THE ECOLOGICAL INTERACTION BETWEEN HABITAT COMPOSITION, HABITAT QUALITY AND ABUNDANCE OF SOME WILD UNGULATES IN INDIA

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ABSTRACT

The ecological interrelationships between the habitat composition, habitat quality and abundance of three wild ungulate species, *viz.* Chital (*Axis axis*), Sambar (*Cervus unicolor*) and Nilgai (*Boselaphus tragocamelus*) were investigated in three National Parks in India. The study sites differ in the structure and composition of the habitat and also occur along a rainfall gradient. The study incorporates a new approach of using forest compartments for gathering baseline ecological data. The significance of these compartments in serving as ecological bench-marks for monitoring habitat condition has been demonstrated. Toe-point transect, a modification of the point-intercept method has been extensively used to obtain rapid, reliable but coarse ecological data on ground and aerial cover and the results obtained are compared with those from the visual estimation method. Motorcycle and foot-based line transects have been used to obtain data on animal abundance. The significance of the results indicating that motorcycle transects are an efficient and reliable means of estimating the abundance of Chital and Nilgai, while foot transects provide more reliable estimates of Sambar abundance is discussed.

Data on 22 habitat variables were gathered in the summer and winter seasons from all the study sites and were statistically analysed using Generalized Linear Interactive Modelling (GLIM) procedures. The habitat requirements of the three ungulate species have been determined, which enhance our understanding of the complex herbivore-habitat relationships. Analyses of habitat selection, central to the understanding of animal ecology, has been done to understand the mechanisms which permit species to co-exist. The results indicate that the three species are ecologically separated and that resource partitioning is achieved primarily by habitat partitioning. Sambar, a forest ungulate, largely occurs in the forest-woodland habitats; Chital, a species of the habitat 'edge', occurs in the woodland-grassland habitats while Nilgai prefers the miscellaneous-open and grassland habitats. The three ungulate species together contribute more than 78% to the total wild ungulate biomass. This is presumably because these species are by nature generalist and are able to exploit the unpredictable resources more efficiently than specialist species. The differential biomass/rainfall relationships of three species observed in the study have been explained on the basis of habitat requirements and feeding strategies adopted by these species.

The ecological biogeography of the three ungulate species has been discussed and their ecological equivalents in Africa have been examined. The significance of above in enhancing our understanding of evolutionary biology is discussed. The study has shown that habitat composition is an all-important factor in large herbivore biology and that animal density may be used as an indicator of habitat quality.

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CHAPTER ONE

PROJECT ORIGINS, OBJECTIVES AND ORGANIZATION OF THE THESIS

1.1 PROJECT ORIGINS

The ideas about the present study originated in April-May, 1987 when I was working with Dr. John Mackinnon, who had come to the Wildlife Institute of India as a Food and Agriculture Organization (FAO) Consultant to initiate the setting up of a microcomputer-based wildlife database. This database is designed to provide an up-to-date assessment of the conservation status of the individual animal species, habitat types, biogeographic regions and the network of wildlife protected areas in India. The database system depends on the ability to predict which species are likely to occur in a particular locality and at what probable densities. The predictive ability of the database is based on the knowledge of the species' geographic distribution, habitat requirements and the typical density on the one hand and the habitat composition and quality of the locality in question on the other. At present, the predictive ability of the system is extremely crude both with respect to the presence/absence of a species in a particular area and its abundance. This is due to the fact that the specific habitat requirements of the major species have not been determined in a variety of habitat types in which they are known to occur. Secondly, there is a lack of appropriately standardised methodologies for the collection and collation of data.

It became obvious to me that the usefulness of the database could be enhanced only by focussing the attention towards answering of specific biological questions about the species. What are the key habitat requirements of a species and do they vary from one locality to another? Do detrimental factors like human habitations, heavy grazing by domestic stock, removal of fuelwood and lopping in a wildlife area affect the wildlife abundance by potentially lowering the habitat quality? Why does abundance of species vary both within and between localities? These questions can be only answered only on the basis of a comprehensive understanding of the interaction of various ecological parameters affecting the species at a particular locality. In order to gain an understanding of the complex herbivore-habitat relationships, I decided to study three ungulate species which have a wide range of geographic distribution and which could be studied in at least three different localities, differing in habitat composition and quality. A subsidiary but important aim of the present study is to explore the validity of using rapid methodologies for collection and collation of ecological data from large areas relatively quickly. Quite understandably, the information so generated would be coarse as compared to the precise but time and resource consuming measurements on habitat parameters. Nevertheless, it would be useful for the wildlife manager to plan interim management strategies and actions.

The relationship between the abundance and distribution of a species and the environmental conditions and population processes which determine them is central to the understanding of both ecology and

biogeography. Although it has long been recognised that abundance and distribution are intimately interrelated, the nature of this relationship has not been investigated systematically over the range of spatial scales from local populations to entire geographic ranges of species (Brown, 1984). The present study is an attempt to study the complex ecological relationships between the abundance and distribution of a species on one hand and the combination of many physical and biotic variables which influence them on the other.

1.2 OBJECTIVES

The specific objectives of the study can be summarised as follows:

1) To investigate and quantify the ecological interrelationships between the abundance of three ungulate species, *viz.* Chital (*Axis axis*), Sambar (*Cervus unicolor*), Nilgai (*Boselaphus tragocamelus*), major habitat components and factors causing destruction and degradation of habitat.

2) To study and explain the patterns of spatial distibution of the these species in localities of differing habitat composition and quality.

3) To explore the validity of using rapid methods for collection and collation of ecological data relatively quickly.

1.3 ORGANIZATION OF THE THESIS

The thesis is presented in eleven chapters. The first chapter deals with the project origins and objectives of the present study. The second chapter contains the description of the three study sites along with a comparative assessment of these sites in terms of major physical, floral, faunal and biotic attributes. Chapter Three contains the description of some key aspects of the biology of the study animals relevant to the understanding of their ecology. Chapter Four is on the methodology of the field work adopted in the study. A new approach has been described and used for monitoring of wildlife habitats in India using the existing forest compartment network. Rapid ecological methods for collection of field data used in the study are described and compared. Chapter Five contains the introduction to the herbivore-habitat relationships studied in the three study sites. The general methods pertaining to collection of data on habitat variables and analyses of data using Generalized Linear Interactive Modelling (GLIM) procedures are described. Chapters Six, Seven and Eight contain the results and discussion on the herbivore-habitat relationships in Tadoba, Sariska and Kanha National Parks respectively. Aspects of habitat management for the ungulate species especially those relating to management of water, fire and grasslands have been discussed. Chapter Nine contains a synthesis of the herbivore-habitat relationships described in Chapters 6-8. A comparison of the two data analyses techniques, Canonical Correspondence Analysis (CCA) and GLIM has also been made. Chapter Ten is on the density and biomass of ungulates. A comparison of the density and biomass of the

ungulate species both within and between the study sites has been made and data from this study is compared with other similar studies in both Asia and Africa. Relationships between the large herbivore biomass and rainfall have been studied in wildlife reserves in India. Chapter Eleven contains a general discussion on the study. The ecological biogeography of the three ungulate species is discussed and their ecological equivalents in Africa have been examined. Management implications of the present study are also discussed. References and Appendices are cited after Chapter Eleven.

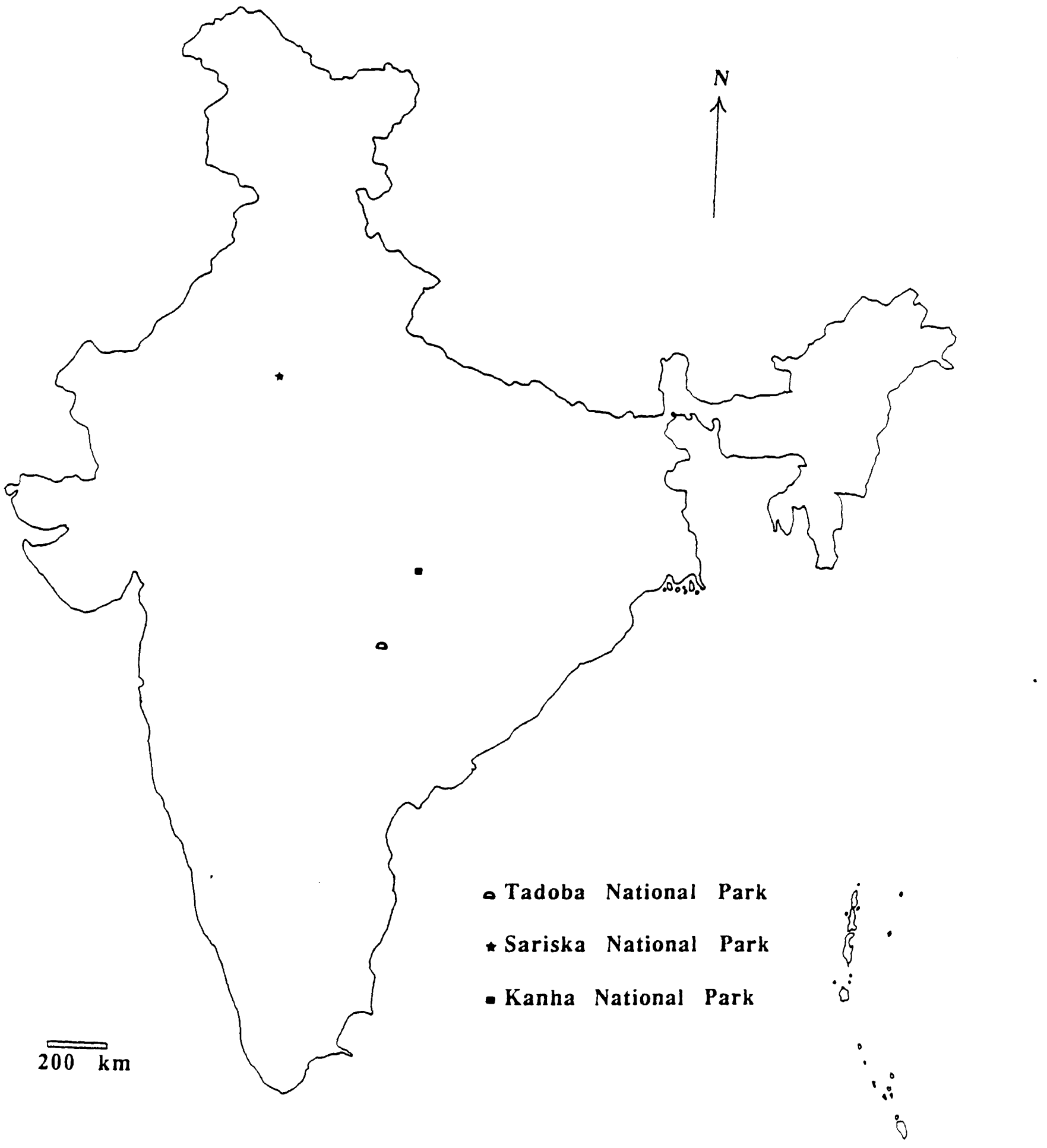
CHAPTER TWO

THE STUDY AREAS

2.1 INTRODUCTION

The objectives of the study demanded that I investigate the three ungulate species, *viz.* Sambar (*Cervus unicolor*), Chital (*Axis axis*) and Nilgai (*Boselaphus tragocamelus*) in a number of field sites, offering a range of ecological conditions which could affect the potentially fragile herbivore-habitat relationships. However, in view of the need to collect the field data from a site in different seasons and limited time available for doing the field work, I had to restrict the number of sites to three. These sites are Tadoba National Park, Sariska National Park and Kanha National Park (Fig. 2.1). The study sites occur in different bio-geographical zones, differ in their basic habitat composition and offer a range of ecological conditions to which the three ungulate species under investigation respond differently. The sites will, from now on be referred to as TNP, SNP and KNP respectively. TNP has Tropical Dry Deciduous Forest dominated by *Tectona grandis* and its associates. SNP has Tropical Dry Deciduous Forest dominated by *Boswellia serrata-Anogeissus pendula* and Tropical Thorn Forest having *Acacia-Zizyphus* communities. KNP has Tropical Moist Deciduous Forest dominated by *Shorea robusta* along with mixed forests and meadows. These sites also occur along a rainfall gradient with SNP being on the drier end of the spectrum with 755 mm annual rainfall to KNP having 1375 mm of annual rainfall and TNP falling in the intermediate with 1169 mm of annual rainfall.

Fig. 2.1 MAP OF INDIA SHOWING THE LOCATION OF STUDY AREAS



One of the study sites (TNP) was used as a major field site on account of its small size (116 km^2) and a good network of roads, both factors ideally suited for the intensive nature of the field work. The other two sites SNP and KNP were used as minor sites, the difference between major and minor sites was in sampling intensity, which varied from 15-25% in the minor sites to nearly 50% in the major site. There are some similarities also in the three sites. All of them have a long history of conservation management and enjoy a higher legal status, being gazetted National Parks. SNP and KNP are also included in the special category of Tiger Reserves under the Project Tiger scheme of the Government of India. The salient features of the three sites are given in Table 2.1.

Long term meteorological data directly from the study sites are not available as records are not maintained systematically by the Park authorities. However, in the district headquarters in which these sites occur, the Indian Meteorological Department (IMD) maintains meteorological stations. I obtained the raw meteorological data from the IMD for a 16 year period from 1969 to 1984 and analysed them to study the trends in various climatic variables. The study areas lie within 50 km radius of the district headquarters and the data can be said to a very large extent be the representative of the conditions inside the study areas. Ecoclimatic maps, a concept introduced by Pandeya *et al.* (1977) to describe the mean total climate of a place in relation to soil and vegetation, have been prepared for the three study areas. Climatic water balance, a concept put forward by Thornthwaite and Mather (1957) has also been computed for all the study sites.

Table 2.1 Salient features of the three study areas

Attribute	**Tadoba NP**	**Sariska NP**	**Kanha NP**
Area	116.5 km^2	298 km^2	940 km^2
State	Maharashtra	Rajasthan	Madhya Pradesh
Biogeograhic unit	6B Chota Nagpur	4B Guj.-Rajputana	6E Southern Plains
Legal Status	National Park	National Park	National Park
Special category	None	Tiger Reserve	Tiger Reserve
Altitude	212-355 m	540-777 m	506-877 m
Temperature	2^0-48^0 C	4^0-48^0 C	0^0-41^0 C
Annual rainfall	1170 mm(628-1547 mm)	755 mm(478-1164 mm)	1375 mm(927-1805)
Rainy days	57 (42-77)	42 (29-51)	68 (51-84)
Vegetation type	TDD	TDD, TTF	TDD, TMD
Major tree species	*Tectona grandis* Miscellaneous spp.	*Anogeissus pendula* Miscellaneous spp.	*Shorea robusta* Miscellaneous spp.
Major shrub species	*Dendrocalamus strictus* *Helicteres isora*	*Capparis, Zizyphus* spp. *Balanites aegyptiaca*	*D. strictus* *Flemingia semialata*

Attribute	Tadoba NP	Sariska NP	Kanha NP
Major grass *spp.*	*Aristida, Heteropogon* spp.	*Choloris, Aristida* spp.	*Saccharum,Heteropogon, Themeda,Dicanthium* spp.
Major predator	Tiger, Leopard	Tiger, Leopard	Tiger, Leopard
Large herbivores	Gaur, Sambar,Chital Nilgai, Barking deer	Sambar, Chital, Nilgai, Chousingha	Barasingha, Gaur, Sambar, Chital, Nilgai,Black Buck
Habitations	No	Yes	Yes
Management Plan	No	No	Yes
Annual visitation	>50,000 Tourists	>30,000 Tourists	>40,000 Tourists
Annual budget	Rs40,000,000	Rs45,000,000	Rs85,000,000

The abiotic environment plays a crucial role in determining the characteristics of the mature vegetation of terrestrial communities (Holdridge, 1947). Actual Evapotranspiration (AE), defined as precipitation minus runoff, minus percolation (Sellers, 1965) is qualitatively related to the amount of vascular plant activity in a terrestrial environment (Major, 1963). AE can also be defined as the amount of water actually entering the atmosphere from the soil and the vegetation during any period of time, i.e., the evaporation plus transpiration. Thus, AE is a measure of the simultaneous availability of water and solar energy in an environment during any given period of time (Rosenzweig, 1968). Potential Evapotranspiration (PE) may be defined as the amount of evaporation that could occur if the soil of a large area having 'vegetation typical of the surroundings' (Sellers, 1965) were kept constantly wet, i.e., at or above field capacity. The PE is the solar energy estimate used in calculating AE and the AE can be used as an environmental variable for predicting production. Thornthwaite and Mather (1957) described a method by which AE could be calculated from a knowledge of the latitude of a place, its mean temperature, month by month, and its precipitation, month by month. I used this method to estimate the AE in the three study areas. Thornthwaite (1944) introduced the term 'Climatic Water Balance' and defined it as the difference between the income of water from precipitation and outflow of water by evapotranspiration. It is a climatic balance since the quantities precipitation and evapotranspiration are active factors of climate. From a comparison of the seasonal march of precipitation with the evapotranspiration, the magnitude of other related moisture parameters such as the water deficit, water surplus, soil storage are determined. Water deficit in any month is the amount by which the

actual and potential evapotranspiration differ in that month. Water surplus is any excess water remaining after the soil moisture storage has reached its water holding capacity. Soil storage is the moisture retained in the soil after a given amount of accumulated potential water loss has occured. Accumulated potential water loss is a measure of the potential water deficiency in a soil. The computation of these variables for the three study sites is shown in Appendix I-III.

Pandeya *et al.* (1977) introduced the concept of 'Ecoclimate' and produced a ecoclimatic classification of India based on the interrelationships between various climatic and biotic variables. Ecoclimate is defined as the mean total climate of a place considered in relation to the soil and vegetation components of that place. Pandeya *et al.* (*op. cit.*) modified the concept of climatic water balance (Thornthwaite, 1944) to that of 'water status' and defined it as follows:

$$WS=P-PE+St$$

where P is the annual precipitation in mm, PE is the annual potential evapotranspiration in mm and St is the soil water storage in mm.

A detailed description of each of the sites is as follows:

2.2 TADOBA NATIONAL PARK

2.2.1 GENERAL, LOCATION AND TOPOGRAPHY

Tadoba National Park, named after the legendary Gond tribal chief, 'Taru', who was killed by a Tiger in this area, was a shooting block till the

beginning of this century (Choudhary, 1986). In 1935, the area was declared a wildlife sanctuary. Subsequently, in 1955 it was elevated to the status of a National Park. TNP has an area of 116.5 km^2 and is located at a distance of 198 km from Nagpur, in the civil district of Chandrapur, Maharashtra State. It lies between 79^0 15' to 79^0 24' East Longitude and 20^0 17' to 20^0 24' North Latitude. The terrain of the Park is undulating and hilly and the elevation decreases from North to South. The altitude varies from 200 m to 285 m and the highest point is 355 m. The centrally situated and picturesque Tadoba lake, having an area of 120 ha and surrounded by evergreen groves of Jamun (*Syzygium cumini*) attracts both the wildlife and tourists during the hot summer months.

2.2.2 GEOLOGY AND SOILS

The important geological formation occuring in this area is Vindhyan sandstone which consists of sandstone, shale and limestones. The shale is intercalated with limestone. The prominent rocks are the the fine grained vitreous sandstone with a uniform or splashed pink colour, brownish sandstone, purplish shale and quartzite. The soil derived from the Vindhyan sandstone is mainly sandy-loam. It is well drained and suitable for tree growth. It bears good quality Teak (*Tectona grandis*) forests with an understorey of Bamboo (*Dendrocalamus strictus*).

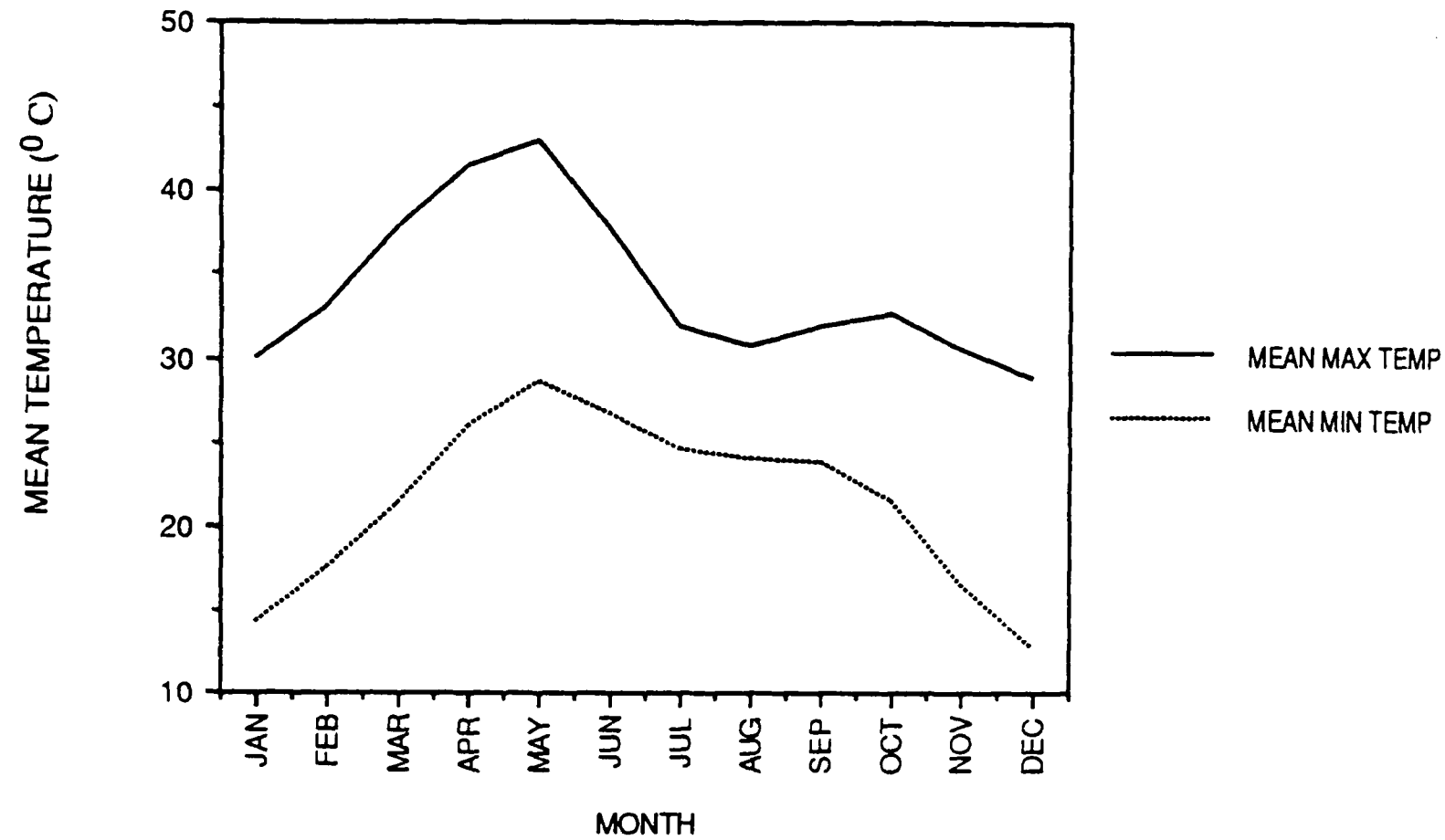
2.2.3 CLIMATE AND THE SEASONAL CYCLE

The area has a sub-tropical climate with 3 distinct seasons; summer, monsoon and winter. The summer season begins in March and continues

till the end of June. It becomes extremely hot in May-June when the temperature may reach 48^0 C. The monthly variations in mean maximum and mean minimum temperatures along with the variations in mean rainfall are shown in Fig. 2.2. The rainy season is sultry and humid and occurs between July-October. The South-West monsoon brings nearly 90% of the total annual precipitation. Most of the rainfall occurs in the months of June through October, winter rains in December-January are sometimes heavy. The winter season begins in November and continues till the end of February. The winters are not very severe although the night temperature may drop to 2^0 C during December-January. The trends in annual rainfall and total rainy days from 1969 to 1984 are shown in Fig. 2.3. Mean annual rainfall is 1375 mm (range 927-1805 mm) and the number of rainy days in a year are 57 (range 42-77).

The ecoclimate of Tadoba and the climatic water balance calculated on the basis of the concepts introduced by Thornthwaite and Mather (1957) and Pandeya *et al.* (1977) is shown in Fig. 2.4. It is evident that in Tadoba the water status i.e. annual precipitation minus potential evapotranspiration plus soil water remains on the negative side from January through June, becomes highly positive from July through September and then again weakly negative from October through December. In other words, except for the monsoon period there is a moderate to heavy deficiency of water in Tadoba. This presumably has a profound effect on the net above ground primary production (NAAP), which in turn influences the carrying capacity of large herbivores.

Fig. 2.2 Monthly variations in (1) Mean maximum temperature (^{0} C) and Mean minimum temperature (^{0} C) and (2) Mean monthly rainfall (mm) in Tadoba National Park



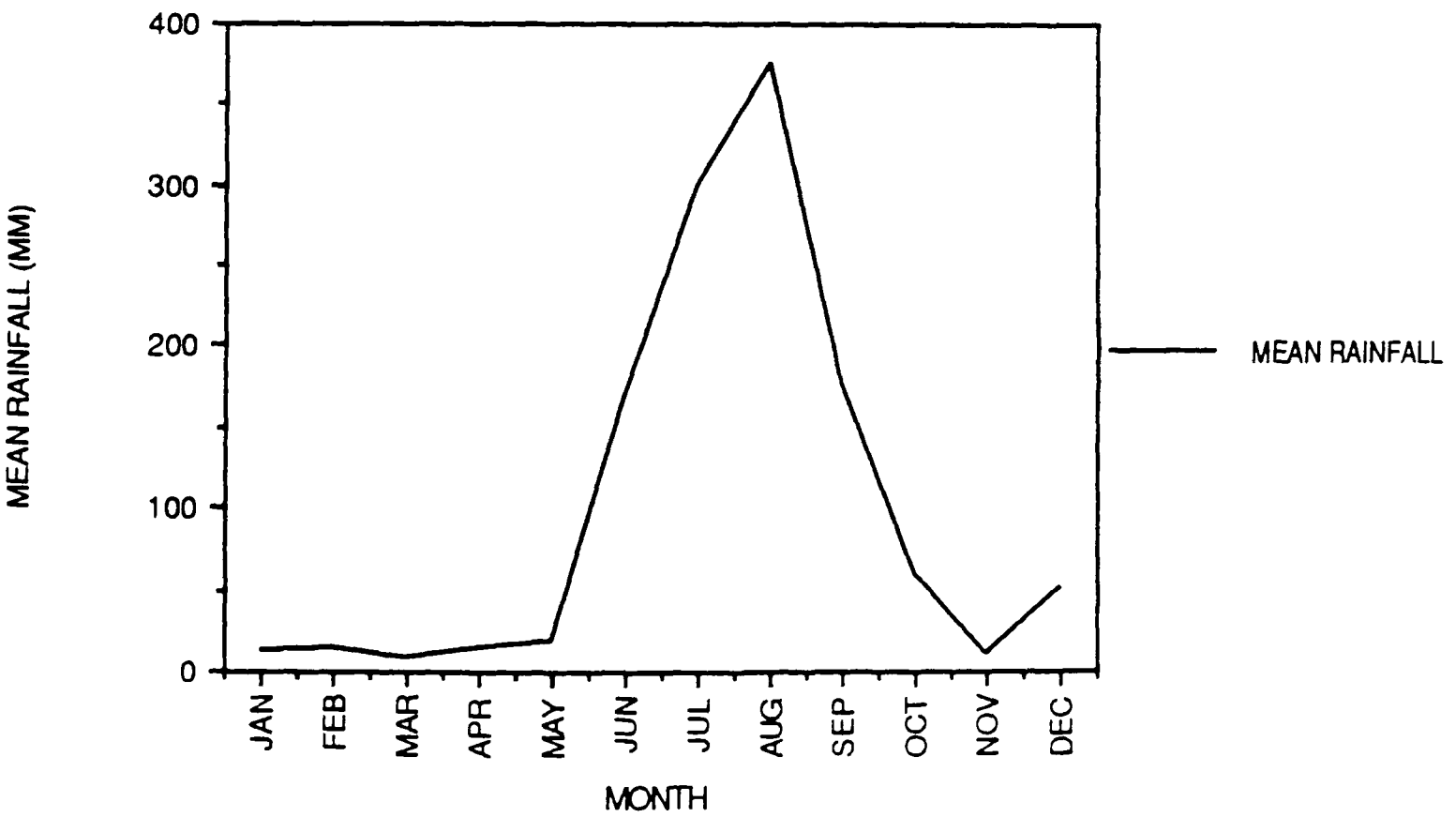


Fig. 2.3 Trends in (1) annual rainfall (mm) and (2) total rainy days in Tadoba National Park 1969-1984

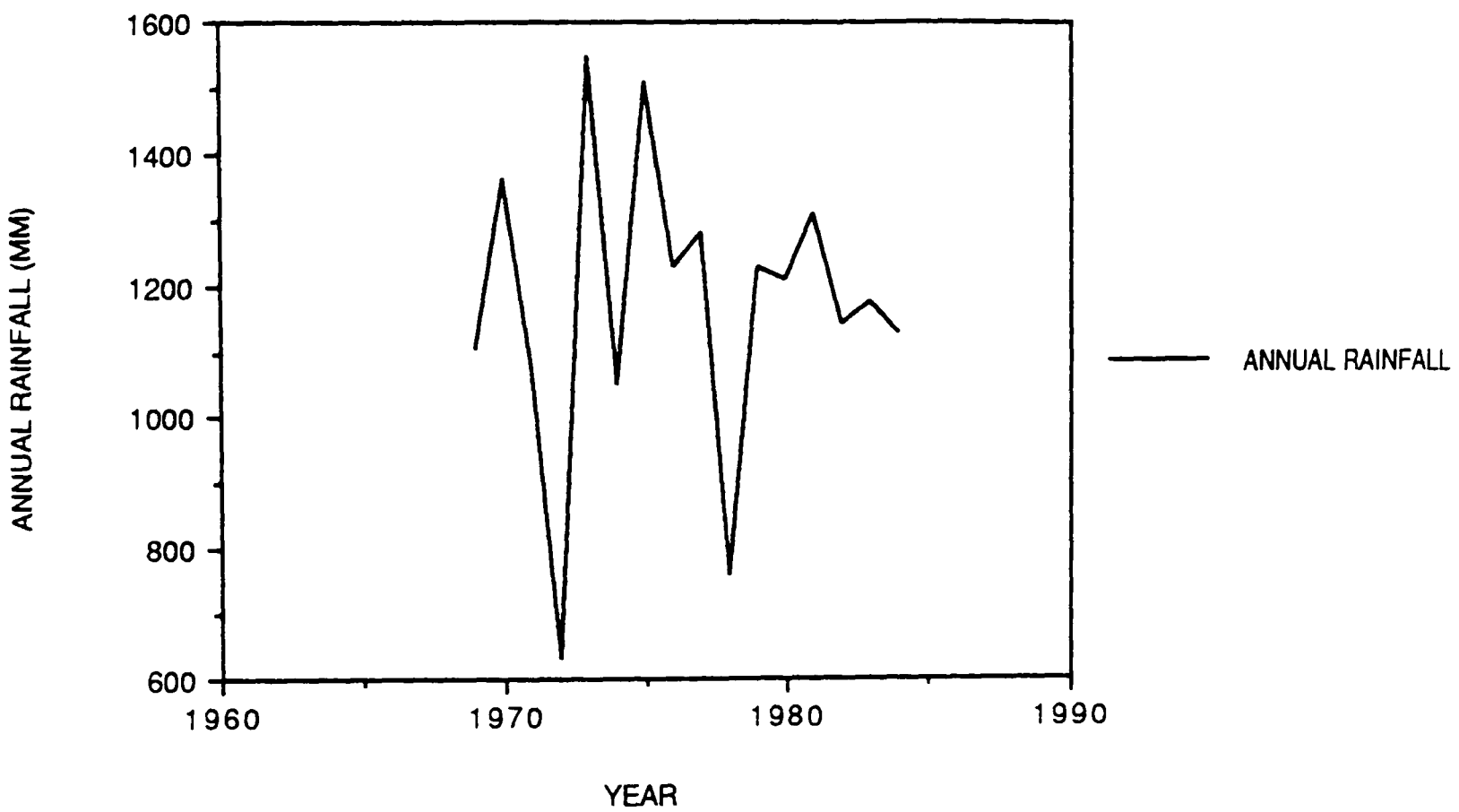
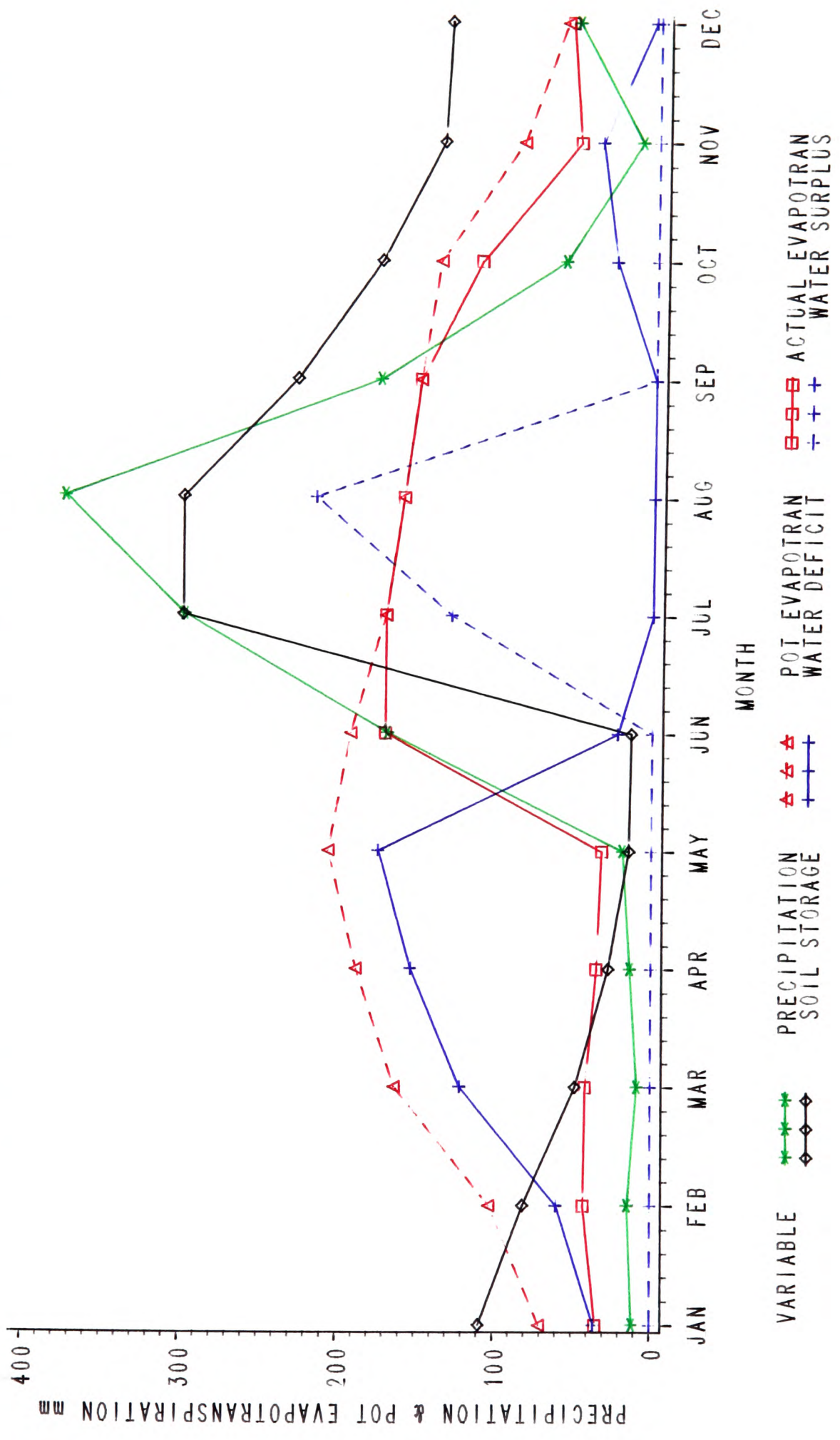


Fig.2.4 ECOCLIMATE AND CLIMATIC WATER BALANCE IN TADOBA



2.2.4 VEGETATION

Champion and Seth (1968) have classified the vegetation of TNP as 'Southern Tropical Dry Deciduous Forest'. The forests are characterized by a high proportion of Teak, commercially a very valuable timber species. A habitat classification map of the study area did not exist and so on the basis of the information contained in forest compartment inventories I prepared a habitat classification map showing the 5 dominant habitat types (Fig. 2.5). Ground truthing was done during the field surveys of the compartments to improve the accuracy of the classification. The habitat types in TNP and their proportions are given in Table 2.2 and are described below.

A) TEAK (*Tectona grandis*)

Forest compartments having pure stands of Teak comprising more than 80% of the canopy cover, fall in this category. It forms 16.5% of the habitat and occurs around Tadoba lake. The natural regeneration of Teak is both by coppice as well as seeds and is extremely good. The understorey is scarce under pure teak forests and mainly comprises small patches of Bamboo (*Dendrocalamus strictus*).

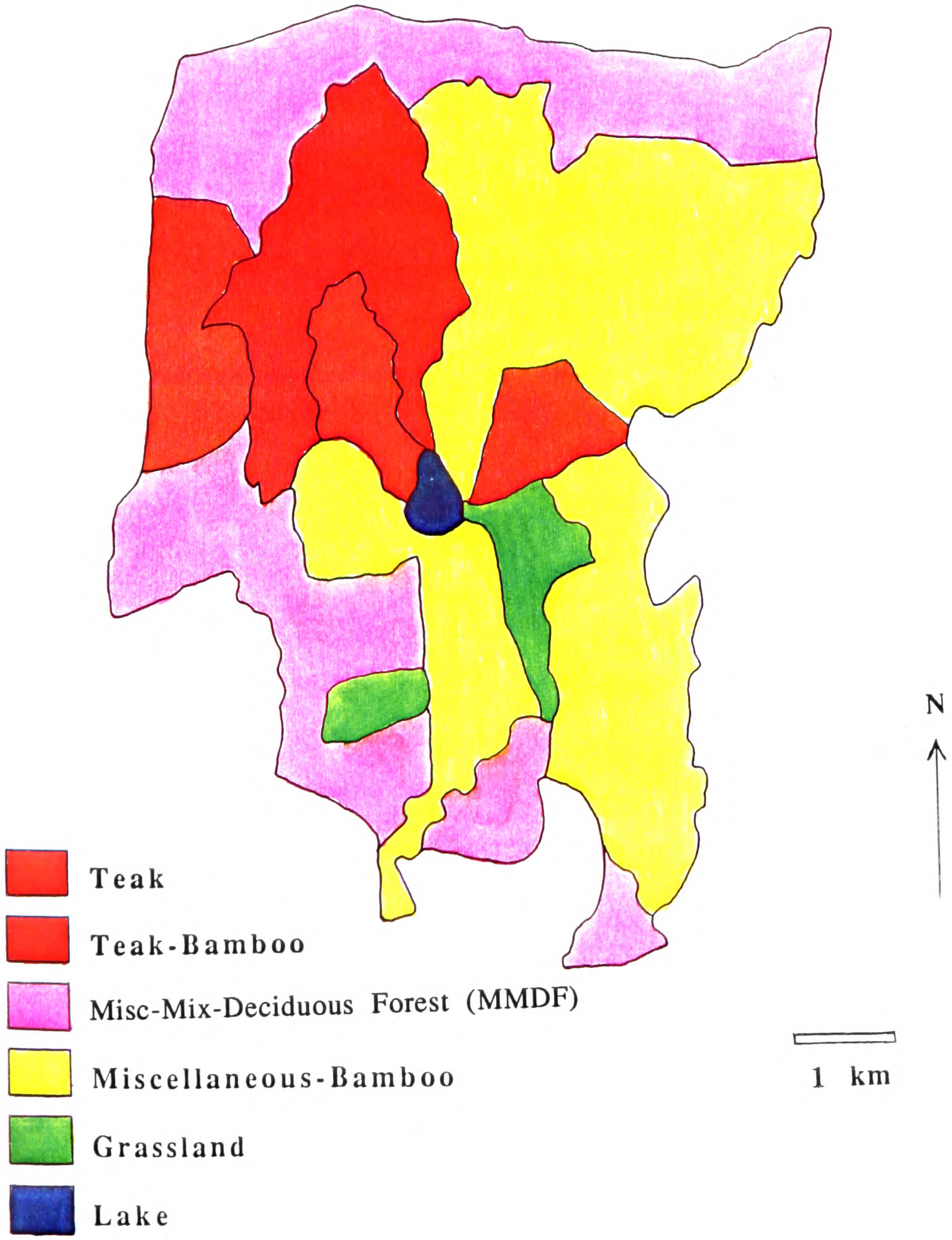
B) TEAK-BAMBOO

This habitat type forms 18.5% of the habitat and has Teak in the top canopy between 60 to 80% while bamboo forms both the middle as well as ground layer. It provides cover and fodder to wildlife and constitutes an important zone for wildlife. The bamboo has a very diffused appearance and its height varies from 0.5-3 m.

Table 2.2 Habitat types in the three study sites

Site	Habitat type	Area (km^2)	Percent of area
Tadoba			
	Teak	19.2	16.5
	Teak-Bamboo	21.5	18.5
	Miscellaneous mixed dry deciduous forest (MMDF)	36.1	31.0
	Miscellaneous-Bamboo	35.0	30.0
	Grasslands	4.7	4.0
Total		116.5	100.0
Sariska			
	Anogeissus	28.3	9.5
	Boswellia	13.4	4.5
	Anogeissus Mix	83.4	28.0
	Boswellia Mix	56.6	19.0
	Miscellaneous mixed dry thorn forest (MDTF)	116.3	39.0
Total		298.0	100.0
Kanha			
	Sal	169.2	18.0
	Sal-Mixed-Bamboo	241.6	25.7
	Miscellaneous mixed dry deciduous forest (MMDF)	150.4	16.0
	Misc-Mixed-Bamboo	233.1	24.8
	Grasslands	111.9	11.9
	Habitations	33.8	3.6
Total		940.0	100.0

Fig. 2.5 A HABITAT CLASSIFICATION MAP OF TADOBA NATIONAL PARK



C) MISCELLANEOUS MIXED DRY DECIDUOUS FOREST (MMDF)

This habitat type forms 31% of the habitat area and contains a large number of associates of Teak in varying proportions. The top canopy is relatively open as compared to the previous two categories and Bamboo is largely absent in this habitat type. The mixture contains *Terminalia tomentosa, Anogeissus latifolia, Madhuca indica, Diospyros melanoxylon, Adina cardifolia, Pterocarpus marsupium, Salmalia malabarica, Lagerstroemia parviflora, Schleichera trijuga, Xylia xylocarpa* and *Chloroxylon swietenia.* The understorey consists *Cleistanthes collinus, Buchanania lanzan, Aegle marmelos and Lannea grandis.* It occurs along the periphery of the Park and is subjected to illicit grazing by livestock from adjoining villages.

D) MISCELLANEOUS-BAMBOO

This habitat type forms 30% of the habitat area and comprises Teak and its associates in the top canopy and bamboo in the middle and ground layer. The habitat type differs from the MMDF habitat type because of the presence of bamboo, whose seedling form thick mats on the ground. *Helicteres isora, Achyranthes aspera* and *Calycopterus floribunda* also occur in the understorey. This type occurs in the Northwestern part of the Park and supports good wildlife.

E) GRASSLANDS

The grasslands which form 4% of the habitat are of two types: Plateau grasslands and Valley grasslands. Edaphic factors are responsible for the different species composition in the two types of grassland. The former occur on plateaus and moderate slopes with boulders and poor soils and are dominated by coarse and dry grasses of mainly *Dicanthium-Imperata* community, seldom reaching a height of more than 1.5 m. The valley grasslands are found on good and well drained soils, usually around old village sites and comprise *Themeda, Saccharum, Heteropogon* and *Bothriochloa* spp. and often grow more than 3 m in height.

2.2.5 PALATABILITY OF THE VEGETATION

The amount of palatable forage available in TNP has increased since the gregarious flowering of Bamboo in 1982. As no silvicultural treatment has been given to the bamboo clumps, it has not gained in height and has become bushy in appearance. Bamboo shoots are plentiful at the browse level 0.5-2 m for herbivores. However, beside bamboo the shrub layer has little to offer during the summer months. The plateau grasslands do not possess palatable grasses but the valley grasslands do provide green and palatable grasses in all seasons. The seasonal fruits of *Syzygium cumini, Madhuca indica, Emblica officinalis, Zizyphus xylocarpa* and *Ficus glomerata* are eaten by a large number of species, including man.

2.2.6 MAMMALIAN FAUNA

There are 37 species of Mammals which have been checklisted in this area. Gaur (*Bos gaurus*), Sambar (*Cervus unicolor*), Chital (*Axis axis*), Nilgai (*Boselaphus tragocamelus*), Barking deer (*Muntiacus muntjak*), Four horned antelope (*Tetracerus quadricornis*) and Wild boar (*Sus scrofa*) are the ungulate species in the area. The carnivores found are Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Hyaena (*Hyaena hyaena*), Wild dog (*Cuon alpinus*), Jungle cat (*Felis chaus*) and Palm civet (*Paradoxurus hermaphroditus*). Sloth bear (*Melursus ursinus*), Mouse deer (*Tragulus meminna*) and Common langur (*Presbytis entellus*) also occur in the area. The Tadoba lake contains the Indian Marsh Crocodile (*Crocodilus palustris*).

2.2.7 HUMAN SETTLEMENTS AND GRAZING CAMPS

There are no villages inside the study area. However, more than 100 villages exist within a distance of 10 km from the Park boundary. Cattle from these villages illegally enter the Park and compete with wildlife for fodder and water resources. People from adjacent villages also enter the park for collection of Mahua (*Maduca indica*) flowers and Tendu (*Diospyros melanoxylon*) leaves and often cause disturbance to wildlife.

2.3 SARISKA NATIONAL PARK

2.3.1 GENERAL, LOCATION AND TOPOGRAPHY

Sariska National Park, nestled in one of the oldest hill ranges in India, the

central Aravalli was once a shooting block of the Maharajah of Alwar (Sharma and Arya, 1981). It became a wildlife sanctuary in 1955 and was elevated to its present status in 1982. SNP has an area of 298 km^2 and is located on the Delhi-Jaipur State Highway at a distance of 198 km from Delhi and 108 km from Jaipur, in the civil district of Alwar, Rajasthan. It forms the core zone of the 800 km^2 of Sariska Tiger Reserve. The major feature of the area is the funnel shaped Sariska valley, running from North to South, with its broad end at Sariska, tapering into a narrow valley at Kalighati. The valley is bounded by the Kankwadi plateau to the West and Kiraska plateau in the East. The highly dissected topography consists typically of steep sided rocky plateaus divided by narrow valleys. The altitude varies from 540-770 m and the highest point is 777 m.

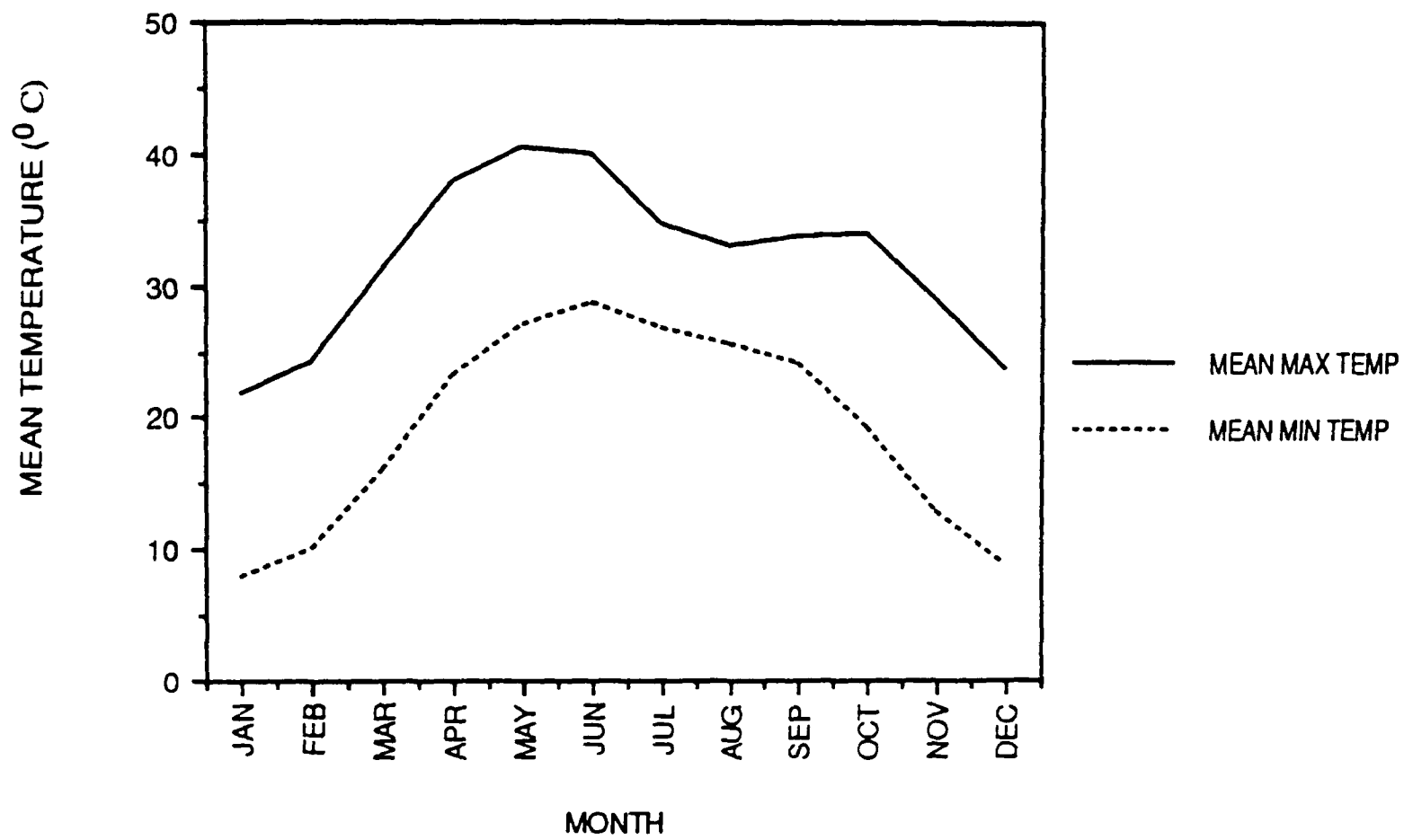
2.3.2 GEOLOGY AND SOILS

The area is occupied by the Pre-Cambrian rocks of the Delhi and Aravalli systems and comprise of quartzite, conglomerates, grits, limestone, granite and schists. A reserve of about 5.2 million tonnes of copper ores with 1% copper is indicated in and around the study area. The ancient crystalline and metamorphic rocks are generally covered by red sandy soils which are poor in nitrogen, phosphorous and humus. In contrast to the hilly areas, the plains and the valleys have better quality soils. On the slopes, the soil is sandy to sandy-loam, shallow and covered with boulders. The soil on the plateaus is sandy-loam to loam, shallow and mixed with gravel and boulders. In depressions and along stream banks the soil is clayey-loam to clayey and is fairly deep. In general, the soils support poor quality forests.

