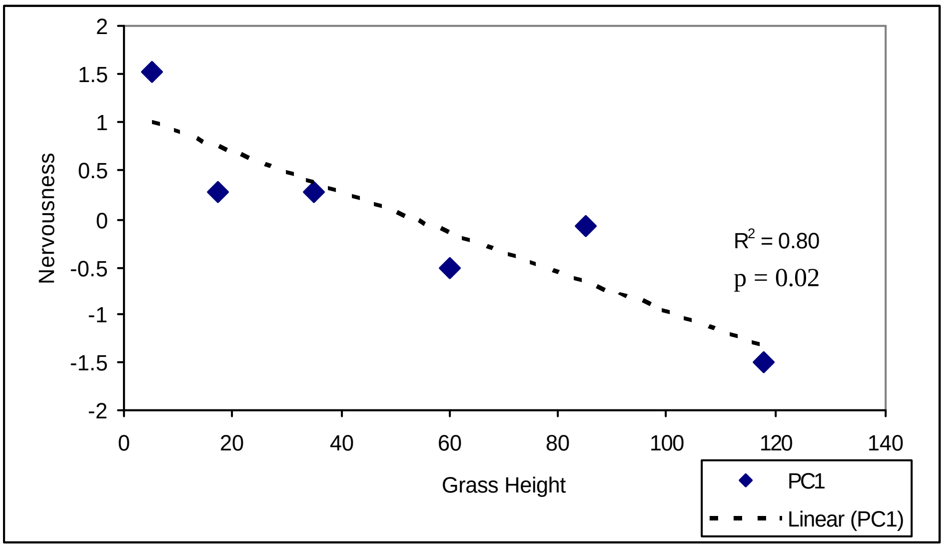


Fig. 6.7 Principal Component Analysis: Nervousness vs. grass height

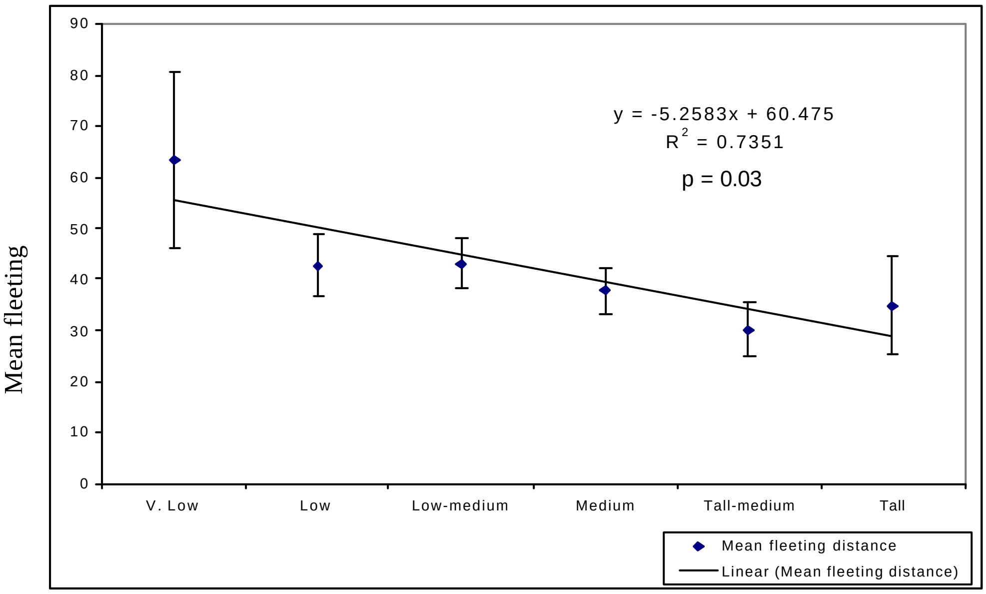


Fig 6.8 Regression of mean fleeting distance with respect to grass height

was obtained between the two variables. Data suggest that Four-horned antelopes preferred not to take long sprints when in tall grass unlike they did when threatened in areas covered with short grass. This supports the hypotheses that taller the grass and hence more the opacity of vegetation, less would be the stress on the Four-horned antelope against predators. We extrapolated our results to propose that undergrowth of all kinds is important for survival of this species in an area.

***a. Freezing* (no movement and mock feeding):** When threatened, the Four-horned antelope usually resorts to the tactic of standing still without any movements. We classified this behavioural bout as '*Freezing*' or '*Alert*'. A record was also taken of the duration of all particular freezing bouts (with resolution in minutes). The moment of frozen alert was observed to last between few seconds and 17 minutes. The success of this freezing technique is evident from an observation in the field on December 12, 2003 when a Four-horned antelope standing still in medium tall grass managed to be missed by a leopard walking just 6 meters away.

b. Evasive Action: Those actions where the animal moved significantly in response to the threats were called as evasive actions. As the bout interval for these events was generally short, all of these events have been termed as Event Instances and instead of time duration, frequencies are used to analyze their occurrence. These patterns were further classified as various behavioural displays were observed when the animal took evasive action (see Fig. 6.9).

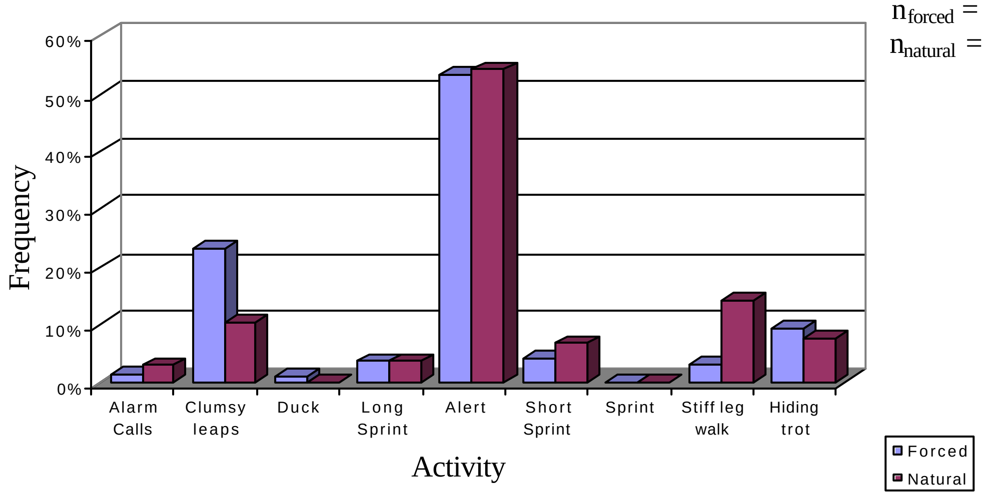
c. Alarm calls (barking):

The Four-horned antelope sometimes make a shriek alarm call. Its alarm calls are recurring, husky *'pronk'* calls repeated at regular intervals. It is rare to hear its alarm calls as its main anti-predatory strategy is to hide. These alarm calls are made only when faced with some special situations. Since the Four-horned antelope is predominantly a solitary species, it is more likely that the alarm calls are used to warn the predator (Zahavi & Zahavi, 1997; Reby *et. al.*, 1999; Bergstrom & Lachmann, 2001) that it has been identified, rather than warning conspecifics about presence of a predator (Hauser, 1996; Blumstein, 2001).