2.3.3 CLIMATE AND THE SEASONAL CYCLE

The area has a sub-tropical climate characterized by distinct summer and winter, small monsoon period and a short spring. The summer season begins in early April and it becomes progressively hotter. May and June are very hot months and 'loo', a feature generated by the hot westerly winds blow throughout the day. These have a very dessicating effect on plant and animal life. The hottest month is June when temperature may reach 48^0 C. The monthly variations in the mean maximum and mean minimum temperatures and mean rainfall are shown in Fig. 2.6. Monsoon arrives late June/early July and intermittent showers continue till September. After a short spell of hot weather in October, the winter season commences. December and January are the cold months when the night temperature falls to 4^0 C. The winters are not very severe and winter showers are rare but frost does occasionally occur in the Sariska valley. The trends in annual rainfall and total rainy days from 1969-1984 are shown in Fig. 2.7. Mean annual rainfall is 755 mm (range 478-1164) and the number of rainy days in a year are 42 (range 29-51). It appears that there has been a gradual decline in annual precipitation in Sariska which may be related to loss in forest cover on the Aravallies. The ecoclimate of Sariska and the climatic water balance is shown in Fig. 2.8. The water deficiency begins to manifest itself from the month of February onwards and reaches its peak in May. April, May and June are the months when the most severe water deficiency occurs. Only in the months of July-August is the water balance is positive, while from August onwards the water deficiency manifests itself again. The prolonged period of water deficit has a significant effect on the management of water resources for the wildlife and water has to be artificially provided during the long dry season.

Fig. 2.6 Monthly variations in (1) Mean maximum temperature (^{0} C) and Mean minimum temperature (^{0} C) and (2) Mean monthly rainfall (mm) in Sariska National Park



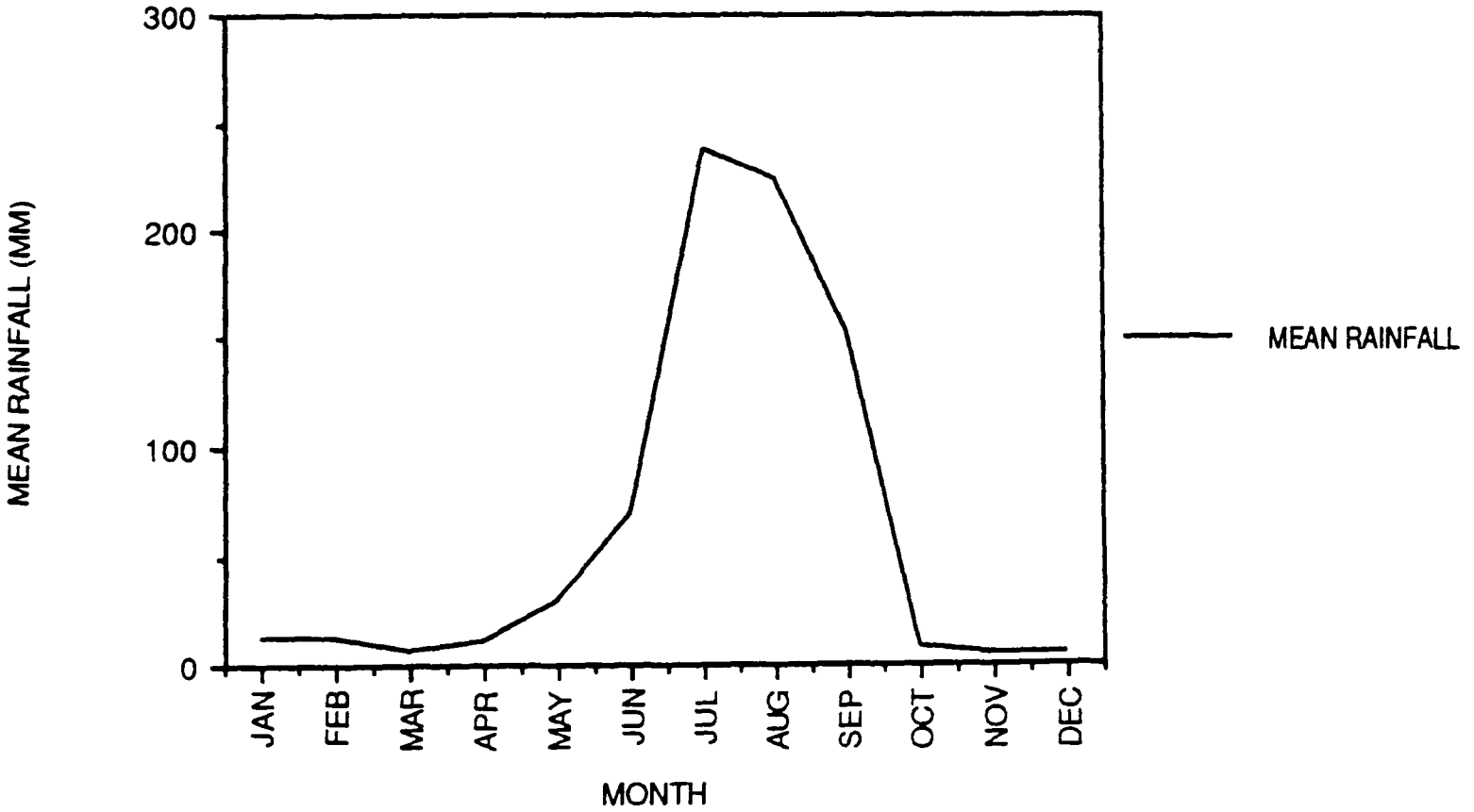
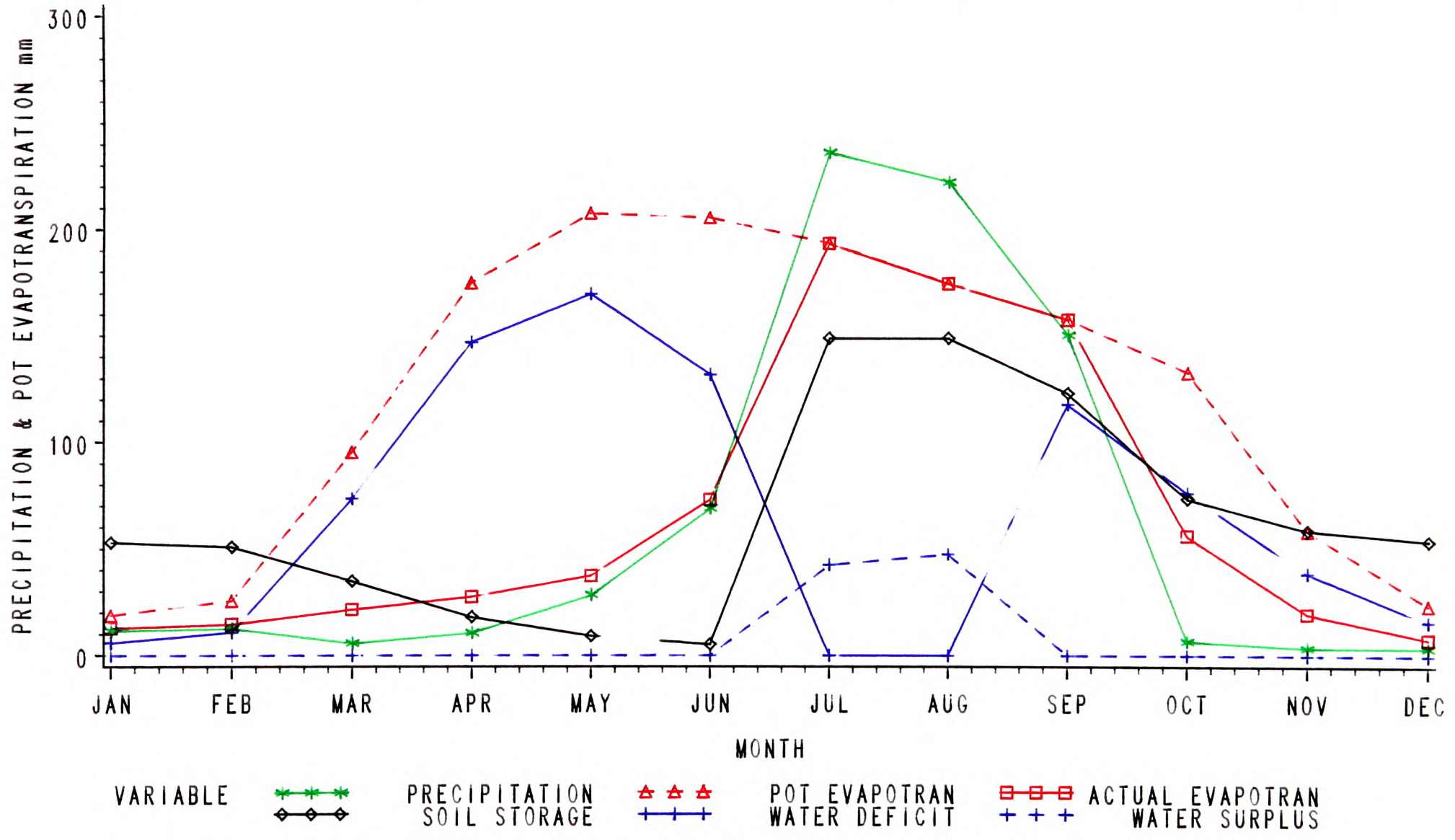


Fig. 2.7 Trends in (1) annual rainfall (mm) and (2) total rainy days in Sariska National Park 1969-1984



Fig.2.8 ECOCLIMATE AND CLIMATIC WATER BALANCE IN SARISKA



2.3.4 VEGETATION

Champion and Seth (1968) have classified the vegetation types of SNP as Tropical Dry Deciduous Forest (TDD) and Tropical Thorn Forest (TTF). The forests vary greatly in their composition and their quality depends on the geological and soil formations on which they occur. The flora of the area is poor in species number perhaps reflecting climatic severity (Rodgers,1985). A habitat classification map of the study area did not exist and so I prepared one on the basis of the information contained in the inventories of the forest compartments (Fig. 2.9). Ground truthing was done during the field surveys of the compartments to improve the accuracy of the classification. The habitat types have been classified on the basis of the relative proportion of the major tree species in the compartments which are given in Table 2.2 and are described below.

A) ANOGEISSUS

Forest compartments having pure stands of naturally occuring *Anogeissus pendula* comprising more than 80% of the canopy cover fall in this category. They form 9.5% of the habitat. *A. pendula* occurs gregariously and dominates the moderate slopes. In favourable localities, the height may vary from 6-11m but the canopy is always light. Regeneration is of coppice origin and is generally suppressed due to heavy browsing. The litter is highly palatable both in green and dry conditions. In areas, especially near the villages, where the forests were subjected to heavy grazing and lopping in the past, *Anogeissus* trees are malformed, branchy and seldom reach more than 3 m height. The *Anogeissus* understorey is

sparse and comprises *Adhatoda vesica, Grewia flavescens* and *Nyctanthes arbor-tristis.*

B) BOSWELLIA

The higher hill slopes are dominated by pure stands of *Boswellia serrata* and form 4.5% of the habitat. *Boswellia* forest forms an edaphic climax and because of their inaccessibility and limited use as timber, are not much prone to human disturbance. *Boswellia* trees are 10-15 m in height and 80-150 cm in girth. Regeneration is only moderately deficient as the trees are not much browsed. The understorey is sparse and comprises *Euphorbia nerifolia, Fluggea leucopyrus* and *Mimosa rubicaulis.*

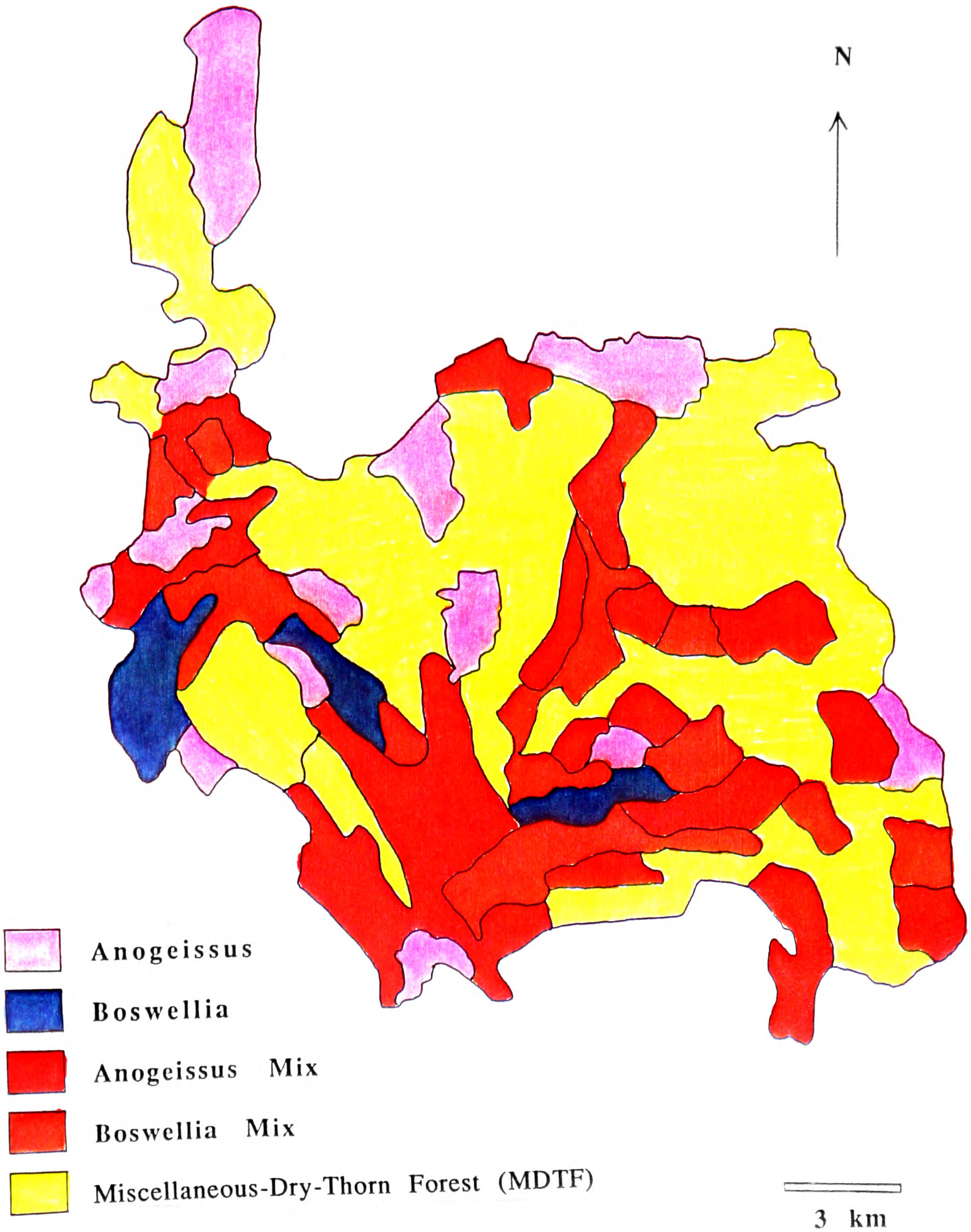
C) ANOGEISSUS MIX

This category forms 28% of the habitat and comprises *Anogeissus pendula* and its associates in varying proportions. The common associates are *Acacia catechu, Acacia leucophloea, Boswellia serrata, Bauhinia racemosa, Mitragyna parviflora, Zizyphus mauritiana, Balanites aegyptiaca.* The understorey comprises *Grewia flavescens, Helicteres isora, Holorrhena antidysenterica.*

D) BOSWELLIA MIX

This category forms 19% of the habitat and occurs at an altitude of 300-400 m. The common *Boswellia* associates are *Lannea coromandelica, Anogeissus latifolia, Anogeissus pendula, Sterculia villosa, Diospyros melanoxylon and Garuga pinnata.* The understorey comprises *Fluggea leucopyrus, Icnocarpus frutescens* and *Indigophera crassiodes.*

Fig. 2.9 A HABITAT CLASSIFICATION MAP OF SARISKA NATIONAL PARK



E) MISCELLANEOUS MIXED DRY THORN FOREST (MMTF)

This category which forms 39% of the habitat comprises mainly the Mixed Dry Thorn Forest species *viz. Acacia leucophloea, Acacia catechu, Albizia lebbek, Tamarindus indica, Zizyphus mauritiana, Balanites aegyptiaca.* The forests along stream banks comprise *Ficus glomerata, Terminalia arjuna, Syzygium cumini* and *Phoenix sylvestris. Butea monosperma* occurs on valley alluvia where its trees present a much branched and stunted appearance, due to heavy lopping and tapping for resin. This habitat type forms an important zone for wildlife because of the presence of a very diverse and highly palatable shrub layer comprising *Capparis sepiaria, C.decidua, C.zeylanica, Zizyphus nummularia, Grewia flavescens, G.hirsuta, Randia dumetorum* and *Salvadora oleoides.*

2.3.5 PALATABILITY OF THE VEGETATION

The palatability of SNP vegetation has been discussed by Rodgers (1985). A very high proportion of palatable plant species both in tree as well as shrub layer exist in the study area. Amongst the trees, *Anogeissus, Acacias, Balanites, Bauhinia, Butea* and *Zizyphus* provide forage to all large herbivores. The shrub layer consisting *Capparis* spp., *Grewia* spp., *Zizyphus nummularia,* and *Rhus mysorensis* is very heavily browsed. Bamboo occuring in small clumps along streams provides palatable fodder. Dry grasslands occur in small patches and serve as forage sites to wildlife and domestic livestock. Annual grasses *Aristida, Chloris* and *Eragrostis* spp. occur on rocky slopes while perennial grasses *Heteropogon, Chrysopogon, Cymbopogon, Saccharum* and

Themeda spp. occur in parts of the valley system. The high forage values of the Sariska vegetation support a very high density of large herbivore populations.

2.3.6 MAMMALIAN FAUNA

The mammalian species composition of SNP is not very diverse. Spotted deer (*Axis axis*), Sambar (*Cervus unicolor*), Nilgai (*Boselaphus tragocamelus*), Wild boar (*Sus scrofa*), Four horned antelope (*Tetracerus quadricornis*), Chinkara (*Gazella gazella*) are the ungulate species occuring in the area. Among the carnivores are Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Striped hyaena (*Hyaena hyaena*), Caracal (*Felis caracal*), Jungle cat (*Felis chaus*), Civet cat (*Paradoxursus hermaphroditus*), Wild dog (Cuon alpinus) and Jackal (*Canis aureus*). Rhesus monkey (*Macaca mulatta*) and Common langur (*Presbytis entellus*) are the two primates found here. Indian porcupine (*Hysterix indica*) and Indian hare (*Lepus nigricollis*) are highly abundant in the Park.

2.3.7 HUMAN SETTLEMENTS AND GRAZING CAMPS

Eighteen human settlements and grazing camps exist in the study area, in addition to more than 80 villages that dot the entire periphery of the SNP. Legally, these people have no rights but were allowed some grazing concessions in the past. The National Park regulations do not permit their continued residence inside a wildlife area but the present schemes for

their rehabilitation have not achieved the desired level of success, due to a large number of conflicting socio-economic and political considerations. These settlements occupy alluvial open areas in the valleys as well on the plateaus and occur in a mosaic pattern inside prime wildlife habitats. They have no agricultural lands and raise no crops and their main occupation is animal husbandry. They keep large numbers of domestic cattle, buffaloes, cows and goats which compete with wildlife for both forage and the scarce water resources. Two grazing camps at Kalighati and Slopka which were translocated in 1967-68 have now become high density areas for Chital and Sambar. This indicates that if other settlements could be shifted, there may be an overall increase in the area of optimal wildlife habitats in the study area.

2.4 KANHA NATIONAL PARK

2.4.1 GENERAL, LOCATION AND TOPOGRAPHY

Kanha National Park forms part of the Central Indian Highlands and is one of the internationally best known National Parks of India. Kanha has the unique distinction of harbouring the only population of the hard ground Barasingha (*Cervus duvauceli branderi*) in the world (Panwar, 1977). It was a shooting block till the early part of this century, was made a wildlife sanctuary in 1935 and was subsequently elevated to the status of a National Park in 1955. KNP has an area of 940 km^2 and forms the core zone of 1945 km^2 of Kanha Tiger Reserve. It is situated at a distance of 164 km from Jabalpur and 250 km from Nagpur, in the civil districts of Mandla and Balaghat, Madhya Pradesh State. The Park lies between 80^0 26' to 81^0 03' East Longitude and 22^0 07' to 22^0 27' North Latitude.

Kanha lies in the biogeographic zone 6E Southern Plains (Rodgers and Panwar, 1988). The dumbell shaped Park consists of two lobes, which form the Western and Eastern portions of the Park and are joined together by a chicken's neck corridor. The topography consists of a rugged tangled mass of flat topped hills and ridges enclosing the valleys. The altitude varies from 450-950 m. The important feature of the configuration is a ridge system running E-W and branching off into a number of spurs which generally project to the north. The hills form the watershed of the Banjar river in the west and Halon and Phen rivers in the east, all of which flow northwards to join the Narmada river. The hill tops on the main ridge as also the branching spurs flatten out into extensive flat or very gently sloping intermediate plateaus, locally called 'Dadars'. A few of the 'dadars' are quite large in extent, running in length upto 6 km or more and with a width of 1-2 km.

2.4.2 GEOLOGY AND SOILS

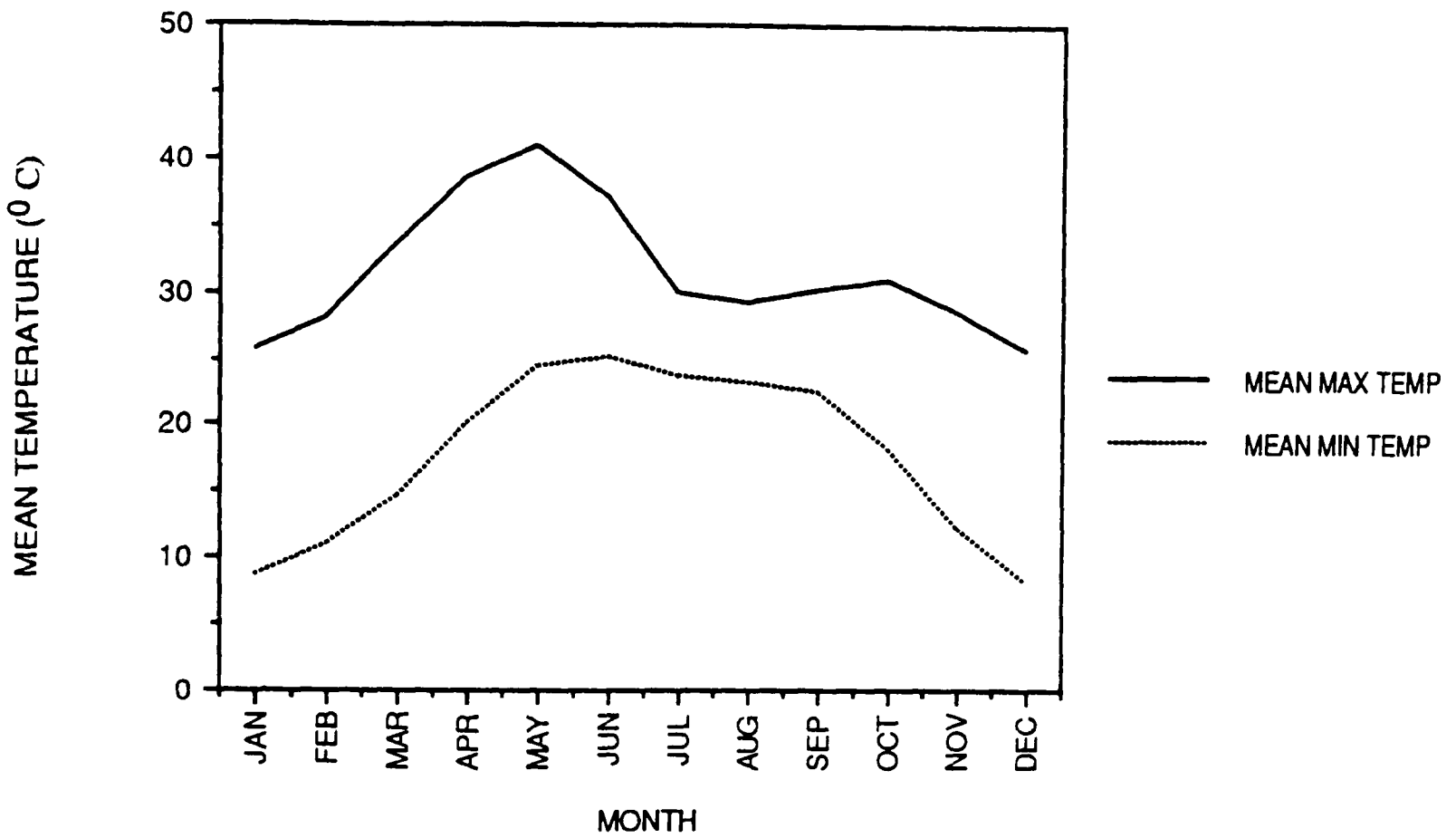
The main geological formation are gneiss and crystalline schists in the western portion and basaltic volcanic overflows of Deccan Trap in the eastern portion of the Park. The 'dadars' are capped by a vesicular and clayey laterite rock which is often rich in bauxite. The characteristic red colour is due to the ferric compounds it contains. There is a high degree of correlation between the distribution of vegetation and the type of rock. In plains and valleys, the rocks are granitic gneisses and micacious schists and they support Sal (*Shorea robusta*) forest. On the 'dadars', the rock is weathered basalt on which mixed forest grows. The proportion of Sal decreases with ascending slope and ultimately it is replaced by the mixed forests. The valleys contain black cotton soils formed from

weathering of Deccan trap rocks. These soils are seasonally inundated and support excellent grasslands but little tree growth. Alluvial soils occur on the banks of all major streams and are mostly a collection of fine silt, which supports Sal forests. A detailed soil survey of the area using aerial photographs and Landsat data is being carried out by the Indian Institute of Remote Sensing, Dehradun.

2.4.3 CLIMATE AND THE SEASONAL CYCLE

The area has 3 distinct seasons: summer, monsoon and winter. The summer season is from March to mid-June. It is usually dry but rain and hail storms may sometime come in March-April. Maximum temperature goes up to 41^0 C. The monthly variations in the mean maximum and mean minimum temperatures and mean rainfall are shown in Fig. 2.10. The availability of surface water decreases and, except in the lower valleys, the streams dry up leaving only scattered and shallow water pools. Pre-monsoon showers normally begin in the second week of June and the regular monsoon breaks in by the end of June. July and August are the wettest months. The trends in annual rainfall and total rainy days are shown in Fig. 2.11. Mean annual rainfall is 1375 mm (range 927-1805 mm) and the number of rainy days in a year is 68 (range 51-84). The absence of winter rains in any year leads to a general decline in the availability of water and fodder in the subsequent summers along with a increase in the frequency of forest fires (Parihar and Kotwal,1989). The winter season is from November to February with December-January being the coldest months. Occasionally, the temperature falls below 0^0 C with severe frost occuring in the meadows and valleys. Relative humidity reaches 100% and during the night, the incidence of dew is heavy.

Fig. 2.10 Monthly variations in (1) Mean maximum temperature (^{0} C) and Mean minimum temperature (^{0} C) and (2) Mean monthly rainfall (mm) in Kanha National Park



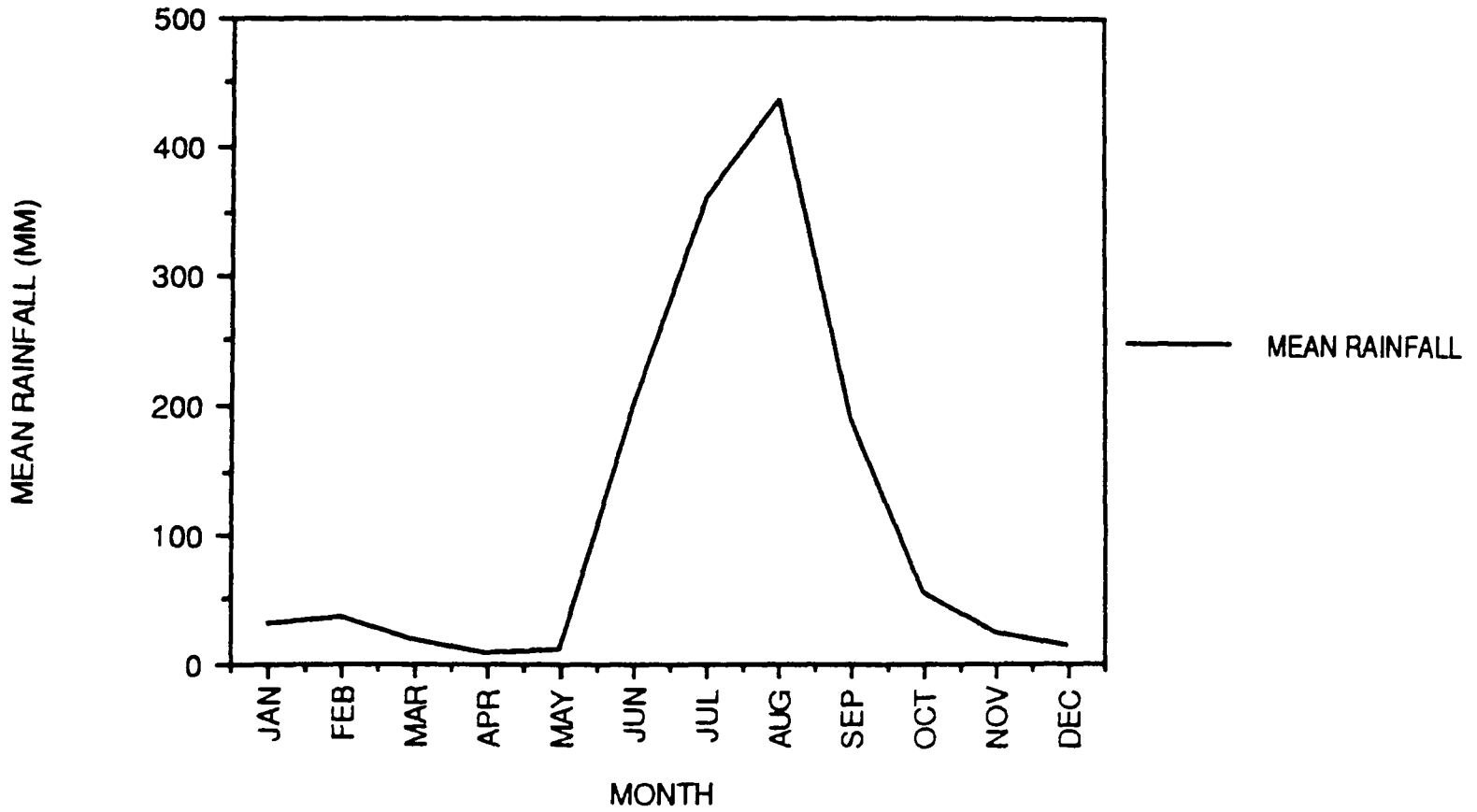
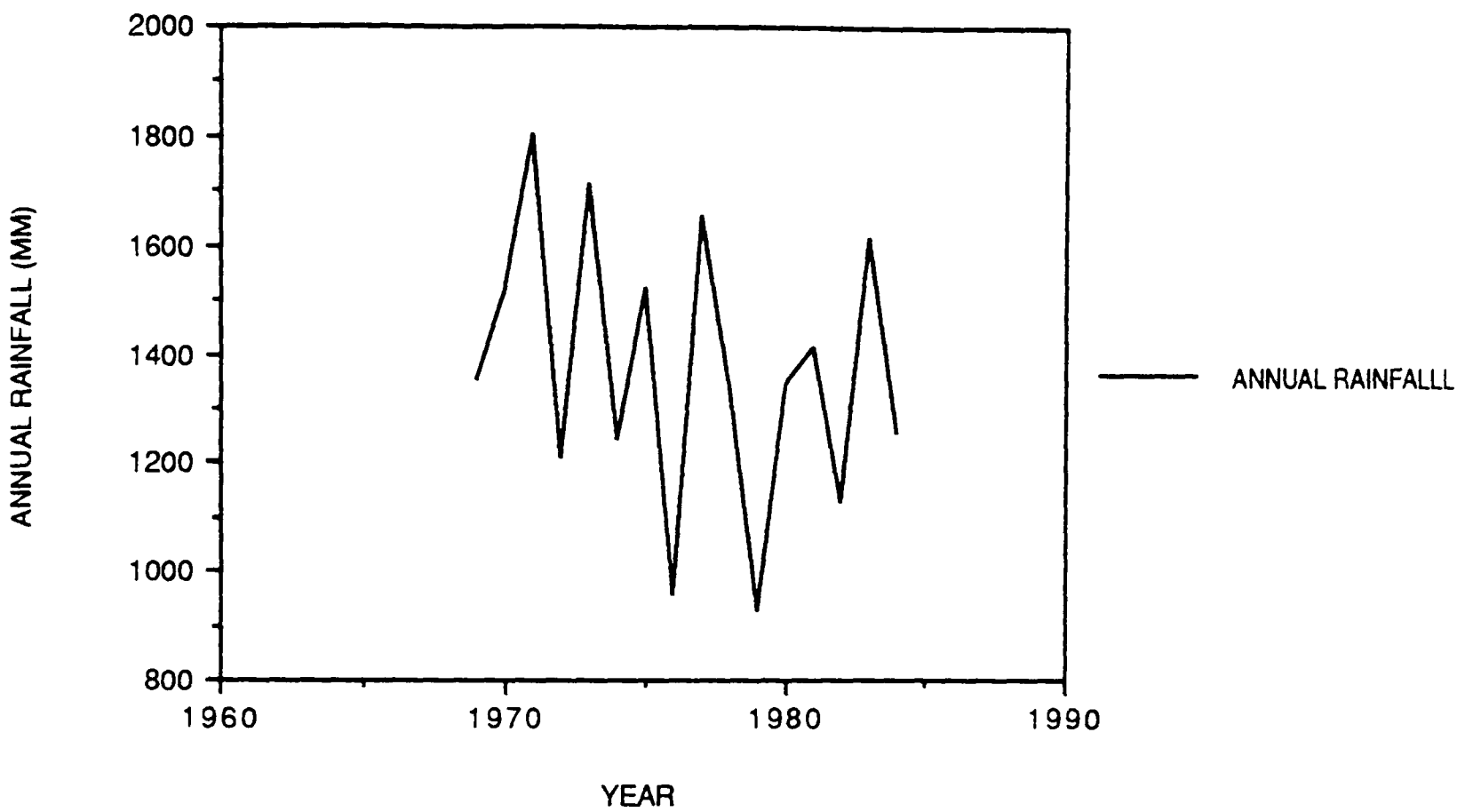
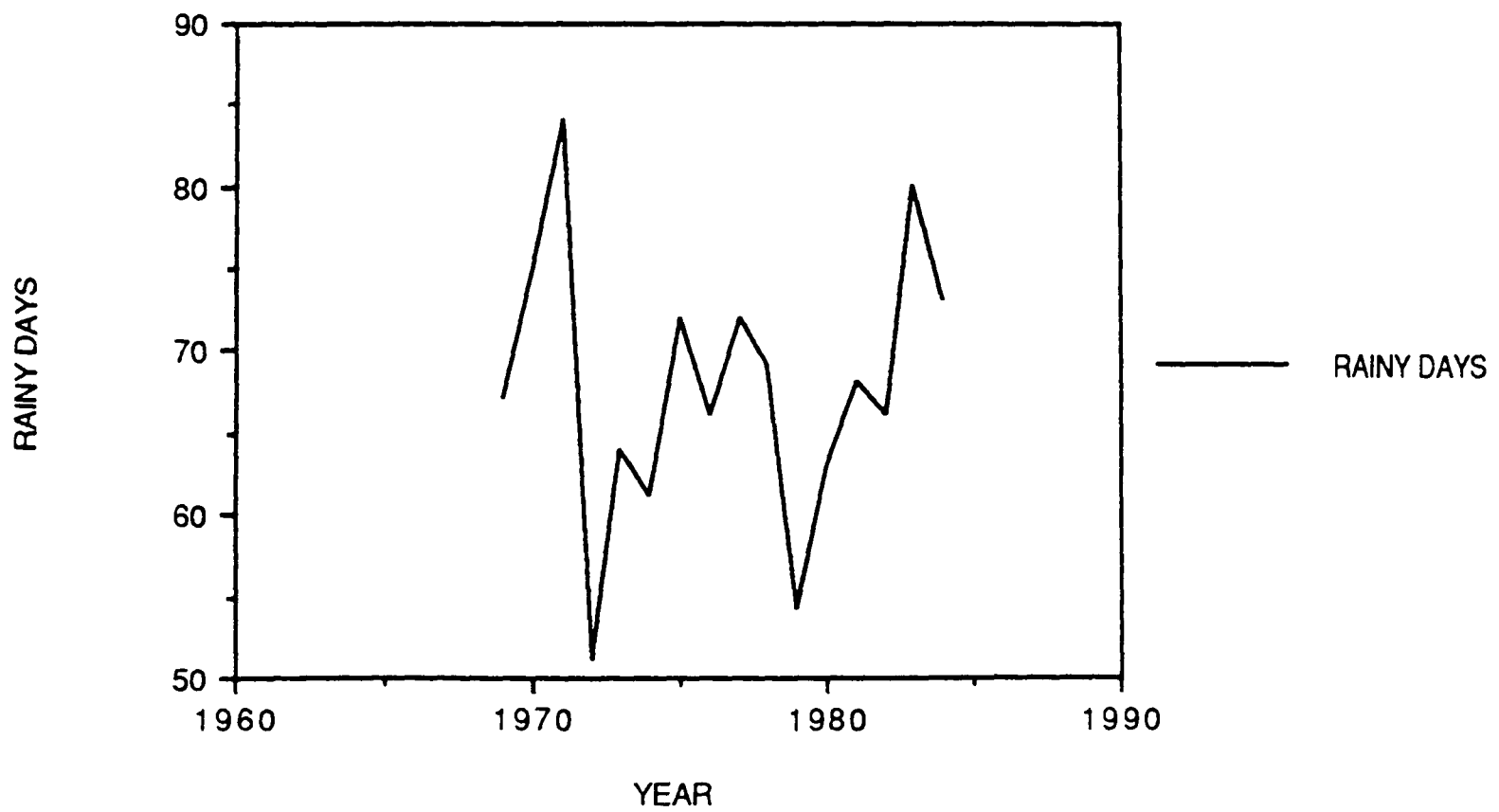


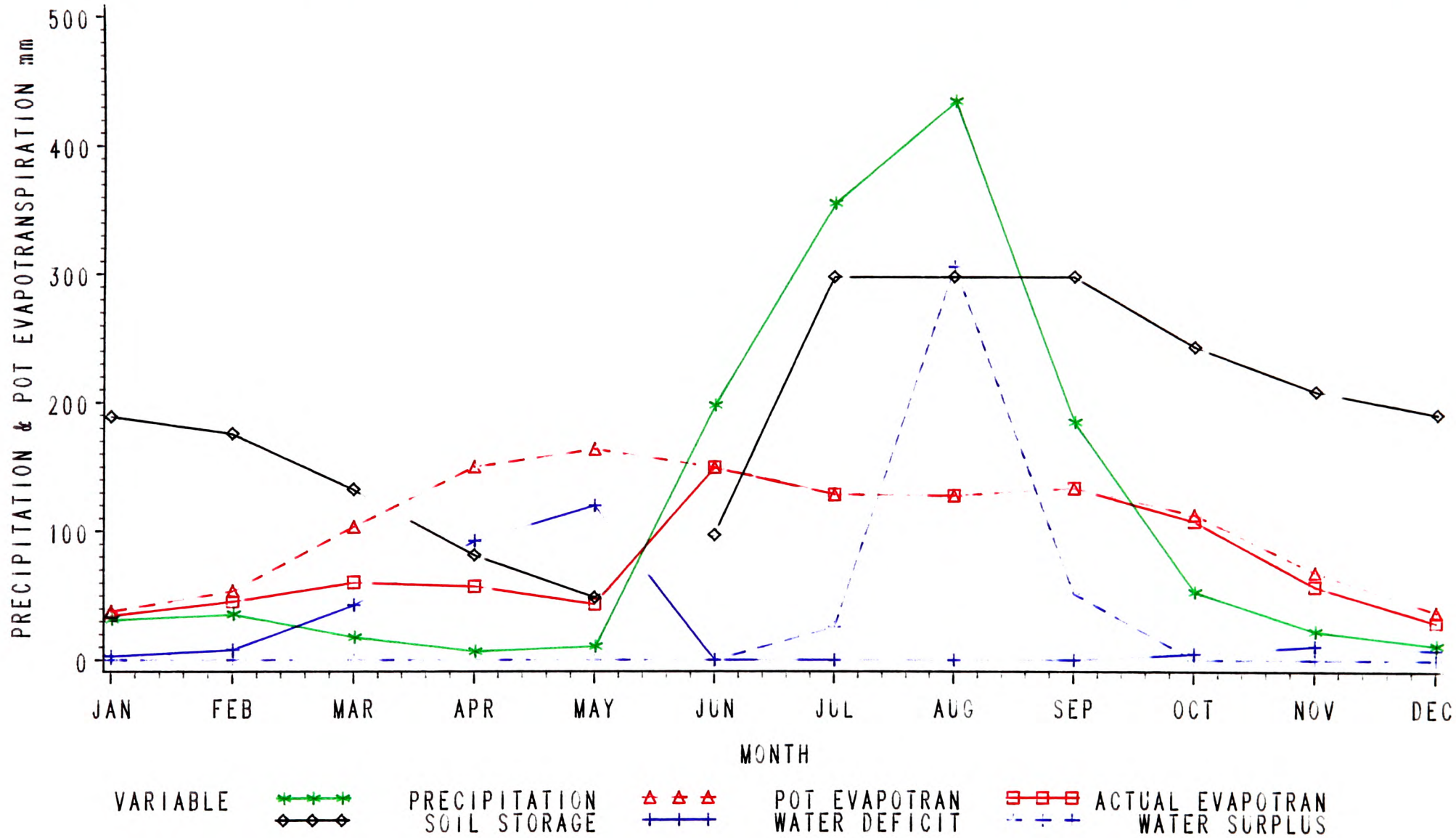
Fig. 2.11 Trends in (1) annual rainfall (mm) and (2) total rainy days in Kanha National Park 1969-1984





The ecoclimate of Kanha and the climatic water balance are shown in Fig. 2.12. The water status, i.e annual precipitation minus potential evapotranspiration plus soil water, begins to move on the negative side by the beginning of March. This is mainly because in this month the Sal trees renew their foliage and the transpirational loss of water increases. The water deficiency, however, is moderate during the months of April, May and June as the water flow in the lower reaches of only some streams ceases. Water balance becomes positive by the end of June when the monsoon strikes and remains almost on the positive side for remaining part of the year. The three rivers Banjar, Halon and Phen which flow through the Park ensure the perennial availability of water. Thus, compared to both Tadoba and Sariska water is available perennially to wild animals and the park management has very seldom to provide water artificially.

Fig.2.12 ECOCLIMATE AND CLIMATIC WATER BALANCE IN KANHA



2.4.4 VEGETATION

Champion and Seth (1968) classified the vegetation of KNP as 'Southern Tropical Moist Deciduous Forest' and 'Southern Tropical Dry Deciduous Forest'. The vegetation of the Park broadly comprises Sal forest, mixed forest and grasslands. A cover map of the KNP on the basis of aerial photographs delimiting 10 vegetation types has been prepared (Parihar and Kotwal, 1989). For the purpose of this study, I pooled the original 10 vegetation cover types into 5 distinct habitat types (Table 2.2 and Fig. 2.13) which are described below.

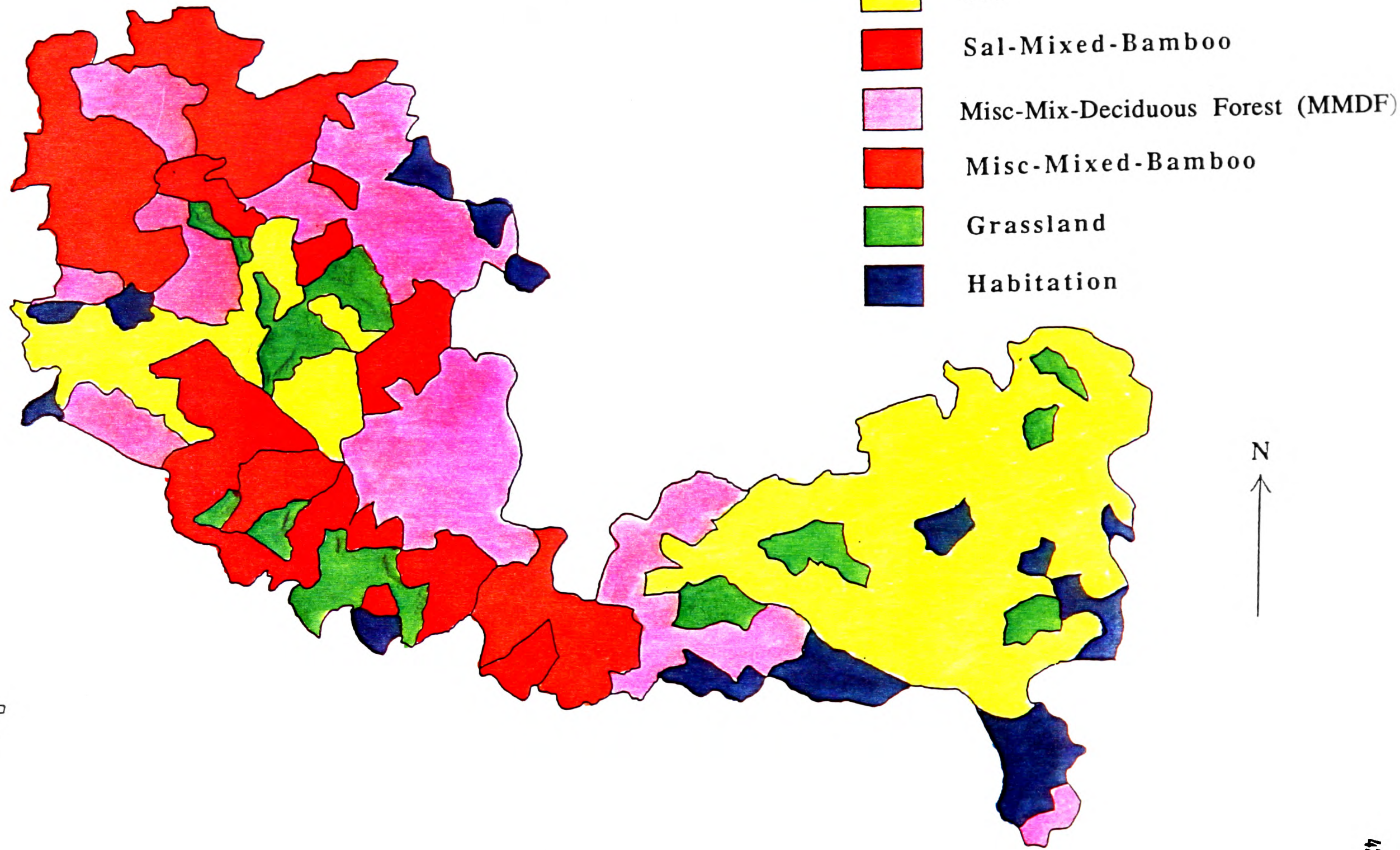
A) SAL (*Shorea robusta*)

The pure patches of Sal forest form 18% of the habitat and occur mostly in the valleys. Common associates of Sal, *viz. Terminalia tomentosa, Mallotus phillipenensis* and *Bauhinia retusa* are also present in small proportions. Seedling density is quite high indicating that the regeneration of all these species is good. The understorey mainly comprises *Flemingia semialata* and *Phoenix acaulis.*

B) SAL-MIXED-BAMBOO

This habitat type forms 25.7% of the habitat and occurs on gentle to moderate slopes. Apart from Sal, the other common species are *Oogenia oojenensis, Terminalia tomentosa, Syzigium cumini, Kydia calycina, Bridelia retusa, Grewia tilaefolia* and *Emblica officinalis.* The understorey comprises *Dendrocalamus strictus, Flemingia semialata* and *Zizyphus rugosa.* Regeneration of all major species is good although the browse pressure on the seedlings is high.

Fig. 2.13 A HABITAT CLASSIFICATION MAP OF KANHA NATIONAL PARK



C) MISCELLANEOUS MIXED DRY DECIDUOUS FOREST

The miscellaneous mixed dry deciduous forest (MMDF) forms 16% of the habitat and mostly dominate the upper slopes and plateaus. They comprise mainly *Casearia graveolens, Oogenia oogenensis, Zizyphus xylopyrus, Terminalia tomentosa, Emblica officinalis, Anogeissus latifolia* and *Lagerstroemia parviflora.* Regeneration of all major species is adequate. The understorey mainly comprises *Embellia robusta* and *Indigophera cassioides* and the seedlings of the tree species.

D) MISCELLANEOUS-MIXED-BAMBOO

This habitat type forms 24.8% of the Park area and occurs on the upper slopes and plateau areas. The common species are *Terminalia tomentosa, Diospyros melanoxylon, Ooogenia oojenensis* and *Dendrocalamus strictus.*

E) GRASSLANDS

The grasslands occupy only 12% of the habitat but are an important feature of the landscape. The grasslands are anthropogenic in origin and were created during slash and burn cultivation and village establishments by the Baiga tribe. They vary in size, soil characteristics, topography, species composition and grazing pressure. On the basis of floristic composition, Pandey (1982), identified 16 grasslands which were named after their dominant and co-dominant species. The grasslands have been

broadly divided into the following three types based on the topography and species composition (Parihar and Kotwal,1989).