The alarm calls are made at intervals of five to ten seconds when the animal is standing, and at a much greater frequency of half a second when sprinting. These calls are diagnostically different from those of Chital and Nilgai as they are shriller than those of a Nilgai and huskier than those of Chital. Fig. 6.10 shows the spectrogram of the alarm calls made by a male which had sensed presence of some predator and made alarm calls continuously for over five minutes.

(v) Communication

Olfaction plays a prominent role in the interactions of many ungulates with their



n_{forced} = 219
$n_{natural}$ = 133

Fig. 6.9 Frequency of occurrence of events of antipredatory behaviour (natural stimuli: n = 133 and forced stimuli: n = 219) environment. It is widely accepted that most forest-dwelling antelopes (e.g. Duikers and Kirk's Dikdik) and deer (e.g. Chevrotains and Muntjacs) appear to rely primarily on their sense of smell for orientation and communication as in the social context (Leuthold, 1977; Geist, 1987).

Modes of communication between the Four-horned antelopes are largely unknown apart from the alarm calls that are made in response to threats. The following modes of intra-specific communication were considered, following field observations.

a. Preorbital gland marking: A captive adult male was first observed in Van Vihar National Park of Bhopal marking all sharp tips of thorns and enclosure fence wire with its preorbitals. Only the adult male showed this behaviour whereas the younger male displayed no such interest. On many occasions in the wild, the Four-horned antelope was seen marking with its preorbital glands. Marking comprised of sniffing the twig or thorn and piercing it in its head sideways through the preorbital glands. This marking leaves a colourless liquid on the substrate that supposedly had no odour whenever we tried smelling it. This liquid crystallizes into white solid film on the substrate within few seconds of deposition. In the field, adult individuals, both male and female, were observed marking on twigs, thorns and grass tips with their preorbital glands. This tendency is widely used by many other territorial antelopes and deer (Brashares & Arcese, 1999; Burger, 2005). The tendency to mark with preorbitals was shown by both males and females but was never observed in fawns.

b. *Urination and defecation*

Urination and defecation are perhaps the most generalized forms of scent marking. This biological waste also plays an important part in establishing the role of ungulates in stimulation of nitrogen cycling and retention, and modification of ecosystems (Hobbs, 1996; Frank *et. al.* 2000). It was observed that the Four-horned antelopes defecated regularly on middens. Few direct observations of defecation on such middens by males, females and even fawns led to the understanding that middens are probably used as communication points. Mapping of middens and their periodical regular monitoring was done in order to understand the parameters influencing site selection and frequencies of defecation on middens.

c. *Calling*

On two occasions, the Four-horned antelope was heard making calls in a lower amplitude which was not very different from its diagnostic alarm calls. On February 6, 2004, a pair was seen courting.

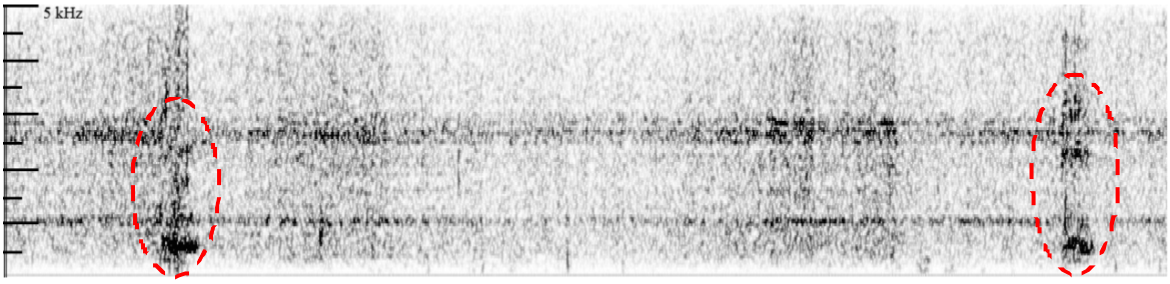


Fig. 6.10 Spectrogram of alarm calls made by the Four-horned antelope

The male walked towards and away from the female while making distinct *'cough'* calls that were milder, more persistent and in a less distressed posture (ears and feet movement relatively relaxed than the typical alert). On another occasion, where tiny fawns were observed hidden amidst thick undergrowth, the female made soft calls. After this call, the fawns followed the direction from where she had called and vanished into thick vegetation.

It is also observed that adult female Four-horned antelope uses shrill calls that sound more like alarm calls to warn or communicate with its young ones. On one occasion a female approached a waterhole with her juvenile fawn. While the juvenile and the female were separated by about 30 meters, the female got distressed about some potential threat and burst into a long sprint continuously making persistent alarm calls at short frequency. The fawn, which was about a year old, followed her immediately after hearing the calls without waiting to look around for the threat.

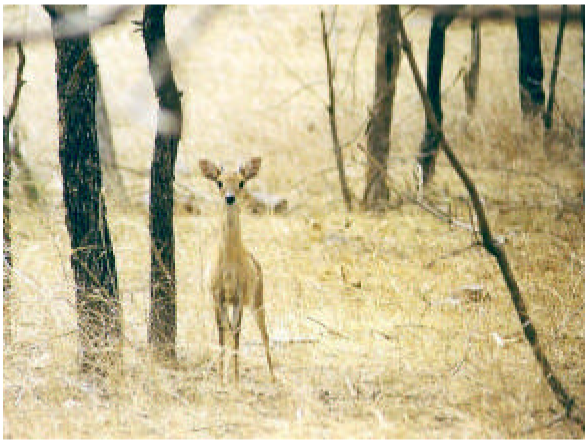
6.3.2 Midden Mapping and Monitoring

The way defecation is distributed in space is often indicative of an animal's social status. Voidance in one animal often induces the same in others (allelomimetic behavior), particularly between mother and young, and even different species. To investigate the behaviour of maintaining middens, each of the identified middens was given a unique midden code for further reference.