1) **Valley grasslands**

They form 6.4% of the habitat and and are found in the valleys. These remain green for a longer period compared to the plateau grasslands. The important grass species are *Bothriochloa odorata, Themeda triandra, Saccharum spontaneum* and *Heteropogon contortus.*

2) **Dadar grasslands**

They form 2.6% of the habitat and occur on the flat hill tops. The important grass species are *Heteropogon contortus, Themeda triandra, Dimeria ornithopoda* and *Ischaemum indicum.*

3) **Mixed grasslands**

They form 3% of the habitat and occur mostly in valleys but some are present on plateaus also. Mixed forest tree species *Butea monosperma, Diospyros melanoxylon* and *Lagerstroemia parviflora* and their saplings occur in these grasslands. The important grass species are *Eragrostris uniloides, Saccharum spontaneum, Bothriochloa odorata* and *Dimeria ornithopoda.*

F) HABITATIONS

Habitations and agriculture form 3.6% of the habitat. These are in the form of small forest villages having few huts and cultivation areas around them. Most of them now occur in the eastern portion of the Park.

2.4.5 PALATABILITY OF THE VEGETATION

The palatability of KNP vegetation is high on account of great diversity in tree species and varied composition of the grasslands. The high species diversity and the phenological variations ensure that a variety of good quality forage is available to the herbivores throughout the year. The habitat utilization pattern by the herbivores changes according to the availability of palatable grasses, leaves, litter, flowers and fruits in different times of the year. Phenological studies on grasslands by Pandey (1982) and on forests by Newton (1984) indicate the availability of forage in all seasons.

2.4.6 MAMMALIAN FAUNA

The description of the mammalian fauna is largely based on Schallar (1967); Newton (1984); Parihar and Kotwal (1989). The fauna of Central Indian Highlands is an amalgam of Indo-Chinese, Ethiopean and Palaearctic elements (Roberts, 1977; Prater, 1971). The mammalian fauna of KNP is quite rich and is represented by 43 species. The faunal richness is probably due to the presence of the mosaic of meadows within the woodland, which presumably results in higher production being

available to terrestial herbivores than in unbroken forest (Newton, 1984). The diversity in habitats has also influenced the distribution of mammals within the Park. The plateaus with sparse mixed forest harbour Four horned antelope and Nilgai. The slopes with Sal, mixed and bamboo forest are occupied by Sambar, Gaur and Barking deer. The valley areas with Sal forest interspersed with grasslands have high abundance of Chital and Wild boar populations. The hard ground Barasingha, once common throughout the Sal forest of Central India, is now confined to the meadows of Kanha, Sonph, Rounda and Bisanpura and the intervening Sal forest (Martin, 1976). Sloth bear, Wild dog and Jackal are frequently seen in all areas of the Park. The carnivores are also distributed all over the Park. Tigers and Leopards are commonly seen, especially around Kanha meadows, Kisli and Mukki, where they are shown to elephant-borne tourists.

2.4.7 HUMAN SETTLEMENTS AND GRAZING CAMPS

There were 44 forest villages inside KNP out of which 26 have been rehabilitated outside the Park till 1988. These settlements occupy the valley bottoms and 'dadars' which are good wildlife habitats because of the presence of fodder and water. There were 15 grazing camps inside the Park whose 10,000 cattle use to graze in the Park until 1975. The relocation of villages and grazing camps has released more than 5,000 ha of prime wildlife habitat. The eastern portion of the Park still has 14 villages, whose populations are totally dependent on the resources of the Park to meet their fuelwood, agricultural wood and other requirements of

minor forest products. The presence of human settlements and livestock grazing in eastern part of the Park and deficiency of bamboo is perhaps responsible for the low abundance of herbivores observed here compared to the western part of the Park.

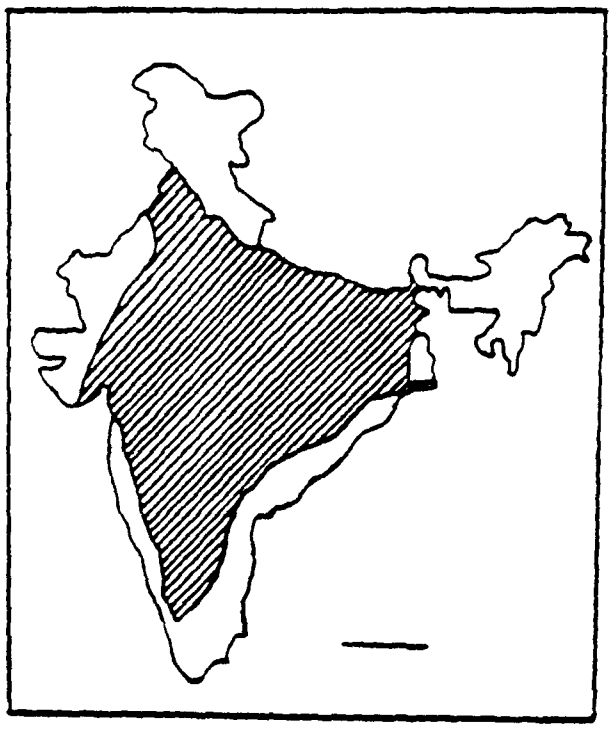
CHAPTER THREE

THE STUDY ANIMALS

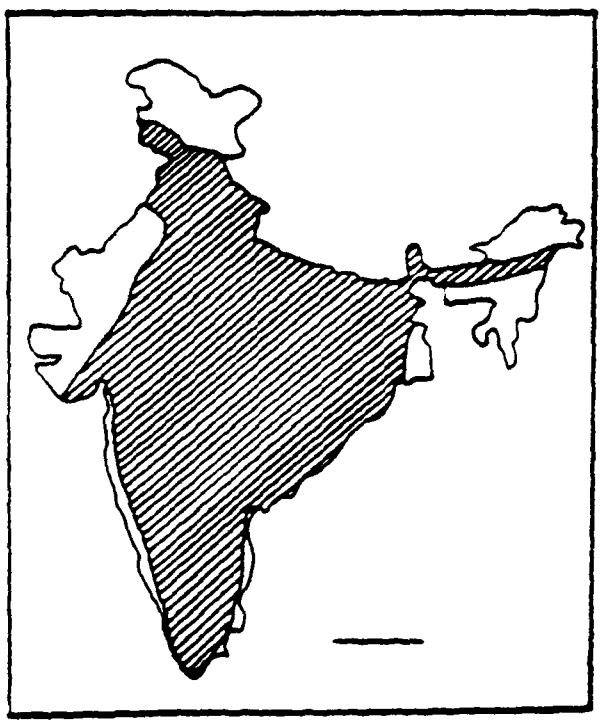
3.1 INTRODUCTION

This chapter is essentially a synthesis of the available information on some aspects of the biology of the study animals which are relevant to the understanding of their ecology and management. Biological data on the ungulate species obtained in the present study has been included in this chapter and is compared with data from other studies done by various co-workers. The selection of animal species for this study was dependent on many factors and the choice was finally limited to those species which had (a) wide range of distribution in different habitats; (b) variety of abundance levels in their geographical range; (c) diurnal nature and relative ease of detection; (d) differential response pattern to factors affecting habitat quality, and (e) conservation significance and management interest. Three ungulate species *viz.* Chital (*Axis axis*), Sambar (*Cervus unicolor*) and Nilgai (*Boselaphus tragocamelus)* largely met all these requirements and were chosen as the study animals. The generalized distribution of these species in India is shown in Fig. 3.1.

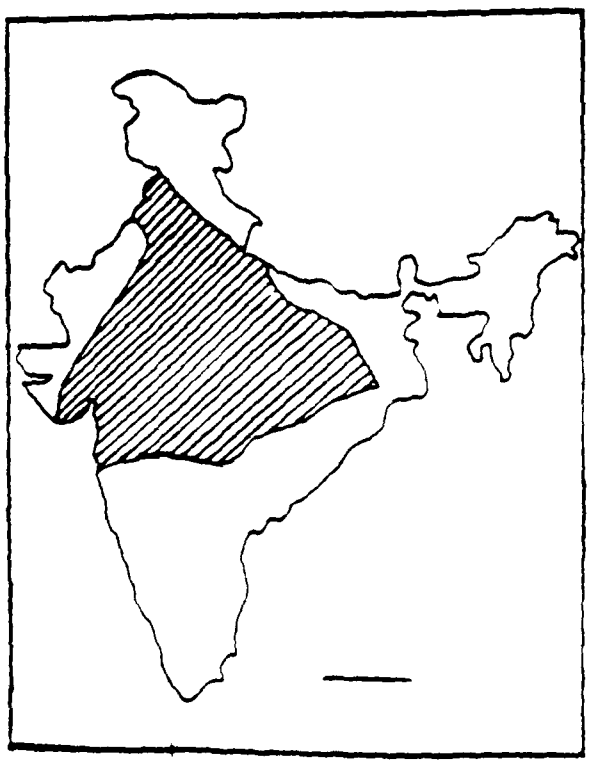
Fig. 3.1 Generalized distribution of three ungulate species in India. Markers represent 500 km



Chital
(*Axis axis*)



Sambar
(*Cervus unicolor*)



Nilgai
(*Boselaphus tragocamelus*)

3.2 METHODS

Data on sex, group size and group composition of the three ungulate species were recorded by visual observation while moving along the transects (see Chapter Four) used for estimation of animal abundance. Sex ratios were computed and have been compared with data from other studies. Feeding data by direct observation of the plants eaten by the three ungulate species were opportunistically recorded in Sariska National Park and are presented in Table 3.1. Feeding observations from the other two sites were limited and have therefore not been been presented in this chapter.

3.3 CHITAL

3.3.1 DISTRIBUTION AND STATUS

The Chital or Spotted deer (*Axis axis*) is one of the most widely distributed deer in India. The deer belongs to the genus *Axis* and has two sub-species, one from Sri Lanka (*A.axis ceylonensis* Fisher, 1829) and the other from India (*A.a.axis* Erxeleben, 1777), according to Ellerman and Morrison-Scott (1951). The geographical and ecological distribution of Chital in India has been described by Schaller (1967). The northern boundary of Chital distribution runs along the foothills of the Himalayas from western Assam through West Bengal and Uttar Pradesh. The eastern boundary of the Chital's range lies in western Assam, northern Bengal and Sikkim. The western boundary extends up to Rajasthan and Gujarat. Chital occur sporadically throughout the peninsular India in the

forested areas of Bihar, Madhya Pradesh, Orissa, Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Kerala. Chital distribution pattern has, to a large extent followed the distribution of the dry deciduous and moist deciduous forests in India. Being a very adaptable species, it occurs in a variety of ecologic types including the evergreen and the thorn forests. They are found in the mangrove swamps of the Sundarbans and have also been successful in the evergreen forests of the Andaman Islands, where they were introduced in the 1920s. Chital have also been introduced in other continents and most of these populations have now naturalized. Chital populations occur in USSR, Yugoslavia, USA, Argentina, Brazil, Uraguay, Australia, Hawaii and on several fenced private ranches in the Western Cape, South Africa (Lever, 1985). Chital occur at a range of abundance levels in its geographical distribution and may achieve very high ecological density (>100/km^2 Kanha National Park, this study, see Appendix VI).

3.3.2 PHYSICAL CHARACTERISTICS

The Chital is a medium-sized deer and has a bright reddish coat covered by white spots. There is a dark dorsal stipe and the underparts, insides of the legs, tail and ears are white. Adult bucks and does may weigh up to 100 kg and 70 kg respectively. Antlers are found in males only which are large and three-tined but are simple in comparison to most of the other species (Ables,1975). There is no seasonal difference in the colour of the coat except that during the cool season it is somewhat glossier, darker and thicker than during the hot and wet season (Schaller, 1967).

3.3.3 SOCIAL ORGANIZATION

The Chital is a social species that displays many interactions between the sexes and between age groups (Ables, 1975). The basic social unit in Chital is a matriarchal family group comprising an adult female, her offspring from the previous year and a fawn. Several such groups combine to form a herd whose composition is unstable: large herds split into smaller groups which may reunite in part or whole or reorganize themselves into new herds. According to Putman (1988), among those species where sociality may be tolerated, the social groups are often impermanent and group composition and size may change with season and circumstance. Large herds of Chital are encountered in comparatively open areas, mainly grasslands (Sawarkar, 1985). In the central meadows of Kanha National Park, Chital herds of 250+ individuals are frequently observed. Chital congregations containing more than 500 individuals occur during the summer season, around the Tadoba Lake (*pers. obs.* 1989).

Herd size appears to be influenced by the availability of food and water. Very large herds of Chital have been reported by Schaller (1967) in Kanha during the monsoon period when the grasses reached their peak standing crop. Similarly, when water availability becomes limited in Tadoba during the summer season, large congregations begin to appear around the Lake.

The frequency of Chital sightings of in various group size classes is shown in Fig. 3.2. Nearly 45% of the sightings in Sariska and Tadoba

occur in groups containing 2-3 individuals, representing the matriarchal family group. Mishra (1982) recorded Chital in groups of between five and ten individuals with a mean group size of 7.5. Groups of adult males referred as 'stag-parties' of 4-10 individuals are common in Chital and are usually observed during the rutting period. According to Krishnan (1972), in no deer do the groups of adult males attain the numerical size that they do in Chital. Krishnan (*op. cit.*) recorded large stag parties of over 100 animals in the Masangudi area of the Mudumalai sanctuary. In herds of stags as also in large mixed herds all stages of antler development can be observed.

Based on the broad classification of feeding types, Rodgers (1988) has categorised Chital as a generalist feeder, which takes grass, forbs and woody plants in its diet. Hofmann (1985) classified Chital on the basis of morpho-physiological ruminant feeding types as an intermediate/mixed feeder. Chital is highly selective for easily digestible plants rich in plant cell contents (Hofmann, *pers. comm.*1990). Feeding data from Sariska National Park suggests that grasses contribute 45% in the diet of Chital while the shrub and tree layer contribute 41% and 14% respectively (Table 3.1).

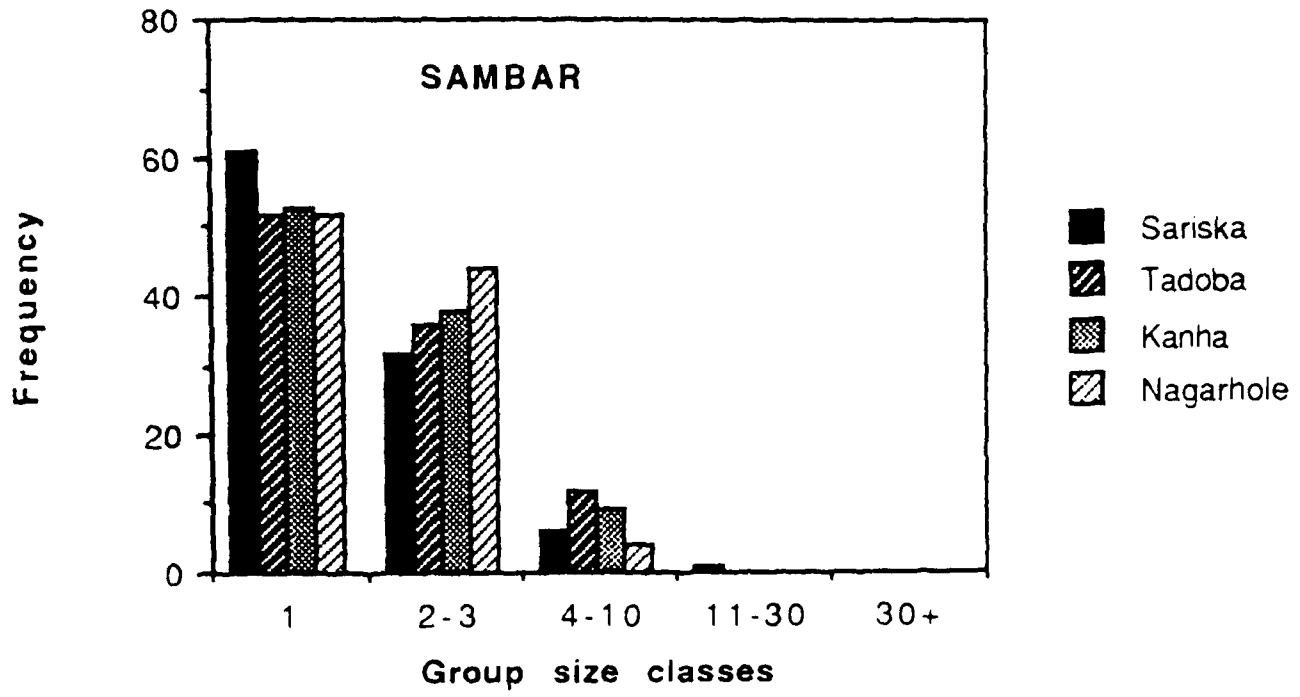
3.3.4 REPRODUCTION

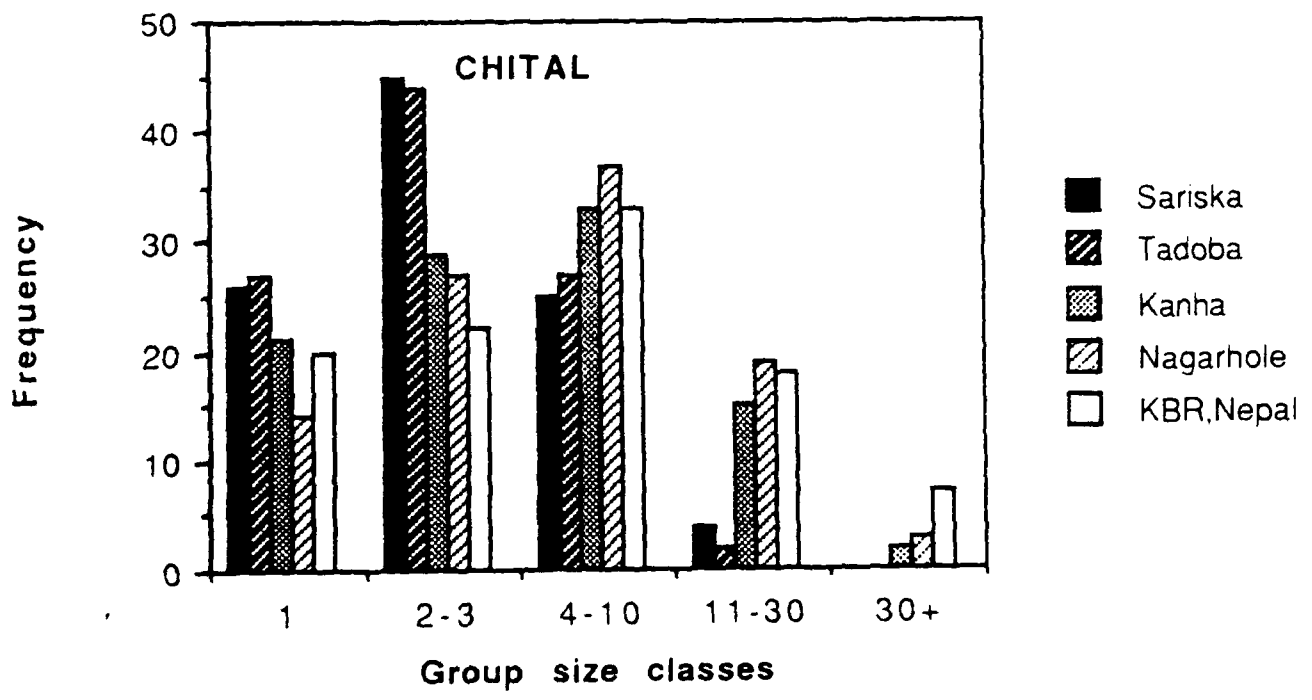
The onset and duration of the rutting period in Chital is variable. In Southern India, the rut is from October to April according to Fletcher (1911), but Krishnan (1959) found no definite mating season. A major breeding season lasting from the latter part of May through August with a

June-July peak was reported for Chital in Texas (Ables, 1975). In Hawaii, the rut of the introduced Chital is April through August, with some mating during the entire year (Graf and Nichols, 1966). In Kanha, the rut occurs from March to June with a peak in May, in Sariska, November through March and in Tadoba from February to June. The lack of a definite season for antler-shedding is perfectly in accord with the fact that breeding is not confined to any season but takes place throughout the year (Krishnan, 1972). The variability in the rutting period may be related to microclimatic factors, plant phenology as well as the availability of open areas to facilitate visual contact and needs to be investigated in detail.

The gestation period is of 8 to 8.5 months. Asdell (1946) lists a gestation period of 7 to 7.5 months, Walker (1964) and Crandall (1964), 7 to 8 months and Graf and Nichols (1966) report a 7.5 month gestation period. The ratio of bucks to does in an introduced Chital population in Hawaii was 0.77:1 in 1959 (Nichols, 1960). Sex-ratios of 0.69:1 in Corbett National Park, 0.70:1 in Keoladev Sanctuary, Bharatpur and 0.70:1 in Kanha has been reported by Schaller (1967). In Sariska, sex ratio of 0.73:1 and in Tadoba of 0.69:1 have been observed during the present study.

Fig. 3.2 Frequency of sightings of the three ungulate species in various group size classes. Nagarhole data from Karanth (1988) and Karnali Bardia Reserve (KBR), Nepal data from Dinerstein (1980)





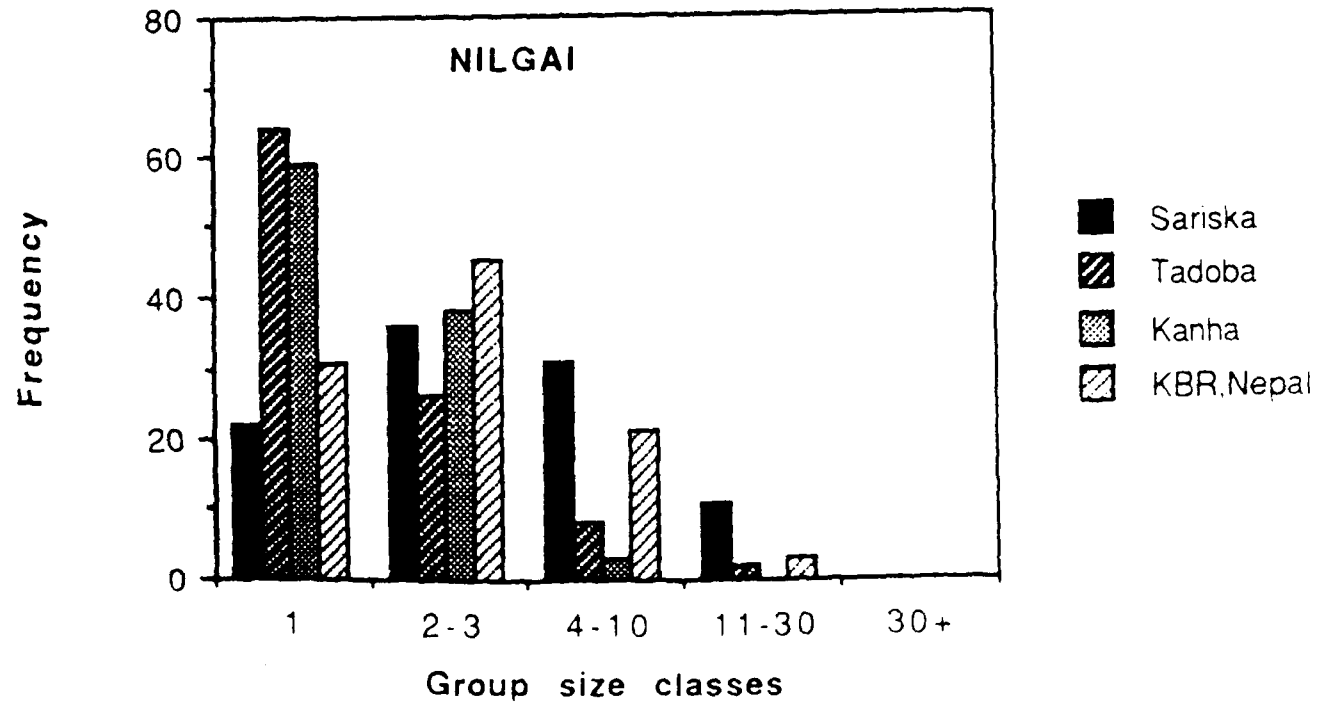


Table 3.1 Feeding data of three ungulate species in Sariska National Park. Frequency expressed as percentage. S=Shrub, T=Tree, N=Total number of observations

Plant	Sambar		Chital		Nilgai	
Species	May-Jun	Nov-Dec	May-Jun	Nov-Dec	May-Jun	Nov-Dec
Capparis sepiaria(S)	12	6	12	4	18	10
Capparis Zeylanica(S)	8	2	6	1	5	4
Capparis decidua(S)	11	3	4	1	7	3
Grewia hirsuta(S)	7	4	5	1	2	7
Grewia flavescens(S)	9	14	12	1	6	11
Ziziphus mauritiana(S)	2	7	2	11	6	9
Ziziphus nummularia(S)	4	8	3	15	4	8
Rhus mysorensis(S)	2	1	1	0	2	0
Balanites aegyptiaca(S/T)	4	1	3	1	11	5
Shrub Percentage	**59**	**46**	**48**	**35**	**61**	**57**
Butea monosperma(T)	1	1	2	1	2	1
Anogeissus pendula(T)	17	24	11	3	10	7
Ficus glomerata(T)	0	1	0	1	0	1
Ficus religiosa(T)	0	1	0	1	0	1
Acacia catechu(T)	3	2	1	0	2	2
Acacia leucophloea(T)	1	1	3	2	6	3
Acacia nilotica(T)	2	1	1	0	3	2
Tree Percentage	**24**	**31**	**18**	**8**	**23**	**17**
Grasses	13	17	34	56	15	25
Bamboo	4	6	0	1	1	1
Grass Percentage	**17**	**23**	**34**	**57**	**16**	**26**
N	114	97	131	105	146	117

3.4 SAMBAR

3.4.1 DISTRIBUTION AND STATUS

The Sambar (*Cervus unicolor niger* Blainville, 1816) is the largest deer in Southeast Asia and has an exceedingly wide geographical distribution. Ellerman and Morrison-Scott (1951) described the approximate range of the species as follows: "Szechuan, Yunnan, Kwantung, Hainan, Formosa, Ceylon, northwards through peninsular India to Kumaon and Nepal, Assam, Burma, Indo-China, Siam, Malay States, Sumatra, Java, Borneo, Celebes, the Phillipines and many small Malayan Islands". Of the four subspecies listed by these authors, viz. *C.u.unicolor, C.u.niger, C.u.equinus and C.u.swinhoei,* only *C.u.niger* occurs in India. According to Schaller (1967), no Indian ungulate has adapted itself to a wider variety of forest types and environmental conditions than the Sambar. It is found in the thorn forests of Gujarat, Rajasthan, and other states, in the dry and moist deciduous forests throughout peninsular India, in the pine and oak forests of the Himalayan foothills up to an altitude of 3000-3500 m (Jerdon, 1874; Baldwin, 1877; Lydekker, 1898), and in the evergreen and semi-evergreen forest regions of Eastern India. Sambar have also been introduced in other continents and most of these populations are now naturalized. Introduced Sambar populations are in California, Texas and Florida in the U.S.A., Victoria and Melbourne in Australia, Auckland and Wellington in New Zealand and on several enclosed estates in Western Cape, South Africa (Lever, 1985). Sambar occur at a range of abundance levels in its geographical range but seldom achieve a density of more

than 5/km^2, although Ngampongsai (1987) reported a density of 10/km^2 in Khao-Yai National Park, Thailand.

3.4.2 PHYSICAL CHARACTERISTICS

The Sambar is a large and somewhat heavily built deer, attaining a height of at least 160 cm at the withers, and characterized by its long and almost uniform dark-coloured coat, heavily maned throat and neck, large spreading ears, evertible face-glands and thick bushy tail (Lydekker, 1907). The long and massive antlers have a peculiarly rugged exterior, and the two tines of the terminal fork are usually approximately equal in length. The space enclosed between the antlers is generally U or V shaped, and the bony pedicles on which they are supported are relatively short. Sambar antlers vary greatly in length and stoutness, the best specimens being found in the forests of Madhya Pradesh. The general colour is brown with a yellowish or greyish tinge and the underparts are paler. Females are lighter in tone. Adult stags may weigh upto 200 kg (Crandall, 1964).

3.4.3 SOCIAL ORGANIZATION

The characteristic social unit is one hind and one fawn or one hind, one yearling and one fawn. Yearling stags generally remain with the hinds. The typical herd is small, numbering fewer than 6 individuals (Schaller, 1967). Average group size is 4 to 5 according to Jerdon (1874) and Prater (1971), 3 to 5 according to Peacock (1933), and 10 to 15 according to Forsyth (1889) and Fletcher (1911). The frequency of sightings of

Sambar in the study areas, in different group size classes is shown in Fig.3.2. Most sightings of Sambar are either solitary or in groups of 2-3 individuals. 8-10% of the sightings are in groups of 4-10 individuals. Sambar are much less gregarious than Chital and the stags are seen alone or in family group of a fawn and its mother, sometimes accompanied by a yearling. 2-3 adult stags may also be seen together (Krishnan, 1972). Only in Sariska National Park, the Sambar are observed in larger groups of 11-30 individuals. These observations were generally made at waterholes where Sambar in smaller groups converge from all directions and make larger congregations. Eisenberg and Lockhart (1972) commented that water holes are places where the Sambar population in a given area comes together in the late evening to form temporary aggregation before dispersing to feed.

Sambar like Chital, are generalist feeders but as they utilize forested areas to a considerable extent they exhibit a broader habitat utilization pattern. Hofmann (1985) has classified Sambar as intermediate/mixed feeder like Chital. Sambar have a seasonally changing capacity to digest fibrous forage rich in cellulose (Hofmann, *pers. comm.*1990). However, data from the present field study suggests that Sambar are more dependent on browse than Chital, which forms more than 52% of their diet as opposed to only 20% grasses (Table 3.1). Sambar are less specialized in their food requirements than most ungulates and food habit studies in Thailand (Ngampongsai, 1977) support this conclusion.

3.4.4 REPRODUCTION

The rutting period of Sambar in peninsular India runs from October to December, with Forsyth (1889), Blanford (1898-91), Lydekker (1898), Russell (1900), Comber (1904) and Stockley (1913) limiting it to October and November and Prater (1934) and Brander (1923) to November and December. However, according to Schaller (1967) the rut of the Sambar in Kanha does not appear to be as discrete as has been suggested but rather to be spread over a period of at least seven months of the year with a peak in November-December. During this study, the rutting period of Sambar was observed to be from November to January in Sariska and from November to December in Tadoba. Each adult female bears young once a year and a single fawn is the rule. The male to female sex-ratio was reported as 0.29:1 by Schaller (1967). During this study, a sex-ratio of 0.43:1 was observed in Sariska and 0.45:1 in Tadoba National Parks. The reason for outnumbering of stags by hinds may be due to selective predation on the males.

3.5 NILGAI

3.5.1 DISTRIBUTION AND STATUS

The Nilgai (*Boselaphus tragocamelus* Pallas, 1766) or Blue bull has a wide range of distribution in India, from the foothills of the Himalayan mountains southwards through the central India to Mysore (Sankhala, 1964; Walker, 1964). The Nilgai is endemic to the Indian subcontinent and widespread in all areas where there is not tropical forest or higher

rainfall (Roberts, 1977). They are found in a variety of habitats from level ground to hillsides, in thin brush with scattered trees to cultivated plains (Blanford, 1888-91). Nilgai have also been reported in Pakistan, mainly along the border with India (Mirza and Khan, 1975) but according to Roberts (1977), the climate of Pakistan is too dry and treeless to have provided a favourable habitat for this species. Nilgai occur in large numbers in the Royal Karnali Bardia Wildlife Reserve in Nepal (Dinerstein, 1979). Nilgai have also been introduced in other continents where their populations have now naturalized. Nilgai populations occur in the U.S.A., Mexico and on the private ranches in the Orange Free State, South Africa (Lever, 1985). Nilgai occurs at a range of abundance levels in its geographical distribution but attains maximum ecological density in semi-arid open environments.

3.5.2 PHYSICAL CHARACTERISTICS

The Nilgai are horse-sized antelopes, with bulls weighing up to 288 kg and standing 120-150 cm high at the shoulder (Prater, 1971). Adult males are steel-gray or blue-gray in colour with black legs. Male calves and all females are light-brown. Both sexes and all ages have similar pattern of dark and white markings on their fetlocks, head, ears, underparts and tail (Sheffield *et al.*, 1983). The front part of the body is heavier and bulkier than the rear and short, sturdy, rather steep horns are only found in the males (Grzimek, 1972). The legs are long and slender, the hooves are narrow with pointed tips. Both sexes have conspicuous white stocking marks round the pastern above the hooves.

3.5.3 SOCIAL ORGANIZATION

Nilgai are partly social in habits (Roberts, 1977) although they do not regularly congregate in large herds. The herds are not stable social units as they do not remain constant in size and composition over long periods. The only firm social unit appears to be the female and her young. According to Schaller (1967), the composition of Nilgai herds changes constantly, but three kinds of herds are discernible: (1) small herds consisting of 1 or 2 cows with young calves, (2) small herds composed of 3 to 6 adult and yearling cows with an occasional calf, and (3) bull herds, varying in number from 2 to 18 animals. Nilgai bulls establish territories and form beeding herds during the rut, each herd consisting of 1 bull and 2 to 10 cows (Dharmakumarsinghji, 1959). The frequency of sightings of Nilgai in the study areas in various group size classes is shown in Fig. 3.2. Most of the sightings of Nilgai are solitary, representing mature bulls, which generally prefer a solitary existence for the greater part of the year. In Sariska National Park and Karnali Bardia Wildlife Reserve, Nepal Nilgai occur in large groups of 11-30 individuals, comprising adult cows, sub-adult bulls, sub-adult cows and calves.

Nilgai are predominantly browsers. However, Hofmann (1985) has placed Nilgai in intermediate/mixed feeder category. Feeding data from Sariska National Park suggests that browse contributes >70% in the diet of Nilgai (Table 3.1).

3.5.4 REPRODUCTION

According to Prater (1934) and Asdell (1946), Nilgai have no regular rutting season. Heape (1901), on the other hand, stated that mating occurs from March to May. In Sariska National Park, the peak rutting period occurs during November and December and the calves are born from July to September. The gestation period of the Nilgai has been variously reported to be 8 months (Crandall, 1964) and 8 to 9 months (Sclater, 1863). Twins seem to be as frequent in occurence as single offspring (Dover, 1933) and the young appear to be rather weak at birth in contrast to most antelopes, spending most of the first 10 days lying down and only standing up to suckle.

The sex ratio of the free ranging adult Nilgai favours the female. Schaller and Spillett (1966) reported a male to female sex ratio of 0.59:1 in Keoladev Sanctuary and 0.37:1 in Van Vihar Sanctuary. The sex ratio observed during the present study was 0.60: 1 in Sariska, 0.54:1 in Tadoba and 0.44:1 in Kanha National Parks. These ratios suggest a higher mortality amongst the males, although Berwick and Jordan (1971) reported a more even ratio of 0.89:1 in the Gir Forest.

CHAPTER FOUR

GENERAL METHODS

4.1 INTRODUCTION

In this chapter, I describe the various methodologies used for obtaining ecological data from the three study areas. As stated earlier, one of the objectives of the present study is to explore the validity of using rapid methodologies for collection and collation of ecological data from large areas relatively quickly. There is an urgent need to develop, standardize and use rapid methods for gathering baseline ecological data in wildlife areas. Wildlife managers, particularly in locations where new wildlife protected areas have recently been established, are often confronted with a situation in which no baseline information on habitats and species under their charge exist. Long term ecological studies cannot be carried out for every species in all habitats due to lack of trained manpower, as well as constraints of time and finances. Rapid ecological methods, if developed and used can provide information to both wildlife ecologist and manager, presumably on a coarse level, but reliable enough to base interim management decisions. Asherin *et al.* (1979) stressed the importance of using rapid assessment methodologies in evaluating the quality of wildlife habitat and for identifying suitable areas for development, so that adverse impacts on wildlife resources could be minimised. In this study, a method called the 'Toe-point transect', which is

a rapid method for the systematic sampling of ground and aerial cover along a straight line has been extensively used to obtain baseline ecological data (See section 4.2.3).

The ability to monitor changes in the habitat in a wildlife area due to natural processes e.g. succession as well as those arising from management inputs such as creation of a new waterbody, is very important for the wildlife manager. A new approach involving the use of existing 'forest compartments' in wildlife areas in India has been used to gather baseline information on habitat composition and habitat quality and also to use them as 'ecological bench-marks' for monitoring purposes. Forest compartments have been used for wildlife studies in England also. Peck (1989) studied the feeding behaviour of six species of arboreal passerines in 31 forest compartments in northern England and found that the bird density and number of species were positively correlated with number of tree species present in a compartment.

In this chapter, a comparison of the rapid ecological methods has been done in order to test their relative efficacy in providing quick and reliable estimates. A broad-based, holistic approach was considered more important and I therefore decided to reduce the precision of data collection rather than reduce the number of field sites and species or the number of habitat variables considered.

4.2 MEASUREMENT OF HABITAT VARIABLES

4.2.1 COMPARTMENT APPROACH

A large proportion of the wildlife protected areas in India comprising of the National Parks and Sanctuaries in India have been constituted from the existing Reserved and Protected forests (Rodgers and Panwar, 1988). Before these forests were gazetted as wildlife areas, they were being intensively managed for the commercial exploitation of timber and other forest products. This commercial exploitation required the division of these forest areas into compartments for intensive management. A compartment is the smallest subdivision of a forest and is defined as a territorial unit of a forest permanently demarcated for purposes of administration, description and record (Osmaston, 1968). Being a permanent unit, the compartment is clearly demarcated on the ground and its boundaries follow natural features such as ridges and water courses, or definite artificial features such as roads or other surveyed lines. In the absence of any definite natural and artificial features their boundaries are marked by fixed boundary pillars. The size of a compartment depends on the intensity of forest working, topography or site variations. In general, it varies from 150 to 250 ha in India. These compartments are very large compared to those in England where the range is from 1-10 ha. The compartment description is made on a prescribed format of the forest department and contains information on the boundaries, area, aspect and the growing stock. Details about silvicultural treatment, fires, diseases and revenue are also included and are periodically updated by the forest department. The forest compartment records generally date from the

time commercial forestry was introduced in India in the later part of the 18th century. However, this system of maintenance of compartments and their histories was abandoned when commercial exploitation ceased and the forest areas were constituted into wildlife reserves. The compartment boundaries, maps and past histories are still available in a majority of wildlife areas but are not being put to any use except that in many wildlife areas the territorial beats of forest personnel are still organised on the basis of compartment numbers and area.

I decided to revive the use of existing forest compartments for gathering baseline information for wildlife management for two reasons: 1) these compartments can not only be shown on a map but can also be easily located on the ground and therefore can be surveyed in different seasons and years. Locating and surveying a compartment by placing transects is simpler than dividing the wildlife area into artificial grids (Ferrar and Walker, 1974) and laying temporary or permanent transects, and 2) the compartment inventory records regarding the physical features and the composition and quality of the forest in the compartment provide an interesting insight into the habitat conditions in the past. The results from the present and subsequent surveys of the compartment can thus be compared with the habitat conditions in the past and a monitoring system using the compartment as a basic unit can be developed.

The first step in the use of compartments for the field survey was the preparation of a compartment map for the entire study area from the

available individual maps of the compartments. The compartments were marked on 1:50,000 topographic sheets, obtained from the Survey of India. The maps of the three study areas representing the compartments are shown in Fig. 4.1, 4.2 and 4.3 respectively. There are 49 compartments in Tadoba National Park, with an average size of 238 ha (range 74 to 469 ha), 177 compartments in Sariska National Park with an average size of 168 ha (range 33 to 558 ha) and 386 compartments in Kanha National Park, average size of 243 ha (range 35 to 655 ha). From the records of the compartment enumeration, the extent and proportional availability of the major habitat types was worked out and a habitat classification map (see Chapter Three) produced for the three study sites. Compartments covering all the habitat types in proportion to their availability were selected for this study. The number of compartments surveyed in Tadoba, Sariska and Kanha National Parks was 49, 40 and 49 respectively. The habitat stratification and transect lengths sampled, along with their area and relative proportions in the study area is shown in Table 4.1. As indicated earlier, Tadoba National Park was selected as the major field site and all the 49 compartments were surveyed in the two seasons. In the two minor sites, Sariska and Kanha 22% and 15 % of the total area was surveyed in the two seasons. The existing network of roads in the study areas was used as transects for estimation of animal abundance using a motorcycle (See section 4.3). In addition, foot transects were established along the longest diagonal in the compartment in each habitat type for animal abundance estimation and collection of data on habitat variables (See section 4.2.2).

Fig. 4.1 Map of Tadoba National Park showing forest compartments

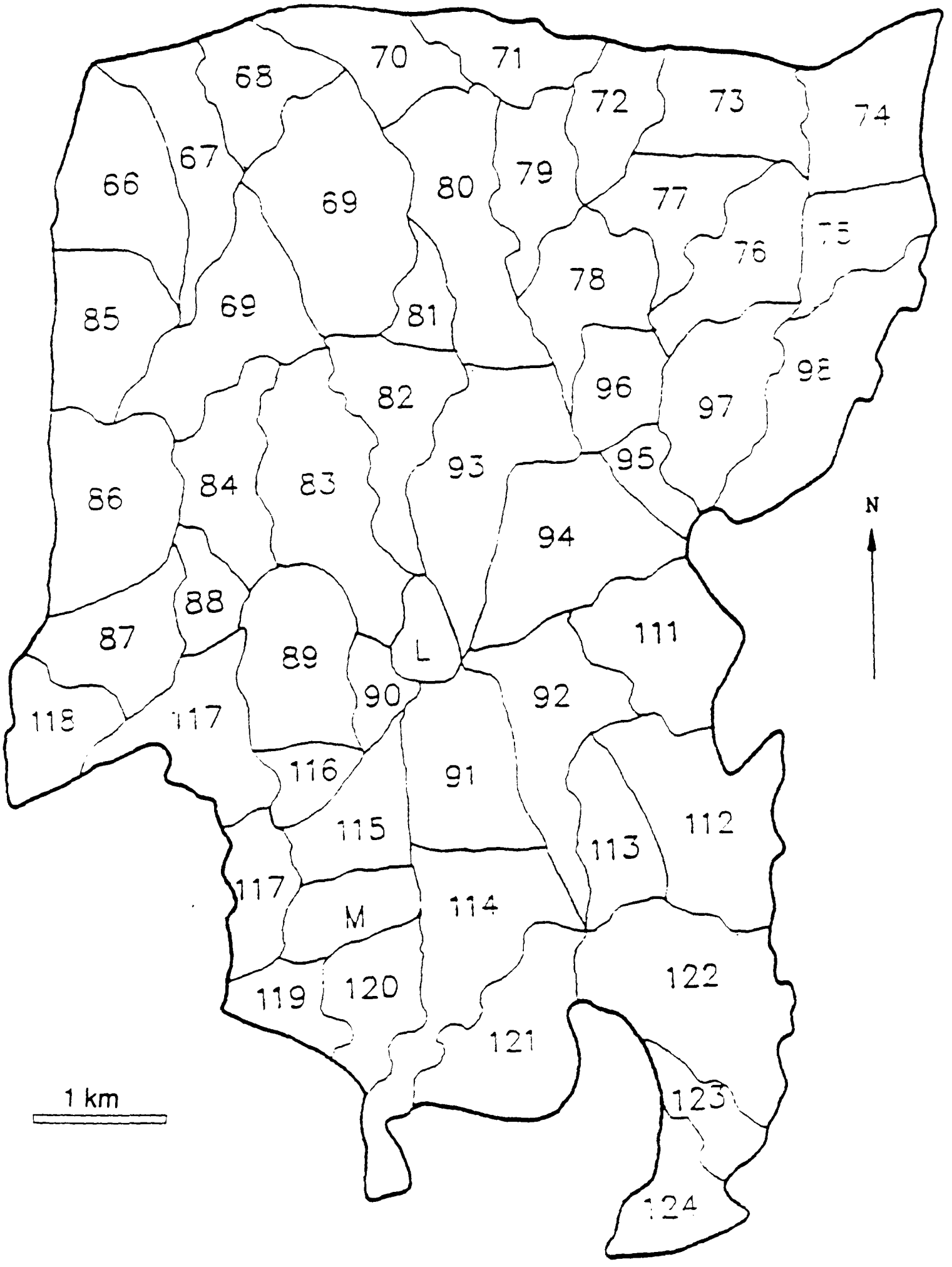


Fig. 4.2 Map of Sariska National Park showing forest compartments

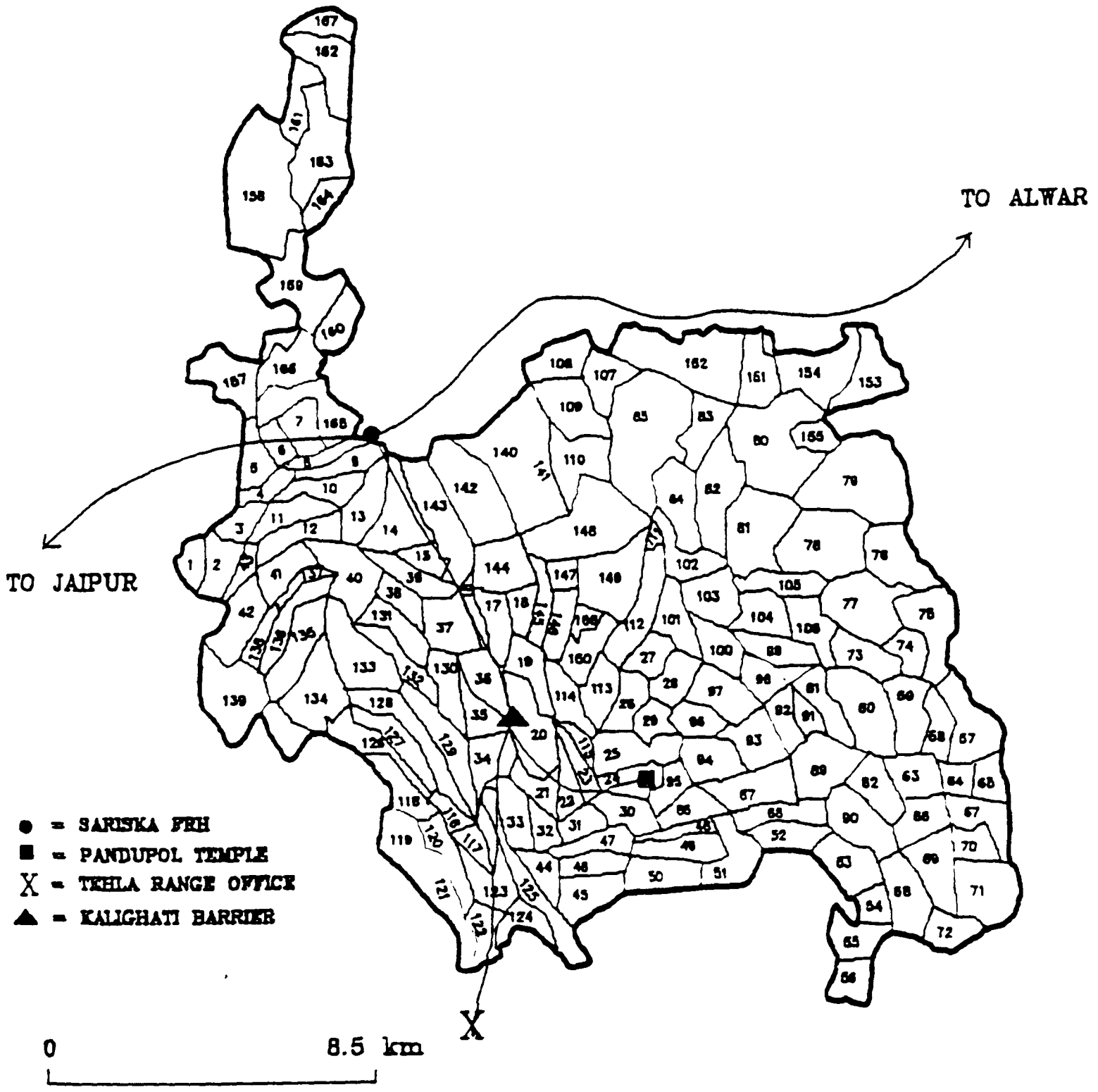


Fig. 4.3 Map of Kanha National Park showing forest compartments

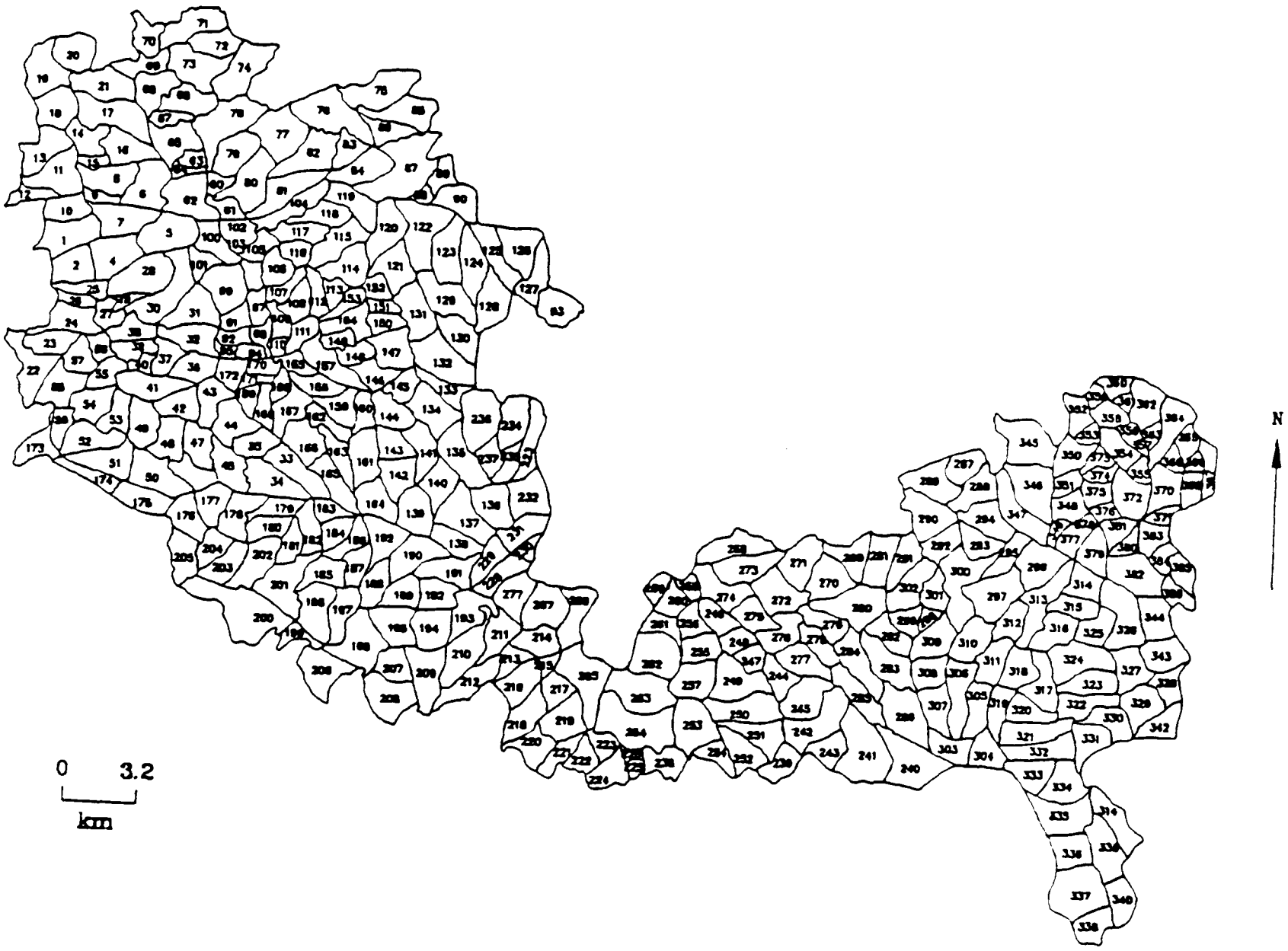


Table 4.1 Habitat stratification and transect lengths sampled by motorcycle and foot based transects. The habitat types are described in the text. The percentages are proportions of areas and transect lengths out of the total area available and length sampled, respectively

Habitat type	Area km^2	%	Motorcycle tran. length (km)	%	Foot tran. length (km)	%
TADOBA						
Teak	19.2	16.5	300.8	16	17.9	10
Teak-Bamboo	21.5	18.5	326.4	17	20.4	12
MMDF	36.1	31.0	588.8	31	57.1	33
Misc-Bamboo	35.0	35.0	556.8	30	74.2	43
Grassland	4.7	4.0	108.8	6	3.5	2
Total	116.5		1881.6		173.1	
SARISKA						
Anogeissus	28.3	9.5	185.6	10	22.5	18
Boswellia	13.4	4.5	-		-	
Anogeissus Mix	83.4	28.0	537.6	29	35.4	28
Boswellia Mix	56.4	19.0	364.8	20	15.2	12
MMTF	116.4	39.0	748.8	41	53.6	42
Total	298.0		1836.8		126.7	
KANHA						
Sal	169.2	18.0	544.0	19	48.5	25
Sal-Mix-Bamb	241.6	25.7	768.0	26	23.7	12
MMDF	150.4	16.0	480.0	16	36.0	19
Misc-Mix-Bamb	233.1	24.8	768.0	26	57.2	29
Grassland	111.9	11.9	384.0	13	29.2	15
Habitation	33.8	3.6	-		-	
Total	940.0		2944.0		194.6	

4.2.2 SELECTION AND ESTIMATION OF HABITAT VARIABLES

To fulfil the specific aims of the study, a list of variables which quantify the basic habitat components, habitat quality and which may potentially affect the habitat-herbivore relationships were selected (Table 4.2). Variables included in the study were limited to (1) which the ungulate species being investigated respond, e.g. degree of slope and (2) those which could be influenced by planning and management decisions, e.g. water availability. Many variables that are known to influence animal abundance but could not be completely estimated during the time frame for field work e.g predation were excluded from the study (see Schamberger and Neil, 1986). Some of the variables included in the study are known to influence the distribution of ungulates in the Himalayan region of Nepal (Bauer, 1990).