Regular monitoring and a few direct observations reveal that the middens are used by both sexes and even the fawns accompanying their mother defecated on them. No determined and directional movement was observed specifically towards the middens, but apart from a few exceptional instances, fecal pellets were almost essentially released whenever a Four-horned antelope came across a midden during.

Identification of pellets was difficult at times when a Nilgai calf defecated on a midden as its pellets look similar to those of a Four-horned antelope. Similarly, pellets of young ones of Chinkara and Four-horned antelope were also confusingly similar. To resolve this problem, based on direct observations of the three species defecating at middens on different occasions, we assume that a fawn would defecate on a midden only when accompanying its mother. This would mean that two fresh defecation heaps (one with small pellets and the other with bigger pellets) would be found on a midden whenever a young one had defecated on it. While there could surely be some deviations from this assumption, we never came across any direct observation contradicting with this assumption.

Overall 145 middens were identified and marked on the map from a sampling effort of six midden maps. We tested the distribution of these middens in space in order to investigate whether there was any clustering of these middens within the selected/sampled microhabitat. Clustering within a microhabitat would mean that the middens have an inductive effect where presence of one midden will stimulate presence of another. It may also suggest that middens are maintained by individuals, in order to demarcate home ranges or lure the other sex. This in turn will infer that their distribution across a habitat would indicate visibility, accessibility and display more than respective habitat use by the animal. G-test for Poisson's (random) distribution was used to check clustering in space. We found that clustering was significant only in one area i.e. Badi-saaj (chi square = 7.18; p = 0.00), which also had the highest number of direct sightings of the Four-horned antelope (Table 6.d). The reasons for such clustering in this area are unknown, but can be credited to high density of population. This, in turn can be credited to concentrated availability of rich stands of trees providing forage throughout the year.



Four-horned antelope: Alert and frozen

CHAPTER VII

Distribution Range and Conservation of Four-horned antelope

CHAPTER VII

DISTRIBUTION RANGE AND CONSERVATION OF FOUR-HORNED ANTELOPE

7.1 Introduction

The Four-horned antelope is unique in having two distinct pairs of horns in adult males. Endemic to the Indian subcontinent, it is found only in India and Nepal, and its distribution range has reportedly fragmented over the few decades (Rahmani, 2001; Mallon, 2003). The fact that it is also termed as an ancient antelope due to characteristics similar to those of the ancestors of present day ungulates makes it a potentially important link between the domesticated cattle and wild ungulates (Macdonald, 1984). While some historic records suggest that the Four-horned antelope was once found throughout most parts of India, recent records indicate highly fragmented populations, especially north of the Gangetic plains in Uttar Pradesh, Bihar and Nepal. While Orissa and West Bengal mark the easternmost limit of its distribution, they are reported from most forest tracts in Central and Peninsular India. In the west, its distribution is restricted and it is possibly found in the form of an isolated population in the Gir Forest in Saurashtra, which is the only site west of Valsad and Rajpipla in Gujarat with known distribution of the Four-horned antelope.

It is important to know the status of current as well as historic distribution of a species for its conservation. Reductions or extensions in distribution range are important parameters that determine the well being of a species. Site occupancy (Carroll *et. al.*, 1999; Orrock *et. al.* 2000; McKenzie *et. al.*, 2002; Clinchy *et. al.*, 2002; Holt *et. al.*, 2002; McKenzie *et. al.* 2003; Royle and Nichols, 2003; Bailey *et. al.*, 2004; Crossland *et. al.*, 2005) is one of the simplest reliable parameters to obtain while assessing distribution of a species. Some recent studies (McKenzie & Nichols, 2004; Royle & Dorazio, 2005) also recommend usage of occupancy as a surrogate of abundance estimates, thereby providing a direct indicator of a populations' well being. It is documented that localized and endemic species are more vulnerable to the threats of extinction than common and widespread species (Wright & Hubbel, 1983)). Although a caveat in the above theory is that the terms localized and widespread are often used relatively and there are no clear benchmarks defining them. It is important to know the distribution range and monitor changes across a longer period of time. These changes indicate trends in the site occupancy of species at a larger scale. This, in turn, can be compared with historical distribution ranges, if known and used for appraising the conservation issues. Different causes can be responsible for the threats faced by a particular species in different areas and may need specific interventions. Information on distribution is useful for better management of sites and assessment of potential threats to the populations.

While much of the wildlife in India, especially those living in forests, is today restricted to protected areas, there are different levels of protection that these protected areas provide to wildlife, depending upon their category (e.g. National Park, Wildlife Sanctuary, Reserve Forest and Forest Division). An assessment of the distribution pattern of a species may provide useful information about the conservation status of different populations of a species and may help in planning a conservation strategy.

7.2 Methodology

Rice (1991) conducted a questionnaire survey for the distribution of the Four-horned antelope. A survey was conducted again as part of this study with postal and internet based questionnaires, interviewing people, and visiting sites personally. The results were expected to provide a better insight into the distribution, present status and threats faced by the animal. To receive a better response from the predominantly Hindi speaking provinces of the country, it was translated and distributed in two languages simultaneously. A postal questionnaire (see Annexure E) was sent through BNHS in November 2002 to various scientists, naturalists, foresters, wildlife enthusiasts and BNHS members. Following a poor response to the postal method, an online questionnaire (see Annexure F) was designed and a web page uploaded as www.treepie.org/chousinga.php in September 2004 with the help of a software engineer Mr. Narayan Raman. This questionnaire was also linked with the official website of BNHS (www.bnhs.org) in January 2005 to widen its reach. An automated algorithm was written to receive the filled-up questionnaire through email as soon as the 'submit' button was pressed by a person on the web page. The data were then received in a specific format which was compatible with spreadsheet utilities. This enabled the information to be easily appended to a database whenever required. The questionnaire sought relevant information about the site that the reporter was referring to, its forest type, approximate population of Four-horned antelopes in the area mentioned, and additional information about its midden usage, population trends and known conservation issues, if any. The questionnaire also provided space for sites with historic distribution and attempts to seek the possible reason of extinction.

Emails with basic information and relevant link to the web page were sent to various people requesting submission of all sorts of relevant information on the species. Links for the same were also posted on many e-groups, discussion forums and other sites on the web. The questionnaire is still available online and will continue being so for additional information in the future. This will help in obtaining regular inputs on the species from different parts of the country.

Personal discussions and meetings were held with old *shikaris* and foresters to obtain information from them about the historic distribution of Four-horned antelope. These discussions and meetings were also useful as they provided information about the basic habitat and behavioural characteristics of the Four-horned antelope. Experts on prehistoric rock art were also met with for discussions regarding possible presence of depictions of the Four-horned antelope on any of the rock paintings.