Table 4.2 Summary of the 22 habitat variables estimated in the present study

Number	Variable	Mnemonic	Categories
1	Slope	SLOPE	1 = Flat 2 = Medium 3 = Steep
2	Surface nature of terrain	TERNAT	1 = Clayey 2 = Bouldery 3 = Rocky
3	Paths	PATH	1 = Absent 2 = Present
4	Lopping	LOPPE	1 = None 2 = Light 3 = Medium 4 = Heavy
5	Grazing	GRAZE	"
6	Weed	WEED	"
7	Wood cutting	WCUT	"
8	Minor forest produce collection	MFPC	"
9	Seasonal availability of artificial water sources	ARTSEA	1 = None 2 = July-Dec. 3 = July-June
10	Seasonal availability of natural water sources	NATSEA	"
11	Tree density	TDEN	1 = Low 2 = Medium 3 = High

Number	Variable	Mnemonic	Categories
12	Shrub density	SDEN	1 = Low 2 = Medium 3 = High
13	Grass height	GRH	1 = None 2 = <30 cm. 3 = 30-1m 4=>1m
14	Human settlements	HUSET	1=None 2=<10Houses 3=10-25 " 4=> 25 "
15	Distance to nearest permanent water source	DNPW	1 = < 1.5 km 2 = 1.5-3 km 3 = 3-4.5 km 4 = 4.5-6 km 5 = 6-7.5 km 6 = 7.5-9 km 7 = 9-10.5 km 8 = > 10.5 km
16	Rockiness	ROCK	1 = 1-10% 2 = 10-25% 3 = 25-50% 4 = > 50%
17	Bareness	BARE	"
18	Litter cover	LITTER	1 = 1-10% 2 = 10-20% 3 = 20-30% 4 = 30-40% 5 = 40-50%
19	Bamboo cover	BAMBOO	"

Number	Variable	Mnemonic	Categories
20	Grass cover	GRSSCOV	1 = 0-10% 2 = 10-20% 3 = 20-30% 4 = 30-40% 5 = 40-50% 6 = > 50%
21 a	Shrub coverI (Upto 1 m ht.)	WVE1	1 = < 25% 2 = 25-50% 3 = 50-75% 4 = > 75%
21 b	Shrub coverII (Between 1-2 m. ht.)	WVE2	"
22	Tree cover	WVE4	"

The description of the variables included in the study follows:

1 SLOPE

Slope was estimated in three categories; flat, medium and steep. Areas between zero and one contour interval were classified as flat. Areas having >1 to 5 contours per cm on 1: 50, 000 scale topographic maps were designated as medium slopes. Areas having >5 or more contours per cm were classified as steep slopes. The contour interval was 200 cm.

2 SURFACE NATURE OF TERRAIN

The surface nature of the terrain (Ternat) was measured in three categories; clayey, bouldery and rocky. This variable was a measure of the surface condition of the habitat. Clayey nature indicated availability of soil and humus on the surface and absence of boulders and rocks. Boulders were defined as loose rocks <30 cm in diameter. Terrain having scattered outcrops of boulders >30 cm diameter was defined as rocky.

3 PATHS

Paths were measured in just two categories, absent or present, perpendicular to the major direction of movement on the transect. Paths are a measure of the domestic cattle activity in an area as fixed paths/trails, devoid of any vegetation are formed in areas where regular movement of cattle occurs.

4 LOPPING

Lopping was measured in 4 categories; from none to light, medium and heavy. Branches of trees and leaves are hacked (lopped) by cattle graziers for use as fodder by the livestock. The categories represent both the severity of lopping on a single tree as well as the number of tree lopped in an area.

5 GRAZING

Grazing by domestic livestock was also measured in 4 categories; from none to light, medium and heavy. The categories were visually estimated on the basis of either direct sighting of domestic livestock in an area or indirectly by observing the signs of overgrazing i.e grass height, proliferation of weeds.

6 WEED

Weeds are aggressive colonizers which spread rapidly, outcompeting other plant species (Sale and Berkmueller, 1988). A plant species gets the label 'weed' if it has little cover or forage value for the wild ungulates. Weed presence was also estimated in 4 categories; from none to light, medium and heavy. Dominant weeds were classified in all the study areas and their frequency and abundance in an area was visually estimated.

7 WOOD CUTTING

Wood cutting was estimated in 4 categories; none to light, medium and heavy. The proportion of illicitly cut poles and trees (>20 cm diameter breast height) as evident from recent tree-stumps and timber was taken as a measure of wood cutting in an area.

8 MINOR FOREST PRODUCE COLLECTION

Minor forest produce like thatch grass, herbs, leaves, flowers and fruit are sometimes illicitly collected from within the National Park boundaries. In Tadoba National Park, leaves of tendu (*Diospyros melanoxylon*) are collected from areas immediately surrounding the Park boundaries during the summer season. This causes a lot of disturbance to the wildlife because of the movement of men and vehicles. The disturbance was estimated in 4 categories; from none to light, medium and heavy.

9 SEASONAL AVAILABILITY OF ARTIFICIAL WATER SOURCES

The seasonal availability of artificial water sources was measured in 3 categories; none, available between July and December and year round availability. Some of the water sources in Sariska and Tadoba National Parks are artificially maintained by the Park Management. A list of all such sources was made on the basis of compartment surveys and by inquiry from wildlife guards and local people. These sources were then located on the compartment map and categorized according to the availability of water in the three different classes.

10 SEASONAL AVAILABILITY OF NATURAL WATER SOURCES

Natural water sources, *e.g.* stream, ponds, and rivers occur in the study areas. All the natural sources were listed and mapped on the basis of

information collected from various sources and then categorized in the same three classes as the artificial water sources.

11 TREE DENSITY

Tree density was visually estimated in 3 categories; low, medium and high. It was estimated in relation to a few dominant trees in the habitat type. If the distance between the stem of a dominant tree, lying nearest to the 'sampling section' on the transect and the stem of the second nearest dominant tree was more than 8 m, the tree density was categorized as low. For distances between 4 and 8 m the tree density was medium and it was high for distances <4 m. Five such measurements were made in every compartment.

12 SHRUB DENSITY

Shrub density was also visually estimated in 3 categories; low, medium and high. Dominant shrubs were defined for each habitat type. If the distance between the main trunk of a shrub lying nearest to the 'sampling section' on the transect and the main trunk of the second nearest dominant shrub was more than 4 m, the shrub density was categorized as low. For distances between 2 and 4 m, the shrub density was medium and it was high for distances <2 m. Five such measurements were made in every compartment.

13 GRASS HEIGHT

Grass height was actually measured in the field in 4 height classes: none, up to 0.3 m, between 0.3-1 m and more than 1 m. The height of the most dominant grass species nearest to the 'sampling section' was considered for this purpose.

14 HUMAN SETTLEMENTS

The human settlements were categorized in 4 different classes based on the number of dwelling units; none, <10, between 10 and 25 and more than 25 dwellings. Each human settlement was surveyed during the field work and marked on the compartment map of the study area. Information on the number of domestic livestock kept by each household was also obtained.

15 DISTANCE TO NEAREST PERMANENT WATER SOURCE

This variable was estimated from the maps. The water distribution map of the study area was overlaid on the topographic map of the compartments. The distance to the nearest source of permanent water from the geometric centre of the compartment selected for study was measured in km and classified in 8 different classes on a graded scale. For distances <1.5 km, class 1 was assigned and for distances 1.5 to 3 km class 2 and so on. The highest class was 8 for distances >10.5 km.

The variables included in the study (Table 4.2) were measured utilising four different methods. Variables 1 to 13 were measured with respect to a graded scale (1-5) by visual estimation rather than time consuming precise measurements. Variable 14 (Human settlements) was measured separately during the survey of all human settlements in the study areas. Variable 15 DNPW (Distance to nearest source of permanent water) was measured from the maps. Variables 16 to 22 were measured using the 'toe-point transect' method (See section 4.2.3). Some of the variables were measured by visual estimation method as well as the toe-point transect method and the results obtained by using these two methods have been comparatively evaluated (See section 4.2.4).

A compartment selected for the measurement of habitat variables was first located on the topographic map and then divided into 5 equidistant sections called 'sampling sections', along the longest diagonal. This was done to ensure greatest coverage of the compartment and also to avoid surveying the compartment 'edge', which could have a different habitat condition. The compartment was then located in the field with the help of topographical features and boundary description and traversed on foot along the longest diagonal. At each sampling section, the variables (No. 1 to 13) were estimated and their appropriate level on the graded scale (1-5) was entered in the habitat description sheet. Thus for every compartment selected for the study, 5 data sets, one each from the 5 sampling sections, were obtained. These data sets were pooled and an average value on the graded scale was calculated for each variable. The gathering of data from 5 sampling sections within a compartment enhanced the representative character of the data and also accounted for

any variability which might occur in different areas of the same compartment. The field work was carried out in the summer and winter seasons in 1988 and 1989 in the three study sites. Prior to this, reconnoitre trips to the study sites were made in 1987. The habitat type *Boswellia* (area 13.4 km^2) in Sariska National Park could not be surveyed adequately because of the inaccessibility of some of the compartments having pure patches of *Boswellia serrata* and has therefore been omitted from this study.

4.2.3 TOE-POINT TRANSECT METHOD

The ground cover was estimated by using a modification of the Point-Intercept Method (Mueller-Dombois & Ellenberg, 1974). The modified method called "Toe-point transect" is a rapid method for the systematic sampling of ground and aerial cover along a straight line. Variables 16 to 20, (Table 4.2) were assigned to estimate the ground cover and Variables 21a, 21b, and 22 (Table 4.2) for estimating the aerial cover. A fine notch is made on the toe of one shoe and 'hits' are recorded on every alternate step as the pacer (observer) walks along the transect. A 'hit' consists of the ground cover material covered by an imaginary, non dimensional point located at the tip of the pacer's toe. The hits are recorded in different categories (bare, rock, litter, etc.) in separate columns on the data sheet. A hit is termed a 'basal hit' if it occurs directly upon the trunk or stem of a plant species or a 'canopy hit' if it occurs under a plant species (Sale & Berkmueller, 1988). A canopy hit occurs whenever the canopy (leaves and branches) of a plant would intercept a drop of rain falling toward the

'hit point', or in other words, where a line originating perpendicularly from the point intersects the canopy. The basal hit estimates the ground cover while the canopy hit estimates the aerial cover.

At each 'sampling section' in the compartment, a transect 200 paces long was laid in a random direction. Hits were recorded on every alternate step in the different ground and aerial cover categories as the observer paced the transect. Thus 100 'points' per transect and 500 points in total from the 5 sampling sections were obtained from every compartment. These points were then converted into percentages and classified in different percentage classes. The variables 16 to 22 estimated by this method are described below:

16 ROCKINESS

This measure was intended to record the percentage of ground covered by rock. It is also a measure of the surface nature of terrain, which is included as an independent variable and is visually estimated. Four classes (1-4) were assigned; Class 1 for <10 % of the ground covered by rocks and Class 4 for >50% of ground covered by rocks.

17 BARENESS

The percentage of bare patches i.e patches devoid of natural vegetation in an area was measured by this variable. It is probably a measure of the erosion also. Its high values reflect the overuse of an area which may be due to overgrazing by domestic livestock leading to trampling and

compaction of the ground. It was also estimated in four classes as described above. Bare patches occuring due to physiographic reasons were excluded.

18 LITTER

Litter is defined as any organic material, including dead annuals and perennials. It was measured in five classes ranging from <10% litter to 40-50% litter in an area. Litter usually forms a part of the diet of wild ungulates, especially in the tropical deciduous forest in India, where leaf litter becomes seasonally available and is utilized by them.

19 BAMBOO

As bamboo forms an important part of the diet of many wild herbivores, bamboo cover in the study area was an essential variable to measure. Like Litter, it was also measured in five different classes.

20 GRASS COVER

Grasses are consumed in different proportion by all wild ungulates and so the amount of grass cover available in an area plays a significant role in determining both their distribution and abundance. It was measured in six diffferent percentage classes ranging form <10% grass cover to > 50% .

21 a SHRUB COVER 1

The Shrub cover 1 (WVE1) includes shrubs up to 2 m height and was measured in four different percentage cover classes ranging from <25% to >75%. This variable was also visually estimated (Shrub density).

21 b SHRUB COVER 2

The Shrub cover 2 (WVE2) includes shrubs between 2 to 3 m height and like Shrub cover 1 it was measured in four different percentage cover classes. This variable was also visually estimated (Shrub density).

22 TREE COVER

Tree was defined as woody vegetation >30 cm diameter breast height and >3 m in height. Tree cover (WVE4) was also measured in four different percentage cover classes ranging from <25% to >75%. This variable was also visually estimated (Tree density).

4.2.4 COMPARISON OF VISUAL ESTIMATION AND TOE-POINT TRANSECT METHODS

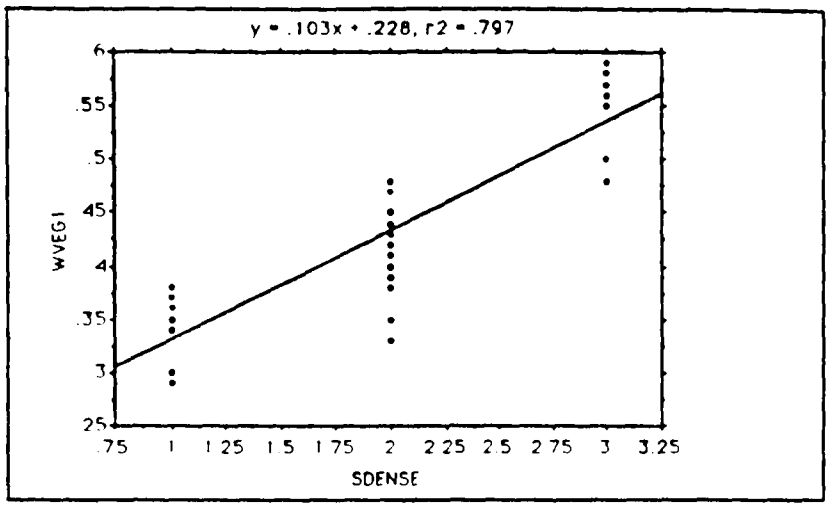
As mentioned earlier, one of the aims of the present study was to explore the validity of using rapid methods for collection of ecological data from large areas relatively quickly. A range of variables was measured by two rapid methods, *viz.* visual estimation and toe-point transect. As some

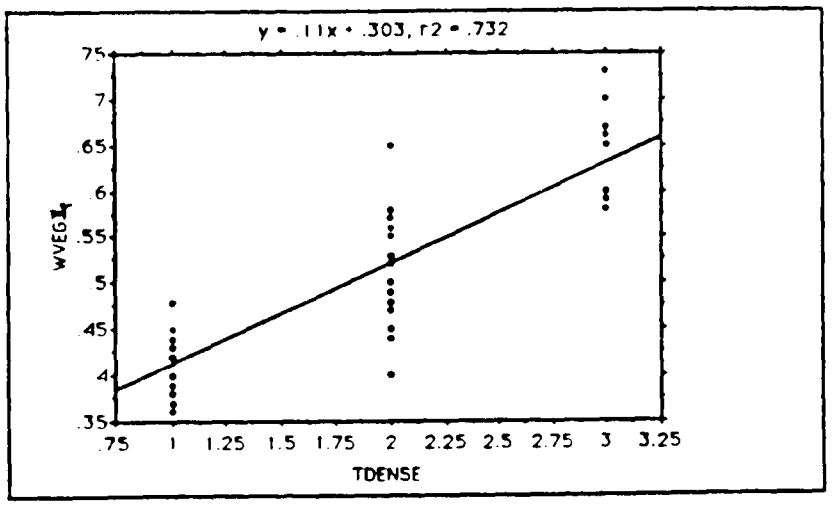
variables were simultaneously estimated by both these methods it would be interesting to compare how similar these estimates may be. The field studies were initiated in Sariska National Park and therefore the data set from this site has been used for comparisons.

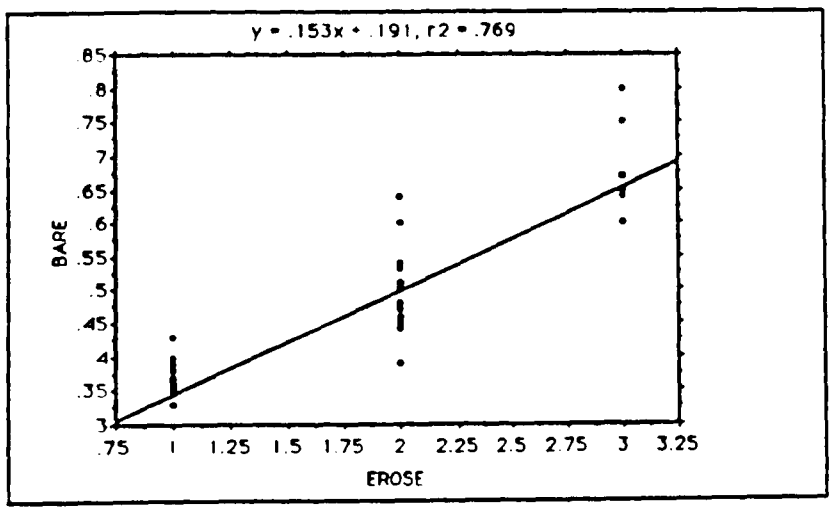
Four pairs of variables measured by visual estimation and toe-point methods respectively have been used for comparison. These are (1) shrub density (SDENSE) and woody vegetation cover (WVEG1), (2) tree density (TDENSE) and woody vegetation cover (WVEG4), (3) erosion (EROSE) and bare ground (BARE), (4) surface nature of terrain (TERNAT) and rock. As data from toe-point method is recorded in 'percentage hits', arcsine transformation of the square roots of the proportions was done to ensure homoscedasticity (See Sokal and Rohlf, 1981).

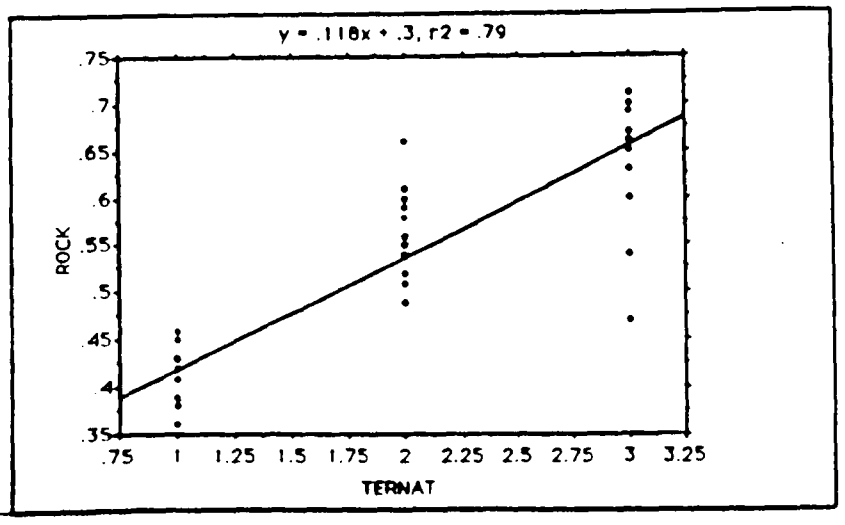
The scattergram showing the correlation between shrub density (Sdense) and woody vegetation cover (WVEG1) is presented in Fig. 4.4. The relationship between these variables is a very significant one ($r^2 = 0.79$, d. f. = 98, $p<0.0001$). A regression line ($y= 0.103 x + 0.228$) is shown to illustrate the relationship. The three set of scatterpoints represent the low, medium and high density levels of shrub density. As can be seen from the scattergram, the scatter of points about the regression line is small. However, as we move from visual estimation of medium to high levels of shrub density the scatter of points increases. This could be the result of difficulties in objectively estimating what constitutes a medium or a high shrub density level. Range of density conditions intermediate to these two classes can sometimes be difficult to assign in either category and can be reponsible for the scatter of points observed here.

Fig. 4.4 Scattergram showing the correlation between four pairs of variables estimated by visual estimation and toe-point transect methods. Variables Sdense, Tdense, Erose and Ternat are visually estimated. Variables WVEG1, WVEG4, Bare and Rock are measured by toe-point transect method









Similar relationships were observed for the other three pairs of variables (Fig. 4.4). The relationships between tree density and WVEG4 ($r^2 = 0.73$, d. f. = 98, $p<0.0001$), surface nature of terrain (Ternat) and rock ($r^2 = 0.79$, d. f. = 98, $p<0.0001$), erosion and bare ground ($r^2 = 0.76$, d. f. = 98, $p<0.001$) are all statistically significant, indicating a high level of correlation between these pairs of variables. The general trend in increase of scatter of points when visually estimating the medium to high category conditions points to the difficulties in objective visual assessment of these conditions.

In the present study, the observer bias was limited as I had taken both sets of measurements and had used predetermined 'reference conditions' for categorizing the low, medium and heavy category conditions. However, the observer bias in visual estimation is likely to increase if data sets from different observers are pooled. Visual estimation depends a lot on the ability of the observer to score the condition correctly. Toe-point transect, on the other hand, is robust and reliable as its results do not depend on the observer's ability as long as the 'hits' are correctly recorded. Moreover, observers can be quickly trained as the field procedures are simple. Large data sets can be generated relatively quickly by using several observers and by increasing the number of paces. In the present study, this method has been used extensively in the three study sites for gathering data on ground and aerial cover conditions. It may be, however, be pointed out that more studies on observer bias on the two methods are needed to reach a definite conclusion on the influence of observer on the results.

4.3 ESTIMATION OF ANIMAL ABUNDANCE

4.3.1 INTRODUCTION

A large variety of field methods are now available for the estimation of animal density. The choice of method depends very much on the nature of population, its distribution over the population area and on the method of sampling the population. Since my basic objective was to derive estimates of absolute densities rather than density indices, I discarded all methods based on indirect animal evidences. Furthermore, the practical constraints relating to the large size of the study areas, number of species involved and limited availability of time and financial resources forced me to abandon methods based on drive counts, aerial counts, mark-recapture and radio tracking. I decided to use the transect sampling technique. Transect sampling has been widely used in wildlife management and research for estimating the size of populations of both animate and inanimate objects (Anderson and Pospahala, 1970). The first known estimator for predicting population density from the line transect method was proposed by R.T.King in an unpublished work reported by Leopold (1933). Webb (1942); Hayne (1949); Yapp (1956); Dasmann and Mossman (1962a); Hirst (1969) modified the strip count method of Leopold, 1933 to describe ungulate census techniques which are inexpensive, reasonably accurate and which could be carried out rapidly by few observers. Robinette *et al.* (1954) presented a discussion of transect methods and attempted to compare the results of several methods. Eberhardt (1968; 1978) did an appraisal of line transects and discussed the estimation of bias, arising from the application of several distance estimators. Density estimation from the use of line transects is

practical, efficient and inexpensive for many populations (Anderson *et al.* 1979). Seber (1982) gave an interesting statistical state-of-the-art in estimating animal abundance.

The estimation of the size of biological populations frequently involves using either strip or line transects. Often, strip transects result in incomplete counts, and some ancillary information is needed to adjust for this bias. Line transect sampling is an application of distance sampling theory (see Gates 1979; Burnham *et al.* 1980). Considerable effort has been made in developing parametric methods for estimating density from line-transect data (Gates *et al.* 1968; Sen *et al.* 1974; Caughley, 1977). There are several assumptions necessary to line transect population estimates and Burnham and Anderson (1976) have listed them as follows:

1. Objects are distributed independently in an infinite plane according to some stochastic process.
2. A series of randomly located lines of known length traverse the plane, and the number of objects on both sides of the line are observed and the right-angle distances are recorded.
3. There is a function that gives the conditional probability of observing an object, given its right-angle distance from the line.
4. Objects exactly on the line are never missed.
5. Objects are fixed, no confusion arises over objects that move during sampling and no object is counted twice.
6. There are no measurement errors.
7. Sightings are independent events.

4.3.2 FIELD PROCEDURES

The design of the field survey is very critical to the success of line transect method and its planning requires advance information on (1) the biological aspects of the population to be studied and (2) a delineation of the area to be surveyed by shape, size and type of habitat. I used the habitat classification map developed for the study areas for systematic placement of transect lines in each habitat stratum, ensuring that sampling was in proportion to the relative availability of the habitat type within the study area. The length of the transect lines and the proportion of area sampled is given in Table 4.1.

Systematic counts were made throughout both the field seasons (summer and winter) from a motorcycle with a field assistant on the pillion, travelling at speeds between 15 and 20 km per hour. I concentrated on a 30-40 m semicircular area ahead of the vehicle, but attempted to observe as many animals as possible. From all sightings, the distance from the animal to the centre of the road when first observed was recorded. Initially, the distance was measured with a tape but later estimated by pacing.

Paces were calibrated and converted into m. In addition, the sex, group size and group composition were recorded when possible. As mentioned earlier, feeding data by direct observation of the plants eaten by the three ungulate species were also opportunistically recorded. Counting was done between 0600 and 0830 hrs in the morning and from 1600 and 1830 hrs in the evening. Motorcycle-based transects were run 32 times (morning + evening) in each habitat type, in both the summer and winter

seasons, giving the total length of the transect run in Tadoba, Sariska and Kanha National Parks to be 1881.6 km, 1836.8 km and 2944.0 km respectively (Table 4.1).

The field data were analysed by using the method developed by Gates *et al.* (1968). This method utilises only the right angle distances from the observer to the sighted animal and is shown to be approximately unbiased. Density (D) is estimated by the formula:

$$D=(n-1)/ 2 L\ddot{y}$$

where n=number of animals observed on the transect, ÿ=mean perpendicular distance and L=length of the transect. All animals observed on the transect were used to compute the estimates, regardless of distance from the centre of the transect.

The density estimates of Sambar, Chital and Nilgai, obtained from motorcycle based transects in different seasons in the three study areas are given in Appendix IV-VI. In addition to the motorcycle based transects, I estimated densities using foot transects, in order to compare the reliability of results obtained from the two methods (See section 4.3.3). Foot transects were run in all the habitat types of the study areas in the two seasons and data on animal numbers were collected through the field procedure described earlier. The density estimates from the foot transects are given in Appendix VII.

The reliability of the line transect estimates obtained in this study depend on the degree to which the assumptions of the mathematical model were or were not met. No assumptions about the spatial distribution of the objects have been made. Eberhardt (1978) and Burnham *et al.* (1980) noted that as long as the transects are randomly located (assumption 2) in reference to the objects, no assumption about random distribution need be made. The assumption 2 would be violated if animals were attracted to or avoided the transects (roads). It is felt that the roads are randomly located within a given habitat type and because of their existence for a considerable period of time the animals have become well habituated to their presence. Moreover, the vegetation on most roads is similar to that in the surrounding area. Thus it can be said that the animals in the study area are neither attracted towards the roads nor avoid them so as to bias the results. Assumption 4 was probably never violated because of the extreme care taken in sighting all the animals and especially those on the transect line.

Assumption 5 that objects are fixed and no confusion arises during sampling and none are counted twice was very likely to be violated in the present study. However, two important features of the study areas were responsible for the non-violation of this assumption. Firstly, as all these areas are very high profile tourist areas, the deer species have become habituated to human presence and do not flee immediately upon spotting the observer. Secondly, the motorcycle used in the study was of the same make as those used by the forest and wildlife personnel in the study area, to which the animals have had continuous contact and therefore the animals did not flee on hearing the sound of the approaching observer.

Finally, unlike other animal species, like the Hog deer (*Axis porcinus*), the species under investigation do not have a tendency to flush.

Assumption 6 stated that the distances were measured accurately and no rounding errors occured. It was not physically possible to measure the distance of each deer observed with a tape and so distances were paced and sometimes estimated. However, the calibration of the paces was done frequently and estimations were randomly checked by actual measurements.

Assumption 7 that sightings are independent events was largely met as the detection of one individual had no influence on the probability of detecting other individuals close by.

4.3.3 COMPARISON OF MOTORCYCLE AND FOOT TRANSECTS

I measured the densities of the three ungulate species *viz.* Sambar, Chital and Nilgai by line transect method using a) Motorcycle transects and b) Foot transects. I wanted to compare the mean densities obtained from these two approaches in order to determine their suitability in estimating ungulate populations. Motorcycle transects can be run faster than foot transects and thus a higher sampling intensity can be achieved through them. I performed ANOVA tests to compare the mean densities obtained from the two approaches in different seasons as well as by pooling the data across season. Pooling of data from the two seasons in case of

Nilgai was not done as seasonal variations in density were observed. The analyses tested the hypothesis that the mean densities obtained from the two approaches differed, against the null hypothesis that they did not differ. The results of the analysis are shown in Table 4.3. It can be inferred that except for Sambar, the mean densities of Chital and Nilgai are not significantly different from the two approaches. Sambar is a forest adapted ungulate species and prefers dense forest cover. Compared to this, Chital and Nilgai prefer the more open woodland and savanna habitats. The roads in the study areas mostly do not pass through the dense forest patches and, therefore, the probability of sighting Sambar, which prefers dense forest cover, from a motorcycle must be low resulting in an underestimation of their abundance. Foot transects, on the other hand, pass through the dense forest patches occuring in a compartment and thus cover the preferred habitat of Sambar more compared to the motorcycle transects. It can be concluded that whereas the use of motorcycle gives reliable estimates for Chital and Nilgai, foot transects should be used for estimating Sambar abundance. In the present study, data from the motorcycle transects have been used for Chital and Nilgai and from foot transects in case of Sambar.

4.3.4 SEASONAL VARIATIONS IN DENSITIES

The estimation of densities of the ungulate species was done in different habitat types within a study area in two different seasons; summer and winter. I performed a Two Factor analysis of variance (ANOVA) to determine whether the densities within the habitat types differed in the two seasons. The results of the analysis are shown in Table 4.4. The mean

densities for the three ungulate species differ significantly within the habitat types of a study area but do not differ significantly, except in case of Nilgai, in the two seasons. This is because unlike other ungulate species *e.g.*, Elephant (*Elephas maximus*) and Gaur (*Bos gaurus*), seasonal movements between habitats are generally absent in Sambar, Chital. The small seasonal change observed in Nilgai abundance is probably due to the increase in sighting of Nilgai during the time of ripening of crops in the adjacent agricultural fields. Cultivation is carried out adjacent to the entire north-western boundary of Tadoba National Park and crops are frequently raided by Nilgai. Dinerstein (1980) also reported increased sightings of Nilgai around agricultural fields near Karnali Bardia Reserve, Nepal.

Table 4.3 Results of the analysis of variance (ANOVA) tests of the hypothesis that the mean density of the three ungulate species obtained from Motorcycle and Foot transects differ. S=Significant differences exist between the two approaches (P<0.05). NS=Diffferences are not significant. D.F=Degrees of freedom

Site	Season	Species	P value	D.F	Mean density differ between Motorcycle Vs Foot transects
Tadoba					
	Summer	Sambar	0.0031	184	S
		Chital	0.4867	184	NS
		Nilgai	0.5011	184	NS
	Winter	Sambar	0.0006	184	S
		Chital	0.2185	184	NS
		Nilgai	0.0847	184	NS
	Combined	Sambar	0.0024	369	S
		Chital	0.2429	369	NS
Sariska					
	Summer	Sambar	0.0242	149	S
		Chital	0.6044	149	NS
		Nilgai	0.7838	149	NS
	Winter	Sambar	0.0086	149	S
		Chital	0.3804	149	NS
		Nilgai	0.0594	149	NS
	Combined	Sambar	0.0007	299	S
		Chital	0.2053	299	NS
Kanha					
	Summer	Sambar	0.0021	189	S
		Chital	0.6021	189	NS
		Nilgai	0.3644	72	NS
	Winter	Sambar	0.0001	189	S
		Chital	0.5730	189	NS
		Nilgai	0.0644	72	NS
	Combined	Sambar	0.0001	379	S
		Chital	0.4574	379	NS

Table 4.4 Results of the Two Factor analysis of variance (ANOVA). The factors analysed are (1) Differences in mean density of the three ungulate species in different habitat types and (2) Differences in mean density between two seasons (Summer and Winter).

Site	Species	Source of variation	df	Mean Square	F-test	P value
Tadoba						
	Sambar	Season	1	69.2189	2.2336	0.1361
		Habitat type	4	834.4824	26.927	0.0001
		Season*Habitat type	4	48.9404	1.5792	0.1796
		Error	310	30.9897		
	Chital	Season	1	1648.4283	2.8162	0.0943
		Habitat type	4	2323.3339	3.9692	0.0037
		Season*Habitat type	4	111.8194	0.191	0.9430
		Error	310	585.3348		
	Nilgai	Season	1	261.1253	6.3047	0.0126
		Habitat type	4	676.1496	16.3253	0.0001
		Season*Habitat type	4	12.2362	0.2954	0.8808
		Error	310	41.4174		
Sariska						
	Sambar	Season	1	12.0032	0.4886	0.4852
		Habitat type	3	493.364	20.083	0.0001
		Season*Habitat type	3	63.8778	2.6003	0.0527
		Error	248	24.5658		
	Chital	Season	1	236.3985	2.9361	0.0879
		Habitat type	3	503.6006	6.2549	0.0004
		Season*Habitat type	3	76.6092	0.9515	0.4163
		Error	248	80.5132		
	Nilgai	Season	1	424.7108	5.0377	0.0257
		Habitat type	3	3051.6426	36.1971	0.0001
		Season*Habitat type	3	196.7978	2.3343	0.0745
		Error	248	84.3063		
Kanha						
	Sambar	Season	1	37.3021	3.3631	0.0676
		Habitat type	4	62.556	5.6400	0.0002
		Season*Habitat type	4	17.9373	1.6172	0.1697
		Error	310	11.0914		
	Chital	Season	1	1358.4436	1.6227	0.2037
		Habitat type	4	99005.083	118.264	0.0001
		Season*Habitat type	4	695.6306	0.8309	0.5063
		Error	310	837.1524		
	Nilgai	Season	1	23.428	4.0929	0.0452
		Habitat type	1	0.2594	0.0453	0.8318
		Season*Habitat type	1	2.8373	0.4957	0.4827
		Error	124	5.724		

4.4 HABITAT SELECTION

The analyses of habitat selection is central to the study of animal ecology (Ben-Shahar and Skinner, 1988) and differential habitat selection is one of the principal mechanisms which permits species to co-exist (Rosenzweig, 1981). The Chi-square goodness-of-fit is a common statistical approach for testing if observed habitat use is equal to expected use. Several associated methods have been used to determine habitat preferences (Neu *et al.*,1974; Singer et al., 1981; Ringelman and Longcore, 1982; Jenkins and Starkey, 1984). Johnson (1980) described the general problem of determining selection when resource use is compared to availability. In this study, I used a test concerning proportions, based on the normal approximation to the binomial distribution (Bhattacharya and Johnson, 1977) to test the preference or avoidance of the different habitat types by the three ungulate species:

$$Z = \frac{p - p_0}{\sqrt{p_0 (1 - p_0)/n}}$$

where n is the total number of independent animal observations, p the proportion of observation made in each habitat type, and p_0 the proportion of each habitat type within the study area. To avoid problems of sample interdependence, solitary animals as well as herds were all treated as independent observations. This test provides unbiased results if the number of habitat types is small (≤5) and the total number of independent observations are >50. These conditions were met in this

study and thus the probability of committing both Type I and Type II errors (Alldredge and Ratti, 1986) was greately reduced. A Bonferroni Z-statistic (Miller, 1981) was used to graphically visualise the degree of preference or avoidance for the different habitat types (see Figures 6.1, 7.1 and 8.1). The proportion of independent animal observation in different habitat types compared with the proportion of area covered by each class within the study area are shown in Table 4.5 and 4.6.

Table 4.5 Proportions of the three wild ungulate species observed in different habitat types compared with the proportion of area covered by each habitat type in Tadoba and Kanha National Parks. Habitat types are described in the text. N=number of independent animal observations.

TADOBA	Habitat types				
Sambar (N=551)	Teak	Teak-Bamb	MMDF	Misc-Bamb	Grassland
Observed proportion of Sambar	0.23	0.27	0.13	0.29	0.08
Proportion of area	0.16	0.18	0.31	0.30	0.05
Z-value	4.60	4.52	-9.13	-0.51	3.26
P-value	<0.01	<0.01	<0.01	0.30	<0.01
Chital (N=435)					
Observed proportion of Chital	0.21	0.19	0.24	0.26	0.10
Proportion of area	0.16	0.18	0.31	0.30	0.05
Z-value	2.87	0.54	-3.18	-1.82	4.80
P-value	<0.01	0.30	<0.01	0.03	<0.01
Nilgai (N=481)					
Observed proportion of Nilgai	0.09	0.11	0.51	0.17	0.12
Proportion of area	0.16	0.18	0.31	0.30	0.05
Z-value	-4.26	-4.02	9.91	-6.37	7.21
P-value	<0.01	0.01	<0.01	0.01	<0.01
KANHA					
Sambar (N=502)	Sal	SalMBamb	MMDF	MiscMBamb	Grassland
Observed proportion of Sambar	0.18	0.30	0.11	0.27	0.14
Proportion of area	0.18	0.26	0.16	0.25	0.12
Z-value	-	2.10	-3.12	1.03	1.36
P-value	-	0.01	<0.01	0.15	0.09
Chital (N=504)					
Observed proportion of Chital	0.10	0.16	0.09	0.26	0.39
Proportion of area	0.18	0.26	0.16	0.25	0.12
Z-value	-4.73	-5.26	-4.37	0.51	19.01
P-value	<0.01	<0.01	<0.01	0.30	<0.03
Nilgai (N=135)					
Observed proportion of Nilgai	-	-	0.50	-	0.50
Proportion of area	0.18	0.26	0.16	0.25	0.12
Z-value	-	-	10.82	-	13.62
P-value	-	-	<0.01	-	<0.01

Table 4.6 Proportions of the three wild ungulate species observed in different habitat types compared with the proportion of area covered by each habitat type in Sariska National Park. Habitat types are described in the text. N=number of independent animal observations.

	Habitat types			
Species	Anog.	Anog. Mix	Bosw. Mix	MMTF
Sambar (N=352)				
Observed proportion of Sambar	0.22	0.34	0.18	0.26
Proportion of area	0.10	0.28	0.19	0.39
Z-value	7.59	2.54	-0.47	-4.65
P-value	<0.01	<0.01	0.34	<0.01
Chital (N=806)				
Observed proportion of Chital	0.06	0.31	0.16	0.47
Proportion of area	0.10	0.28	0.19	0.39
Z-value	-3.84	2.01	-2.18	4.54
P-value	<0.01	0.02	0.01	<0.01
Nilgai (N=1253)				
Observed proportion of Nilgai	0.03	0.23	0.10	0.64
Proportion of area	0.10	0.28	0.19	0.39
Z-value	-8.43	-4.23	-8.49	20.16
P-value	<0.01	<0.01	<0.01	<0.01

CHAPTER FIVE

HERBIVORE-HABITAT RELATIONSHIPS: INTRODUCTION AND METHODS

5.1 INTRODUCTION

The concept of habitat is of central importance in ecology as the habitat forms the basic link between the organisms and their external environment. Habitat has been defined theoretically as the location that supports a population including space, food, cover and other animals (Giles, 1978) and is often characterized by vegetation, landform and hydrology (Odum, 1971). Although the emphasis on studying wildlife habitat relationships is fairly recent, it is neither a new philosophy nor a new approach to resource management (Salwasser *et al.*, 1980). It is simply the comprehensive organization of the vast array of existing information in a format that is useful for managing animals through the management of their corresponding habitats.

What constitutes a good habitat for a species is of fundamental importance to both wildlife ecologist and manager. Every organism is dependent on its habitat for food, cover and other resources. The variations in these resources and other physical features of habitat often result in differences in animal abundances. The habitat quality is reflected

in the spatial arrangement of various habitats and their ability to provide the necessary life requisites (Lancia *et al.*, 1982). Until recently, very few studies have attempted to describe in detail the various attributes of a habitat and to explain their significance in determining habitat quality and thereby influencing species abundance. Moreover, as Van Horne (1983) has pointed out, our knowledge of species' specific requirements is often poor and interactive effects among resources are ignored while assessing the habitat suitability.

In this chapter, I discuss the analytical methods used in studying the herbivore-habitat relationships. The next three chapters i.e. Chapter Six, Seven and Eight discuss the results obtained from studying the herbivore-habitat relationships in the three study sites Tadoba, Sariska and Kanha National Parks respectively. The study of these relationships is vital not only for determining the habitat requirements of Sambar, Chital and Nilgai but also for understanding the mechanisms by which these sympatric species co-exist. The information gained from the identification of biotic and abiotic variables which influence the species abundance could be used in conjuction with our knowledge of the species habitat requirements to assess the suitability of the habitat for various species.

5.2 METHODS

The general methodology for obtaining data on the species abundance and habitat parameters has already been described in Chapter Four. In this section, I discuss the methods applied in the analyses of above data. The data were analysed using Generalised Linear Interactive Modelling as implemented in the package GLIM (NAG, 1986). GLIM provides powerful statistical modelling facilities which extend beyond the standard normal linear model and enable many different types of response variable to be modelled in a consistent way. GLIM allows models to be developed based on the concept that a random variable has an underlying structure which may explain the observed values from the variable and predict future variables (NAG, 1986). The variable is defined as being composed of two parts, a systematic component and a random component. By defining the error distribution as either Poisson or Binomial, GLIM initially fits a model to the dependent (response) variable which accounts for the variation as being due to the random component (hereafter called the Null Model). One then adds predictor (explanatory) variables which form part of the systematic component of the model. The order in which variables are included in the model can be decided using one of four readily available procedures (see Draper and Smith,1966). I used the forward stepwise procedure as it is very powerful and convenient to use when constructing statistical models. Table 5.1 summarises the steps used in the forward selection procedure for determining the order in which the explanatory variables are incorporated into a model.

Table 5.1 Details of the forward selection procedure used to determine the order in which explanatory variables are incorporated into a Model (after Nicholl, A. O. 1989)

Step 1	For each variable not currently in the model determine the change in deviance resulting from the addition to the model of this variable. To do this, each variable to be tested is first added to the model and then removed from the model before the next variable is tested.
Step 2	Determine the significance of the change in deviance for each variable added by assuming the change in deviance is distributed as a chi-squared statistic with degrees of freedom equal to the number of parameters needed to be estimated for each variable.
Step 3	Select from those variables which resulted in a significant change in deviance the one associated with the largest change in deviance and add this variable to the model. If no variable caused a significant change in deviance add no variable and accept the current model and proceed to step 5.
Step 4	If a variable was added at step 3 and further variables remain then proceed to step 1 and start the next pass of the forward selection procedure. If no further variables remain to be included in the model then proceed to step 5.
Step 5	Start the model evaluation by examining the fitted parameters, standard errors, residuals and regression diagnostic variables.

The addition of explanatory variables can significantly reduce the amount of variation (deviance) of the model. This change in deviance from the original null model is used to test the significance of adding or subtracting a variable. This method gives a predictive power to the systematic component of the model and reduces the amount of variation that still needs to be explained with respect to the dependent variable. A 5% significance level was used as a criterion for the inclusion of a new variable.

In the analyses of the species-habitat relationships, the habitat variables were treated as categorical as they formed ranked classes (I to VIII) (Table 5.2). These variables were fitted to the response variable *viz.* Sambar, Chital and Nilgai abundance. Due to the discrete nature of the response variable, the distribution was assumed to be Poisson. The consideration of the relationship between the explanatory variable and the response variable, and the nature of the latter determines the possible link function (Dobson, 1983; McCullagh and Nelder, 1983). For Poisson data a log link is commonly used. The analysis of deviance was conducted and a null model was initially fitted and a deviance value, D, calculated, which approximates a chi-squared distribution. The model terms were then entered and a term was retained whenever its addition significantly reduced the deviance with respect to the null model and any model term already fitted. A significant change of deviance after the addition of a term indicates that the independent variable makes a statistically significant contribution in explaining any pattern in the data.

During the exploratory model building phase I discovered that in some of the models, the habitat type when fitted as an independent variable, resulted in very large changes in deviance and masked the effect of other variables which were subsequently added to the model. To overcome this problem I adopted the following steps. Firstly, the data sets from the different habitat types in a study area were pooled to form a combined data set. Secondly, I decided to construct two statistical models, Model A and Model B. In Model A, the habitat variables (Table 5.2) are fitted in the order in which their addition at each stage results in the maximum change in deviance. Model B introduces the concept of habitat categories. In this Model, the habitat type (Table 5.3) causing the maximum change in deviance is fitted first and other habitat variables are then added to the model if their addition results in any significant change in deviance. Thus Model B helps in identifying the independent variables which can explain the patterns in abundance of the dependent variable after the effects of the dominant habitat types have been considered. The influence of the various factor levels of the variables included in the model can be further studied by examining the coefficients and standard errors of the parameters appended to each model. It must be noted that the ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable.

To check that the Generalised Linear Models constructed truly represent the data and model the variance/mean relationships adequately I evaluated Models A and B using the following standard procedure: 1) examination of the residuals for detecting lack of fit, 2) estimation of model parameters and 3) plotting the standardised residuals against the fitted values.

Table 5.2 Summary of the categorical habitat variables used in the statistical analyses by GLIM

Variable	Mnemonic	Categories
Slope	SLOPE	1 = Flat 2 = Medium 3 = Steep
Surface nature of terrain	TERNAT	1 = Clayey 2 = Bouldery 3 = Rocky
Paths	PATH	1 = Absent 2 = Present
Lopping	LOPPE	1 = None 2 = Light 3 = Medium 4 = Heavy
Grazing	GRAZE	"
Weed	WEED	"
Wood cutting	WCUT	"
Minor forest produce collection	MFPC	"
Seasonal availability of artificial water sources	ARTSEA	1 = None 2 = July-Dec. 3 = July-June
Seasonal availability of natural water sources	NATSEA	"

Variable	Mnemonic	Categories
Tree density	TDEN	1 = Low 2 = Medium 3 = High
Shrub density	SDEN	1 = Low 2 = Medium 3 = High
Grass height	GRHT	1 = None 2 = <30 cm. 3 = 30-1m 4=>1m
Human settlements	HUSET	1 = None 2 = <10Houses 3 = 10-25 " 4 = > 25 "
Distance to nearest permanent water source	DNPW	1 = < 1.5 km 2 = 1.5-3 km 3 = 3-4.5 km 4 = 4.5-6 km 5 = 6-7.5 km 6 = 7.5-9 km 7 = 9-10.5 km 8 = > 10.5 km
Rockiness	ROCK	1 = 1-10% 2 = 10-25% 3 = 25-50% 4 = > 50%
Bareness	BARE	"

Variable	Mnemonic	Categories
Litter cover	LITTER	1 = 1-10% 2 = 10-20% 3 = 20-30% 4 = 30-40% 5 = 40-50%
Bamboo cover	BAMBOO	"
Grass cover	GRSSCOV	1 = 1-10% 2 = 10-20% 3 = 20-30% 4 = 30-40% 5 = 40-50% 6 = > 50%
Shrub coverI (Upto 1 m ht.)	WVE1	1 = < 25% 2 = 25-50% 3 = 50-75% 4 = > 75%
Shrub coverII (Between 1-2m. ht.)	WVE2	"
Tree cover	WVE4	"

Table 5.3 Summary of the habitat types used as explanatory variables in statistical analyses by GLIM

Site	Variable	Mnemonic	Categories
Tadoba	Teak	TEAK	1 = None 2 = 1-25% 3 = 25-50% 4 = 50-75% 5 = > 75%
	TeakBamboo	TEAKBAM	"
	Misc-mixed	MMDF	"
	MiscBamboo	MISCBAM	"
	Grassland	GRASS	"
Sariska	Anogeissus	ANOG	1 = 1-25% 2 = 25-50% 3 = 50-75% 4 = > 75%
	Anogeissus Mix	ANOGMX	"
	Boswellia Mix	BOSWMX	"
	Misc-dry	MDTF	"
Kanha	Sal	SAL	1 = 25-50% 2 = 50-75% 3 = > 75%
	SalMixBam	SALMXBAM	1 = None 2 = 1-25% 3 = 25-50% 4 = 50-75% 5 = > 75%
	Misc-mixed	MMDF	"
	MiscMixBam	MISCMXBAM	"
	Grassland	GRASS	"

CHAPTER SIX

TADOBA NATIONAL PARK: RESULTS AND DISCUSSION

6.1 RESULTS

The results of the statistical analyses carried out on data from Tadoba National Park using the Generalized Linear Interactive Modelling (GLIM) procedures are presented in this chapter separately for the three ungulate species *viz.* Sambar, Chital and Nilgai. Statistical Models A and B (see Chapter Five) have been developed for each ungulate species and are presented in the following sections.

6.1.1 SAMBAR

The Null model has deviance 1688.9 with 319 d.f.(Table 6.1). Model A explains the abundance of Sambar in the study area on the basis of three categorical variables. These are Litter (χ^2= 68.0, d.f. =2, p<0.001), Huset (χ^2= 194.1, d.f. = 3, p<0.001) and Dnpw (χ^2= 28.1, d.f. = 4, p<0.001) which all have very significant effects on Sambar numbers. The presence of leaf litter in an area has a positive influence on Sambar abundance presumably because it forms part of the Sambar's diet especially in the dry season. The relationship between the variable Dnpw (Distance to nearest source of permanent water) and Sambar abundance shows an interesting pattern.

Table 6.1 Analysis of deviance showing the factors which effect the abundance of Sambar in Tadoba National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1688.9	319			
+Litter(3)	1620.9	317	68.0	2	<0.001
+Huset(4)	1426.8	314	194.1	3	<0.001
+Dnpw(5)	1398.7	310	28.1	4	<0.001

The coefficients and standard errors for the Model A. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.8620	0.0470	1
0.5939	0.0683	Litter(2)
0.3498	0.0648	Litter(3)
0.0624	0.1967	Huset(2)
-0.9510	0.0868	Huset(3)
-0.4499	0.1926	Huset(4)
0.1068	0.0524	Dnpw(2)
-0.0812	0.0769	Dnpw(3)
-0.4219	0.1109	Dnpw(4)
-0.4323	0.1440	Dnpw(5)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1688.9	319			
+Teakbam(4)	1451.0	316	237.93	3	<0.001
+MMDF(5)	1256.0	312	194.94	4	<0.001
+Tden(2)	1234.5	311	21.50	1	<0.001
+Litter(3)	1227.8	309	6.70	2	<0.05

The coefficients and standard errors for the Model B. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.8310	0.2015	1
-0.0668	0.0927	Teakbam(2)
-0.0030	0.1093	Teakbam(3)
0.3970	0.1017	Teakbam(4)
0.1019	0.2223	MMDF(2)
-0.0249	0.2323	MMDF(3)
-0.9102	0.2451	MMDF(4)
-0.9254	0.2709	MMDF(5)
0.9410	0.0642	Tden(2)
0.2401	0.0936	Litter(2)
0.1849	0.0780	Litter(3)

If water is available within a radius of 3 km the habitat remains suitable for Sambar. As the distance increases beyond 3 km and more i.e. (Dnpw(4) and Dnpw(5)), the suitability of the habitat decreases as water increasingly becomes a limiting factor. In other words, permanent sources of water should not be located more than 3 km apart in a prime Sambar habitat. Similarly, while moderate levels of human settlements have little negative influence on Sambar abundance, the higher levels of Huset (3) and Huset (4) have significant negative effects.

Model B accounts for the abundance of Sambar in the study area on the basis of four variables. These are Teakbam (χ^2= 237.93, d.f. = 3, p<0.001), MMDF (χ^2= 194.94, d.f. = 4, p<0.001), Tree density (χ^2= 21.50, d.f. = 1, p<0.001) and Litter (χ^2= 6.70, d.f. = 2, p<0.05). The presence and relative proportion of two habitat types Teakbam (4) and MMDF (5) have opposing effects on Sambar abundance. Low proportion of Teakbam and high proportion of Miscellaneous-mixed dry deciduous (MMDF) have a negative influence on Sambar abundance but high proportion of Teakbam and low of MMDF habitat type have a strong positive influence. This may be because a higher proportion of Teakbam probably means a greater availability of both cover and fodder. Similarly, as shown in Model A also the presence of litter in the habitat has a significant positive effect (p<0.05) in enhancing Sambar abundance.

6.1.2 CHITAL

The Null Model has the deviance 6453.8 with 319 d.f. (Table 6.2). Model A explains the abundance of Chital in this study area in terms of four variables. These are Natsea (χ^2= 311, d.f. = 2, p<0.001), Grsscov (χ^2= 46, d.f. = 3, p>0.001), Paths (χ^2= 122, d.f. = 1, p<0.001), and Mfpc (χ^2= 30, d.f. = 2, p<0.001). The perennial availability of water i.e. Natsea(3) enhances the suitability of a habitat for Chital as it depends on the presence of surface water for drinking. Similarly, grass cover also has a positive influence on Chital abundance as grass provides both forage and cover to Chital. Paths and Mfpc both have negative influence on Chital abundance. Paths, probably are an indicator of cattle activity in the habitat as permanent cattle paths or tracks are formed in areas where regular movements of the herds of domestic livestock occurs. The negative influence of Paths on Chital abundance suggests that Chital avoid areas with intense cattle activity. Mfpc (Minor forest produce collection) is a very important variable in this study area and is found to have a significant (p<0.001) negative impact on the abundance of Chital. There are a number of commercially important tree species in the area and during the months of May and June collection of leaves of *Diospyros melanoxylon* takes place in and around the park boundaries. Similarly, fruits of *Syzygium cumini, Ficus glomerata and Madhuca longifolia* are collected by people of the area. Incidentally, these fruits are highly preferred by Chital and form an important part in their diet during the summer months when grasses become very dry and coarse to eat.

Model B explains the abundance of Chital on the basis of five variables. Two habitat types MMDF (5) and Teak (5) have very significant effects ($p<0.001$) and so have the three habitat variables Natsea ($\chi^2= 47.0$, d.f. = 2, $p<0.001$), Grasscov ($\chi^2= 82.0$, d.f. = 2, $p<0.001$) and Mfpc ($\chi^2= 20.0$, d.f. = 2, $p<0.001$). The positive influence of habitat type Teak on Chital abundance, though it has very little forage values may be explained on the basis that this habitat type in Tadoba occurs along the periphery of the Tadoba lake, which is a preferred site for Chital due to presence of water and palatable grasses.

Table 6.2 Analysis of deviance showing the factors which effect the abundance of Chital in Tadoba National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	6453.8	319			
+Natsea(3)	6143.0	317	311.0	2	<0.001
+Grsscov(4)	6097.2	314	46.0	3	<0.001
+Paths(2)	5975.1	313	122.0	1	<0.001
+Mfpc(2)	5944.8	311	30.0	2	<0.001

The coefficients and standard errors for the Model A. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
2.9650	0.0244	1
0.2079	0.0680	Natsea(2)
0.3295	0.0300	Natsea(3)
0.2013	0.0450	Grsscov(2)
0.2898	0.0302	Grsscov(3)
0.0654	0.0202	Grsscov(4)
-0.2384	0.0696	Paths(2)
-0.3018	0.0803	Mfpc(3)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	6453.8	319			
+MMDF(5)	6110.4	315	343.4	4	<0.001
+Teak(5)	5959.4	311	151.0	4	<0.001
+Natsea(3)	5912.6	309	47.0	2	<0.001
+Grsscov(3)	5830.5	307	82.0	2	<0.001
+Mfpc(3)	5810.9	305	20.0	2	<0.001

The coefficients and standard errors for the Model B. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
2.8880	0.1482	1
0.1888	0.1074	MMDF(2)
0.3054	0.1189	MMDF(3)
0.2283	0.1231	MMDF(4)
0.1386	0.1375	MMDF(5)
-0.4394	0.0560	Teak(2)
-0.3647	0.0702	Teak(3)
0.3183	0.1031	Teak(4)
0.1596	0.1046	Teak(5)
-0.0107	0.0771	Natsea(2)
0.1657	0.0308	Natsea(3)
0.3715	0.0762	Grsscov(2)
0.5007	0.0773	Grsscov(3)
-0.2446	0.0586	Mfpc(2)
-0.3943	0.1107	Mfpc(3)

6.1.3 NILGAI

The Null Model has the deviance 1986.8 with 319 d.f. (Table 6.3). Model A explains the abundance of Nilgai in the study area on the basis of five habitat variables. These are Tden (χ^2= 118.2, d.f. = 1, p<0.001), Huset (χ^2= 126.7, d.f. = 3, p<0.001), Ternat ((χ^2= 21.9, d.f. = 2, p<0.001), Grsscov (χ^2= 61.8, d.f. = 1, p<0.001) and Paths ((χ^2= 17.5, d.f. = 1, p<0.001). Tree density (Tden) has a negative influence while Grass cover (Grsscov) has a positive influence on Nilgai abundance. This suggests that Nilgai prefers an open grassy habitat rather than dense woodland/forest. The relationship of Nilgai with human settlements shows an interesting pattern. Compared to both Sambar and Chital, Nilgai is able to tolerate higher levels of disturbance from human settlements. Only when the number of human dwellings become quite high (Huset (4)) the negative impacts begins to appear.

Model B explains the abundance of Nilgai in the study area on the basis of two habitat type variables, MMDF((χ^2= 214.9, d.f. = 4, p<0.001) and Teakbam (χ^2= 61.1, d.f. = 3, p<0.001), both of which have a positive influence and two other variables, Tden (χ^2= 48.1, d.f. = 1, p<0.001) and Huset (χ^2= 14.9, d.f. = 2, p<0.05), which both have a negative effect. The MMDF habitat type, as mentioned earlier represent a habitat condition in which a number of mixed tree species are present and the canopy cover is relatively open. Thus, it offers optimal habitat conditions for Nilgai which are present in higher numbers. The effects of tree density and human settlements have already been discussed in relation to Model A.

Table 6.3 Analysis of deviance showing the factors which effect the abundance of Nilgai in Tadoba National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1986.8	319			
+Tden(2)	1868.7	318	118.2	1	<0.001
+Huset(4)	1742.0	315	126.7	3	<0.001
+Ternat(2)	1720.1	313	21.9	2	<0.001
+Grsscov(3)	1658.2	311	61.8	1	<0.001
+Paths(2)	1640.7	310	17.5	1	<0.001

The coefficients and standard errors for the Model A. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.4520	0.0979	1
-0.3102	0.0549	Tden(2)
0.6697	0.2820	Huset(2)
0.5491	0.0948	Huset(3)
-0.4957	0.2090	Huset(4)
0.3653	0.0617	Ternat(2)
0.7092	0.0960	Ternat(3)
-0.2136	0.0767	Grsscov(2)
0.3494	0.0709	Grsscov(3)
0.4640	0.1123	Paths(2)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1986.8	319			
+MMDF(5	1771.9	315	214.9	4	<0.001
+Teakbam(4)	1709.8	312	61.1	3	<0.001
+Tden(2)	1661.7	311	48.1	1	<0.001
+Huset(4)	1646.7	309	14.9	2	<0.05

The coefficients and standard errors for the Model B. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.5350	0.2805	1
-0.0553	0.3105	MMDF(2)
-0.0173	0.3264	MMDF(3)
0.7333	0.3204	MMDF(4)
0.6664	0.3267	MMDF(5)
0.5252	0.1484	Teakbam(2)
0.4223	0.1773	Teakbam(3)
0.1278	0.1603	Teakbam(4)
-0.3480	0.0490	Tden(2)
0.0000	aliased	Huset(2)
0.1150	0.0824	Huset(3)
-0.5593	0.1916	Huset(4)

6.2 DISCUSSION

One of the basic assumptions in the present study on species-habitat relationships is that a species selects and uses areas which are best suited to meet its life requisites and therefore greater use occurs in better quality habitats. This assumption can be validated if it can be shown that the measure of use i.e. species abundance in this study and habitat quality are related. Van Horne (1983) has argued that animal abundance levels do not necessarily reflect habitat quality and has given examples when density-habitat quality relationship is likely to be decoupled. He considers that densities of species having social dominance interactions, high reproductive capacity and generalist nature may not be positively correlated with habitat quality. However, the species investigated in the present study apart from being generalist do not have the other two

characteristics. Sambar, Chital and Nilgai are all generalist species and because of their diurnal nature, relatively large body size and lack of shyness, are very easy to detect in the field. They are, therefore, eminently suitable for studying the species abundance and habitat relationships. Moreover, in the present study, these species have been investigated in a range of habitat types. Furthermore, density measurements have been made in different seasons so that the effects of seasonal variations on density have already been accounted for. It may, therefore, be safely concluded that their densities reflect the quality of the habitats they occupy.

The results indicate that the habitat types within a study area have predominant influence on the abundance level of different animal species. The influence of habitat types on species abundance can be graphically shown (Fig. 6.1) by plotting the Z-statistic obtained in Chapter 4, Table 4.5. Fig. 6.1 shows the avoidance and attraction for the habitat types in the study area by the three ungulate species. Sambar exhibits a preference for the forested habitats comprising of Teak and other associated species (especially bamboo) and shows avoidance for miscellaneous open habitats. The miscellaneous open habitats in the study area are characterized by the presence of human settlements and livestock grazing. These factors along with the absence of dense vegetation cover are primarily responsible for the avoidance behaviour by Sambar. Chital shows a distinct preference for grassland and like Sambar an avoidance for the miscellaneous open habitat.

The preference exhibited for the Teak habitat is mainly because of the Tadoba lake, which lies in the centre of this habitat type and serves as a perennial source of water for Chital. Nilgai exhibits a marked preference for the miscellaneous open habitat and the grasslands. It is absent or only present in very low numbers in other habitat types of the Park.

The habitat types have structural and compositional differences (such as grassland *vs* woodland) which are primarily responsible for influencing a species selection/avoidance response. Within a habitat type a range of biotic pressures operate to which these species show a differential response. A habitat type which provides most of the species life requisites would certainly be the most preferred habitat type for that species. Sambar habitat requirements are a moderate degree of slope, perennial availability of water, 25-50% woody vegetation cover up to a 2 m height level and over 75% cover at 8 m height. Availability of bamboo at browse level and the absence of human settlements further enhances the suitability of the habitat for Sambar in Tadoba National Park. The bamboo (*Dendrocalamus strictus*), which occupies a significant proportion of the the Park as a middle storey associate of Teak and other miscellanous species, flowered gregariously in 1981-82. Since this flowering, which is a natural process occuring in the area on a forty year cycle, it has regenerated naturally. As no silivicultural treatment has been given to the bamboo clumps they have not grown in height but have assumed a bushy appearance. Bamboo now occurs at browse level and its tender shoots form a significant proportion of the Sambar's diet. On the basis of the above knowledge about the habitat requirements of Sambar it is easy to

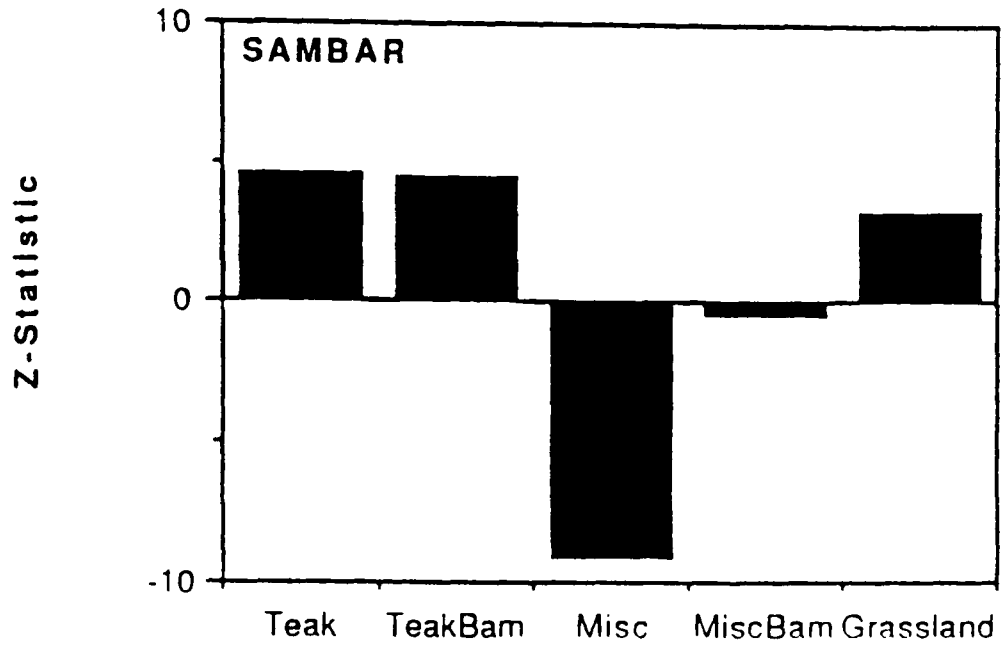
understand why the density of Sambar in habitat type TeakBam is 12.69 ± 1.97/km^2 (see Appendix IV) and in Miscellaneous (MMDF) habitat type is 2.85 ± 0.26/km^2 respectively. The overall density of Sambar in Tadoba is 7.72 ± 0.70/km^2 which compares very favourably with the density of Sambar in other study sites (see Table 10.4) indicating that in general the suitability of the habitat is quite good.

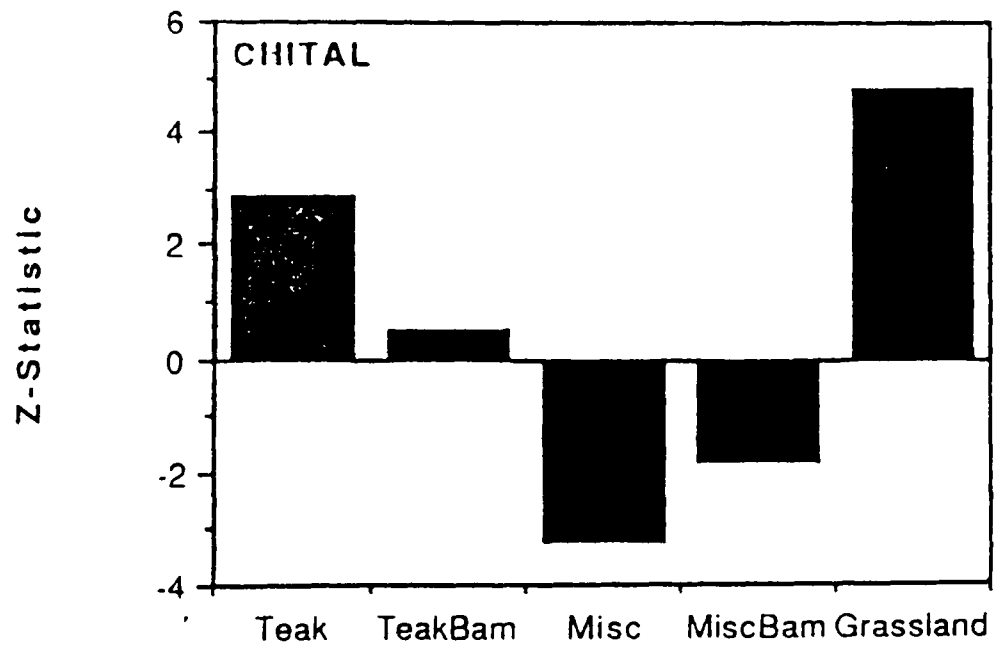
Chital requires gentle slopes, perennial availabilty of water, moderate level of shrub and tree cover, high degree (>50%) grass cover and grass height between 0.3-1 m. It is relatively more tolerant towards the disturbance caused by the presence of human settlements but cannot remain far away from water sources. In the Park, Chital density is highest in grassland habitat (28.79 ± 8.17/km^2) but this is very low compared with grasslands in Kanha where the Chital density is 96.16 ± 15.65/km^2 . This is probably because the meadows in Tadoba are very small (4.7 km^2) as compared to Kanha (111.9 km^2) and are dominated by coarse and unpalatable grasses. Chital in Tadoba are mainly concentrated around the centrally situated Tadoba lake, on the edge of which, green grasses are always available, and on whose periphery fruit bearing trees *Syzyium cuminii* and *Ficus glomerata* have been planted.

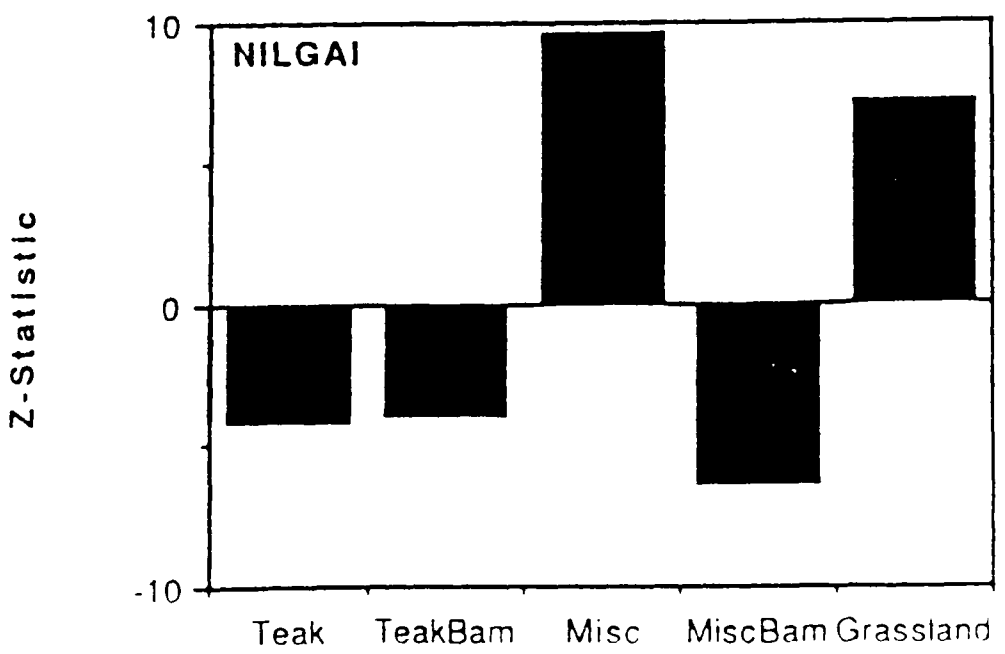
The habitat requirements of Nilgai are flat to medium slopes, high degree of shrub cover but very low levels of tree cover. The dependence of Nilgai on water is very low and its cruising radius for water is around 6 km. This is higher than that of both Chital and Sambar. Like Chital, Nilgai also prefers 30-40% grass cover and grass height of 0.3-1.0 m. Unlike Sambar and Chital, Nilgai thrives well in habitats where human

settlements are present. This is probably because it is an opportunistic feeder and mixes both browse and grazed material in its diet. It therefore has a greater ability to survive in low quality habitats. In Tadoba, the distribution and abundance of Nilgai correlates with the distribution of Miscellaneous (MMDF) habitat type. In this habitat its density reaches 10.71 ± 2.74/km^2 as compared to habitat type Teak (which is mainly distributed around the central lake) where its density is 3.88 ± 0.93/km^2. Thus the three ungulate species in Tadoba are ecologically separated; Chital in central Tadoba around the lake, Nilgai along the periphery following the distribution of Miscellaneous (MMDF) habitat type and Sambar in the middle, associated with the densely wooded slopes free from human and cattle disturbances. This ecological separation ensures the optimal utilisation of forage resources by limiting any mutual competition. As a result, these species contribute to over 67% of the total wild ungulate biomass in the Park. This is discussed in more detail in Chapter Ten.

Fig. 6.1 The relationship between habitat type and the Z-Statistic for the three ungulate species in Tadoba National Park. Positive Z-values show the degree of attraction to a given habitat type and negative Z-values indicate avoidance. Data from Table 4.5







CHAPTER SEVEN

SARISKA NATIONAL PARK: RESULTS AND DISCUSSION

7.1 RESULTS

The results of the statistical analyses carried out on data from Sariska National Park using the Generalized Linear Interactive Modelling (GLIM) procedures are presented in this chapter separately for the three ungulate species *viz.* Sambar, Chital and Nilgai. Statistical Models A and B (see Chapter Five) have been developed for each ungulate species and are presented in the following sections. The results from motorcycle based transects run along the 22 km metal road from Sariska Gate to Pandupole temple in order to monitor changes in ungulate distributional pattern during 1987 and 1988 are presented in Fig. 7.3 to 7.5 and are discussed later in this chapter.

7.1.1 SAMBAR

The Null Model has the deviance 1317.5 with 255 d.f. (Table 7.1). Model A explains the abundance of Sambar in the study area on the basis of four habitat variables. These are WVE4 (χ^2= 24.7, d.f. = 3, $p<0.001$), Slope (χ^2= 73.4, d.f. = 2, $p<0.001$), Natsea (χ^2= 22.4, d.f. = 2, $p<0.001$) and Huset (χ^2= 35.4, d.f. = 3, $p<0.001$). The positive influence of woody vegatation cover (WVE4) and Slope on Sambar abundance indicates that well wooded slopes are an important habitat requirements of Sambar.

However, when the slope becomes steep i.e Slope (3) in an area, then the suitability of that area for Sambar decreases. In other words, steep slopes are avoided by Sambar. The perennial availability of water Natsea (3) has a positive influence on Sambar abundance. This is probably because Sambar requires surface water for drinking as well as wallowing. The relationship of Sambar abundance with human settlements shows an interesting pattern in the study area. Generally, and as was observed in Tadoba National Park, as the number of human dwellings increases, the competition for scarce fodder and water resources between man and cattle on one hand and the wildlife on the other increases. As a result, the suitability of the area for Sambar decreases. In Sariska National Park, there appears to be a significant departure from this. Within the Park there are areas around Bandipul, Algual and Pandupole springs where large scale disturbances occur due to presence of large human settlements, Huset (4), and temples nearby. These locations still remain the preferred habitats for Sambar. This may be because of the availability of permanent natural water sources, dense cover and palatable forage.

Model B explains the Sambar abundance on the basis of five variables. Two habitat types MMTF (4) and BoswMx (4) have very significant ($p<0.001$) negative impacts on Sambar abundance in Sariska National Park. Slope ($\chi^2= 13.3$, d.f. = 2, $p<0.05$), Natsea ($\chi^2= 22.4$, d.f. = 2, $p<0.001$) and WVE4 ($\chi^2= 25.2$, d.f. = 3, $p<0.001$) have positive effects in influencing abundance. The habitat type MDTF is characterized by the presence of human settlements and livestock and the absence of dense wooded slopes. The two most important perennial water sources are located in Kankwari and Kiraska villages where, during the daytime, the

presence of domestic livestock inhibits the utilization of water by wildlife. Thus, the limitation of cover and water make it a less preferred habitat for Sambar. This is also reflected by the low levels of Sambar abundance (see Appendix V).

Table 7.1 Analysis of deviance showing the factors which effect the abundance of Sambar in Sariska National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1317.5	255			
+WVE4(4)	1292.7	252	24.7	3	<0.001
+Slope(3)	1219.3	250	73.4	2	<0.001
+Natsea(3)	1196.9	248	22.4	2	<0.001
+Huset(4)	1161.5	245	35.4	3	<0.001

The coefficients and standard errors for the Model A. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.5970	0.1046	1
-0.2605	0.1021	WVE4(2)
0.2109	0.1271	WVE4(3)
0.3087	0.1285	WVE4(4)
0.1727	0.0714	Slope(2)
-0.6421	0.1240	Slope(3)
0.6443	0.3400	Natsea(2)
0.2840	0.0840	Natsea(3)
-0.0756	0.0939	Huset(2)
-1.0570	0.2895	Huset(3)
0.2449	0.0947	Huset(4)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1317.5	255			
+MMTF(4)	1153.7	252	163.8	3	<0.001
+BoswMx(4)	1057.4	249	96.3	3	<0.001
+Slope(3)	1044.1	247	13.3	2	<0.05
+Natsea(3)	1021.7	245	22.4	2	<0.001
+WVE4(4)	996.6	242	25.1	3	<0.001

The coefficients and standard errors for the Model B. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.3320	0.1873	1
-0.0490	0.0817	MMTF(2)
-0.8779	0.1366	MMTF(3)
-0.3691	0.2131	MMTF(4)
-0.6506	0.1279	BoswMx(2)
-0.9939	0.2082	BoswMx(3)
-0.7287	0.0924	BoswMx(4)
0.1527	0.0746	Slope(2)
-0.3090	0.1474	Slope(3)
0.8294	0.2060	Natsea(2)
0.5205	0.1378	Natsea(3)
0.5881	0.1812	WVE4(2)
0.8451	0.1931	WVE4(3)
0.6652	0.2064	WVE4(4)

7.1.2 CHITAL

The Null Model has the deviance 1977 with 255 d.f. (Table 7.2). Model A explains the abundance of Chital in the study area on the basis of five habitat variables. These are Artsea (χ^2= 59.7, d.f. = 2, p<0.001), Tden (χ^2= 30.8, d.f. = 2, p<0.001), WVE1 (χ^2= 13.2, d.f. = 2, p<0.05), Rock (χ^2= 59.6, d.f. = 4, p<0.001) and Grht (χ^2= 32.9, d.f. = 3, p<0.001). The positive influence of Artsea (3) on Chital abundance indicates the importance of artificial sources of water maintained by the Park authorities in Sariska National Park. Chital avoid dense forest i.e Tden (3) as well as rocky areas. The positive influence of WVE1 (3) on Chital abundance reveals the significance of shrub layer for Chital. Shrub layer contributes about 41% in the diet of Chital (see Table 3.1). Grass height also has a positive influence in determining Chital abundance.

Model B explains the abundance of Chital in terms of two habitat types AnogMx and MMTF which have significant positive effects on Chital abundance in this study area. AnogMx represents a woodland habitat, situated as it is between open miscellaneous mixed habitat and dense *Anogeissus* patches. This interspersion of habitats creates large regions of 'edge'. This is greatly preferred by Chital, which are present in larger social groups compared to other habitat types in the Park. A major proportion of this habitat type occurs in the Sariska valley, where the artificial sources have been maintained for a very long time and where, during the dry season, there is a high concentration of animals. MMTF habitat type, as mentioned earlier, has a very open canopy cover and also a highly diverse shrub layer.

These features are preferred by Chital which is reflected by the increased abundance in this habitat type (see Appendix V). Grass, water and tree density are the other three variables which influence Chital abundance. The importance of water as a key habitat requirement of Chital comes out very clearly in this analysis. It plays a major role in determining the pattern of distribution as well as abundance of Chital in the Park.

Table 7.2 Analysis of deviance showing the factors which effect the abundance of Chital in Sariska National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
+Artsea(3)	1917.3	253	59.7	2	<0.001
+Tden(3)	1886.5	251	30.8	2	<0.001
+WVE1(3)	1873.1	249	13.2	2	<0.05
+Rock(5)	1813.5	245	59.6	4	<0.001
+Grht(4)	1780.6	242	32.9	3	<0.001

The coefficients and standard errors for the Model A The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
2.6780	0.1172	1
0.1607	0.1350	Artsea(2)
0.5727	0.0650	Artsea(3)
0.2229	0.0782	Tden(2)
-0.5153	0.1088	Tden(3)
0.2288	0.0684	WVE1(2)
0.3778	0.1217	WVE1(3)
-0.6369	0.1281	Rock(2)
-0.5905	0.1329	Rock(3)
-0.7570	0.1393	Rock(4)
0.2636	0.0687	Grht(2)
0.3881	0.0811	Grht(3)
0.4085	0.1580	Grht(4)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1977.0	255			
+Anogmx(4)	1858.9	252	118.1	3	<0.001
+MMTF(4)	1844.2	249	14.7	3	<0.05
+Artsea(3)	1818.2	247	26.1	2	<0.001
+Tden(3)	1800.4	245	17.8	2	<0.001
+Grht(4)	1747.0	242	53.4	3	<0.001

The coefficients and standard errors for the Model B The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.7910	0.0719	1
0.1804	0.0667	Anogmx(2)
0.2465	0.0701	Anogmx(3)
0.5141	0.0604	Anogmx(4)
0.3577	0.0621	MMTF(2)
0.3708	0.0754	MMTF(3)
0.2527	0.1147	MMTF(4)
-0.1421	0.1227	Artsea(2)
0.3581	0.0621	Artsea(3)
0.0276	0.0663	Tden(2)
-0.5136	0.1113	Tden(3)
0.3449	0.0812	Grht(2)
0.8249	0.0692	Grht(3)
0.5939	0.1498	Grht(4)

7.1.3 NILGAI

The Null Model has the deviance 2605.6 with 255 d.f. (Table 7.3). Model A explains the abundance of Nilgai in terms of four habitat variables. These are WVE2 (χ^2= 108.7, d.f. = 2, p<0.001), Litter (χ^2= 248.3, d.f. = 4, p<0.001), Natsea (χ^2= 182.2, d.f. = 2, p<0.001) and Grht (χ^2= 107.2, d.f. = 3, p<0.001). The shrub layer (WVE2) has a very significant positive effect in determining Nilgai abundance. This is probably because Nilgai is predominantly a browser and the shrub layer contributes about 59% in its diet (see Table 3.1). Being an opportunistic feeder Nilgai also feeds on litter, especially during the dry season when other forage resources are scarce. The results also indicate that the perennial availability of water (Natsea (3)) does not have any positive influence on Nilgai abundance. Thus, unlike both Sambar and Nilgai surface water availability is not a critical requirement for Nilgai. Sheffield *et al.* (1983) also reported that water requirement of Nilgai is not high and it probably has a larger cruising radius with respect to water compared to both Sambar and Chital.

Model B explains the abundance of Nilgai on the basis of seven variables. The habitat types which have very significant effect on the abundance of Nilgai are MMTF (χ^2= 465.4, d.f. = 3, p<0.001), BoswMx (χ^2= 99.6, d.f. = 3, p<0.001) and AnogMx (χ^2= 210.2, d.f. = 3, p<0.001). The miscellaneous-mixed (MMTF) habitat with its open canopy cover and presence of a rich and diverse semi-evergreen shrub layer is the most preferred habitat for Nilgai in Sariska. Several thorn forest shrub species such as *Capparis decidua, C. sepiaria, Balanites aegyptiaca, and Zizyphus nummularia* are a major source of forage to Nilgai (see Table 3.1). The presence of a diverse shrub layer in the other two habitat types i.e. AnogMx and

BoswMx also make them a suitable habitat for Nilgai. The results also shows that flat to medium slopes are preferred by Nilgai while steep slopes have a negative influence on Nilgai abundance.

Table 7.3 Analysis of deviance showing the factors which effect the abundance of Nilgai in Sariska National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	2605.6	255			
+WVE2(3)	2496.9	253	108.7	2	<0.001
+Litter5)	2248.6	249	248.3	4	<0.001
+Natsea(3)	2066.4	247	182.2	2	<0.001
+Grht(4)	1959.2	244	107.2	3	<0.001

The coefficients and standard errors for the Model A The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
2.2620	0.1793	1
0.0518	0.1252	WVE2(2)
0.3923	0.1262	WVE2(3)
0.5558	0.1381	Litter(2)
0.5072	0.1507	Litter(3)
0.4713	0.1390	Litter(4)
0.9850	0.1545	Litter(5)
-0.9963	0.1146	Natsea(2)
-0.1374	0.0631	Natsea(3)
0.3182	0.0629	Grht(2)
0.7463	0.0769	Grht(3)
0.9588	0.1169	Grht(4)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	2605.6	255			
+MMTF(4)	2140.2	252	465.4	3	<0.001
+Boswmx(4)	2040.6	249	99.6	3	<0.001
+Anogmx(4)	1830.4	246	210.2	3	<0.001
+Slope(3)	1818.5	244	11.9	2	<0.05
+Natsea(3)	1790.4	242	28.1	2	<0.001
+WVE2(3)	1735.7	240	54.7	2	<0.001
+Litter(5)	1671.3	236	64.4	4	<0.001

The coefficients and standard errors for the Model B The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.2580	0.2197	1
0.0110	0.0785	MMTF(2)
0.7744	0.1012	MMTF(3)
1.0140	0.1045	MMTF(4)
0.3455	0.0843	Boswmx(2)
1.2940	0.1470	Boswmx(3)
0.4241	0.1041	Boswmx(4)
0.1755	0.1060	Anogmx(2)
1.9930	0.0997	Anogmx(3)
1.0360	0.0993	Anogmx(4)
0.2063	0.0756	Slope(2)
-0.2144	0.1002	Slope(3)
-0.3028	0.1479	Natsea2)
-0.3552	0.0989	Natsea(3)
0.0080	0.1392	WVE2(2)
0.4621	0.1497	WVE2(3)
0.3145	0.1567	Litter(2)
0.2416	0.1416	Litter(3)
0.1094	0.1416	Litter(4)
0.7129	0.1852	Litter(5)

7.2 DISCUSSION

The relationship between animal populations, their habitats and food supplies form a central problem both in theoretical ecology and for the management of natural and man-modified systems (Owen-Smith and Novellie, 1982). The study of habitat preferences of ungulate species in relation to the habitat features of their environment is important for assessing their habitat requirements. The results of the herbivore-habitat analyses in Sariska show that the distribution of Sambar, Chital and Nilgai is related to the distribution of the habitat types, while their abundance is greatly influenced by the extent of forage and water resources available in these habitat types. The influence of habitat types on species abundance can be graphically shown (Fig. 7.1) by plotting the Z-statistic obtained in Chapter 4, Table 4.6). Fig. 7.1 shows the degree of attraction/avoidance for each habitat type by the ungulate species. Sambar exhibits a strong preference for the forested habitat (Anog) and avoids miscellaneous open habitat (MMTF). The woodland habitat (AnogMx) is also preferred by Sambar as it provides forage and water, especially during the dry season. The habitat type Boswellia Mx (BoswMx) occurs on the steep slopes and is therefore not used much by Sambar. Chital prefers the woodland habitat (AnogMx) and the miscellaneous habitat (MMTF). These habitat types occur in the Sariska valley, which also has a very diverse, palatable shrub layer and the availability of water. Nilgai exhibits a very strong preference for the miscellaneous open habitat (MMTF) where its density reaches 20.1 $\pm$ 3.10 km^{-2} (see Appendix V).

The Miscellaneous-mixed dry thorn forest (MMTF), which forms nearly 40% of the habitat in Sariska, occurs mainly in the valley and has a very large number of palatable semi-evergreen shrub species. Traditionally, from the hunting days, water sources have also been maintained artificially in the valley. These two factors are responsible for the very high abundance of Sambar (5.16 ± 0.67 km^{-2}), Chital (10.0 ± 1.14 $km^{-2)}$ and Nilgai (11.11 ± 1.35 km^{-2}) (see Appendix V) in the study area. The feeding data of these species in the pre-monsoon and post-monsoon periods on important plant species are shown in Table 3.1. The overall contribution of the shrub layer in the diets of Sambar, Chital and Nilgai is 52%, 41% and 59% respectively. Grasses contribute 20%, 45% and 21% while the tree layer contributes 27%, 13% and 20% in the diets of these species. It is evident that the shrub layer plays a significant role in their diets throughout the year. Although Chital is predominantly a grazer, it is able to reduce its dependance on grasses from 57% in the post-monsoon to 34% in the dry season when the grasses become very coarse, dry and of low nutritive value. During summer, Chital increases the browse proportion to 48% from 35% in the post-monsoon period and is thus able to meet the high nutritional requirements of rutting. Fruits and seeds, mainly from shrubs/trees (*Acacia* spp., *Balanites aegyptiaca*) in summer and of *Ziziphus* spp. in winter form a highly seasonal part of Chital's diet. A similar strategy for maintaining a high quality diet by eating dicot fruits, pods, seeds and leaves in the dry season as the availability of green grass leaf declines has been reported by Jarman (1973) in Impala (*Aepyceros melampus*), an ecological equivalent of Chital in Africa.

The availability of water, which is highly seasonal in the semi-arid environment in Sariska has an important bearing on the distribution and numbers of ungulates. Western (1975) suggested that water availability had a significant influence on the structure and dynamics of large mammal community in the semi-arid savannah environment of the Amboseli ecosystem. Lamprey (1964) commented "The extent and distribution of permanent water in the dry season throughout the Masai area of Tanganyika is probably the most important limiting factor in the number and distribution of game animals in the savanna of East Africa and the carrying capacity of the country as a whole is closely related to the carrying capacity of the land within the 'cruising range' of the dry season water supplies". Artificial waterholes have been used as a management tool to bring about a favourable distribution of wildlife. Providing water (Yoakum *et al.* 1980) by building waterholes, ponds, guzzlers (Glading, 1943) and other developments (Humphrey and Shaw, 1957) has been practiced widely. In Sariska, many waterholes were built along with the watch-towers in the days of Shikar (hunting) where live bait was kept to attract the Tiger. The present distribution of the natural and artificial water sources is shown in Fig. 7.2. Most of these water sources lie in the Sariska valley, in which the dry season concentration of animals occurs. Some of these water sources are predominantly used by the domestic livestock from the grazing camps and villages which continue to exist inside the National Park. The vegetation around the waterholes exhibit distinct signs of overgrazing during the dry season due to the domestic and wild ungulate populations. In a year, when the rainfall is normal (*ca* 755 mm) the vegetation recovers to a large extent in the post-monsoon period. However, the area occasionally suffers periods of continuous

drought when the rainfall falls to *ca* 300 mm. Between 1984-1988 the area was affected by drought and its impact was first observed in the dry season (March-June) of 1988 when mortality in ungulate population occured. The dry season in the study area is also characterized by high temperatures (≥48^0 C) and hot dry winds locally called 'loo', which have a very dessicating effect on both animals and humans. The maximum mortality occured around the artificial waterholes in the woodland habitat. While fewer Nilgai and Chital suffered mortality, the impact was very severe on the Sambar population. More than 300 lower jaws of Sambar were collected in a 5 km^2 area (Laxman Singh, *pers. comm.* 1988). The major reason of this mortality was the combination of nutritional and heat stress. The high build up of ungulate populations in the valley had overgrazed the area to a great extent. The Park management was also unable to maintain regular supplies of water to the artificial waterholes in the critical dry period which further induced water stress in the Sambar population. The low mortality of Nilgai was probably due to its better ability to withstand heat stress and its less dependance on water, as vegetation away from the waterholes was not in an overgrazed condition. According to Krishnan (1972), the Chital has a unique ability to exist in a reduced physical condition and this attribute has a great survival value in environments where nutritional stresses occur.

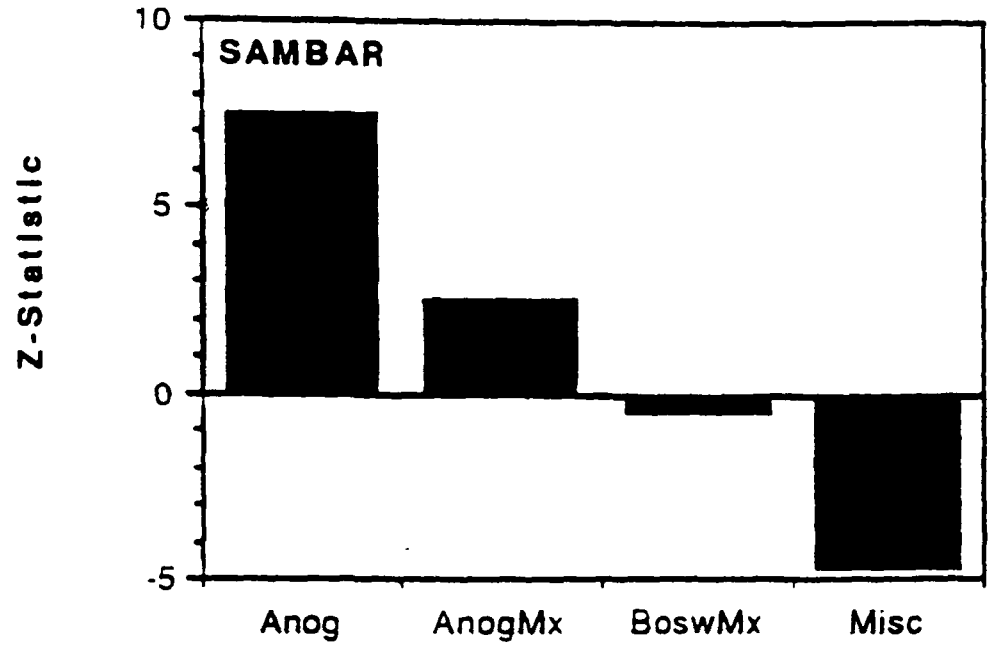
The four years of continuous drought was followed by an above normal rainfall during the monsoon period (July-October) of 1988. The mortality in the preceding summer and the availability of water in the post-monsoon period greatly influenced the distribution pattern of the ungulates in the Sariska valley. The number of Sambar, Chital and Nilgai observed within

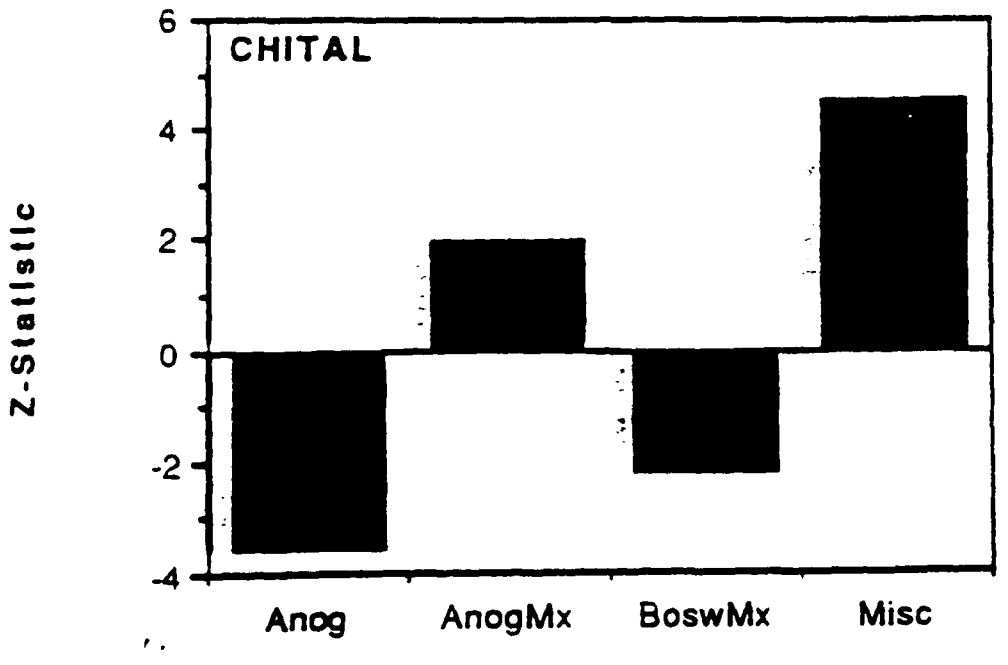
a 30 m strip width, along the 22 km metal road from Sariska Gate to Pandupole temple, during 10 vehicle based morning and evening transect counts in the post monsoon periods of 1987 and 1988 are shown in Figures 7.3, 7.4 and 7.5. The number of Sambar (Fig. 7.3) observed between km segment 4-5 to 9-10 in 1988 drastically declined. It was in these segments where maximum mortality of Sambar had occured in the preceding summers. The number of Sambar observed beyond 10-11 km segment only declined marginally. The overall distribution pattern in Chital (Fig. 7.4) did not change much in 1988 although the number observed in each km segment was marginally lower. The distribution pattern in case of Nilgai (Fig. 7.5) differed from that of Sambar and Chital and a greater number of Nilgai were observed beyond km segment 13-14 in 1988. This may be because of the increase in shrub cover along the road, following the rains which was utilized by Nilgai.

The excessive development of water in the Sariska valley was carried out to meet the major objective of increasing the sightings of animals around the waterholes. However, this has important management implications. The availability of water in the valley attracts the animals and the animal biomass in the narrow Sariska valley increases. This in turn increases the grazing pressure on the vegetation, much beyond its capacity to sustain these populations on a long-term basis. Since the productivity of the vegetation is related to rainfall, in years in which rainfall is below normal, the productivity of the vegetation declines and nutritional stresses begin to appear in the ungulate populations (as in 1988). Moreover, the artificial provision of water in waterholes, maintained along roadside by means of tractor-trailers, pumps and polyvinyl tubes, is not only expensive, but is

also unaesthetic and often unreliable. The development of water in semi-arid environments has the potential to severely alter the carrying capacity of the habitat and must be undertaken only after detailed investigations have been carried out into the water requirements of the animals and the ability of the vegetation to withstand the changes in animal numbers. Wildlife managers often have the tendency to 'overdo' it without considering the imminent dangers of 'population crashes' in the long run.