Rapid surveys were also conducted in some areas to assess the distribution pattern and more importantly, vet the report of presence of the Four-horned antelope wherever possible. These surveys were not conducted extensively and systematically due to shortage of resources and time as they were usually associated with other programs. As a result, although the surveys are not statistically competent to provide information on presence/absence of the Four-horned antelope, they usually attempted at confirming presence through field surveys and interviewing local people and forest staff.

Literature was reviewed to understand the distribution of the Four-horned antelope in India and neighbouring countries. Shikar reports, memoirs, books and papers were reviewed and the collections section of BNHS surveyed, to collect information about sites from where Four-horned antelope specimens were collected.

Initially about 100 questionnaires were sent via post in November, 2002. Following a poor response, about 5,000 questionnaires were sent to all members of BNHS. Out of these only 23 questionnaires came back with relevant information about the Four-horned antelope. A much better response was observed when the same questionnaire was uploaded on the internet and its link posted on many egroups and discussion fora. About 170 emails with relevant link and information were sent to various persons seeking information, and 41 people responded. Of these responses, eight mails mentioned that the responder had never seen a Four-horned antelope whereas the rest of them discussed issues related to the antelope study or were returned due to delivery failure. Till October 2006 the website recorded 702 hits in the 25 months since it was uploaded with 43 filled –up questionnaires received by us via email.

A number of people were interviewed personally and telephonically for information regarding the Four-horned antelope. These interviews provided information about recent or historic presence of Four-horned antelope from 15 different sites that could not be obtained through other sources. Apart from these, some old time hunters also informed about three sites where the Four-horned antelope was found till a few decades ago, but is now extinct.

Presence or absence of the Four-horned antelope was reviewed during visits to the following areas: Kanha National Park (Mandla), Bandhavgarh National Park (Umaria), Satpura National Park (Hoshangabad), Madhav National Park (Shivpuri), Karera Wildlife Sanctuary (Shivpuri), Orchha Wildlife Sanctuary (Tikamgarh), Gangau Wildlife Sanctuary (Panna), Ratapani Wildlife Sanctuary (Sehore), Omkareshwar National Park (proposed, Khandwa), Ralamandal Wildlife Sanctuary (Indore), Shyamgiri People's Protected Area (Panna) and Sardarpur Wildlife Sanctuary (Dhar) in Madhya Pradesh, Sanjay Gandhi National Park (Mumbai) in Maharashtra, Keoladeo National Park (Bharatpur) in Rajasthan, and Corbett National Park (Nainital) in Uttaranchal. Of these areas, no evidences of presence of Four-horned antelope could be obtained from Karera WLS, Orchha WLS, Corbett NP, Ralamandal WLS, Sanjay Gandhi NP and Sardarpur WLS.

7.3 Results

The total number of point locations from where one or more reports of presence of the Four-horned antelope (historic as well as current) were obtained is 196. Out of these, eight locations were scrapped as they mention presence of the Four-horned antelope from the north-eastern states of the country, as the species has never been reported from east of the Bay of Bengal. The remaining point-locations consolidate data from field visits, interviewing people, postal questionnaires, electronic questionnaires, published references and the survey conducted by C. Rice (1991).

The questionnaires, visits to various areas and discussions with different people indicated that Four-horned antelope was restricted mostly in the dry deciduous forest. Areas with moist deciduous forests had its distribution restricted to the drier regions and there were no evidences of presence of the Four-horned antelope in the open scrubland and grasslands such as those of Karera WLS and Sardarpur WLS.

Using the Forest Map (1976), historic presence of Four-horned antelope was also reviewed. This map seems to be incorrect. This map reports Four-horned antelope from 59 sites, distributed south of the Gangetic plains up to north-west Tamil Nadu. Interestingly the map shows distribution of the Four-horned antelope all the way up to Assam and Nagaland! Since there are many known reports and instances where the Four-horned antelope is confused with the Barking Deer (Jerdon, 1867; Blanford, 1888; Brander, 1923; Prater, 1980), it is important to cross check these records with other contemporary hunting or sighting records from the north-eastern parts of the country. On reviewing other relevant literature (Jerdon, 1867; Brander, 1923; Ellerman and Morrison-Scott, 1951) on distribution of Four-horned antelope, it was found that Orissa and some portions of Bengal largely demarcate the easternmost boundary of the distribution of the Four-horned antelope. It is therefore possible that these records from the north-eastern states reported in the forest atlas were those of Muntjack rather than those of the Four-horned antelope.

Our recent survey reported presence of Four-horned antelope from 122 sites. This information was then overlapped by the one published by Rice (1991) who reported presence of Four-horned antelope from about 75 sites. Our study reports presence of Four-horned antelope from 71 new sites that were not listed in the previous survey. Jointly the two surveys report Four-horned antelope from 146 sites. This study reveals that local extinction of the species took place mostly at sites located north of the Gangetic plains and in Maharashtra. At these few sites, earlier studies reported presence of the Four-horned antelope but no reliable evidences of the presence of Four-horned antelope could be obtained during our study.

Figure 7.1 shows the distribution of Four-horned antelope based on historic records including descriptions by Jerdon (1867), Blanford (1888), Brander (1923), Ellerman and Morrison-Scott (1951), Das Gupta (1976), Prater, 1980; Rice (1991); Singh (1998), Harshey and Chandra (2001), Finn (2002) and Roberts (1977). Based on data collected during this study and by Rice, a consolidated map of current distribution of Four-horned antelope is presented in Figure 7.2. Sites where Four-horned antelope's presence could not be asceratined in the current survey are classified as unknown status. Further surveys are sought in these areas in the