Fig. 7.1 The relationship between habitat type and the Z-Statistic for the three ungulate species in Sariska National Park. Positive Z-values show the degree of attraction to a given habitat type and negative Z-values indicate avoidance. Data from Table 4.6





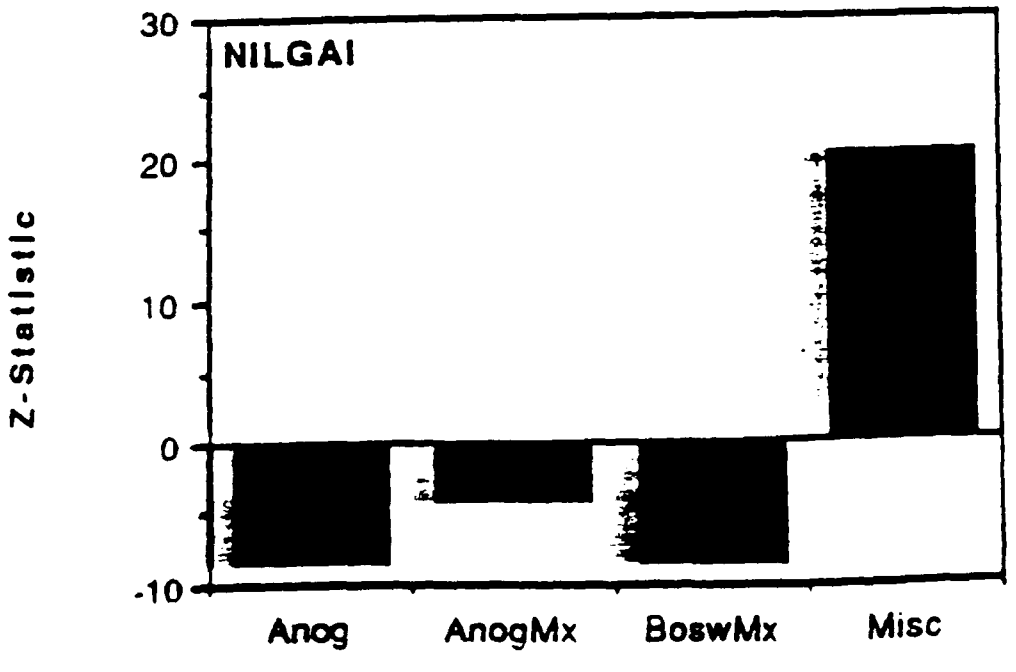
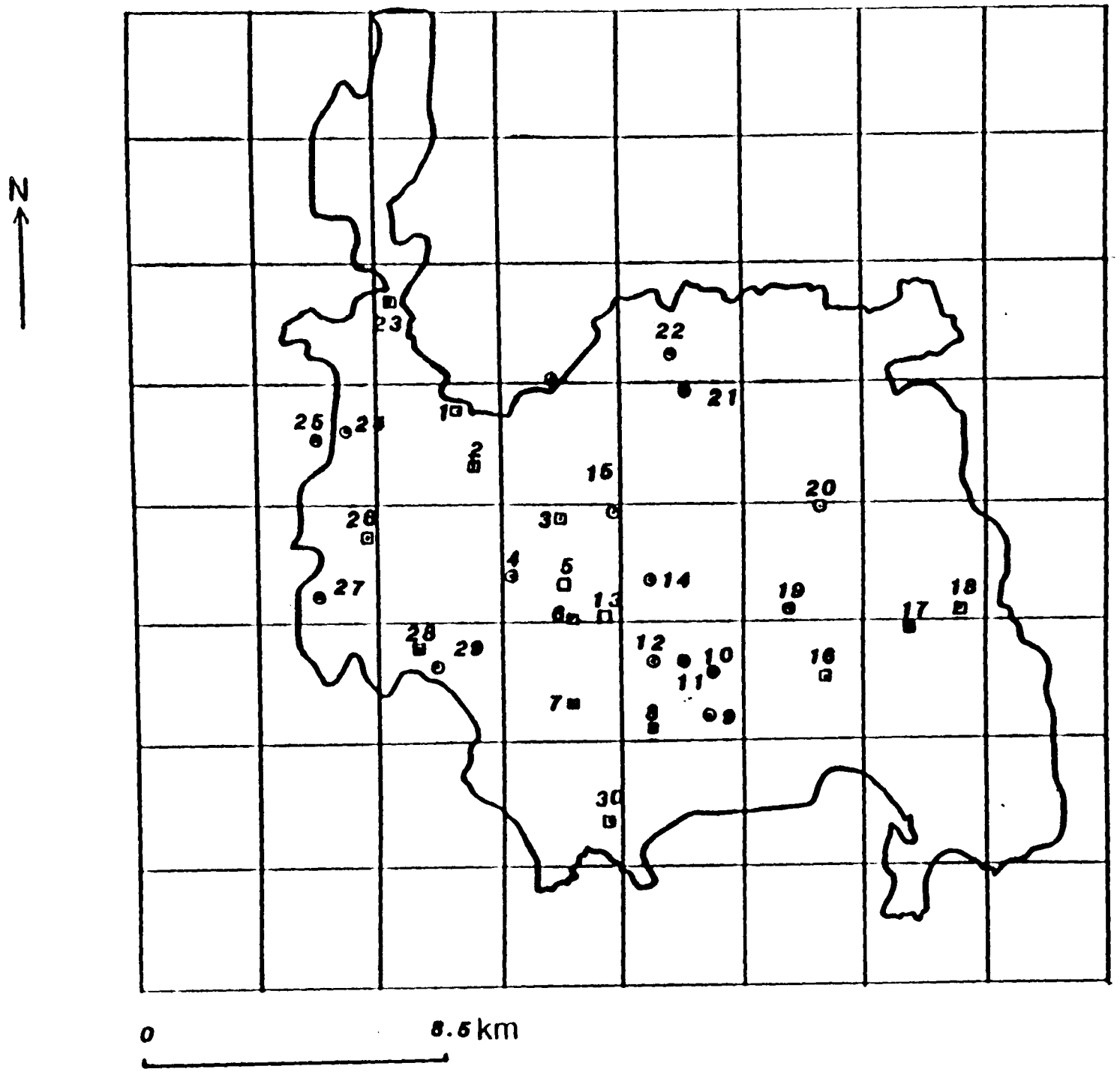
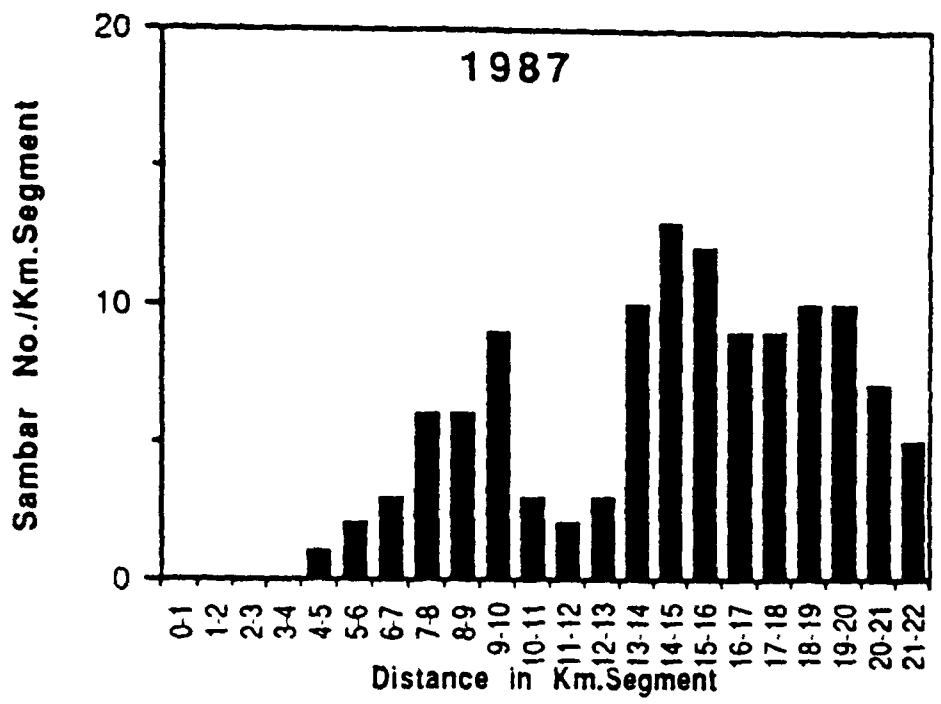


Fig. 7.2 Distribution of natural and artificial water sources in Sariska National Park



1. TIGERDEN WELL (A)
2. HARIPURA WELL (A)
3. KARNAKABAS WELL (A)
4. TARUNDA (N)
5. BUJA (A)
6. BRAHMNATH (A)
7. KALIGHATI WELL (A)
8. SLOPKA (A)
9. PHENTAPAL (N)
10. PANDUPOLE SPRING (N)
11. PANDUPOLE SPRING (N)
12. PANDUPOLE SPRING (N)
13. KUNDLI (A)
14. KIRASKA (N)
15. ALGUAL (N)
16. UMRI WELL (A)
17. ISAWALA WELL (A)
18. NAHARSATI WELL (A)
19. HARSAWAL SPRING (N)
20. ROTKALA SPRING (N)
21. NALDI SPRING (N)
22. NALDI SPRING (N)
23. SIRONDA WELL (A)
24. BANDIPUL SPRING (N)
25. BANDIPUL SPRING (N)
26. GMANKA WELL (A)
27. UDAINATH SPRING (N)
28. KANKWARI (N)
29. TUDA SPRING (N)
30. CHAMARI BEDA (A)

Fig. 7.3 Mean number of Sambar observed in 1 Km Segment during vehicle transect on the Sariska gate-Pandupole temple metal road in post-monsoon 1987 and 1988 in Sariska National Park. Mean calculated from 10 morning and evening transects



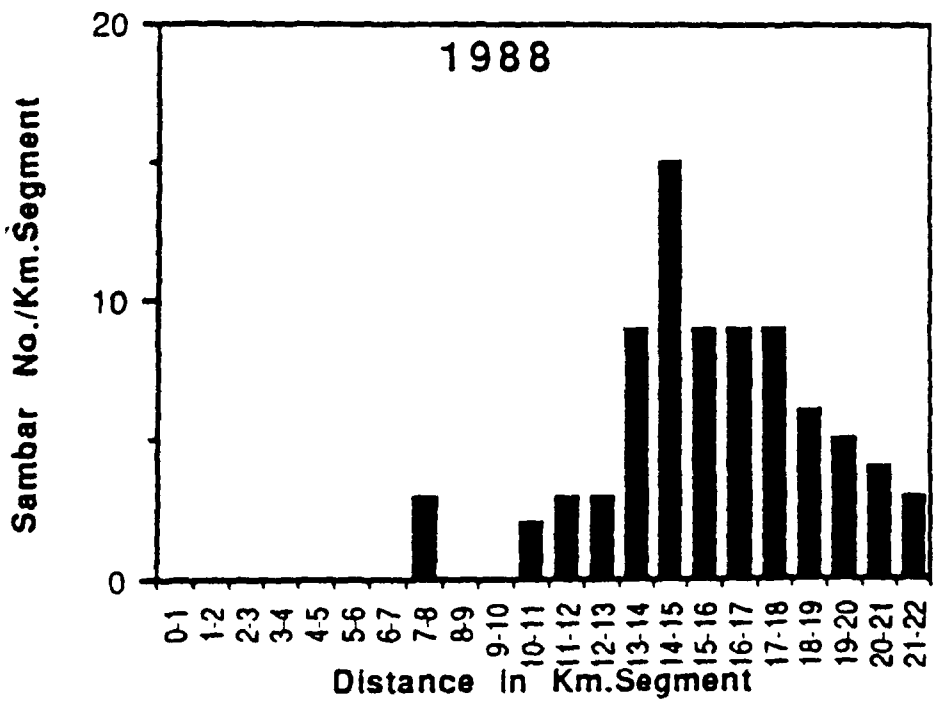
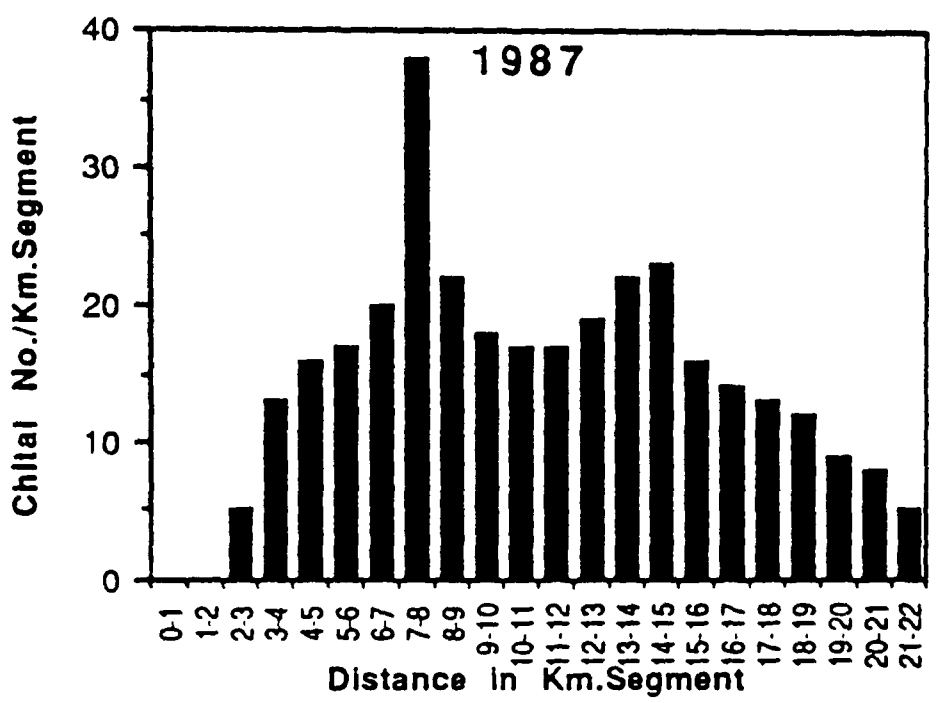


Fig. 7.4 Mean number of Chital observed in 1 Km Segment during vehicle transect on the Sariska gate-Pandupole temple metal road in post-monsoon 1987 and 1988 in Sariska National Park. Mean calculated from 10 morning and evening transects



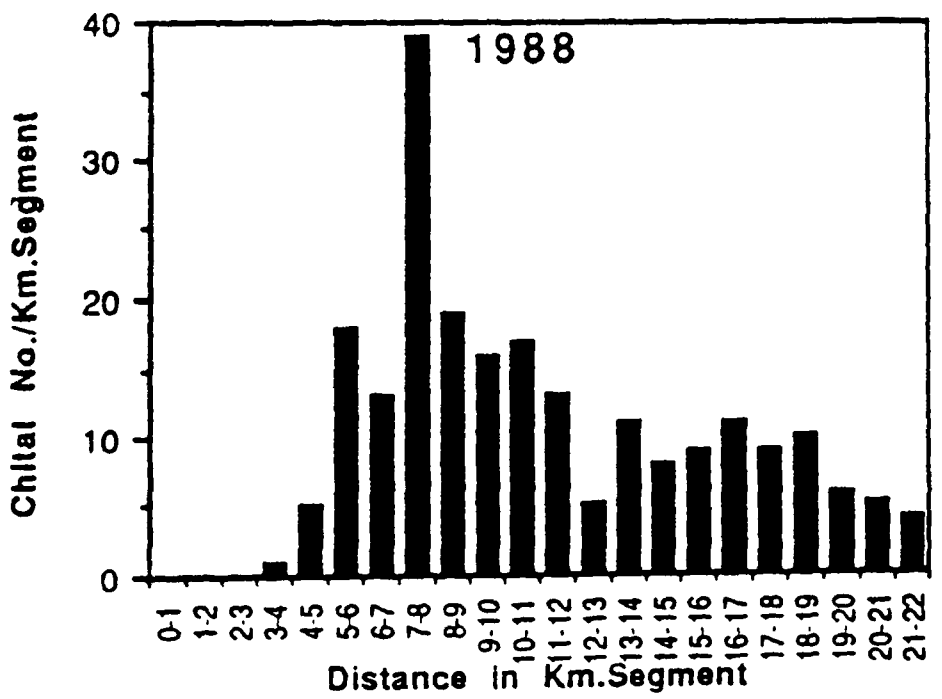
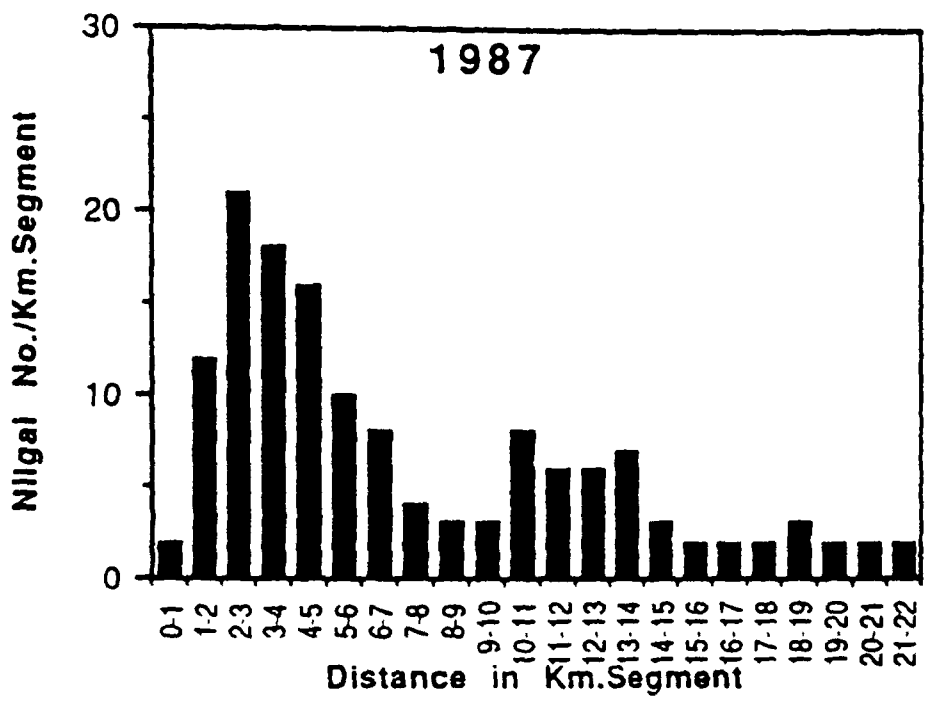
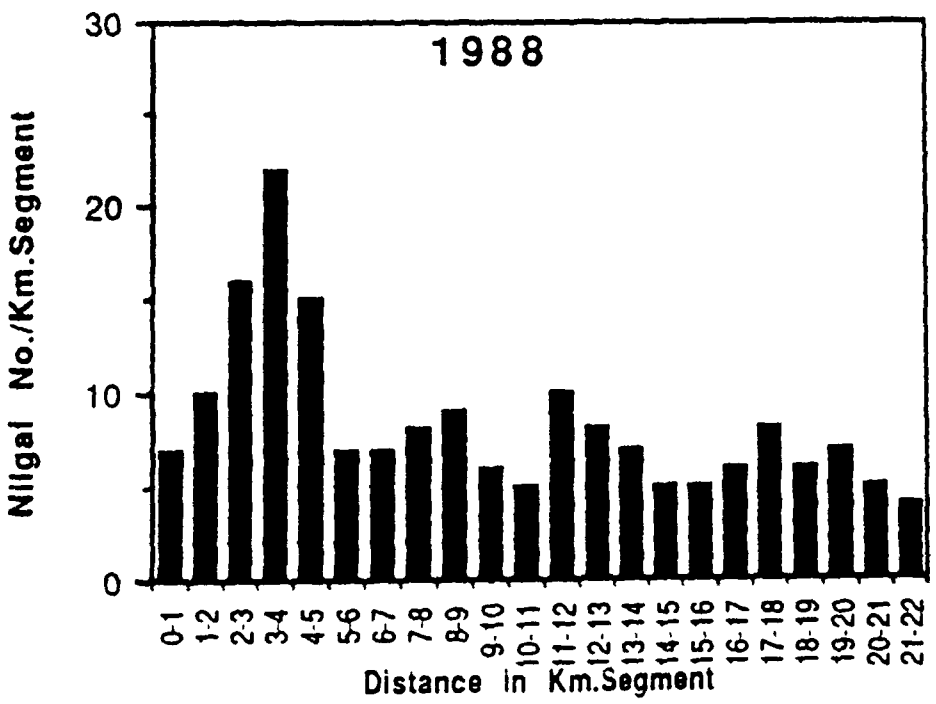


Fig. 7.5 Mean number of Nilgai observed in 1 Km Segment during vehicle transect on the Sariska gate-Pandupole temple metal road in post-monsoon 1987 and 1988 in Sariska National Park. Mean calculated from 10 morning and evening transects





CHAPTER EIGHT

KANHA NATIONAL PARK: RESULTS AND DISCUSSION

8.1 RESULTS

The results of the statistical analyses carried out on data from Kanha National Park using the Generalized Linear Interactive Modelling (GLIM) procedures are presented in this chapter separately for the three ungulate species *viz.* Sambar, Chital and Nilgai. Statistical Models A and B (see Chapter Five) have been developed for each ungulate species and are presented in the following sections. In addition, the population estimates of three major grassland species *viz.* Chital, Blackbuck and Barasingha from 1974-1989 obtained from the Park census records have been analysed in order to study the trends in population increase in relation to the climatic and biotic factors. These are discussed later in this chapter.

8.1.1 SAMBAR

The Null Model has the deviance 1035.8 with 319 d.f. (Table 8.1). Model A explains the abundance of Sambar in terms of four habitat variables. These are Litter (χ^2= 52.55, d.f. = 4, p<0.001), Bamboo (χ^2= 27.29, d.f. = 4, p<0.001), Tden (χ^2= 14.12, d.f. = 2, p<0.001) and Huset (χ^2= 11.86, d.f. = 3, p<0.001). The results suggest that Litter, Bamboo and Tree density have a positive influence on Sambar abundance while the human settlements have a negative impact. Bamboo was commercially

harvested in the Park till 1974 and was given silvicultural treatments to ensure the growth of long culms. When the commercial exploitation stopped, the silvicultural treatment to bamboo was also discontinued. As a result, bamboo does not grow in height but has a bushy appearance and is therefore readily available to both Sambar and Gaur at browse level. The lower abundance of Sambar observed during the study in the eastern portion of the Park comprising Supkar forest range may be because of bamboo deficiency in that area.

Model B shows the impact two habitat types SalMxBam and MMDF. The habitat type SalMxBam (5) has very significant (χ^2= 57.5, d.f. = 4, p<0.001) positive influence on Sambar abundance while habitat type MMDF (5) has the opposite influence. SamMxBam appears to be the most preferred habitat type as it provides both cover and forage to Sambar. On the other hand, MMDF is characterized by relatively open canopy cover and presence of human settlements. As the proportion of MMDF increases in an area it becomes increasingly less optimal for Sambar. The influence of other two variables Litter and Bamboo present in Model B has already been discussed in relation to Model A.

Table 8.1 Analysis of deviance showing the factors which effect the abundance of Sambar in Kanha National Park.

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1035.8		319		
+Litter(6)	983.4	314	52.33	4	<0.001
+Bamboo(5	956.1	310	27.29	4	<0.001
+Tden(3)	942.0	308	14.12	2	<0.001
+Huset(4)	930.2	305	11.86	3	<0.001

The coefficients and standard errors for the Model A. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
0.9083	0.3053	1
0.1937	0.3102	Litter(2)
0.4007	0.3114	Litter(3)
0.6598	0.3146	Litter(4)
0.9776	0.3535	Litter(5)
0.8076	0.3623	Litter(6)
0.3443	0.0953	Bamboo(2)
0.2532	0.0901	Bamboo(3)
0.2340	0.0971	Bamboo(4)
0.2647	0.0946	Bamboo(5)
0.0337	0.1298	Tden(2)
0.2708	0.1310	Tden(3)
0.3371	0.1529	Huset(2)
-0.3394	0.1644	Huset(3)
-0.3890	0.1448	Huset(4)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	1035.8	319			
+SalMxBam(5)	978.2	315	57.5	4	<0.001
+MMDF(5)	949.0	311	29.1	4	<0.001
+Litter(6)	923.7	306	25.3	5	<0.001
+Bamboo(5)	907.5	302	16.1	4	<0.001

The coefficients and standard errors for the Model B. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
0.9880	0.2999	1
0.2090	0.2193	SalMxBam(2)
0.5044	0.0996	SalMxBam(3)
0.3900	0.1172	SalMxBam(4)
0.4707	0.1830	SalMxBam(5)
0.2240	0.1251	MMDF(2)
0.0316	0.1538	MMDF(3)
-0.3102	0.1830	MMDF(4)
-0.4190	0.1541	MMDF(5)
0.1660	0.2941	Litter(2)
0.3397	0.3045	Litter(3)
0.3051	0.1926	Litter(4)
0.6466	0.3038	Litter(5)
0.6942	0.2925	Litter(6)
0.1961	0.1395	Bamboo(2)
0.2371	0.1445	Bamboo(3)
0.4365	0.2121	Bamboo(4)
0.3434	0.1341	Bamboo(5)

8.1.2 CHITAL

The Null Model has the deviance 15331 with 319 d.f. (Table 8.2). Model A explains the abundance of Chital on the basis of four habitat variables. These are Grsscov (χ^2= 7482, d.f. = 5, p<0.001), Slope (χ^2= 1155, d.f. = 2, p<0.001), Natsea (χ^2= 48, d.f. = 1, p<0.001) and WVE1 (χ^2= 152, d.f. = 2, p<0.001). Chital being a grassland species increased levels of grass cover have a positive influence on its abundance. The strong influence of Grsscov (5) and Grsscov (6) on Chital abundance was also reflected in the very high density (96.6 km^{-2}, Appendix VI) of Chital observed on the grasslands in this study. Gentle slopes i.e (Slope (2)) are preferred by Chital while steep slopes are avoided. The shrub layer (WVE1 (3)) has a positive influence on Chital. This is to be expected as Chital is capable of switching over to browse from grass, especially during the dry season, when grasses become dry and less nutritious. The analysis also shows the positive influence of the perennial availability of water on Chital abundance.

Model B shows the very significant effect of the habitat type Grassland on Chital abundance. The ecological status of grasslands in Kanha has been investigated in detail (Martin, 1977; Panwar, 1982; Pandey, 1982; Kotwal, 1979, 1989) and its present status is discussed in detail in Section 8.2. The effects of the other three variables, Grass cover, Slope and water have already been discussed in relation to Model A.

Table 8.2 Analysis of deviance showing the factors which effect the abundance of Chital in Kanha National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	15331	319			
+Grsscov6)	7849	314	7482	5	<0.001
+Slope(3)	6694	312	1155	2	<0.001
+Natsea(2)	6646	311	48	1	<0.001
+WVE1(3)	6494	309	152	2	<0.001

The coefficients and standard errors for the Model A. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
3.0970	0.0481	1
-0.3395	0.0483	Grsscov(2)
-0.4397	0.0898	Grsscov(3)
0.7798	0.0588	Grsscov(4)
1.0840	0.0600	Grsscov(5)
1.1690	0.0569	Grsscov(6)
0.6724	0.0424	Slope(2)
-1.2830	0.0438	Slope(3)
0.2793	0.0421	Natsea(2)
-0.2153	0.0293	WVE1(2)
0.2213	0.0351	WVE1(3)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	15331	319			
+Grassland(5)	4151	315	11180	4	<0.001
+Grsscov(6)	3903	310	248	5	<0.001
+Slope(3)	3879	308	24	2	<0.001
+Natsea(3)	3862	306	17	2	<0.001

The coefficients and standard errors for the Model B. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.0300	0.1580	1
0.1710	0.0796	Grassland(2)
0.1008	0.0918	Grassland(3)
2.5670	0.0973	Grassland(4)
2.5010	0.1023	Grassland(5)
0.5973	0.0539	Grsscov2)
0.3252	0.0944	Grsscov(3)
0.7007	0.0490	Grsscov(4)
0.6309	0.0580	Grsscov(5)
0.5995	0.0510	Grsscov(6)
0.2488	0.0553	Slope(2)
-0.4450	0.0582	Slope(3)
0.4387	0.1198	Natsea(2)
0.4475	0.1166	Natsea(3)

8.1.3 NILGAI

The Null Model has the deviance 154.9 with 63 d.f. (Table 8.3). Model A explains the abundance of Nilgai in the study area on the basis of three variables. These are Huset (χ^2= 7.33, d.f. = 7.33, $p<0.05$), WVE1 (χ^2= 14.50, d.f. = 2, $p<0.001$) and Grht (χ^2= 17.13, d.f. = 2, $p<0.001$). The positive influence of WVE1 which represents the shrub layer on Nilgai abundance is to be expected as Nilgai is predominantly a browser. Similarly, grass height also has a positive influence on Nilgai abundance. In Kanha, small groups of a relict Nilgai population exist on a few plateau grasslands dominated by *Heteropogon contortus-Themeda triandra* community and few miscellaneous-mixed tree species. Model B shows that the habitat type Sal has a negative influence on Nilgai abundance indicating that the dense wooded cover found in this habitat type is not

preferred by Nilgai. Model B also shows that Nilgai is able to tolerate some level of disturbance from human settlements.

Table 8.3 Analysis of deviance showing the factors which effect the abundance of Nilgai in Kanha National Park

Model A

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	154.97	63			
+Huset(3)	147.63	61	7.33	2	<0.05
+WVE1(3)	133.13	59	14.50	2	<0.001
+Grht (3)	117.13	57	17.13	2	<0.001

The coefficients and standard errors for the Model B. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.135	0.1464	1
0.5281	0.2579	Huset(2)
-0.6167	0.2528	Huset(3)
0.5057	0.2600	WVE1(2)
0.9866	0.3769	WVE1(3)
0.8814	0.1612	Grht (2)
0.9824	0.1412	Grht (3)

Model B

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	154.97	63			
+Sal(3)	147.26	61	7.70	2	<0.05
+Huset(3)	142.82	60	4.45	1	<0.05
WVE1(3)	133.10	58	9.71	2	<0.05

Parameter estimate	Standard error	Parameter
1.135	0.1464	1
-0.6167	0.2528	Sal(2)
-0.5441	0.2300	Sal(3)
0.7447	0.3612	Huset(2)
0.0000	aliased	Huset(3)
0.5057	0.2600	WVE1(2)
1.024	0.4476	WVE2(3)

8.2 DISCUSSION

The utilization of a habitat by animal species is dependent on the interaction between the abiotic and biotic factors in the environment. Many factors like the phenology of forage species and the availability of water play an important role in determining the seasonal occupance of a species in any habitat. As all animals are inclined to obtain high quality food for survival and reproduction, the general strategy adopted is to preferentially select certain habitat types, food types and plant parts in order to delay an inevitable seasonal decline in food quality (Jarman and Sinclair, 1979). The results of the present analyses show that the distribution of Sambar, Chital and Nilgai is related to the distribution of the various habitat types in the study area. The influence of habitat types on species abundance can be graphically shown (Fig. 8.1) by plotting the Z-statistic obtained in Chapter 4, Table 4.5. Sambar, a forest ungulate shows preference for the forested habitats comprising of Sal and other associate species (especially bamboo) and avoidance for miscellaneous open habitats. However, as compared to a pure Sal forest, in which a palatable shrub layer is invariably absent or at least greatly reduced, the SalMxbamboo forest is the most preferred habitat for Sambar. Chital, being predominantly a grazer, shows significant preference for grassland habitats, where it is occurs in large associations. Grassland habitats not only provide forage to Chital but the year around availability of water especially during the summer months attracts large concentrations of Chital during dry season. Dinerstein (1980) also found that the Sal forest (which formed about 70% of the habitat in Karnali Bardia Wildlife Reserve in Nepal) was a marginal habitat for Chital from November through May. This was mainly because of the limitation of forage and water. Nilgai

prefer the miscellaneous mixed open habitats and occur on a few plateaus. They are locally extinct in the forested habitats of the Park. Dinerstein (1980) on the basis of the observation that Nilgai were never encountered more than 4 km from the border with cultivation concluded that they are more closely associated with croplands than any other ungulate. This differential preference for the habitat types ensures the first level of ecological separation amongst the three ungulate species. Preference for graze/browse in different seasons further allows each species to maximise intake of high quality food. This is usually achieved by consuming more graminoid species during rainy and winter seasons and more dicotyledonous species with young leaves, flowers and fruits during the summer season.

The population trend of the three major grassland species Chital, Blackbuck (*Antilope cervicapra*) and Barasingha (*Cervus duvauceli branderi*) from 1974-1989 along with the trend in annual rainfall based on the data from the Park authorities is shown in Fig. 8.2. These changes in the population structure have occured since the study area was first declared as a 'Project Tiger Reserve' in 1974 and administered under the Panwar (1973) wildlife management plan. From 1974 to 1988, grazing by 10,000 cattle from grazing camps and another 15,000 from adjoining villages in the prime areas of the National Park has been stopped. During this period, 5380 ha of prime wildlife habitat in the valley bottoms and plateaus of the Park were made solely available for wildlife by rehabilitating 26 villages outside the study area (Parihar and Kotwal, 1989).

The Chital population has increased at a phenomenal rate having doubled itself in a 15 year period (Fig. 8.2). Most of the Chital population in the study area is confined to the Kanha meadows, where its ecological density is greater than 100/km^2 (this study). The Kanha meadows also form the habitat for nearly all the population of Barasingha (500+), whose population has registered a steady increase over the period. The Blackbuck in Kanha seem to have followed man into the interior woodland habitat who created suitable pastures through slash and burn agricultural practices and by clearing areas for livestock grazing. Subsequently, these practices gave way to sustained agriculture and under the impact of poaching also the Blackbuck began to decline. With the stoppage of annual burning in 1972 the grass composition and height changed to the disadvantage of Blackbuck. This decline in population was accelerated by Jackals (*Canis aureus*), who inspired by the high crop of Chital fawns, took to pack hunting and also started predating Blackbuck fawns (Parihar and Kotwal, 1989).

There appears to be no direct correlation between the population trend of these species and the annual precipitation. However, the sharp decline in Chital numbers in 1984 (Fig. 8.2) may be due to a drop in the annual precipitation to 1253 mm from 1612 mm in 1983. The forage availability on the meadows, as well as the availability of free water, are both influenced by the annual precipitation. The absence of winter rains in any year drastically reduces the available forage and the amounts of available water in the subsequent summer.

Although fire has long been used as a management tool its application has not always achieved the desired results. The present situation on meadows of Kanha provide a good example of the complex interaction between fire, grazing and encroachment of grassland by woody species. Since the beginning of this century, the Kanha meadows have been subjected to annual cool season burning (Brander, 1923) in order to increase the forage availability for the grazing ungulates in the dry season. However, the early burning at the end of the growing season damaged perennial grasses. These were still partially green and had not returned all their food reserves from leaves to storage in roots. They were induced by fire to sprout again, out of season, at the expense of the partially replenished root stock. As the grazing ungulates were attracted to the meadows for water, the resulting regrowth was grazed and the root reserves further depleted. The final effects were manifested in the reduction in flowering and fruiting of the perennials and an increase in the proportion of unpalatable species. These eventually left the meadows in a state of 'retrogressive succession'. Martin (1977) postulated that the combined effect of burning and heavy grazing was responsible for the disappearance of the taller and more leafy perennials of *Bothriochloa odorata, Themeda triandra* and their replacement by small annuals like *Dimeria connivens, Pseudopogonatherum contortum* and more resistant perennials like *Mnesithlea laevis.* Piennar (1968) commented on the dangers of overgrazing in areas where annual burning was practiced, particularly in the vicinity of watering places. Although the annual burning practices were stopped in 1972, the wild ungulate grazing pressure has continuously increased on the meadows-chiefly because of the increase in Chital population (which contribute more than 95% of the ungulate

biomass on the grasslands). The long term viability of the Kanha meadows is important not only for the local management of the Park but also for the conservation community worldwide because these meadows form the last remaining habitat for the hard ground Barasingha.

The meadows in Kanha which constitute just 10% of the study area are also under pressure from the encroachment by woody species. The meadows are anthropogenic in origin and were formed by the clearing of forests for agriculture, grazing and habitation and were maintained by people through annual fires. With the relocation of the human settlements outside the National Park these evacuated sites have developed into excellent meadows and attract grazing ungulates. However, as the climax vegetation of the area is Sal forest, these meadows are being encroached by woody species *Butea monosperma, Lagerstroemia parviflora, Diospyros melanoxylon* and *Shorea robusta.*

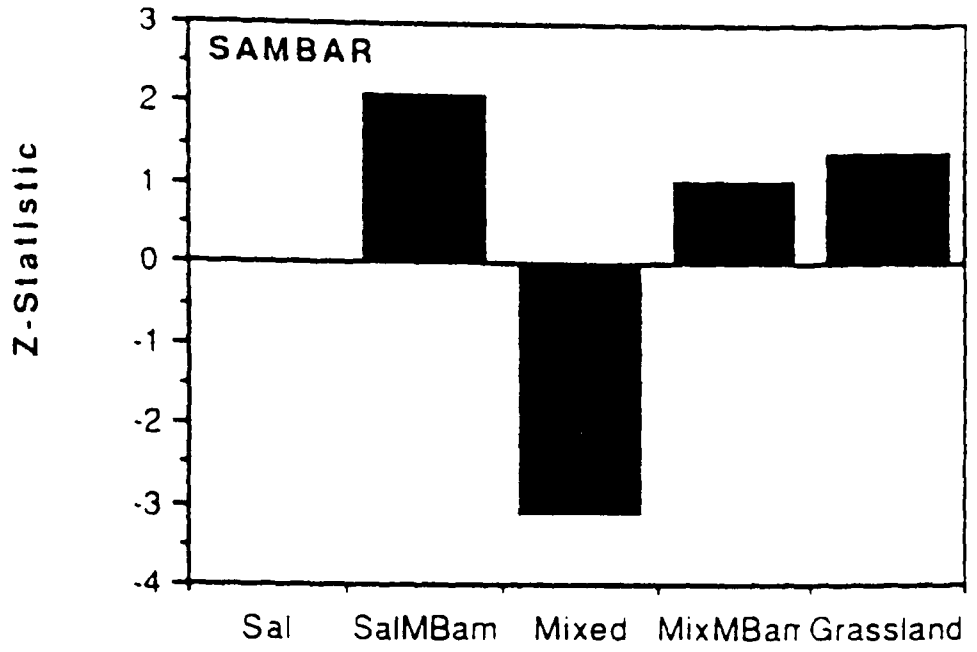
The impact of encroachment by these species is manifold; firstly, it directly reduces the grassland area of the Park which is vital for the survival of the Barasingha and highly utilized by Chital. Secondly, the shading of the potential grassland beneath the canopy of these species and the competition for nutrients and water by them inhibits grass growth and production. Finally, the regenerating young trees physically inhibit ungulates from grazing. This phenomenon was clearly demonstrated by Olivier and Laurie (1974) in their work on Hippopotamus in the northern Serengeti. A recent study (Anon. 1989a) has indicated that the problem of meadow encroachment in Kanha is potentially serious as it affects the conservation value of the Park. This study stresses the need for the

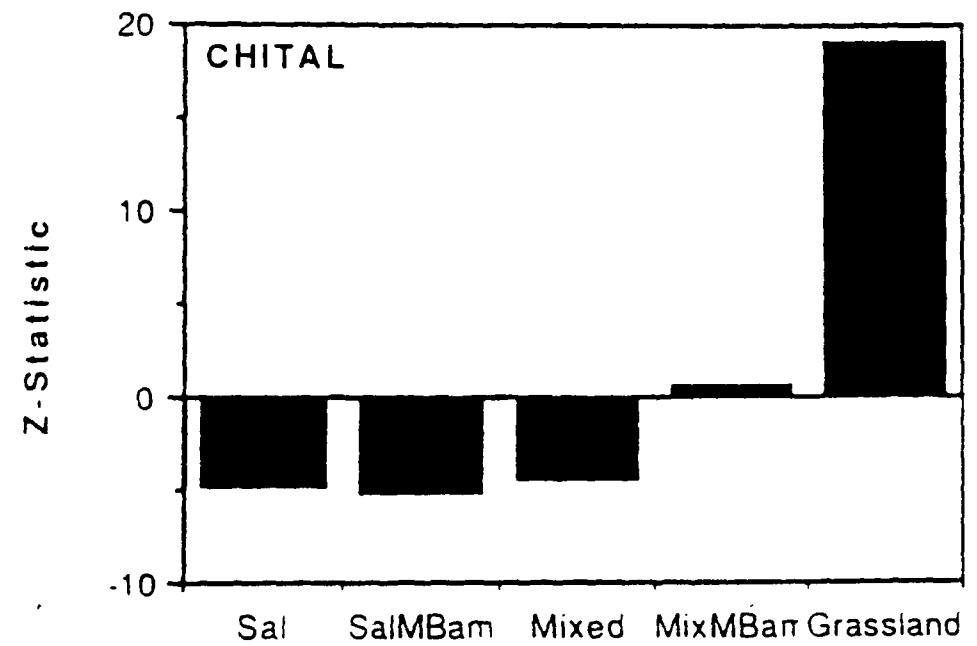
initiation of detailed investigation of the encroachment phenomena for development of management strategies to counter these effects. The complete fire protection policy adopted in the Park has probably resulted in this increase in woody vegetation cover. Several workers (Trapnell, 1959; Eiten, 1972; Brookman-Amissah *et al.*, 1980; San Jose and Medina,1975; San Jose and Farinas, 1983) have also suggested that total fire protection leads to an increase in tree density, particularly of fire resistant species, leading to the establishment of woodland in many savanna areas and to the development of forest in the high rainfall areas of the transition zone from savannas to forest. Humphrey (1962) remarked that fire has been a dominant factor down though the ages in maintaining grasslands areas that are climatically capable of growing woody plants and West (1971) said 'while the importance of fire in limiting the development of climax vegetation is widely appreciated, the overriding importance of the activities of man and of wildlife in influencing the effects of fire are perhaps not so generally recognized'.

It is obvious that fire has a definite role to play in maintaining balance in bush-grass vegetation pattern in Kanha and a suitable burning regime/cycle has to be adopted which can not only check the advancement of woodland but also prevent the grasslands from deterioration under the twin pressure from fire and heavy grazing. Further, urgent steps are needed to reclaim the degraded meadows and to remove the woody encroachment which is establishing or has just established. Experiments by Van Wyk (1971) have shown that where grazing intensity is abnormally high there seems to be very little or no qualitative or quantitative changes in the grass stratum in the triennially

burnt plots and that bush encroachment is also controlled. However, because of the present condition of the Kanha meadows it would be appropriate to withhold grazing, possibly by use of electric fences, for a full growing season before the triennial burning and also for four to six weeks afterwards. In meadows, where woody species have established, the present strategy of manual uprooting of seedlings (Parihar, *pers.comm.* 1989) should continue as burning is not successful in killing the established seedling. It is also imperative to simultaneously reduce the grazing pressure on the meadows, coming mainly from Chital. This can be achieved by a) selective, systematic and gradual reduction in Chital numbers by culling and b) by dispersing them to other meadows of the Park where their density is low. Both these measures are likely to face opposition; the former because of politico-religious compulsions and the latter mainly on account of practical considerations, as it involves dispersing very large numbers of Chital. Culling in this case should, however, be seen as a conservation-management strategy, devoid of any commercial or recreational considerations, for the better mangement of the habitat for ensuring the long term survival of the world's last surviving population of hard ground Barasingha (*Cervus duvauceli branderi*). Incidentally, the major objective of management of Kanha National Park is the 'preservation and maintenance of diversity and interspersion of habitats of the Park by securing the perpetuation of grasslands by manipulative management, including the use of fire as a major tool, so as to secure the survival of Barasingha and enhance welfare of other ungulates'. Systematic and selective culling of Chital population should therefore be seen as an important means of achieving this objective.

Fig. 8.1 The relationship between habitat type and the Z-Statistic for the three ungulate species in Kanha National Park. Positive Z-values show the degree of attraction to a given habitat type and negative Z-values indicate avoidance. Data from Table 4.5





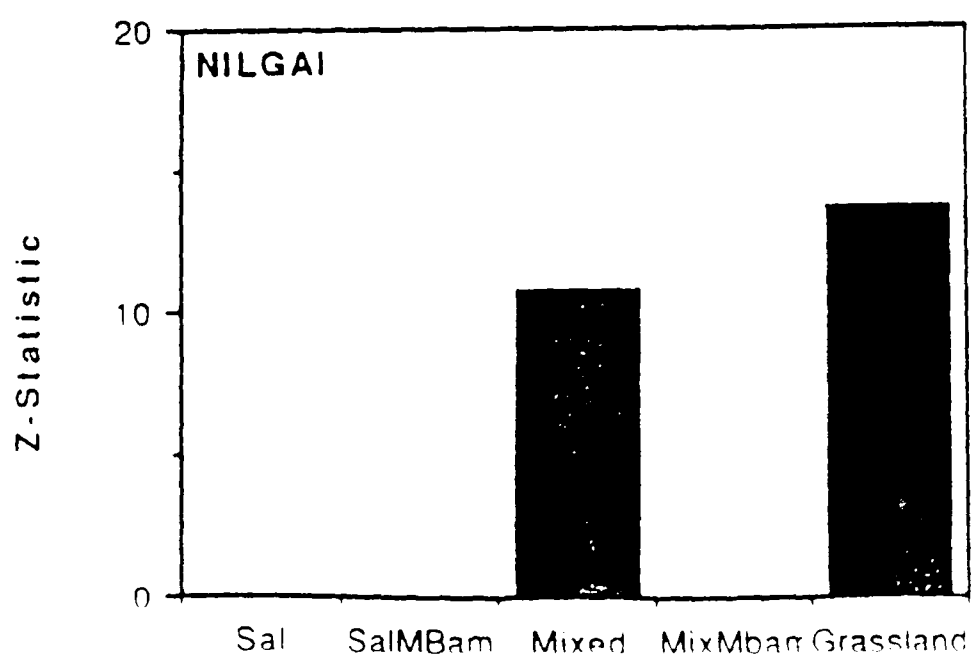
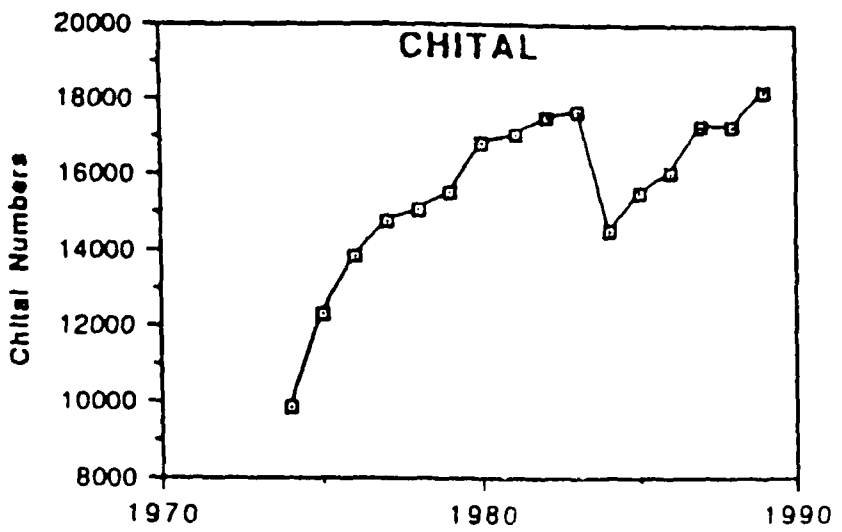
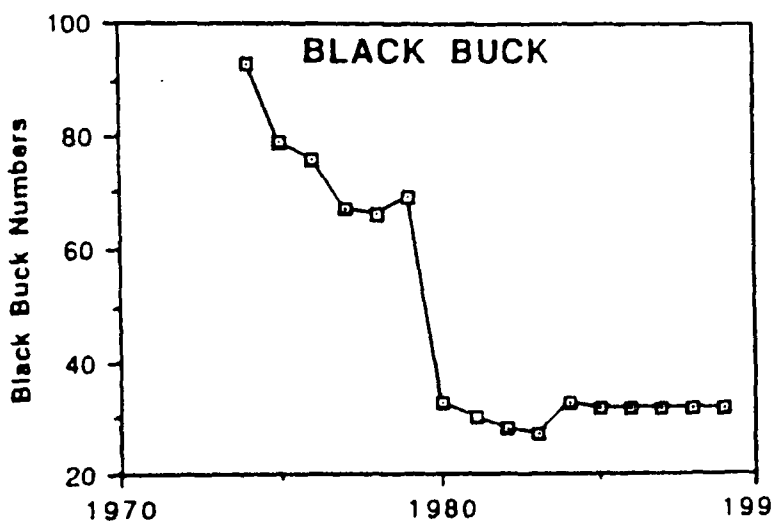
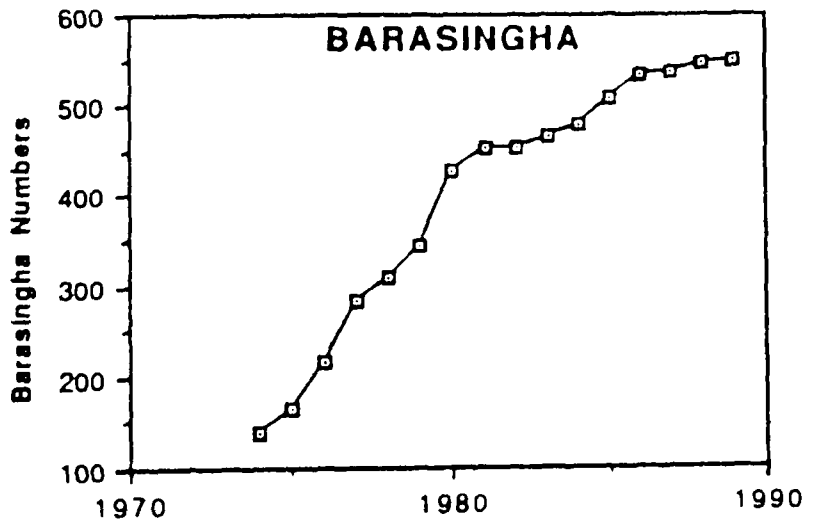
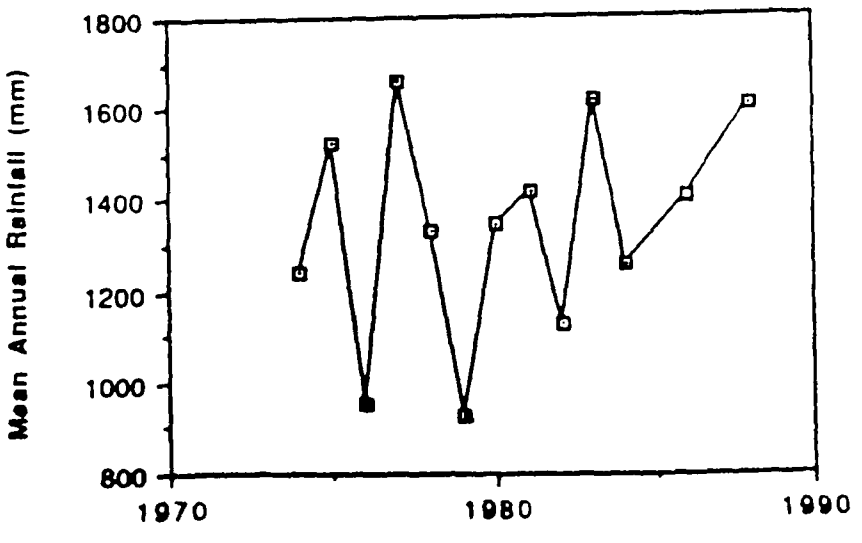


Fig. 8.2 Population trends (1974-1989) of the three grassland species in Kanha National Park. Data from Parihar and Kotwal (1989). Trend in annual precipitation during this period is also shown









CHAPTER NINE

HERBIVORE-HABITAT RELATIONSHIPS: A SYNTHESIS

9.1 INTRODUCTION

In the present study, the herbivore-habitat relationships were studied in three different sites and the variables which significantly influence the abundance of the three ungulate species were determined using a generalized linear modelling approach. Since the same methods have been used in the collection and analyses of data from all the three sites it would be of great interest to be able to make an inter-site comparison of the effects of these variables in influencing species abundance. This can be achieved by pooling the data sets from the three sites. These comparisons are also important because the sites differ in their basic habitat composition and quality and therefore the nature of site-variable interaction may vary across sites. For example, in general the presence of a human settlement in an area has a negative influence on Sambar and Chital abundance but the biological impact of a settlement, having the same number of human dwellings and cattle population, is greater in Sariska than in Kanha. This is probably because the moist deciduous forests and the grassland mosaic in Kanha have higher primary productivity because of higher rainfall compared to the thorn forest in Sariska. Thus the competition for forage resources between wild ungulates and domestic livestock is relatively lower in Kanha. Similarly, other physical features of a site could interact with a variable to modify its influence. In this chapter, I attempt to study the various site-variable

interactions and discuss their biological significance in influencing species abundance.