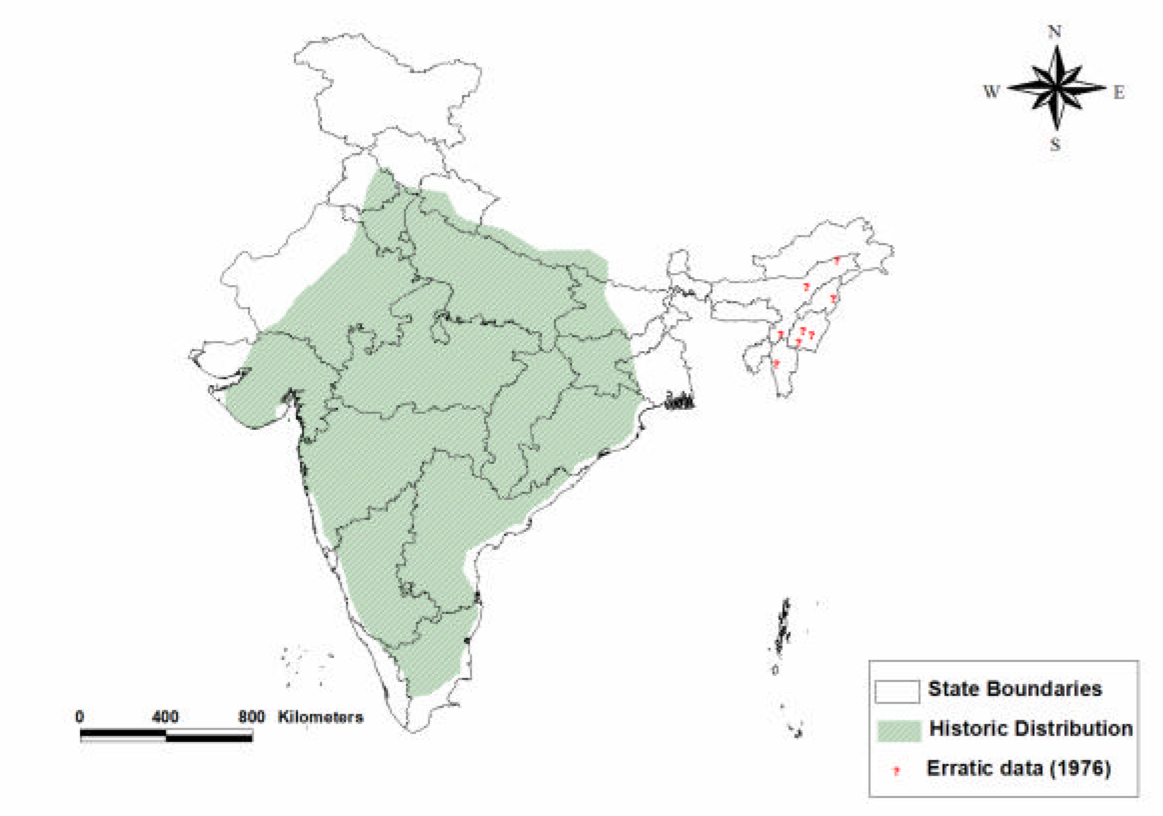


Fig. 7.1 Historic distribution range of Four-horned antelope

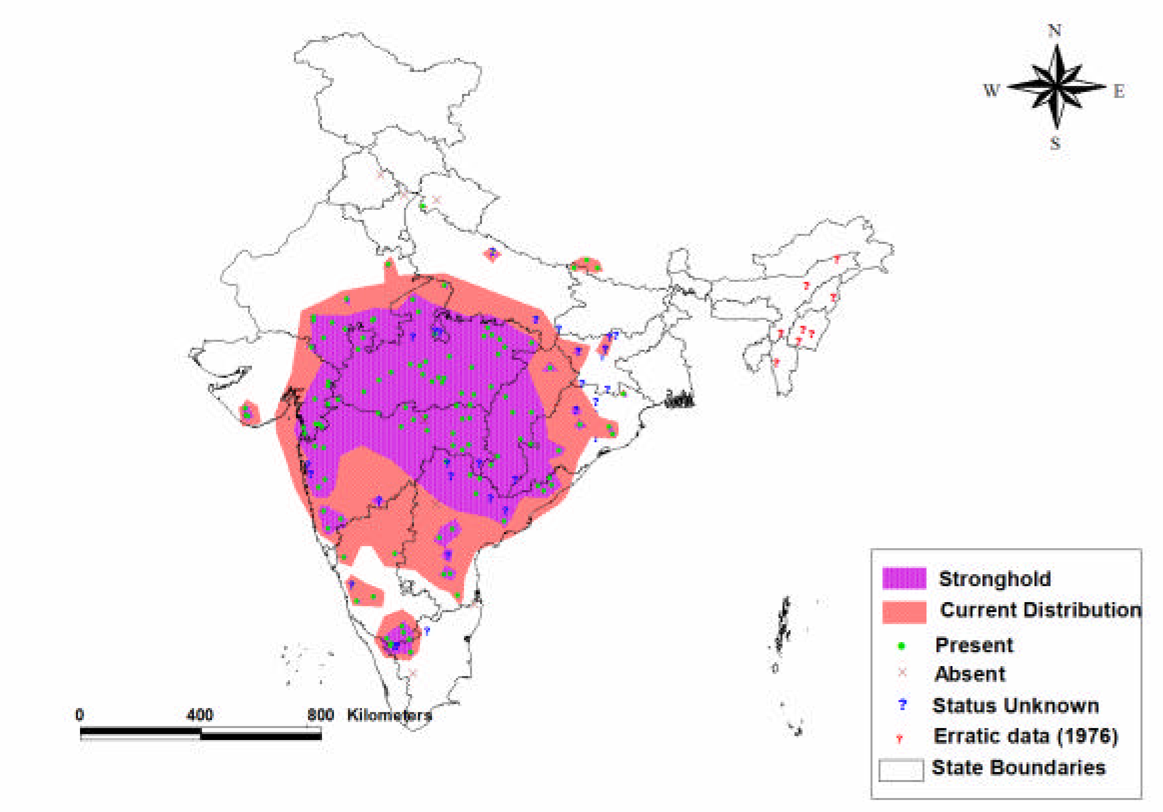


Fig. 7.2 Present distribution range of Four-horned antelope

near future to ascertain presence of the species.

While our data suggest that while the Four-horned antelope is mostly reported from protected areas, its presence is not very rare even in unprotected and slightly degraded forests.

7.4 Discussion

Questionnaire surveys are usually unable to provide results beyond mere presence of a species from individual sites. It is hence proposed that a further intensified effort is required to improve the data and hence provide better understanding of the present status of the distribution range of the Four-horned antelope.

The Four-horned antelope seems widespread throughout central and southern India. The only recent record of this species reported from outside India was in Parsa Wildlife Reserve, Nepal (Karan Rana, naturalist, *pers. comm.* 2002) and its neighbouring forests. This forest is in fact adjacent to Valmiki Tiger Reserve in India from where the species is reported. There are reports of Four-horned antelope from Lakhimpur-Kheri and Roorkee districts that may need further field verification. Jim Corbett (1953) reports a Four-horned antelope in one of his writings where, he saw one female with a fawn in the Sandni Gaga plains near the road connecting Kala-dhungi with Powalgarh. There was a recent report of a skull of Four-horned antelope being found from the Rajaji National Park (R. S. Chundawat, *pers. comm.*, 2005). Some old time shikaris (hunters) told us about having shot this animal in Haryana and Punjab, which, as of now can be termed as the northern most records of the Four-horned antelope. The species has never been reported from the Sindh region, including Pakistan (Roberts, 1977). It is worth noting though that over the years, the distribution range of the Four-horned antelope has shrunk and it is not reported any longer from Haryana, Punjab and Uttaranchal.

In the west, there seems to be a break in the contiguity of its distribution range where it is not found anywhere between Gir, and Vansda in South Gujarat and Vagheshwari forests (district Sabarkantha) in North Gujarat. Close analysis of the land use pattern of this area revealed that there are no contiguous forests left in this region. The grasslands and agricultural areas comprising most of the Deccan plateau in central and western Maharashtra, vast Gangetic plains that have been totally converted to cropland, and industrialized sections of eastern Gujarat break the continuity of natural distribution of the Four-horned antelope. Having said that, none of the historic records reviewed ever mentioned presence of the Four-horned antelope from the Gangetic plains. The strongholds of its existing populations are in the central provinces of India.

Although the Forest Atlas (Das Gupta, 1976) indicated presence of the Four-horned antelope from the north-eastern states of the country, there are no authentic records of their presence in the area. It is hence believed that Simlipal Tiger Reserve is probably the easternmost limit of the Four-horned antelope's distribution. As one goes further east, the forest type changes from tropical to temperate and moist evergreen, which is not the preferred habitat of the Four-horned antelope.

Mudumalai National Park marks the southern boundary of the Four-horned antelope's presently known distribution range, though some historic records reported its presence from the Palni hills further south. It was reported from areas adjacent to the Western Ghats, where it is found in many sites even today. These areas have patches of dry deciduous or mixed thorn forest and are therefore expected to be preferred by the Four-horned antelope.

Despite its vast distribution, the Four-horned antelope is not common in any of the sites from where it is reported. The best known population exists in our study area within Panna National Park, with a high density of about 2.7 animals km^{-2} (Chundawat, 2003; this study). Another site from where high number of sightings is reported is the Kumbhalgarh Wildlife Sanctuary in Rajasthan, where this species is supposedly the prime prey available to the carnivores (R. S. Chundawat, *pers. comm.*, 2003).

Data from various sites suggest a preference for dry deciduous mixed forests by this antelope. In places like Panna TR, Pench TR, Kuno WLS and Kumbhalgarh WLS that are dominated by dry forests; the Four-horned antelope population is evenly distributed (see section 8, Habitat Use). Sites that have different forest types (e.g. Kanha TR, Bandhavgarh TR, Nagarhole TR), the species is confined to the drier patches. This potentially puts them at a higher risk of getting poached, as often the drier patches circumvent the core of moist vegetation type (e.g. Nagarhole N.P.) and are more vulnerable in terms of protection. Hunting records from Madhya Pradesh mention frequent encounters with the Four-horned antelope where it could be found in 'sub-optimal' habitats comprising of dry and thorny vegetation. Chapter III (Habitat Use) and Chapter VI (Behavioural Ecology) discuss the crucial factors that are important for its survival, and it seems that the species survives in areas with rich floral diversity and sufficient undergrowth to provide cover to its young ones. It is probably the skill of avoiding detection that helps it survive even in areas where the protection levels are not as high, though in areas completely devoid of undergrowth, canopy and grass they would find it difficult to survive.

Fragmentation and loss of habitats is mostly responsible for the shrinking distribution range of the Four-horned antelope. Conversion of mixed forests to monoculture, excessive collection of Non Timber Forest Produce (NTFP), uncontrolled or widespread forest fires, improper management practices, and changing land use patterns contribute significantly to this fragmentation and loss of habitat. Systematic site occupancy surveys from the peripheral states of its distribution i.e. Bihar, Jharkhand, Uttar Pradesh, Uttaranchal, Karnataka, Rajasthan and Gujarat are needed for better assessment of the present status of Four-horned antelope in India.

7.5 Conservation

7.5.1 *Distribution*

The Four-horned antelope is mostly confined in the drier forests throughout its distribution range. It is found in both, dry deciduous as well as mixed thorn forests classified by Champion & Seth (1968). Within such dry deciduous forests, it is nowhere abundant although some areas have higher occupancy/density than others. On testing various variables ranging from elevation, forest type, availability of water, disturbance, protection level, slope and terrain type; it was learnt that none of these had significant effect on the distribution of Four-horned antelope. Detailed habitat study and mapping showed that Four-horned antelope has specialised habitat requirements— it prefers areas with high floral diversity (see Chapter III, Habitat Use). Data from Kuno Wildlife Sanctuary (Faiyaz Khudsar, *pers. comm.* 2006) showed that within a few years of removal of biotic pressure, the vegetation composition has changed and a better undergrowth including grass can now be seen. This change is complemented with a rapid increase in the encounter rate of Four-horned antelopes during the road transects that are conducted every year (Khudsar *et. al., in prep*).

Study of the phenology of the flora of Panna Tiger Reserve, which is a dry deciduous forest, reveals that there is a continuous availability of palatable fruits, flowers or pods throughout the year in areas with high density of Four-horned antelope (see *Annexure B*, phenology of flora of Panna Tiger Reserve). This is an important factor for a species which needs to forage on high protein diet (see Chapter III, Habitat Use; and Chapter VI, Behavioural Ecology). Being a cryptic animal preferring to hide and freeze rather than flee, Four-horned antelope needs good undergrowth cover which is just right to hide, and at the same time helps them keep an eye on the predator. Areas that have extremely thick understories are usually avoided (Chapter III, Habitat Use), and so are areas with no or minimal undergrowth. Sufficient overhead canopy is also sought at the same time whereas a completely closed canopy is avoided, probably because it results in thin undergrowth. Data collected from waterholes and zoos suggest that Four-horned antelope needs to drink water at regular intervals. Even in our study area, data suggest that they are often not too far from water, although the fact remains that there are few areas in Panna with acute shortage of water (see Fig. 3.5, Habitat Study). In general, the presence of the Four-horned antelope can easily be termed as an indicator of protection to the floral diversity and controlled grazing in a particular area.

The Four-horned antelope is the only antelope in India that depend solely on forests. Unlike all other antelopes that either prefer deserts, open grasslands, scrubs and savannahs or sometimes use forests (e.g. Nilgai), the Four-horned antelope is distinctly dependent on forest habitats (see Chapter III, Habitat Use). With fruits and pods constituting a major portion of its staple diet, the Four-horned antelope plays an important role in spreading the seeds and helping regeneration. Like most other ungulates, it is also known to regurgitate seeds and pile them at a place where it ruminates. The nitrification of soil by dung (Hobbs, 1996; Frank *et. al.* 2000) is another service provided to the forest ecosystem by the Four-horned antelope.