Multivariate analytical techniques involving regression and ordination have been commonly used in community ecology to discover how a multitude of species respond to external factors such as environmental variables, pollutants and management regime (Ter Braak, 1987a). I also used a particular analytical technique called Canonical Correspondence Analysis (CCA) (Ter Braak, 1987b) for the initial analysis of data from Sariska National Park. It is believed that this technique escapes the assumption of linearity and is able to detect unimodal relationships between species and external variables. In this chapter, I present the results obtained from this analysis. I have also included a section on choosing the methods for data analyses in which I discuss the relative capabilities of CCA and GLIM in explaining the underlying patterns in data.

9.2 METHODS

The data sets from the three study areas were pooled to form a combined data set for the study areas. Variables which were found statistically not significant in the earlier analyses (Chapters 6-8) were dropped from the data set. The general procedures of the GLIM analyses have been discussed earlier (See section 5.2). The Y variates were defined as the abundance of Sambar, Chital and Nilgai respectively. For each species the variable accounting for the highest change in deviance was fitted first

in the model. Other variables were included only if their inclusion caused a statistically significant change in deviance. Study sites (Tadoba, Sariska and Kanha) were included as an independent variable to determine their influence on each model. Since the site-habitat variable interaction could modify the influence of that variable in a particular site an interaction term was fitted for each of the variable included in the model. To check that the Generalized Linear Models constructed truly represent the data I evaluated the statistical models using the following standard procedures: 1) examination of the residuals for detecting lack of fit, 2) estimation of model parameters and 3) plotting the standardised residuals against the fitted values.

Canonical Correspondence Analysis (CCA) was carried out using data from Sariska National Park through procedures described in CANOCO manual (Ter Braak, 1987a). An ordination diagram of species and habitat variables was constructed which displays how the three ungulate species are distributed in relation to the habitat variables.

9.3 RESULTS

The results of the GLIM analyses of the pooled data set are presented species-wise in the following sub-sections. Results from the CANOCO analysis are presented later in the chapter (Section 9.5) and are compared with those obtained from the GLIM analyses done earlier.

9.3.1 RESULTS OF GLIM ANALYSES OF POOLED DATA ACROSS SITES

9.3.1.1 SAMBAR

The Null Model has a deviance 4467.2 with 895 d. f. (Table 9.1). Four variables *viz.* Tden (χ^2= 41.2, d.f. = 3, p<0.001), Slope (χ^2= 42.6, d.f. =3, p<0.001), Huset (χ^2= 202.6, d.f. = 3, p<0.001) and Natsea (χ^2= 19.7, d.f. = 3, p<0.001) are statistically significant in explaining the abundance of Sambar in the three study areas. The analysis shows that as the tree density increases the area becomes more suitable for Sambar. This is probably because Sambar is a forest ungulate and prefers the dense canopy cover. The result also show that gentle-medium slopes are preferred by Sambar but steep slopes (i.e. Slope (4)) have a negative influence. The perennial availability of water (Natsea) and the increased number of human dwellings (Huset (4)) in an area appear to a have opposite influence on Sambar abundance. Study site, when fitted as an independent variable has a significant (χ^2= 419.7, d.f. = 2, p<0.001) influence on Sambar abundance. This indicates that site can have significant influence in modifying the nature of influence of the variables included earlier in the model and Sambar numbers differ between sites. This is further observed when the interaction term of site with all the four variables is individually included in the model. All four interactions i.e. Tden*Site, Slope*Site, Huset*Site and Natsea*Site are statistically significant (p<0.001). Medium tree density (Tden (2)) in Sariska and Kanha have a similar positive influence on Sambar abundance but this

influence becomes stronger in Kanha in the case of Tden (3). As this category is not present in Sariska its influence cannot be studied. The

slope-site interaction in the study sites shows an interesting pattern. Flat-medium slopes have a stronger positive influence on Sambar abundance in Sariska compared to Kanha where medium-moderate slopes are preferred by Sambar. Similarly, the site-human settlement interaction varies considerably across sites. While the lower level of human settlement (Huset (2)) is tolerated by Sambar in all the sites, the impact begins to differ as the number of human dwellings in an area increases. The negative influence of Huset (3) is stronger in Sariska as compared to Kanha and becomes stronger when the dwellings increase to Huset (4). The perennial availability of water has a stronger positive influence in Sariska compared to Kanha. This may be because water is a limiting factor in Sariska and the water status remains on the negative side from Feb-June and then again from August onwards (Fig. 2.8).

Table 9.1 Analysis of deviance showing the factors which effect the abundance of Sambar in the three study sites

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	4467.2	895			
+Tden (4)	4426.0	893	41.2	3	<0.001
+Slope (4)	4383.5	890	42.6	3	<0.001
+Huset (4)	4180.9	887	202.6	3	<0.001
+Natsea (3)	4161.2	885	19.7	2	<0.001
+Site (3)	3742.1	883	419.7	2	<0.001

+Tden*Site	3721.2	880	20.9	3	<0.001
+Slope*Site	3641.0	876	79.6	4	<0.001
+Huset*Site	3610.8	870	30.8	6	<0.001
+Natsea*Site	3587.3	866	23.5	4	<0.001

The coefficients and standard errors for the Sambar Model. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
2.130	0.0601	1
0.1753	0.0500	Tden (2)
0.4166	0.1044	Tden (3)
0.2160	0.0591	Slope (2)
0.2150	0.0574	Slope (3)
-0.1885	0.0760	Slope (4)
0.4049	0.1966	Huset (2)
-0.9094	0.0890	Huset (3)
-0.9336	0.0880	Huset (4)
-0.1920	0.1230	Natsea (2)
0.8091	0.0495	Natsea (3)
0.6061	0.0965	Site (2)
0.8864	0.2598	Site (3)
0.2943	0.1009	Tden (2)*Site (2)
0.2719	0.1082	Tden (2)*Site (3)
0.3478	0.1078	Tden (3)*Site (2)
0.0000	aliased	Tden (3)*Site (3)
0.4770	0.0943	Slope(2)*Site (2)
0.3219	0.1057	Slope (2)*Site (3)
0.4193	0.1276	Slope (3)*Site (2)
0.0000	aliased	Slope (3)*Site (2)
0.0000	aliased	Slope (4)*Site (3)
0.6452	0.2211	Huset (2)*Site (2)
0.7383	0.2195	Huset (2)*Site (3)
-0.7478	0.1709	Huset (3)*Site (2)
-0.5589	0.1792	Huset (3)*Site (3)
-0.8387	0.0271	Huset (4)*Site (2)
-0.3518	0.0256	Huset (4)*Site (3)
0.3920	0.1921	Natsea (2)*Site (2)
0.2932	0.2891	Natsea (3)*Site (3)
0.4499	0.1310	Natsea (3)*Site (2)
0.3192	0.1432	Natsea (3)*Site (3)

9.3.1.2 CHITAL

The Null Model has a deviance 25997.5 with 985 d.f. (Table 9.2). As seen in case of Sambar earlier, four variables are statistically significant in explaining the abundance of Chital in the three study sites. These are Grsscov (χ^2= 7429, d.f. = 5, p<0.001), Grht (χ^2= 704, d.f. = 4, p<0.001), Artsea (χ^2= 242, d.f. = 2, p<0.001) and Huset (χ^2= 304, d.f. = 3, p<0.001). The analysis shows that as the percentage grass cover (Grsscov) increases in an area it begins to have a stronger positive influence on Chital abundance. This is to be expected as Chital is a grassland species and the increased grass cover meets its essential habitat requirement. Similarly, the grass height is also important for Chital as it provides escape cover against predation, especially to the fawns. However, when the grasses become too tall (Grht (5)), they have a negative influence on Chital abundance. This may be because tall grasses lower the visibility, which is essential for Chital for making visual contacts with other members of the group. As in case of Sambar, the perennial availability of water and increased number of human dwellings have opposite influence on Chital abundance.

Study site, when fitted as an independent variable is statistically significant (χ^2= 832, d.f. = 2, p<0.001) indicating that site-variable interactions are important for Chital also. The grass cover-site interactions in Kanha have stronger positive influence on Chital abundance as compared to the other two sites Tadoba and Sariska. This is mainly because true grasslands are present in Kanha only and the grassland-forest 'edge' provides an excellent habitat for Chital. This is also reflected

in the very high Chital density (96.6 km^{-2}, Appendix VI) in Kanha grasslands observed in this study. The grass height-site interactions in Kanha show that these interactions have negative influence on Chital abundance when the grass height becomes taller than 1m (i.e Grht (4)). The influence of the perennial availability of water on Chital abundance is stronger in Sariska compared to the other two sites. This was also observed in case of Sambar and it probably indicates that water may have a significant role in influencing both distribution and abundance in arid environments. Similarly, the negative influence of increased number of human dwellings on Chital abundance is stronger in Sariska as compared to the other two sites.

Table 9.2 Analysis of deviance showing the factors which effect the abundance of Chital in the three study sites

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null Model	25997.5	895			
+Grsscov (6)	18568.0	890	7429	5	<0.001
+Grht (5)	17864.0	886	704	4	<0.001
+Artsea (3)	17622.0	884	242	2	<0.001
+Huset (4)	17318.0	881	304	3	<0.001
+Site (3)	16486.0	879	832	2	<0.001
+Grsscov*Site	14910.0	873	1576	6	<0.001
+Grht*Site	14870.0	869	41	4	<0.001
+Artsea*Site	14832.0	866	37	3	<0.001
+Huset*Site	14693.0	860	140	6	<0.001

The coefficients and standard errors for the Chital Model. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
2.028	0.1524	1
1.398	0.0866	Grsscov (2)
1.451	0.0856	Grsscov (3)
1.362	0.0762	Grsscov (4)
1.720	0.0745	Grsscov (5)
1.910	0.0736	Grsscov (6)
0.070	0.0644	Grht (2)
0.321	0.1283	Grht (3)
0.601	0.1535	Grht (4)
-0.428	0.1391	Grht (5)
0.141	0.0148	Artsea (2)
0.378	0.0419	Artsea (3)
0.352	0.1378	Huset (2)
-0.680	0.0508	Huset (3)
-0.720	0.0921	Huset (4)
0.224	0.1505	Site (2)
0.349	0.0793	Site (3)
1.477	0.1041	Grsscov (2)*Site (2)
1.638	0.0764	Grsscov (2)*Site (3)
1.522	0.1241	Grsscov (3)*Site (2)
2.162	0.1170	Grsscov (3)*Site (3)
1.396	0.2576	Grsscov (4)*Site (2)
0.000	aliased	Grsscov (4)*Site (3)
0.000	aliased	Grsscov (5)*Site (2)
3.484	0.2238	Grsscov (5)*Site (3)
0.000	aliased	Grsscov (6)* Site (2)
0.000	aliased	Grsscov (6)*Site (3)
0.000	aliased	Grht (2)*Site (2)
0.221	0.1176	Grht (2)*Site (3)
0.308	0.1756	Grht (3)*Site (2)
0.407	0.0911	Grht (3)*Site (3)
0.000	aliased	Grht (4)*Site (2)
-0.210	0.0955	Grht (4)*Site (3)
0.000	aliased	Grht (5)*Site (2)
0.000	aliased	Grht (5)*Site (3)
-0.411	0.1900	Artsea (2)*Site (2)
0.000	aliased	Artsea (2)*Site (3)
0.484	0.0787	Artsea (3)*Site (2)
0.428	0.0725	Artsea (3)*Site (3)
0.249	0.1033	Huset (2)*Site (2)
0.504	0.1541	Huset (2)*Site (3)
-0.676	0.1381	Huset (3)*Site (2)
0.331	0.1112	Huset (3)*Site (3)
-0.957	0.1180	Huset (4)*Site (2)
-0.773	0.1133	Huset (4)*Site (3)

9.3.1.3 NILGAI

The Null Model has deviance 8595.0 with 895 d.f. (Table 9.3). Five variables viz. WVE4 (χ^2= 1253.6, d.f. = 4, p<0.001), WVE2 (χ^2= 62.3, d.f. = 3, p<0.001), Slope (χ^2= 19.0, d.f. = 3, p<0.001) and Natsea (χ^2= 963.1, d.f. = 2, p<0.001) are statistically significant in influencing the abundance of Nilgai in the three study areas. Increased levels of woody vegetation cover i.e. (WVE4(4) and WVE4(5)) have very strong negative influence on Nilgai abundance. This indicates that Nilgai avoids areas with high woody vegatation cover and prefers areas with relatively open canopy. On the other hand, the increase in woody vegetation cover WVE2, which represent the shrub cover upto 2m height has a very strong positive influence on Nilgai abundance. This is to be expected as Nilgai is predominantly a browser and the shrub layer contributes 59% in its diet (see Table 3.1). Site, when fitted as an independent variable has a statistically significant (χ^2= 1317.6, d.f. = 2, p<0.001) influence on the model suggesting that as in case of both Sambar and Chital, site-variable interactions are important for Nilgai also. The interactions between woody vegetation cover (WVE2) and site are very powerful in influencing Nilgai abundance in Sariska then they are in either Tadoba or Kanha. This is probably because the miscellaneous dry thorn forests (MDTF) forms nearly 40% of the total area in Sariska and is dominated by a diverse layer of semi-evergreen shrub species. This is also reflected in the very high density (20.1 km^{-2}, Appendix V) of Nilgai observed in MDTF during this study. The slope-site interactions indicate that in all the areas Nilgai prefers flat-gentle slopes. The human settlement-site interactions show

that compared to both Sambar and Chital, Nilgai is able to tolerate higher levels of disturbance from the human settlements in all the study areas. Similarly, the perennial water availability and site interactions for Nilgai are not so strong as they were in case of Sambar and Chital. This probably indicates that Nilgai is able to tolerate greater variations in water availability as compared to the other two sympatric species present in the study areas.

Table 9.3 Analysis of deviance showing the factors which effect the abundance of Nilgai in the three study sites

Model variable	Residual deviance	d.f.	ΔD	Δd.f.	P
Null model	8595.0	895			
+WVE4 (5)	7222.7	891	1253.6	4	<0.001
+WVE2 (4)	7160.8	888	62.3	3	<0.001
+Slope (4)	7141.4	885	19.0	3	<0.001
+Huset (4)	7078.2	882	63.0	3	<0.001
+Natsea (3)	6115.1	880	963.1	2	<0.001
+Site (3)	4797.5	878	1317.6	2	<0.001
+WVE4*Site	4741.8	874	55.6	4	<0.001
+WVE2*Site	4581.1	870	160.7	4	<0.001
+Slope*Site	4371.4	866	209.7	4	<0.001
+Huset*Site	4320.7	860	50.7	6	<0.001
+Natsea*Site	4212.6	856	108.1	4	<0.001

The coefficients and standard errors for the Nilgai Model. The ratio of the parameter to its standard error is approximately distributed as Student's 't'-variable

Parameter estimate	Standard error	Parameter
1.256	0.3042	1
0.403	0.1631	WVE4 (2)
0.402	0.1661	WVE4 (3)
-0.867	0.1187	WVE4 (4)
-5.517	1.459	WVE4 (5)
0.442	0.2643	WVE2 (2)
0.710	0.2538	WVE2 (3)
1.018	0.2746	WVE2 (4)
0.907	0.0708	Slope (2)
-0.282	0.0789	Slope (3)
-0.312	0.0700	Slope (4)
0.458	0.1881	Huset (2)
0.766	0.0614	Huset (3)
-0.410	0.1964	Huset (4)
0.218	0.0970	Natsea (2)
0.127	0.0646	Natsea (3)
0.489	0.0444	Site (2)
1.259	0.0699	Site (3)
0.092	0.0403	WVE4 (2)*Site (2)
0.215	0.0397	WVE4 (2)*Site (3)
-0.313	0.0420	WVE4 (3)*Site (2)
-0.625	0.1694	WVE4 (3)*Site (3)
0.000	aliased	WVE4 (4)*Site (2)
0.000	aliased	WVE4 (4)*Site (3)
1.372	0.3252	WVE2 (2)*Site (2)
0.816	0.3070	WVE2 (2)*Site (3)
2.730	0.3105	WVE2 (3)*Site (2)
1.168	0.3520	WVE2 (3)*Site (3)
0.000	aliased	WVE2 (4)*Site (2)
0.000	aliased	WVE2 (4)*Site (3)
0.186	0.0919	Slope (2)*Site (2)
-1.664	0.2654	Slope (2)*Site (3)
-1.034	0.1169	Slope (3)*Site (2)
-1.935	0.3773	Slope (3)*Site (3)
0.000	aliased	Slope (4)*Site (2)
0.000	aliased	Slope (4)*Site (3)
0.446	0.1983	Huset (2)*Site(2)
5.581	1.7640	Huset (2)*Site (3)
0.582	0.1317	Huset (3)*Site (2)
1.332	0.3245	Huset (3)*Site (3)
-0.557	0.2086	Huset (4)*Site(2)
0.558	0.2164	Huset (4)*Site (3)
0.361	0.1802	Natsea (2)*Site (2)
0.481	0.2380	Natsea (2)*Site (3)
0.223	0.1005	Natsea (3)*Site (2)
0.851	0.4209	Natsea (3)*Site (3)

9.4 DISCUSSION

The present analyses of the pooled data set has shown that only 9 variables are statistically as well as biologically significant in explaining the abundance of the three wild ungulates Sambar, Chital and Nilgai across the three study sites. Thus from the original 22 variables included in the study only nine variables are important in explaining the patterns in species abundance data. The analyses has also shown that the site-variable interaction may modify the influence of a variable in the three study sites. This is to be expected as the three sites vary in the structure and composition of habitat and also the climatic factors and biotic pressures operate differently. The impact of a human settlement varies not only for the three ungulate species but also for the three study sites. The negative impacts are stronger in areas where primary productivity of the site is lower. In Sariska, the low and unpredictable rainfall levels lead to a lower primary productivity, which is reflected in the shortage of forage resources in the dry season. The sharing of scarce forage resouces with domestic livestock appears to have a severe negative impact on Sambar and Chital abundance. Nilgai, being an opportunistic feeder is able to mix the available browse and coarse grass in its diet and is able to reduce some competition from domestic livestock. Moreover, its relatively less dependance on the availability of surface water allows it to to utilize areas deficient in water.

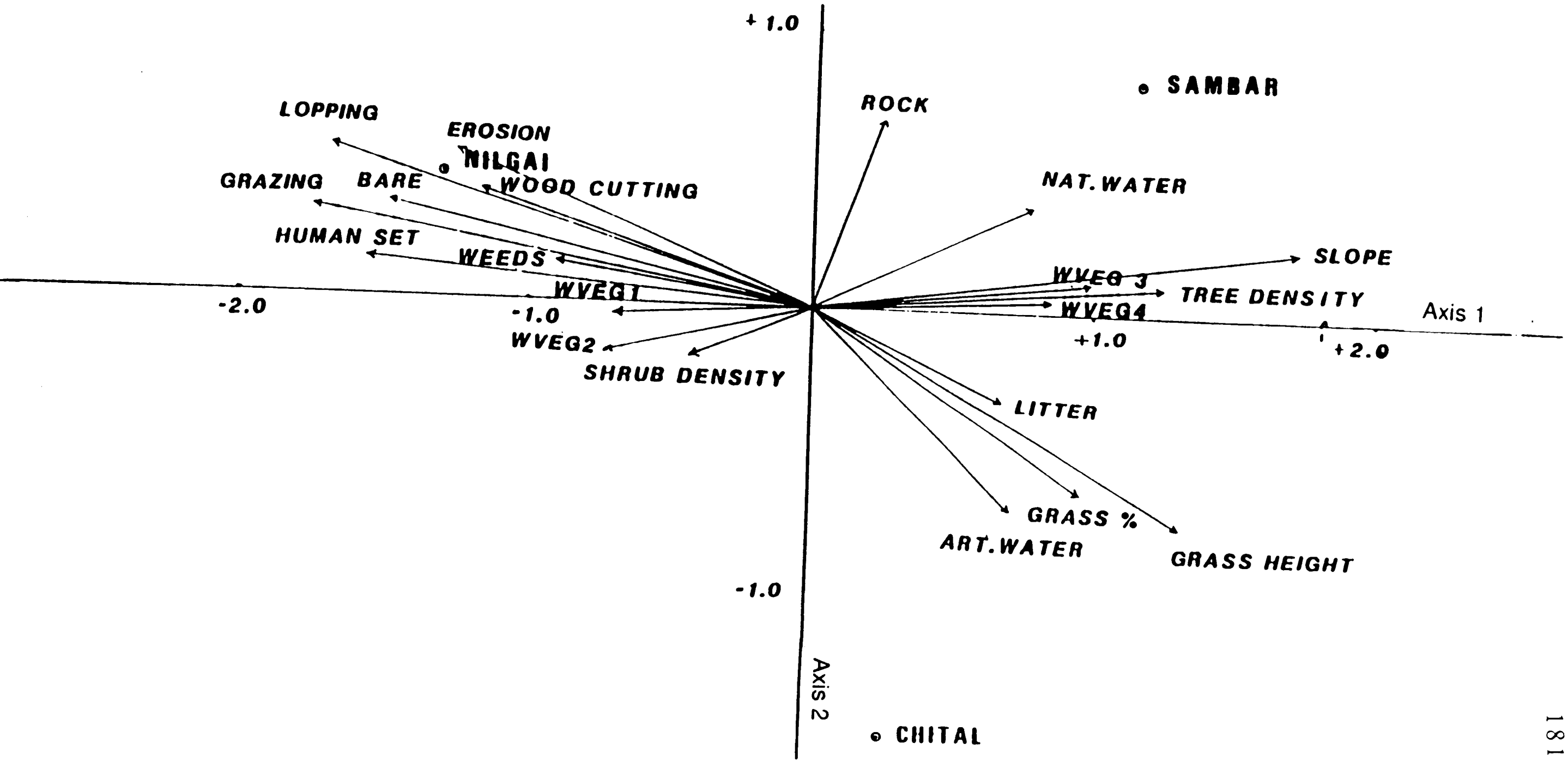
Thus on the basis of this study we may conclude that slope, woody vegetation cover, water, grass cover, grass height and human settlements are the variables which probably influence the abundance of Sambar, Chital and Nilgai. These seven habitat variables are able to explain between 20 and 50% of the variation in the pattern of abundance of the

three ungulate species in three different sites. However, as the site-variable interactions have been found to be significant, it must be emphasized that the magnitude of influence of these variables would vary according to the physical and biotic features of the site. It may further be said that the analyses has shown that counting the animals is a good practical way of assessing the habitat quality.

9.5 RESULTS OF CANONICAL CORRESPONDENCE ANALYSIS (CCA)

The results of the Canonical Correspondence Analysis (CCA) can be displayed in an Ordination Diagram (Fig. 9.1). In this diagram, species are represented by points and habitat variables by arrows. Habitat variables with long arrows are more strongly correlated with the ordination axes than those with short arrows, and so are more closely related to the pattern of community variation shown in the Ordination Diagram. The sum of all canonical eigenvalues was 0.0707. Nearly, 80% of the explained variance is attributed to the first axis of the Ordination Diagram. The second axis accounts for the remaining 20% of the explained variance. From the Ordination Diagram it is evident that the first axis is a vegatation structure axis, which ranges from the open woodland to dense bushland. Habitat variables lopping, grazing, erosion, woodcutting, bareness, human settlements and weeds are negatively loaded on this axis. These variables are infact a measure of the level of disturbance/degradation of the natural forest and therefore the first axis probably represents the disturbed versus undisturbed forest. Slope, water (artificial and natural sources), grass cover, grass height have positive loadings on Axis 1. The second axis is largely determined by rockiness.

Fig. 9.1 Ordination Diagram based on Canonical Correspondence Analysis (CCA) of the three wild ungulate species (Sambar, Chital and Nilgai) with respect to 20 habitat variables (arrows). First axis is horizontal, second axis is vertical. WVE1 and WVEG2 represents shrub cover at 1 and 2 m height respectively. WVEG3 and WVEG4 are tree covers at 4 and 8 m respectively. HUMAN SET= Human settlements, ART. WATER= Artificial water sources, NAT. WATER= Natural water sources



Variables grass height, grass cover, water and litter are negatively loaded on this axis while erosion, lopping, bareness and woodcutting are positively loaded.

The Ordination Diagram also shows that the three wild ungulate species, Sambar, Chital and Nilgai are spatially separated, presumably on the basis of their ecological requirements. Sambar, a forest ungulate is seen to be heavily loaded on habitat variables tree cover and slope. Higher values of slopes and cover indicates that it prefers a well wooded hilly topography. Sambar abundance levels are quite low around human settlements as it avoids degraded, open and flat habitats. In contrast to Sambar, Nilgai prefers a scrub-savanna habitat. It is also able to tolerate higher levels of habitat degradation and is not a water dependent species. The Ordination Diagram shows that Chital is highly correlated with grass cover, grass height and water. It also reflects that Chital is an animal of the 'edge', as its spatial position is in the centre of the woody vegetation axis, slightly more towards the woodland with small canopy openings.

9.6 CHOOSING THE METHODS FOR DATA ANALYSES IN COMMUNITY ECOLOGY

My purpose in including a discussion on the above topic in this chapter is not to undertake an extensive review of the various multivariate methods available for data analyses in community ecology. Rather, my limited aim is to compare the two approaches I have used in the data analyses in

order to know their relative capabilities in explaining the underlying structure in data.

Ordination serves to summarize community data by providing a low-dimension ordination space in which similar species and samples are close together and dissimilar entities far apart (Gauch, 1982). The Ordination Diagram constructed from the CCA effectively summarizes the data set. It shows that the three ungulate species are spatially separated and also indicates how habitat variables are correlated with species. CCA assumes linear relationships among variables but we know that in ecology non-linear, non-monotonal reponses of species to environmental variables frequently occur. Similarly, bimodal distributions sometimes occur, but ordination has to assume that species 'on average' have simple distribution.

GLIM, on the other hand, is more flexible as one can specify 'link functions' and 'error distribution' other than the normal distribution. The type of response model used in GLIM may be determined by seeing the characteristics and resolution of the data. Moreover, the inspection of the data and the residuals after regression can be done to show whether the model being used is adequate for the purpose. The parameter estimation in GLIM allows us to see the influence of each factor level in case of a categorical variable. For example, it has been shown both by CCA and GLIM analyses that Slope influences the abundance of Sambar. But an analysis of the parameter estimates of the statistical model of Sambar using GLIM reveals that Slope (3) and Slope (4) have different effects

(see Table 9.1). While Slope (3) i.e medium-moderate Slope has a positive influence on Sambar abundance, Slope (3) i.e steep Slope has a negative influence. Similarly, the Chital model (Table 9.2) shows that factor levels of variable grass height can have different influence on Chital abundance. In other words, grass height upto 1 m has a positive influence on Chital abundance but grass height >1m has a negative effect, probably because it reduces the visibility. These effects cannot be studied from the results of CCA. Moreover, interaction between variables often modifies the nature of response. As has been observed in this study, site-variable interactions may be critical in determining the species response to various variables in the three study sites.

Thus we may say that CCA is a better tool for the exploratory data analysis of community data with no prior information about the environment. It provides a very informative overall description of the multiple species-habitat variables data set. GLIM, on the other hand, provides a better means of investigating the nature of individual species' response to various habitat variables and their mutual interactions. It may, therefore, be useful to first analyse the data set using an ordination method to have an overall description and then proceed to examine the nature of influence on individual species of the variables found important, using a generalized linear interactive modelling approach.

CHAPTER TEN

DENSITY AND BIOMASS OF UNGULATES

10.1 INTRODUCTION

Density and biomass of ungulates have been used extensively to compare estimates of carrying capacity for different habitats (Petrides, 1956; Bourliere, 1963; Lamprey, 1964; Sharkey, 1970, Coe *et al.*, 1976; Eisenberg and Seidensticker, 1976; Bell, 1982; East, 1984). Talbot (1964) pointed out that biomass figures can be valid and useful, but they must be carefully defined and applied, particularly when comparing results of different studies. The concept of carrying capacity has often been interpreted differently by the range and wildlife managers (Caughley, 1976). Carrying capacity represents an equilibrium between animals and vegetation and is usually measured in units of animal density (Caughley, 1979). The vegetation and the herbivore systems interact to produce this equilibrium. Therefore, one should not only consider the density of the herbivores, but also the composition of the vegetation, while determining the carrying capacity of a habitat.

Unlike the extensive studies carried out in Africa (Eisenberg and Seidensticker, 1976) ecological studies on ungulate populations in Asia have not been comprehensive. In particular, little has been done to determine carrying capacities.

Ungulates form an important group for the wildlife manager because they are associated with conservation, cropping and control. These are the three main challenges for wildlife management. These challenges can be met only by having a comprehensive knowledge of the population dynamics of the ungulate species' and the understanding of their interaction with the habitat. The present chapter deals with the analyses of the density and biomass estimates of three ungulate species and specifically attempts to answer the following questions:

1) What are the density and biomasses of the ungulate species in the three study areas and what is the species-wise contribution to the total wild ungulate biomass?
2) What is the relationship between the degree of forest cover in a habitat, mean annual rainfall and the biomass of ungulates that it can support?
3) How are the wild herbivore biomass in Indian reserves compared to other South Asian and African reserves?

The information obtained could then be used in improving the management strategies for ungulates in various wildlife protected areas and would also enhance our knowledge of ungulate-habitat relationships.

Eisenberg & Seidensticker (1976) did a comparative study on the density and biomass estimates of ungulates in different habitat types in South Asia and concluded that the degree of forest cover affects the biomass of larger mammals which can be supported. The mammalian biomass increases along a rainfall gradient from dry thorn forests to moist deciduous forests, except at the extreme wet end, comprising of continuous evergreen forest where the biomass of terrestrial herbivores

decreases. In the wildlife and pastoral areas in savannas of the east and southern Africa, Coe *et al.* (1976) studied the relationships between the standing crop biomass of large herbivores and their energy expenditure, production, mean annual precipitation and predicted above ground net primary production. This study demonstrated that it is possible to establish significant relationships between rainfall data and large herbivore biomasses, their production and energy expenditure in a majority of savanna systems with mean annual precipitation less than 700 mm.

10.2 METHODS

10.2.1 BIOMASS ESTIMATES

Biomass density i.e. the sum total of live mass per unit area, is a convenient measure for making comparisons between different areas. A major problem in calculating accurate biomass figures is that there is no easy way to determine the 'unit mass' i.e. the mean mass of all individuals in a given population. This may vary considerably within a species, depending on age-structure, nutritional status and location. It is important that unit mass be given whenever biomass figires are presented, so that other workers can recalculate them according to their own criteria. In the present study, the conversion of density estimates of the three ungulate species (obtained in Chapter Four) to biomass estimates was done by multiplying the mean density of each species by its unit mass given by Schaller (1967). The species unit masses and their biomass densities in different habitat types and the overall study areas are shown in Table 10.1.

Table 10.1 Biomass density estimates for the three ungulate species in different habitat types and the overall study area (OSA). The Unit Mass (U.M) are in kg and the biomass density figures are expressed in $kg.km^{-2}$. Habitat types are described in the text. *= Not found in the habitat type.

Tadoba NP

Species	Biomass density in habitat types						
	U.M	Teak	TeakBam	MMDF	MiscBam	Grlan	OSA
Sambar	136	1227	1726	388	1058	855	1050
Chital	47	1321	963	663	1067	1349	1075
Nilgai	182	706	733	1947	788	1662	1168

Kanha NP

	U.M	Sal	SalMBam	MMDF	MixMBam	Grlan	OSA
Sambar	136	582	684	335	574	468	529
Chital	47	323	625	173	489	4540	1227
Nilgai	182	*	*	453	*	437	444

Sariska NP

	U.M	Anog	AnogMx	BoswMx	MDTF	OSA
Sambar	136	1209	726	559	314	702
Chital	47	304	616	446	508	470
Nilgai	182	832	2275	1301	3658	2022

Since the present study focussed on only three ungulate species, data on other ungulate species present in the study area were obtained from the National Park authorities. Data on population densities and biomass of ungulate species from other sites were compiled from a number of sources. The Project Tiger Directorate, Ministry of Environment & Forests, Government of India which compiles the census estimates of 18 Tiger Reserves provided the bulk of the information (Anon. 1987). Data from core area of the Tiger Reserves and National Parks have been used in the analyses. Additional information was gathered from Spillett (1967), Eisenberg & Lockhart (1972), Berwick (1974), Saratchandra & Gadgil (1975), Eisenberg & Seidensticker (1976), Dinerstein (1980), Johnsingh (1983), Karanth (1988), Uniyal (1989), Gogate (1988) and Bist (*pers. comm.* 1990). Rainfall data were obtained from the same sources as population estimates or from the Indian Meteorological Department, Pune.

It must be pointed out that the methods applied for the estimation of ungulate abundance in the present study differ from those used by the National Park authorities. The density and biomass estimates of ungulates in the three study sites obtained from the present study and those from the Park authorities are presented in Table 10.2.

10.2.2 PARK CENSUS

A wide variety of census techniques are used for estimating the ungulate abundance in various National Parks in India. The two more commonly used techniques are (1) Block Counts and (2) Waterhole Counts. The Block Count method is used in Kanha National Park and the term 'block'

in this context refers to a small area with natural and/or artificial boundaries which can be easily identified on maps as well as in the field. The entire area of the National Park is divided into counting blocks, which are generally formed by pooling 4-5 contiguous compartments. Observers move through assigned blocks in a predetermined pattern and count all the animals seen. The total numbers of animals in the National Park are ascertained by counting all the blocks and adding up the figures thus obtained. The above method depends on the assumption that all individuals of the target species are counted and that double counting of animals is avoided by moving on a predetermined strip.

In Sariska and Tadoba National Parks, animals are counted during the peak of dry season from a observation tower/hide as they visit the waterholes during a 24 hr period. This method is based mainly on two assumptions: (a) there is a linear correlation between the numbers of animal seen drinking per time period and the total number of animals in the area and (b) the frequency with which a certain species drinks is known. However, as both these assumptions are untested in the field situation it is difficult to evaluate this method. The method can, however, be used to study the trends in animal population over a period of time. In summary, it can be said that both block count and waterhole count methods depend on a number of untested assumptions and it is difficult to statistically define their precision and establish confidence limits. However, the density estimates from these methods alone are available as the modern line transect sampling is little used in the Indian National Parks, they have been considered in this chapter for wild ungulates other than Sambar, Chital and Nilgai. Moreover, since the three ungulate

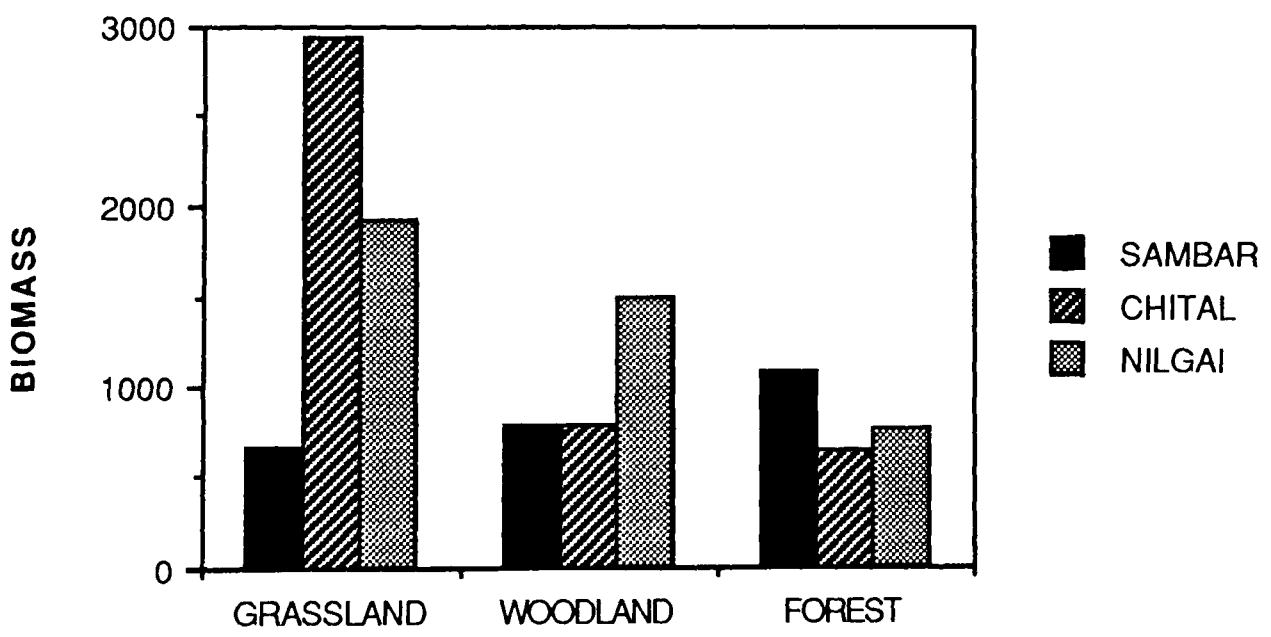
species whose abundance estimation has been been done using the line transect method contribute significantly (Table 10.2) to the total wild ungulate biomass in the three study areas, the general conclusions about their functional roles are probably valid.

10.3 RESULTS

The different habitat types within the study areas support different biomass levels of the three ungulate species (Table 10.1). Sambar biomass levels are comparatively higher in the forested (1227 $kg.km^{-2}$) and woodland (726 $kg.km^{-2}$) habitats while the miscellaneous-mix habitats support a lower (335 $kg.km^{-2}$) biomass. In contrast to this, a very high biomass of Nilgai is supported by the more open miscellaneous-mix habitats (3658 $kg.km^{-2}$) while the forested habitats (706 $kg.km^{-2}$) support low biomass levels. Chital attains the highest biomass levels in the grassland habitats (4540 $kg.km^{-2}$) followed by woodland habitats. Fig. 10.1 shows the biomass of the three ungulate species in grassland, woodland and forest habitats. The general trend is that Sambar attains highest biomass levels in forested habitats which decreases in woodland habitat and is lowest in the miscellaneous/grassland habitats. Nilgai biomass levels show just the opposite trend while Chital biomass is highest in the grassland, followed by woodland habitats and is the lowest in forest habitats. These differential patterns in the relative biomass levels of the three ungulate species may be explained on the basis of the habitat requirements and the feeding strategies of these species. The forested habitats with higher percentage of canopy cover, relatively less human disturbance and greater diversity and availability of browse are able to support a higher biomass of Sambar, which is essentially a browser and is solitary in habit.

Chital, which are grazers reach highest biomass levels in grassland habitats. The woodland habitat which occurs interspersed between the forest and the grassland habitats also supports high Chital biomass. Chital, being an animal of the edge (Leopold, 1933), benefits from the cover and forage found in the woodland habitats. The Miscellaneous-mixed forests are characterized by open forest cover and presence of relatively coarse grasses. Disturbance from both human and livestock is quite high in these habitats as most of the human settlements occur here. Nilgai beng an opportunistic feeder is able to graze and browse on the limited forage resources in the habitat and reaches its highest biomass levels in these and grassland habitats.

Fig. 10.1 Biomass ($kg.km^{-2}$) of three ungulate species in the major habitat types of the study areas



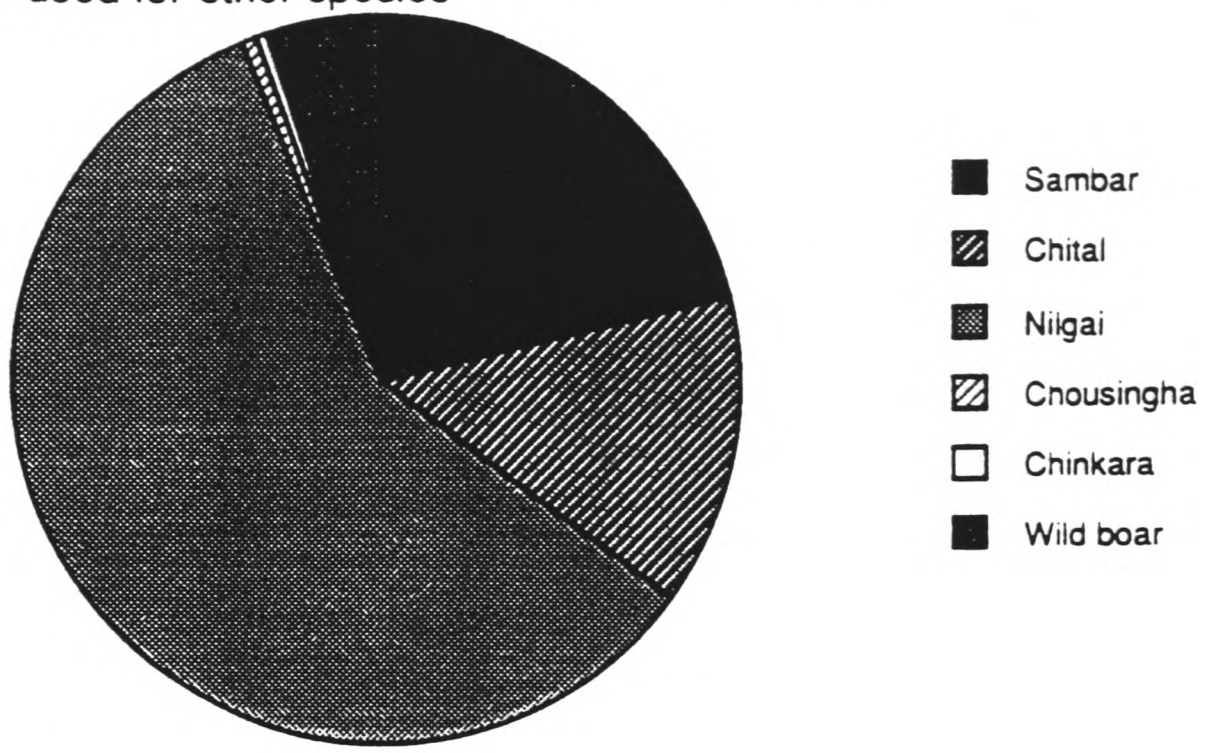
I wanted to compare the percentage contribution to the total wild ungulate biomass by each ungulate species found in the study area in order to determine which species emerged as dominants in terms of biomass. The relative abundance expressed as density is not necessarily an indicator of relative contribution to biomass (Eisenberg, 1980). Table 10.2 gives the density, biomass and species-wise contribution to the total wild ungulate biomass and Fig. 10.2 displays this information in a pie-chart. The total ungulate biomass is highest in Tadoba NP (4875 $kg.km^{-2}$) and lowest in Kanha NP (2552 $kg.km^{-2}$) and 3388 $kg.km^{-2}$ in Sariska NP. Sambar contribution to the total biomass was constant around 20% in all the study areas wheras Chital contribution varied between 48% in Kanha to 14% in Sariska. Nilgai contributed as much as 59% in Sariska but its contribution in Kanha dropped to only 5%. Gaur which occur at a numerically low density in Kanha and Tadoba contributed 17% and 30% respectively in these study areas. Barking deer, Chousingha, Chinkara and Blackbuck contributed negligibly to the overall biomass. The three ungulate species, Sambar, Chital and Nilgai together contributed significantly to the total ungulate biomass. Their contribution is highest in Sariska (94%) and lowest in Tadoba (67%) and is 73% in Kanha. These figures reveal the relative importance of these species in forming the major prey base in all these sites. Dinerstein (1980) reported that Chital and Nilgai contributed 88% of the total wild ungulate biomass in Royal Karnali-Bardia Reserve in Nepal and Karanth (1988) found that Chital and Sambar contributed over 21% to the ungulate biomass in Nagarhole NP where Gaur and Elephant were also present.

Table 10.2 Density, biomass and species wise percent contribution to the total wild ungulate biomass in the three study sites. Unit masses (U.M) are adapted from Schaller (1967). *= Present study. **=Park Authority Estimates (Anon. 1988, Anon. 1989b, Anon. 1989c)

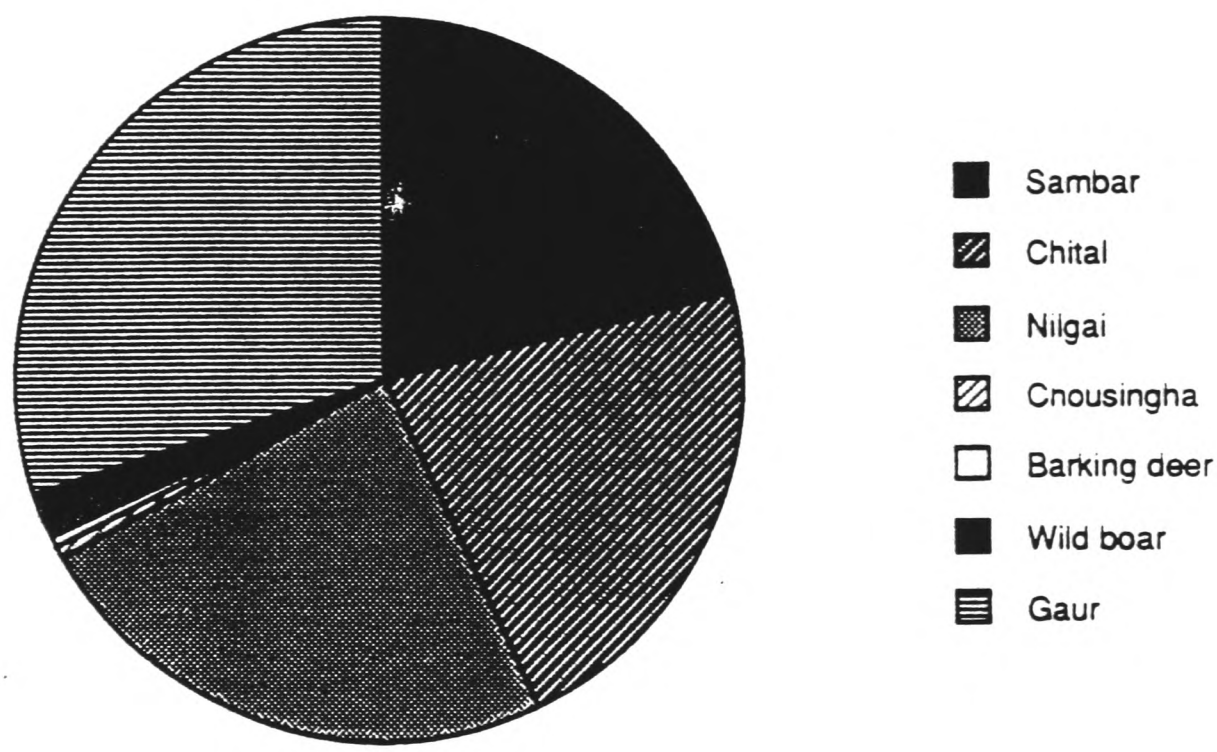
Site	Species	Density* (N/km^2)	Density** (N/km^2)	U.M (kg.)	Biomass (kg.km^{-2})	Percent contribution to total wild ungulate biomass
Tadoba						
	Sambar	7.72	3.87	136	1050	21
	Chital	22.79	23.73	47	1071	22
	Nilgai	6.42	1.87	182	1168	24
	Gaur	---	2.58	561	1447	30
	Barking deer	---	0.86	18	15	<1
	Chousingha	---	0.43	18	8	<1
	Wild boar	---	4.31	27	116	2
Total					4875	99
Kanha						
	Sambar	3.89	2.10	136	529	20.5
	Chital	26.11	19.35	47	1227	48
	Nilgai	0.68	0.74	182	124	5
	Gaur	---	0.77	561	432	17
	Barking deer	---	0.84	18	15	<1
	Chousingha	---	0.22	18	4	<1
	Swamp deer	---	0.57	159	91	3.5
	Black buck	---	0.03	23	<1	<1
	Wild boar	---	4.83	27	130	5
Total					2552	99
Sariska						
	Sambar	5.16	15.42	136	702	21
	Chital	10.0	9.96	47	470	14
	Nilgai	11.11	13.77	182	2022	59
	Chousingha	---	0.33	18	6	<1
	Chinkara	---	0.17	12	2	<1
	Wild boar	---	6.91	27	186	5
Total					3388	99

Fig. 10.2 Percent contribution to the total wild ungulate biomass by each species in the three study areas. Data on Sambar, Chital and Nilgai is from present study. Park authority estimates have been used for other species

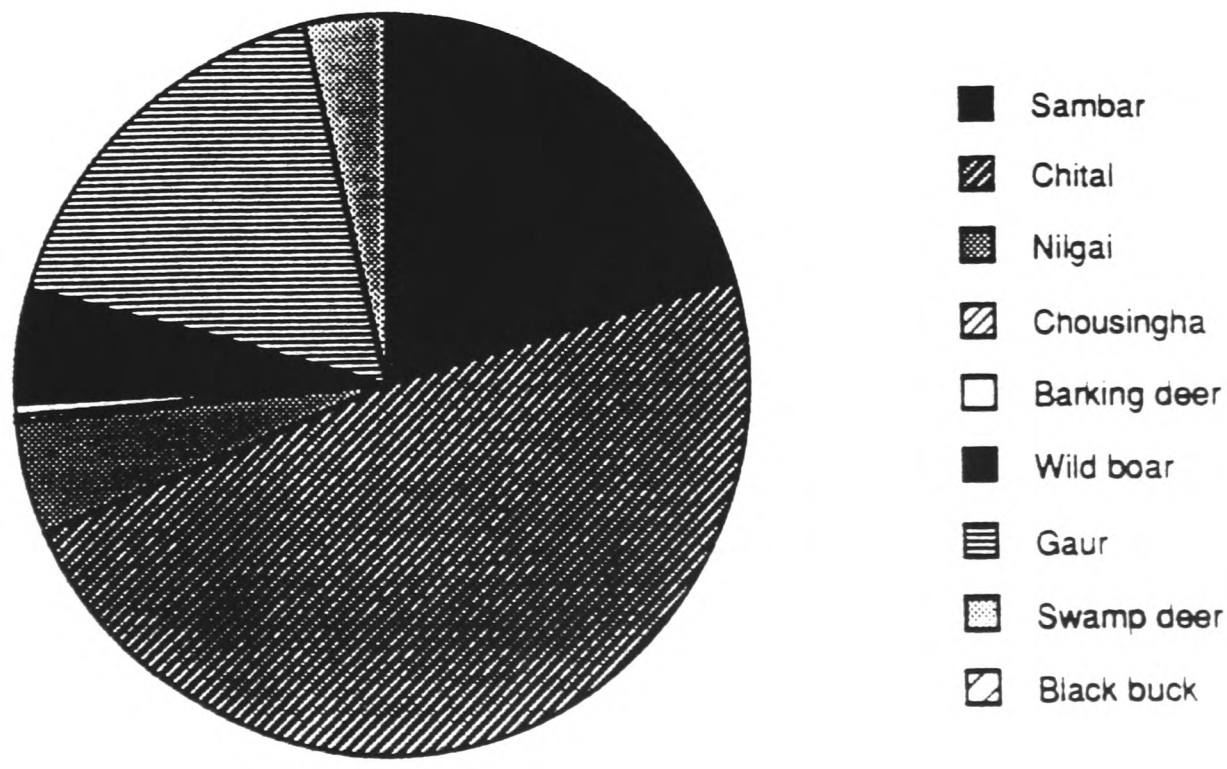
SARISKA NP



TADOBA NP



KANHA NP



The contribution of over 60% to the total wild ungulate biomass by the three ungulate species indicates that in areas of comparable habitat, they occupy a uniform position in the ecosystem. McKay & Eisenberg (1974) concluded that almost invariably only a few species contribute 80% or more to all herbivore biomass in the ecosystem. Table 10.3 summarises the information on the total number of species and the biomass contribution by a few dominant species in wildlife reserves of India, South Asia and Africa. It can be observed that a general pattern exist, where just 3 to 5 species, make a major contribution towards the total biomass. This is true for areas having just 6 species in total (e. g. Sariska, India) and is also valid for areas having 18 species in total (Umfolozi, S. Africa). The dominant species reported from non Indian studies are Elephant, Wildebeest, Hartebeest, Zebra and Cape buffalo while the Indian species are the Asian elephant, Gaur, Sambar, Chital and Nilgai. McKay & Eisenberg (1974) argued that mobile species are often among those which contribute most to the biomass. These species are able to respond better to proximate conditions of rainfall and food availability and are therefore able to maintain higher density levels. The high abundance of the three ungulate species in the present study cannot be due to their mobility alone but probably is due to the absence of a large spectrum of species resulting in less competition, and also efficient resource exploitation. As has been pointed out in the context of environmental exploitation strategies (MacArthur and Wilson, 1967; Pianka, 1974; Cody, 1974), low resource abundance and low environmental predictability are conditions which favour the generalist species over the specialist. Sambar, Chital and Nilgai are all generalist species and are presumably very much better able to exploit the resources than all other species.