The Four-horned antelope is a small antelope and may not be a preferred prey of a large predator such as the Tiger. Data from the study site suggest that it constitutes about 2.8% of the diet of the Tiger (Chundawat *et. al.*, 1999, 2006), whereas in Pench National Park, it constituted 1.8% of the Tiger's diet. Leopards are not abundant in areas with high tiger density. It was observed that there was an overlapping niche between Leopards and the Four-horned antelope, where both avidly used the terrain adjacent to cliffs, though the extent of predation is unknown. Other sympatric predators, viz. Dhole, Leopard, Rock Python, Grey Wolf and Golden Jackal are also possibly among the potential predators of the species. In Nagarhole National Park, the Four-horned antelope constituted 0.4% of Leopard's diet and 0.7% of the Dhole's diet (Karanth & Sunquist, 1995). During four years of our study, we could only see the Dhole and Jackal either chasing or having made a kill of the Four-horned antelope.

The Four-horned antelope is known to survive even in sub-optimal habitats that provide it the necessary food and cover, though it thrives in areas where good grass and undergrowth are available. Within the peripheries of Panna National Park, there are some areas that have an extremely low density of the Four-horned antelope whereas in the area studied intensively, their populations are among the highest in the country. Habitat study and GIS based mapping of species richness indicates that it is the high floral species richness of trees (>20cm GBH) that has a significant role to play.

7.5.2 *Threats*

This study shows a shrinking distribution of the Four-horned antelope across the country. Sites where it was found a few decades ago report no recent sightings and there is considerable fragmentation in its distribution. In India, the Blackbuck, Nilgai and Chinkara have benefited largely by proliferation of agriculture, though Blackbuck and Chinkara in particular have been under pressure by conversions of grasslands into forests in areas that have been provided protection. It is understood that Nilgai occupies habitats ranging from dense forests to open savannah like forests (see Chapter III, Habitat Use), and are known for causing extensive crop damage (Qureshi, 1992). The Four-horned antelope on the other hand has a specific requirement where it seeks forest cover, forages on high protein diet and avoids areas with excess anthropogenic pressures. Its specialist nature makes it especially vulnerable to the threats of fragmentation of habitat, monoculture forest plantations, habitat alterations and to some extent poaching.

It is also observed that in areas where single prey species such as the Chital attain superabundance, there is a negative impact on specialist species such as the Four-horned antelope, Muntjac and Sambar. This change in the proportion of populations can be understood by comparing the densities of different species from areas with different Chital populations. Areas such as Panna Tiger Reserve, Satpura Tiger Reserve and Kuno Wildlife Sanctuary, not only have higher diversity of prey species but also have higher densities of specialist species than those in places like Kanha Tiger Reserve, Bandhavgarh Tiger Reserve, Nagarhole Tiger Reserve, Ranthambore Tiger Reserve and Bandipur Tiger Reserve. A systematic research is required to understand the complex dynamics of the prey-prey and prey-predator interrelationships.

Most Tiger Reserves in India are managed with a management objective of increasing the prey populations. Chital being one of the most common and hardy prey species found in the subcontinent, respond quickly to some of the common management practices employed in the country. This unintentional Chital-centric approach represents only one strand of the complicated web of the forest ecosystem. It is hypothesized that super abundance of single prey species such as Chital affects the prey biodiversity and its composition in one or all of the three possible ways:

(i) Habitat alteration: Herbivore populations play a major role in altering or modifying habitats (Hobbs, 1996; Frank *et. al.,* 2000; Suominen & Olofsson 2000; Daufresne & Loreau 2001; Rooney & Waller 2003; Goheen *et. al.* 2004). Super abundance of a single herbivore species such as chital and its effects on the natural vegetation composition in the Indian conditions are still unknown. Chital may act as a catalyst in changing the habitat composition of the area, but the long-term effects can not be evaluated unless baseline data is collected on the implications of these possible changes from areas with varying proportions of prey species.

***(ii) Artificial predator population*:** Increase in the overall prey biomass availability to predators due to super abundance of a single species may add an increased artificial predator population to the ecological unit. This artificial predator population can be a mix of the prime predators like the Tiger, Leopard and Dhole as well as meso-predators like the Golden Jackal. Predation by these artificial predator populations may not necessarily be selective towards species that are in super abundance, but a higher predator population would also mean an increased predation on the specialist species such as the Sambar, Four-horned antelope, Swamp deer and Muntjack, which might not be able to achieve densities as high as those of Chital and Wild pig. The Chital populations may sustain this increased predator pressure due to their large number but a downward spiralling trend can be hypothesized for other ungulate populations facing this situation.

***(iii) Competition with sympatric ungulates*:** Competition for food is a well-known phenomenon (Keesing 1998; Smit *et. al.* 2001; Mishra *et. al.* 2002; Gates *et. al.* 2005). Dependence on resources for forage and protection are the two major components regulating the ecology of animals. Increased competition between species may result in a progressively dominating single species system. Examples from places like Van Vihar National Park, Bhopal (*pers. obs.*) suggest that due to no significant predation pressures, the chital populations have exploded at the cost of those of Blackbuck, Chinkara, Nilgai, Sambar and Wild pigs. Extent of competition in being one of the factors responsible for this phenomenon of Chital Superabundance is unknown and needs further investigation.

7.5.3 *Recommendations*

Various strategies need to be devised for the conservation of the Four-horned antelope:

(i) Grass management: Wise management of grasslands is one of the most critical strategies one needs to follow. Extensive early burning of grasslands is a common practice in many protected areas to prevent fires as well as stimulate the grasses to regenerate (e.g. Chawdhry, 1997). This practice favours Chital to a great extent, but may affect species such as the Four-horned antelope adversely by removing the grass cover and regeneration of many palatable plants. Since the Four-horned antelope is found predominantly in dry deciduous forests which are quite vulnerable to the threats of fire, it is equally important to protect these areas from such wild fires. Moreover since most of the grasslands in the tropical forests are not climax stages, they need to be continuously managed for controlling invasion of non-palatable tree species such as Palash *Butea monosperma* and Teak *Tectona grandis*. Considering all this, it is recommended that a systematic plan be made for early burning of grasses. The plan may envisage burning of plots in existing grasslands for the purpose of regeneration and protection from fire. In areas that have higher floral regeneration of other shrub and tree species, such burning should be avoided and only fire lanes should be cleared. These fire lanes can provide the necessary protective cushion to different sections of a forest in case there is an event of forest fire.

(ii) Habitat amelioration and alteration: It is recommended that in areas with existing populations of Four-horned antelope, habitat alterations should be done with extreme caution, and that too only if inevitable. Backed with scientific data on existing forest composition, attempts should be made to minimize the impact of these alterations on specialist species such as the Four-horned antelope. Using the GIS based maps of floral species richness and site occupancy data of Four-horned antelope, areas with high occurrence of Four-horned antelope can be demarcated. It is also equally important to monitor these sites regularly over time in order to understand whether the vegetation composition is changing and thereby affecting the Four-horned antelope populations. Invasion of non-native species, drastic changes in tree species composition and conversion of grass cover into impenetrable shrubs are the potential threats to non-climax forest classes especially in the dry deciduous forests. The Four-horned antelopes thrive in areas that show improvement in vegetation diversity and grass cover. Considering the declining trends of its populations from most areas and reducing distribution range, areas may need to be earmarked for habitat alterations that would help the Four-horned antelope, and also many other sympatric species.

(iii) Managing Water availability: In the study area, there is a fairly even availability of surface water even during the summer. This is mainly due to some natural, perennial and many artificial water-bodies. We could observe a gradual increase in the number of sightings near waterholes during summer. Unlike most of the other antelopes, Four-horned antelopes have a relatively high dependence on water. Few waterholes recorded visits by over 13 groups of Four-horned antelope within the first six hours in the morning between 0600 hrs and 1200 hrs. It is recommended that availability of water should be ensured in areas with known populations of Four-horned antelope, especially during summer. In many protected areas, waterholes and check dams are created, often without careful consideration of existing availability of perennial waterholes. Moreover only few checkdams retain water till summer. GIS based mapping of the water availability is recommended so that access to water can be ensured to animals within about 2-4 km radius, wherever required. It is not advisable to create dams at the cost of salinization of large chunks of forests. Instead, less invasive methods such as Stepwise Gabian Structures can be made on seasonal streams to provide for perennial water availability. Artificial waterholes act as animal magnets in areas where there are no perennial waterholes or major streams. It is important to maintain and ensure availability of water in these artificial waterholes.

(iv) Controlling anthropogenic pressures: Four-horned antelope is known to inhabit areas that range from sub-optimal in terms of protection, to those that have been declared inviolate for anthropogenic activities. Due to its specific food choice, the Four-horned antelope does not cause any crop damage and hence enjoys a good reputation amongst farmers located in and around the forests. Among the main anthropogenic pressures, excessive grazing, commercial collection Non Timber Forest Produce (NTFP) collection and hunting are the most conspicuous.

a. Grazing: Excessive grazing devoids an area of good understorey and cover thereby compromising the antipredatory strategies of the Four-horned antelope (see Chapter VI, Behavioural Ecology). The Four-horned antelope fawns also depend on their ability to hide, and hence, are vulnerable to opening up of the understorey.

b. NTFP Collection: Commercial collection of NTFP is known to have adverse effect in the regeneration of flora in many regions (Shaanker *et. al.*, 2004; Bystrom, 2004). It is understood that people collect fruits prematurely in fear of their rivals plucking it before them. As a result not only do people get less money for the premature seeds and fruits, there is virtually no fruit or seed available for birds and animals, and the regeneration cycle of vegetation gets hampered as well.

c. Hunting: Four-horned antelope being a small animal has been hunted over the years opportunistically for meat. Its major distribution that is limited to dry deciduous forests exposes it to more biotic as well as human pressures. It is recommended that whilst grazing and NTFP collection needs to be controlled in areas with existing populations of the Four-horned antelope, proactive measures to control poaching are also bound to benefit the species in the long run.

d. Flagship and awareness: The Four-horned antelope is an indicator of high floral diversity, good grass and understorey cover, and protection. The dry deciduous forest that it inhabits is home to about 40% of the total available habitat to the Tiger (Wikramanayake *et. al.*, 1998). Its ancient lineage makes it an important component of the wild ungulates community. Being unique in having four horns and endemic to the Indian subcontinent, it is an important species. Since it is easily confused with the Muntjac, there is a possibility that it is either misidentified at or not reported from many sites. Careful management practices that are not invasive to the species inhabiting the dry deciduous forests are envisaged for long term survival of the Four-horned antelope. Awareness about this species, its importance and role in forest herbivore community, and access to information about the species to Park managers, decision makers and general public are amongst a few essentials for the species' long-term survival.

***(v)* Policy and legal:** The Four-horned Antelope is protected by Indian law and is listed in Schedule I of the Wildlife Protection Act, 1972. It is also listed in the Vulnerable category by the IUCN (Rahmani, 2001; Mallon, 2003). This category is assigned to species that are considered to be facing a high risk of extinction in the wild (Fig. 7.3).

***(vi)* Research:** Rahmani (2001) and Mallon (2003) recommend development of corridors, and research on population, range, biology and ecology of the species. The Four-horned Antelope was the least studied antelope in India so far. There are aspects that were beyond the scope of this research and need to be addressed in the future works:

- Site occupancy surveys throughout its historic and predicted distribution range.

- A thorough study on pattern of habitat use, home range and behaviour using telemetry
- Carbon dioxide (CO_2) isotope tests (Provenza, 1995) are proposed in the future with pellets collected from different seasons in order to obtain further information about its foraging preferences.
- Assessment of potential threats faced by its populations due to super-abundance of sympatric prey species.

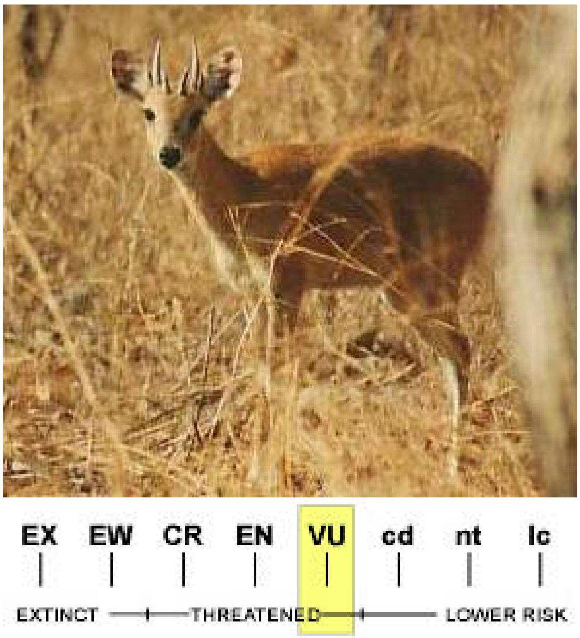


Fig. 7.3 IUCN categories for threatened species

(Ex= Extinct; EW= Extinct in wild CR = Critically endangered, EN = Endangered, VU = Vulnerable, cd = Conservation dependent, nt = Near Threatened, lc = Least concern)

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