Table 10.3 Composition of terrestrial ungulate community in some wildlife reserves of India, South Asia and Africa.

Site	Total No. of species	Numbers contributing ≥70% Biomass	(and %)	Authority
Tadoba, India	7	3	76.0%	This study
Kanha, India	9	3	85.5%	This study
Sariska, India	6	3	94.0%	This study
Nagarhole, India	7	2	81.0%	Karanth (1988)
KBR, Nepal	6	2	88.0%	Dinerstein (1980)
Gal Oya, Ceylon	6	2	82.0%	McKay and Eisenberg (1974)
Wilpattu, Ceylon	9	3	85.2%	McKay and Eisenberg (1974)
Udjung Kulon, Java	6	2	74.3%	Hoogerwerf (1970)
Umfolozi, S.Afr.	18	5	75.4%	Mentis (1970)
Nairobi, Kenya	16	4	77.2%	Foster & Coe(1968)
Tarangire West, Tanzania	14	5	83.6%	Lamprey (1964)
Tarangire East,	14	3	78.9%	Lamprey (1964)

Eisenberg (1980) distinquished between two types of density estimates: a) Crude density, where the number of animals is expressed for the entire area surveyed, and b) Ecological density, which is an estimate corrected for habitat differences. The latter takes into account that a given species will not occur uniformly throughout a non-homogenous habitat. Table 10.4 shows a comparison of ecological densities and biomass of the three ungulate species with data from other wildlife areas in India and South Asia. The number of sites compared is limited as few studies report the ecological densities and biomass. Ecological density of Sambar in the present study areas is higher than those reported from South Asian reserves. The high density of Sambar observed in all the three study areas probably reflects the fact that these sites have been under wildlife management for over four decades and the Park Managements have been able to keep in check the deleterious effects of livestock grazing, poaching, fires and weeds besides taking up other habitat management practices. The ecological density of Chital in Karnali-Bardia Wildlife Reserve (KBR) reported by Dinerstein (1980) is considerably higher than those reported by the present study. This could be because the study was carried out in a small intensive study area of 11.8 km^2 and includes data gathered from the observation tower located in prime Chital habitat. Ecological density of Nilgai fluctuates widely within the present study sites, being very high in Sariska and very low in Kanha. The density of Nilgai in Sariska is quite high compared to most of the other sites probably because nearly 40% of the habitat comprises miscellaneous-open thorn forest, having a very large proportion of palatable browse species. This habitat is thus able to support a very high density of density of Nilgai population. On the other hand, the Sal forest and its associates,

Table 10.4 Comparison of ecological density and ecological biomass of the three wild ungulate species with data from other wildlife areas in South Asia

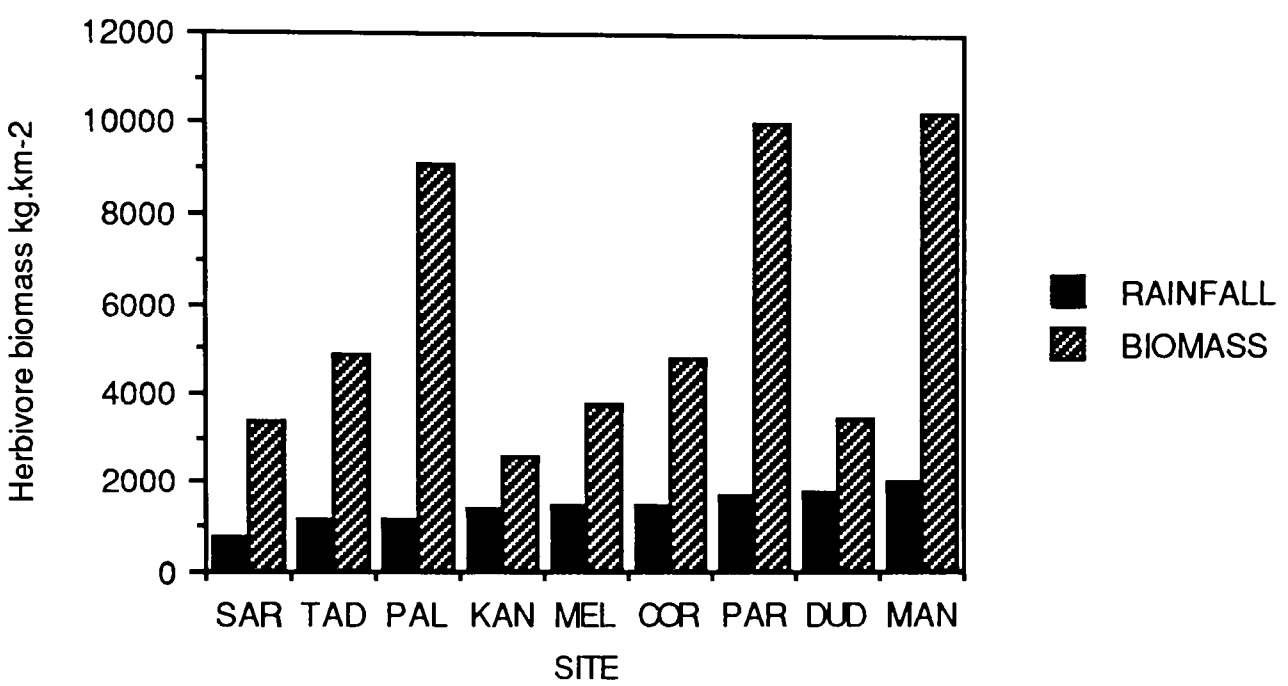
Species	Location	Unit weight (kg)	Ecological density (N/km^2)	Ecological biomass ($kg.km^{-2}$)	Authority
Sambar	Tadoba	136	7.02-8.42	955-1145	This study
	Kanha	136	3.52-4.26	479-579	This study
	Sariska	136	4.49-5.83	611-793	This study
	Chitwan,Nepal	113.6	3.9	443	Seidensticker (1976)
	Wilpattu,S.L	131.5	1.2	157	Eisenberg &Lockhart (1972)
Chital	Tadoba	47	20.0-25.40	940-1194	This study
	Kanha	47	21.1-31.1	992-1462	This study
	Sariska	47	8.86-11.14	416-524	This study
	Bandipur	45	36	1620	SaratchandraGadgil (1975)
	Chitwan,Nepal	54.8	17.3	948	Seidensticker (1976)
	KBR,Nepal	47.2	29.7-33.9	1440-1644	Dinerstein (1980)
	Wilpattu,S.L.	45.3	12	544	Eisenberg &Lockhart (1972)
Nilgai	Tadoba	182	5.65-7.19	1028-1309	This study
	Kanha	182	2.02-2.86	367-521	This study
	Sariska	182	9.75-12.45	1774-2270	This study
	KBR,Nepal	144.2	5	721	Dinerstein (1980)

which form moderate to dense canopy cover in Kanha make the habitat sub-optimal for Nilgai and so in 3 out of 5 habitat types in Kanha, the Nilgai is completely absent. The miscellaneous open forest and a few of the grasslands in Kanha support a very low density of Nilgai population. Thus we find that the habitat composition plays an important role in determining the biomass density of ungulates in these study areas.

The relationship between the plant and herbivore biomass and rainfall in Africa has evoked considerable interest among ecologists (Watson, 1972; Sinclair, 1974; Western, 1975; Coe *et al.*, 1976; Leuthold and Leuthold, 1976; Bell, 1982; East, 1984). Comparable studies in Asia have been generally lacking due to a variety of reasons. Eisenberg & Seidensticker (1976) said that the mammalian biomass increases along a rainfall gradient as one moves from a low rainfall area to a high rainfall area. I wanted to confirm whether there existed a positive correlation between the total herbivore biomass and rainfall in arid/eutrophic savannas (Coe *et al.*, 1976) in the Indian wildlife areas. Unlike the studies in Africa which have included areas having annual rainfall up to 1200 mm I have included areas which have rainfall up to 2500 mm. This was done for two reasons; first of all, in peninsular India where most of the wildlife areas in India occur, the range in annual rainfall is very wide. Secondly, preference was given to those sites for inclusion in the present study from where reliable biomass estimates could be obtained, although their annual rainfall could be above 1200 mm.

The relationship between total herbivore biomass and annual rainfall is shown in Fig. 10.3. As one moves from Sariska (SAR) National Park, annual rainfall 755 mm to Palamau (PAL) N.P., (annual rainfall 1200 mm), the total herbivore biomass increases from 3388 kg.km^{-2} to 9178 kg.km^{-2}. However, this does not hold for Kanha (KAN) and Melghat (MEL) National Parks. The biomass estimates for Kanha (annual rainfall 1375 mm) and Melghat (MEL) N.P. (annual rainfall 1500 mm) are considerably lower, although their annual rainfall levels are high. Parambikulam (PAR) Sanctuary has a herbivore biomass of 10028 kg.km^{-2} and annual rainfall 1723 mm while Manas (MAN) Sanctuary has the highest herbivore biomass of 10297 kg.km^{-2} with 2500 mm of rainfall. Although Dudwa (DUD) N.P. has a annual rainfall of 1800 mm, its herbivore biomass is only 3470 kg.km^{-2}. The low herbivore biomass levels in Kanha, Melghat and Dudwa National Parks needs to be examined in greater detail in order to analyse the decoupling of biomass/rainfall relationship. It has to be emphasized that the uniformity of rainfall influences the biomass of larger mammals which can be supported. Within limits, the absolute amount of rain is not important as how evenly the rain is distributed throughout the annual cycle. Most of the areas in India have just one rainfall peak. Kanha, Melghat and Dudwa National Parks have a number of features in common. These Parks have a large tract of land under continuous forest cover and thus a considerable proportion of the plant biomass is locked up in the trees and therefore unavailable to the grazing/browsing ungulates. Eisenberg & McKay (1974) explained on the basis of data from Africa that as the forest cover becomes continuous, the biomass of terrestrial herbivores declines although the biomass of arboreal species may increase. The same analogy can be perhaps be

Fig. 10.3 Relationship between large herbivore biomass (kg.km^{-2}) and rainfall in some wildlife reserve in India. Biomass and rainfall data from Anon. 1987



applied in explaining the low herbivore biomass levels in these areas. Besides, the absence of the megaherbivore species Elephant from these Parks is perhaps responsible to a large extent, for the low herbivore biomass being reported from these areas. Elephants and wild buffaloes were both present in Kanha at the beginning of this century (Brander, 1923) although, at present, neither species occurs within a one-hundred-fifty-mile radius. Similarly, the Rhinoceros which once spanned throughout the flood plains of the Indus, Ganges and Brahmputra rivers from the Hindu Kush in the west to the present Indo-Burmese border in the east now only remain in eastern India and Nepal. Rhinos were exterminated from Dudwa in the early part of the nineteenth century. It was only in 1984 that a group of 5 Rhinos were reintroduced in Dudwa as a strategy to improve their conservation status (Sale & Singh, 1987). The

diversity of terrestrial herbivore species in Asia is quite low as compared to Africa and a large number of grazing/browsing ungulate species do not occur in Indian reserves or have been exterminated (e.g. Elephants and wild buffalo in Kanha and Rhinoceros in Dudwa) in the comparatively recent past.

Coe (1980) suggested that the turnover time or the ratio of the annual production over the standing crop biomass (P/B) plays an important role in determining the potential food available for large herbivores. Although in a humid forest the above ground standing crop biomass of big woody plants is quite large (P/B = 0.04), the percentage of material turned over each year is very small. Whereas in a grassland the P/B ratio is 0.33, and the turnover of nutrients is quite high and thus a large number of herbivores can be supported. Thus we can see that although the rainfall of a semi-arid environment produces quite a low level of primary production, the nutrient available for plant growth are turned over relatively rapidly while that of dense woodland or forest has a great deal of the living material and nutrients locked up in wood, which are unavailable to large herbivores. This analogy explains why the ungulate biomasses supported by habitats in Sariska and Tadoba are quite high as compared to Kanha and Melghat National Parks.

The biomass/rainfall relationships for the three ungulate species Sambar, Chital and Nilgai shows a very interesting pattern (Fig. 10.4). Sambar biomass shows a very significant positive correlation ($r = 0.88$, $n = 8$, $p = 0.0039$) with the rainfall. Nilgai biomass decreases significantly ($r = 0.80$, $n = 9$, $p = 0.0057$) with the increase in rainfall level. However, the

correlation between biomass and rainfall is not apparent (r= 0.56, n = 11, p = 0.0722) for Chital. The positive correlation with rainfall shown by Sambar is probably because with increase in rainfall, the primary productivity also increases, leading to an overall increase in both the quantity and the quality of available food (East, 1984) and a concomitant increase in water availability. The degree of forest cover also increases with rainfall and as Sambar is a forest ungulate, its abundance increases in forest habitat, showing a positive correlation with rainfall. The negative correlation with rainfall found in Nilgai seems to strongly suggest that it is a water independent species. Nilgai reaches very high density levels in open miscellaneous woodlands/grasslands with plenty of grass and shrub cover and is absent in areas having high (>1500 mm) rainfall levels. Chital, being a highly adaptable species has a wide range of geographic distribution. Although Chital may not become locally extinct like the Nilgai at rainfall level mentioned above, its abundance is definitely reduced drastically in high rainfall areas, when the canopy becomes too dense and the forest-grassland 'edges' disappear.

East (1984) found interesting patterns in the biomass rainfall relationships for the three potential ecological equivalents Waterbuck (*Kobus ellipsiprymnus*), Impala (*Aepyceros melampus*) and Eland (*Taurotragus oyyx*) of the Asian ungulate species Sambar, Chital and Nilgai respectively. Waterbuck like Sambar showed a significant positive relationship with rainfall in the moist savanna areas. Impala and Eland showed different response to increasing rainfall in the arid savanna areas having high, medium and low nutrient status. The biomass of Eland increased with rainfall on low nutrient status soil, reached a peak at 700

mm and then declined as the rainfall increased. Impala showed a positive relationship with rainfall and reached its peak biomass level on medium nutrient status soils of rift valley habitats at 700 mm rainfall. However, the relationship between Impala biomass and rainfall could not be worked out in higher rainfall areas due to insufficient data. It is obvious that the ungulate biomasses have some degree of correlation with rainfall although several factors such as water and soil nutrient status may modify the nature of these relationships.

East (*op. cit.*) has commented that the biomass/rainfall relationships for individual herbivore species lack precision because of the fluctuations in population estimates and the habitat preferences shown by the species. Nevertheless, at the community level they provide an important basis for the understanding of the complex functioning of the ecosystem and reveal the effects of the interaction between plant and animal biomass, rainfall, geomorphology and soil nutrient availability.

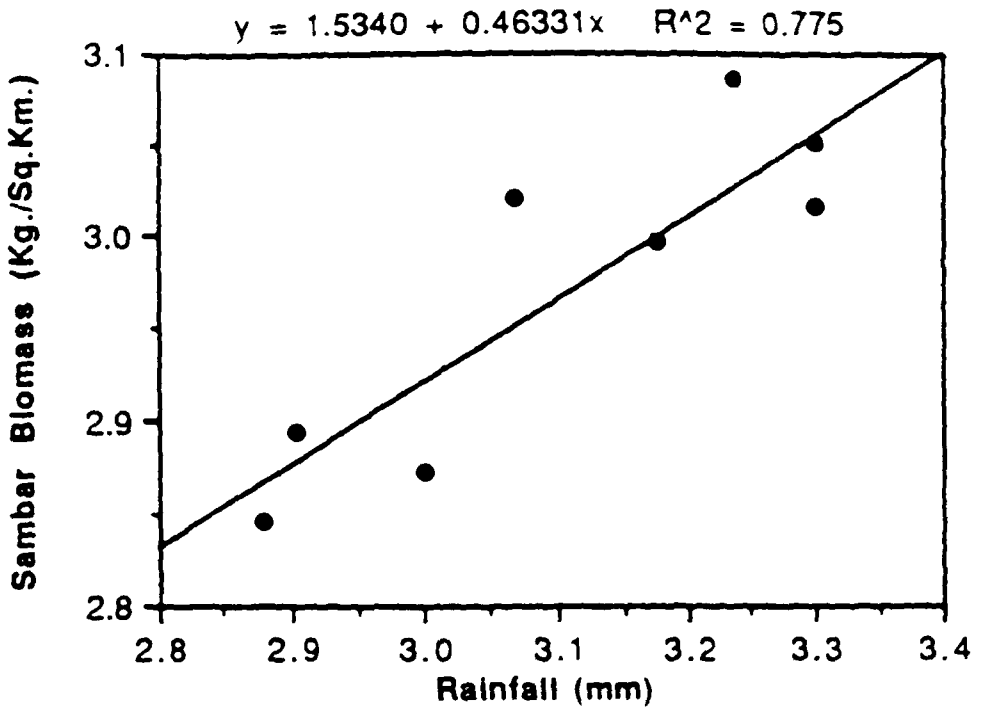
10.4 CONCLUSION

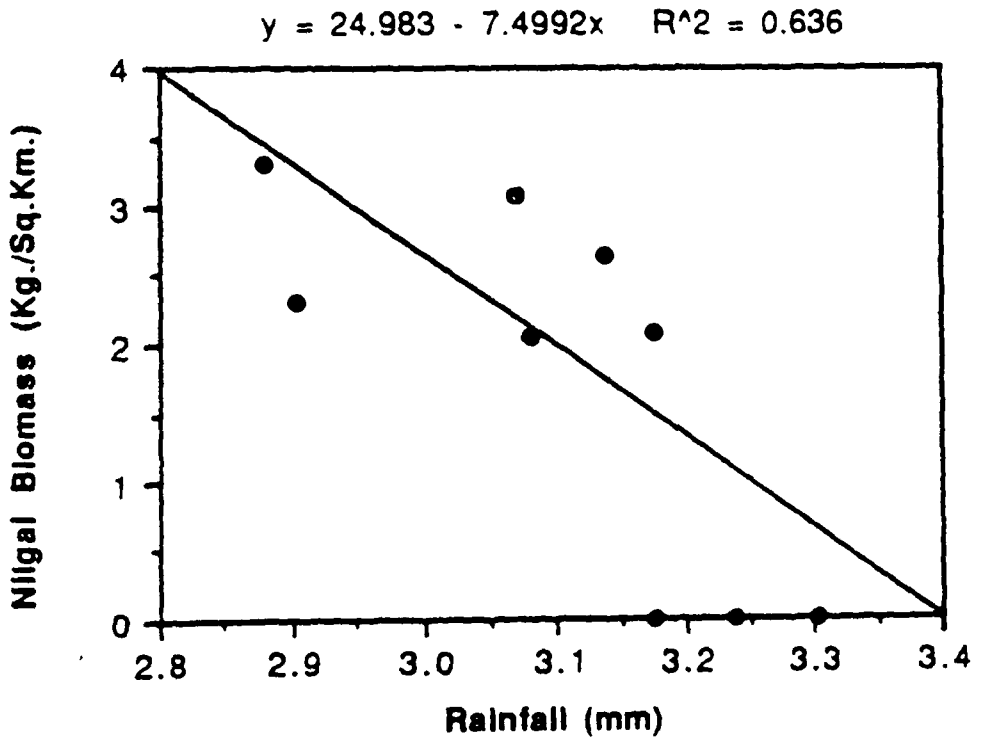
Several interesting generalizations about the ungulate species being investigated in this study may be made on the basis of information now available. However, as Eisenberg (1980) has pointed out, although our data base is approaching the point where we can move beyond simple discussions on animal numbers, biomass and habitat requirements, our progress towards developing a holistic approach is still in its infancy. This is mainly because of the complex interrelationships between the concepts of habitat quality and carrying capacity on one hand and social

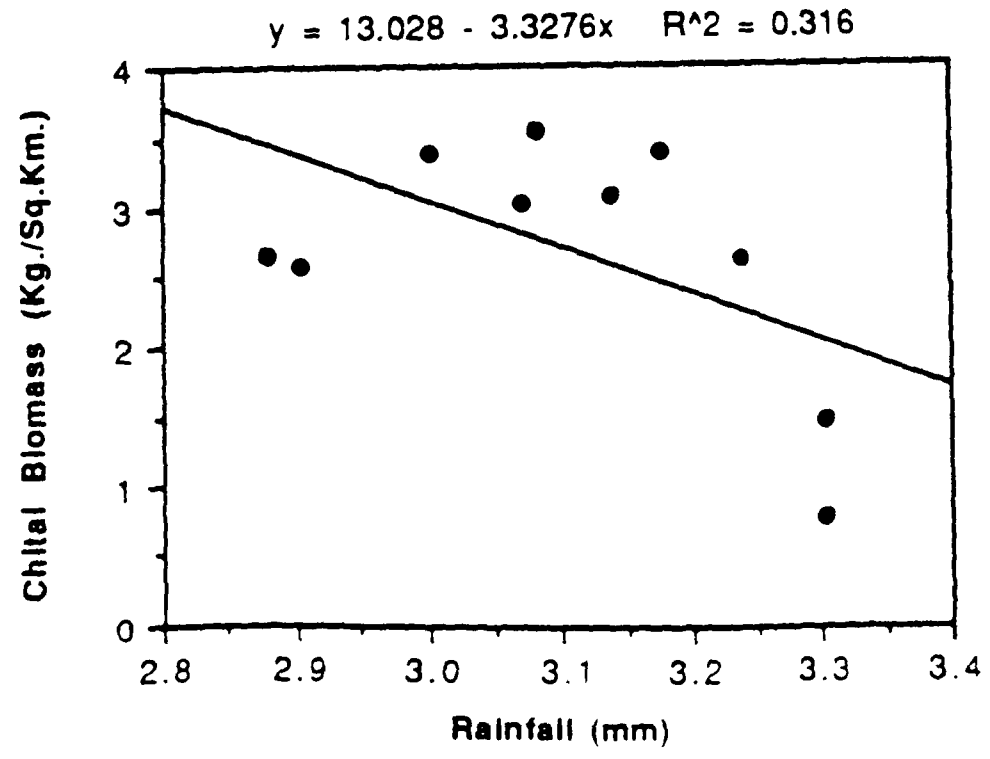
organization and trophic strategies of the species on the other. Nevertheless, we can see some interesting parallels as well as deviations in the levels of biomass achieved by ungulate species in savannas in Africa and in habitats in India and other Asian wildlife reserves. The total ungulate biomasses in Asian reserves are generally lower than those in Africa with the notable exception of Nagarhole National Park in India (Karanth, 1988) where biomass density of 18375 $kg.km^{-2}$ has been reported from the moist deciduous forest habitat of the Park. Karanth (*op. cit.*) has argued that the generalization that the tropical moist forest are inferior to tropical savannas in terms of supporting large herbivore biomass is simplistic and perhaps true only of climax tropical evergreen forests. However, as more than 56% of this biomass is contributed by Elephant, whose density has been calculated to be $5.0/km^2$, it is likely that such a high density reflects the transient concentration of elephants in this habitat due to widespread habitat degradation in the adjacent forests and the very high biomass levels cannot be supported on a sustained basis. The absence of the diverse assemblage of grazing herbivores which restricts the exploitation of the available niche as well as the shrinkage in the distribution of megaherbivore species like elephant, wild buffalo and rhinoceros are probably the two important reasons for the low herbivore biomass levels in Asia as compared to Africa. In other words, the 'faunal poverty' in the Asian reserves as opposed to the 'complete spectrum' of species in Africa, each of which efficiently exploits a portion of the total habitat without overexploiting it, is responsible for the lower ungulate biomass levels in Asia. There is a general trend in the increase in total herbivore biomass with rainfall with some exceptions which can of course be accounted for but more data is needed to reach definite conclusions

on this trend. The positive correlation of Sambar biomass with rainfall and the reverse exhibited by Nilgai may be explained on the basis of habitat requirements and the feeding strategies adopted by these species. The increase in woody vegetation cover and the availability of water are both influenced by the annual precipitation levels and therefore areas with higher rainfall are able to support high numbers of Sambar. Conversely, the habitat becomes less optimal for Nilgai with increasing precipitation, as it leads to denser woody cover and lesser availability of grasses and shrubs. The apparent limits of Nilgai distribution appear to reach beyond 1500 mm annual rainfall.

Fig. 10.5 Biomass/rainfall relationships of three ungulate species (note logarithmic scales)







CHAPTER ELEVEN

GENERAL DISCUSSION

11.1 INTRODUCTION

The central objective of ecology is stated as understanding the distribution and abundance of organisms. The present study investigated the abundance of three wild ungulates in India in relation to habitat structure and composition, as well as factors which influence the habitat quality. The between-site and between-species comparisons have already been discussed in Chapter Nine. In this chapter, I discuss the significance of the results obtained in the study and their management implications. In addition, I also discuss the concept of ecological biogeography which attempts to account for distribution patterns in terms of the interactions between the organisms and their physical and biotic environment at present and in the recent past. There are many examples in the animal and plant kingdoms to show that organisms evolving independent of each other have sometimes responded to similar selective pressures with nearly identical consequences. It would be interesting to understand the relationship between the array of habitat conditions and the range of adaptation in the ungulate species occuring in two biogeographically different regions, Asia and Africa. It is important both from the standpoint of evolutionary biology of the species as well as from a conservation-management perspective to look for the presence of ecological equivalents of ungulate species in Asia and Africa.

Ecological equivalents are pairs of independently evolved, but ecologically similar, species which occupy similar niches in different communities (Pianka, 1974). From the present study, we have information on the distribution, abundance, physiognomy, social organization, feeding behaviour and habitat requirements of the three ungulate species. These characteristics are considered in comparing Sambar, Chital and Nilgai with other African ungulates in order to determine their potential ecological equivalents. This is discussed in detail in Section 11.3.

11.2 HABITAT REQUIREMENTS AND ECOLOGICAL SEPARATION OF THREE UNGULATE SPECIES

The essential habitat requirements of the three wild ungulate species Sambar, Chital and Nilgai were determined during this study. Sambar requires well wooded moderate slopes, perennial availability of water and presence of shrubs and grasses. Nilgai, on the other hand, prefers flat-open areas with low canopy cover and an abundant shrub layer. Chital prefers woodland-grassland habitats with moderate cover, perennial water and abundant grasses. The study indicates that a knowledge of the habitat preferences and other ecological requirements is an essential pre-requisite to the understanding of the distribution and abundance of species. Further, it has been shown that habitat composition is an all-important factor in large herbivore biology. The Sal (*Shorea robusta*) forests in Kanha, Teak (*Tectona grandis*) in Tadoba and the miscellaneous dry thorn forest species in Sariska provide varying habitat conditions to the ungulate species to which Sambar, Chital and Nilgai respond differently. Their abundances vary both within sites and between

sites. The study has shown that the abundances of these species may be taken as an indicator of the quality and composition of the habitat they occupy. Chital abundance levels tend to reach very high (100 km^{-2}) in preferred sites whereas Sambar abundance in highly favourable sites varies between 5-10 km^{-2}. Nilgai reaches high abundance levels (15-23 km^{-2}) in semi-arid open environments. In all the study sites, these species contribute a very high proportion to the wild ungulate biomass. This is presumably because these species are by nature generalist and are able to exploit the low resource abundance and low environmental predictability conditions.

The three ungulate species Sambar, Chital and Nilgai co-exist in the three study sites and also in other sites in their geographic ranges. The results of the analyses of habitat selection done in order to understand the mechanisms which permit these species to co-exist show that they are ecologically separated and that resource partitioning is achieved primarily by habitat partitioning. Sambar, a forest ungulate, largely occurs in the forest-woodland habitats; Chital, a species of the 'habitat edge', occurs in the woodland-grassland habitats while Nilgai prefers the miscellaneous-open and grassland habitats. Although there is a dietary overlap between Sambar and Nilgai, as both are predominantly browsers, the habitat segregation ensures that these species can have substantial overlap in their diets. The ecological separation of these species ensures the optimal utiliation of forage resources by limiting any mutual competition. Similar conclusions were arrived at by Bodmer (1991) in his study on the resource partitioning in Amazonian ungulates.

11.3 ECOLOGICAL BIOGEOGRAPHY OF THREE UNGULATE SPECIES

The concept of a pair or group of species that are ecological equivalents pervades the literature of both ecology and biogeography (Odum, 1971; Emlen, 1973; Pianka, 1974; Krebs, 1985; Cox and Moore, 1985). Odum (1971) stated that organisms that occupy the same or similar ecological niches in different geographical regions are known as ecological equivalents. It is important to understand that the existence of a wide diversity of habitats has been an important driving force behind the evolution of the rich variety of animals and plants that we observe today. Grinnell (1924) said 'evolution of habitats came first-comes first; it is going on continually and in a fashion significantly correlated with the gradual modification of the animals themselves'. The course of organic evolution has been moulded and is being moulded by environmental circumstance. In support of his ideas Grinnell (*op cit.*) said that a great number of similar ecologic types of animals which have developed in widely separated regions are derived from unrelated stocks. The Kangaroo Rat of North American deserts corresponds ecologically to the Jerboa of the Sahara; but is derived from squirrel ancestry, while the Jerboa is more closely related to house mice. Recher (1969) recognised ecological counterparts in the avifaunas of Australia and North America, many of which were both morphologically and behaviourally similar.

Ecological equivalents arise from convergent evolution, and it is interesting to see how similar such species can be in their morhphology and behaviour. The African longclaw, *Macronyx croceus*, a pipit, is

ecologically very similar to the American meadowlark, *Sturnella*, an icterid. Both are similar to starling in size and shape, inhabit grasslands and forage by prodding the ground with their bills. Inspite of the fact that they have different phylogenetic histories and differences in internal anatomy, these birds are clearly ecological equivalents (Cody, 1975). In other words, these birds do not just look similar but they also play a similar ecological role, both the birds being largely ground-dwelling insectivores in open habitats.

Coe (*pers. comm.* 1991) has suggested that the term 'ecological analogues' is more appropriate than 'ecological equivalents'. However, in order to prevent the addition of another term to the already vast number of synonyms in ecological terminology I am sticking to the term 'ecological equivalents'. The potential ecological equivalents of Sambar, Chital and Nilgai are discussed in sub-sections 11.3.1 to 11.3.3 respectively.

11.3.1 SAMBAR

Waterbuck (*Kobus ellipsiprymnus*) and Greater Kudu (*Tragelelaphus strepsiceros*) are the two African species which appear to be potential ecological equivalents of the Asian deer species, Sambar. The summary of characteristics used for comparison of the ecological equivalents is given in Table 11.1.

Table 11.1 Summary of the characteristics used for comparison of Sambar with its potential African ecological equivalents Waterbuck and Greater Kudu

Characteristic	Sambar	Waterbuck	Greater Kudu
a) Distribution	Wide range of habitat types[a]	Woodland-Grassland ecotone along water courses[b]	Wide range of habitat types[c]
b)Body weight	136 kg[d]	M 200-300 kg[e] F 160-200 kg[e]	M 190-315 kg[e] F 120-215 kg[e]
c)Sexual dimorphism	Low, antlers in males only[a]	Pronounced, horns in males only[f]	Pronounced, horns well developed in males[c]
d) Territorial behviour	Transient, only during rut[g]	Pronounced[b]	Not pronoued[c]
e) Adult Sex ratio M:F	0.60:1[a]	1:1.6[b]	1:2.4[h]
f) Typical group size	1-3[a]	5-25[i]	2-35[i]
g) Home range	1-4[d] km^2	0.8-2.2[f] km^2	4-12[j] km^2
h) Typical density range	3-7[a] km^{-2}	0.2-9.1[k] km^{-2}	1.9-3.2[l] km^{-2}
i) Feeding type	Mixed feeder, predominantly browser[a]	Predominantly grazer[m]	Predominantly browser[m]
j) Habitat requirements	Moderate-dense woody canopy, medium slopes, water and browse availability[a]	Lightly wooded canopy near permanent water and good green grass cover[n]	Densely wooded canopy and nutritious browse[c]

Sources: a=This study, b=Spinage (1970), c=Novellie (1983), d=Schaller (1967), e=Kingdon (1982a), f=Melton (1978), g=Prater (1971), h=Wilson (1965), i=Jarman (1974),j=Owen-Smith(1977), k=Spinage (1969), l=Owen-Smith (1975), m=Hofmann(1973), n=Lamprey (1964)

The Waterbuck is a large African antelope, the genus *Kobus*, being widely distributed from about 15^0 N to 30^0 S (Spinage, 1970). Adult males stand 126 cm high at the withers and weigh 240 (200-300) kg, whilst females stand about 120 cm high and weigh 180 (160-200) kg (Table 11.1). The horns, present only in the male, are imposing bovid structures, reaching almost 90 (55-99) cm in length, with annulations on the anterior face and terminating in sharp points. Territories are maintained throughout the year by males and scrupulously defended against occupation by other adult males. Females adopt home ranges covering several male territories, restricting ranging with increasing age. The Waterbuck breeds throughout the year, and although there are peaks of births there is no season of rut (Pienaar, 1963). Waterbuck are water dependent antelope which invariably inhabit lightly wooded country near permanent water (Table 11.1). The tendency for Waterbuck populations to have a littoral distribution into linear habitats along margins of rivers, valleys and lakes makes meaningful estimates of density rather difficult (Kingdon, 1982a). Spinage (1969) arrived at a mean density of 2.1 km^{-2} for the optimum habitats of the Ruwenzori Park while for less favourable habitats in the Nairobi National Park, Foster and Kearney (1967) reported a density of 0.73 km^{-2}. Melton (1978) reported a density of 0.6 km^{-2} in Umfolozi Game Reserve. Spinage (1970) found a male to female sex ratio of 1:1.6. The mean percentage contribution by Waterbuck to the total biomass for grazing species from 14 study areas in Eastern and Southern Africa was 11% (Melton, 1978). Studies on the habitat utilization by Waterbuck have shown that their main requirement is the proximity to water (Lamprey, 1963; Hanks *et al.*1969; Taylor *et al.*1969; Spinage, 1969). Hirst (1975) and Melton (1978) suggested that the attraction to water may also be due

to the availability of good quality long grasses such as *Panicum maximum,* being restricted to areas near water.

Hofmann (1973), on the basis of morphological features of the stomach, classified Waterbuck as a grazing species requiring fresh grass growth and dependent on water. The Waterbuck has a typical grass-eater's ruminoreticulum with a very rich papillation which provides a much greater enlargement of the absorptive surface. Lamprey (1963) recorded 95% grazing by Waterbuck and Field (1972) found a maximum of 4% dicotyledons in the diet during the summer months. Compared to this, Shea *et al.* (1990) reported that browse occured in significantly higher amounts (76.1%) in the winter diet of Sambar whereas grasses, sedges and forbs were at their lowest levels, 11.8% and 4.8% respectively. Melton (1978) found 1.1% and 3.2% dicotyledons in faecal analysis in summer and winter months respectively and concluded that browse is taken only under conditions of extreme poor grazing. Further, Melton (*op cit.*) concludes that Waterbuck appear to have strict habitat requirements which include the availability of grass of certain minimum height and minimum quality, such as only found in the riverine communities. Thus we find that although Waterbuck may be physiognomically like the Sambar, ecologically their requirements are further apart (Table 11.1). Waterbuck is found in the vicinity of permanent water sources only, while for Sambar, although water is very important, it is able to utilise a wide variety of habitats and occurs at an elevation of up to 3500 m.s.l. There are important differences in the the feeding behaviour of the two species. Waterbuck is predominantly a grazer whereas the proportion of grasses in Sambar diet is around 20% only (this study, Table 3.1). Browse from trees

and shrub contributes 83% in summer and 77% in winter months in the diet of Sambar. Unlike Waterbuck, the habitat requirements of Sambar are moderate degee of slope, dense woody vegetation cover and availability of browse (Table 11.1). Territorial behaviour as shown by both Waterbuck males and females is not found in Sambar although some dominance heirarchy operates among the males during the rutting period.

Greater Kudu, on the other hand shows a number of ecological similarities with Sambar (Table 11.1). The Greater Kudu is widely distributed through the wooded savannas of Africa from the Cape in the South to Somalia in the North. Among the southern African antelope species it is one of the most successful species and is able to exploit a wide range of ecological situations. The sexual dimorphism, characteristic of the genus *Tragelaphus* is very pronounced in the Greater Kudu. The body weight ranges from 190-315 kg in males and 120-215 kg in females (Table 11.1). The male to female sex ratio is 1: 2.4 (Wilson, 1965). Greater Kudu are almost entirely browsers and a wide variety of plants is eaten, which probably accounts for the wide distribution of the species in many habitat types (Wilson, 1965). Palatable trees and shrubs form the dietary staple of Kudu through most of the wet season and the early part of the dry season. The ratio of woody plants to other food types in the diet of Greater Kudu is highest in the early growing season as the woody plants tend to start leaf production earlier than plants in the herb layer and thus offer higher quality browse (Conybeare, 1975; Owen-Smith, 1979). Grass is normally eaten only at the beginning of the rainy season when the grass is immature and the protein content is >15% (Novellie,1983). This would

be expected since the digestive system of Greater Kudu is not anatomically adapted to a diet of mature grass (Hofmann and Stewart, 1972). Owen-Smith and Cooper (1989) commented that the browsing deer of various species consume somewhat higher proportions of grass in North America and Northern Europe than do equivalent-sized African browsing antelopes (Baker and Hobbs, 1982; Stains *et al.*,1982; lasan *et al.*,1986). Like the North American browsing ungulate species, the Asian Sambar also seasonally consumes around 20% grasses in its diet (this study, Table 3.1). The low intake of grasses by the African browsing species may be related to the high fibre content of many African savanna grasses (Casewell *et al.*, 1973).

The absence of territoriality in Greater Kudu and the marked similarity in the habitat requirements, social organization and feeding behaviour (Table 11.1) seem to suggest that the Greater Kudu may be considered as a better ecological equivalent of Sambar than Waterbuck. Studies on the gut structure of Sambar are needed in order to make morpho-physiological comparisons and to arrive at a more accurate conclusion.

11.3.2 CHITAL

Impala (*Aepyceros melampus*), a medium-sized, sexually dimorphic, gregarious antelope appears to be the closest ecological equivalent of the Asian deer species, Chital. The summary of the characteristics used for comparison of the ecological equivalents is given in Table 11.2. The Impala are found throughout most of the deciduous woodland and savanna of eastern, central and southern Africa (Jarman and Jarman, 1974). Adult males weigh 60 (53-76) kg, females 45 (40-53) kg and only the males carry horns (Table 11.2). The ecological flexibility paralleled by social flexibility exhibited by Impala (*op cit.*) is also found to a great extent in Chital. Like Chital, Impala also avoid forest, dense woodland and thickets and are found in large numbers in light deciduous woodland and grassland (this study, Fig. 10.1). Basically, both species are animals of the habitat 'edge' or 'ecotone'. The social organization of the two species is also comparable (Table 11.2). Although territorial behaviour is exhibited by the Impala male, its expression varies with the habitat conditions. In the regions of eastern Africa, which have two dry seasons of 2-2.5 months and 5 months respectively, the expression of this behaviour extends beyond the rutting period, whereas, in the central and southern Africa, where rainfall is confined to one period each year and the dry season is correspondingly longer and severe, the full expression of territorial behaviour is confined to the rut (Jarman and Jarman, 1974). The composition of the bachelor herds and female groups is similar to Chital. The herds are temporary, loose aggregation of individuals, without fixed membership. The basic social unit in Chital is a matriarchal family

Table 11.2 Summary of the characteristics used for comparison of Chital with its potential African ecological equivalent Impala

Characteristic	Chital	Impala
a) Distribution	Wide range of habitat types, woodland-grassland ecotone[a]	Deciduous woodland-bushland ecotone[b]
b) Body weight	47kg[c]	M 40-53 kg[b] F 53-76 kg[b]
c) Sexual dimorphism	Low, antlers in males only[a]	Pronounced, horns in males only[d]
d) Territorial behaviour	Absent[a]	Transient, pronounced during rut[d]
e) Adult sex ratio M:F	0.69:1[a]	0.60:1[b]
f) Typical group size	5-10[e]	9.8-23.4[f]
g) Home range	1-3[c] km^2	Adult M 50-80[g] km^{-2}
h) Typical density range	10-30[a] km^{-2}	8-40[h] km^{-2}
i) Feeding type	Mixed feeder, predominantly grazer[a]	Mixed feeder, predominantly grazer[i]
j) Habitat requirements	Moderate-open woody canopy, water and good grass cover[a]	Woodland-grassland mosaic and availability of water[j]

Sources: a=This study, b=Kingdon (1982b), c=Schaller (1967), d=Jarman and Jarman (1974), e=Mishra (1982), f=Murray (1980), g=Vincent (1979), h=Owen-Smith (1977), i=Hofmann (1973), j=Schenkel (1966)

group consisting of an adult female, her offspring from the previous year and a fawn. Subadult males and females and also adult females join the matriarchal group to form large aggregations, which may again split and re-unite. In Impala, the basic social bond is between the mother and her young. Bachelor herds and small female groups join to form larger groups. According to Jarman and Jarman (1974), this general tendency to aggregate is the most pervasive of all aspects of Impala behaviour. Like Chital, the onset and duration of the rutting period is variable. Differences in the timing of reproduction have been reported for Impala (Dassman and Mossman, 1962b) and the peak fawning varies from September through January, depending on the locality. The variability in the rutting period observed in these species in different locations may be related to microclimatic factors, plant phenology as well as the availability of open spaces to facilitate visual contact. The gestation period in Impala is *ca.* 6.5 months compared to *ca.* 8.5 months in Chital, but the young in both species are born in secluded spots, after which the calves 'lie out' in dense vegetation.

The roaring behaviour in Impala (Schenkel, 1966; Leuthold, 1970) is quite similar to the bellowing (Schaller, 1967) in Chital; their function being an auditory complement to the visual and olfactory signals left by the buck in his environment during agonistic displays. Kingdon (1982b) suggests that the evolution of this accoustic signal is a solution to a problem posed by high densities and breakdown of the territorial system observed in these species. These accoustic signals are also known to attract the does in oestrus. However, as visibility is greatly variable in ecotones between

woodland and grassland it is possible that these accoustic signals are an important means of communication.

Impala feed selectively on diet of grasses, herbs and shrubs in different parts of their habitat. Talbot and Talbot (1962) reported that Impala ate 56% grass and 44% dicotyledon material while Lamprey (1963) recorded 92.5% grasses in the diet of Impala. Ables and Ables (1969) described Impala as 'grazers by choice' and said that they browse woody vegetation during drought periods when little grass or forb is available. Chital are also predominantly grazers and green short grasses forms the favoured forage. Schaller (1967) found that in the rumen samples collected from Chital killed by predators the grass comprised 96% by volume, followed by browse and fruits in equal amounts. Ables (1975) reported that Chital consumed 81% grass and grass-like forage. Although Chital are grazers, browse is seasonally consumed, especially in the dry season. Browse includes the leaves from a number of trees, shrubs and forbs as well as several kinds of pods and fruits.

During the present study in Sariska National Park, it was observed that the Chital reduced the dependance on grasses in their diets from 57% in the post-monsoon period to 34% in the dry season (Table 3.1), when the grasses became very coarse, dry and of low nutritive value. During the dry season, Chital increased the browse proportion to 48% from 35% in the post-monsoon period. Fruits and seeds from shrubs/trees (*Acacia* spp., *Balanites aegyptiaca*) in summer and of *Ziziphus* spp. in winter form a highly seasonal part of Chital diet. Jarman and Jarman (1974) observed a similar strategy in the Serengeti by Impala to counteract the

declining food quality in the dry season. When wet season supply of abundant, highly nutritious grasses decreased in both quality and quantity, Impala switched their diet to include more browse, in order to maintain diet quality. This strategy proved effective, as the animals were observed to maintain good condition for a prolonged period after the food supplies had declined. Hofmann (1973) commented that the remarkable adaptability of mixed feeders like Impala, to a great variety of dicotyledon and monocotyledon plants according to their availability, is reflected in apparently reversible adjustments in the structural components of the stomach. He found that changes occur mainly in the rumen papillation and on the omasal laminae and also in the mucosa of the reticulum and abomasum, when a switch over in diets occur.

Both Impala and Chital are water dependent species and their distribution in the dry season is greatly influenced by the availability of water. Ayeni (1975) demonstrated that Impala move near the permanent water source during the dry season. Results from the present study in Tadoba and Sariska National Park indicate that the distribution of Chital in the dry season is strongly influenced by the availability of water sources, around which Chital aggregate in large numbers. From the above comparison it is clear that Chital and Impala may be considered as fairly good ecological equivalents.

11.3.3 NILGAI

The Eland (*Taurotragus oryx*), a tragelaphine antelope appears to be the closest ecological equivalent of the Boselaphine antelope Nilgai. The summary of the characteristics used for comparison of the ecological equivalents is given in Table 11.3. Wells (1957) suggested that the tribe *Tragelaphini* originated in Eurasia from a common stock with the *Boselaphini.* However, no tragelaphine fossils have been found in Eurasia (Gentry, 1968; 1970) indicating that the tragelaphines are probably of African and not of Eurasian origin. Nevertheless, there are distinct morphological, behavioural and ecological similarities between the Nilgai and the Eland (Table 11.3).

The Eland occurs over a large part of the African continent in a wide variety of habitats. Sexual dimorphism, unlike other Bovids is very distinct in Eland as pronounced morphological and behavioural differences occur between the males and females. Adult males measure 1.8 m at the shoulder and weigh 690 (400-942) kg (Table 11.3). Females measure 1.4 m at the shoulder and weigh 450 (390-595) kg (Kingdon, 1982a). Males have a dark grey body, thick and muscular neck and short thick horns. Females are chestnut brown with thin neck and long thin horns. Similar morphological differences occur in the Nilgai also although the females do not have horns. As in Nilgai, the territorial behaviour in Eland is not distinct but dominance heirachies are maintained in both the species (Table 11.3).

Table 11.3 Summary of the characteristics used for comparison of Nilgai with its potential African ecological equivalent Eland

Characteristic	Nilgai	Eland
a) Distribution	Widespread in semi-arid open environments[a]	Wide range of habitat types[b]
b) Body weight	160-200 kg[c]	M 690 (400-942) kg[b] F 450 (390-595) kg[b]
c) Sexual dimorphism	Pronounced, males heavier[a]	Pronounced, males heavier[b]
d) Territorial behaviour	Transient, pronounced during rut[d]	Dominance heirarchies in males and females[b]
e) Adult sex ratio	0.54:1[a]	0.53:1[e]
f) Typical group size	2-18[d]	25-70[f]
g) Home range	1-5[d] km^2	25-100[f] km^2
h) Typical density range	2-12[a] km^2	0.02-6.6[e] km^{-2}
i) Feeding type	Intermediate/mixed feeder[g], predominantly browser[e]	Intermediate feeder[g], predominantly browser[a]
j) Habitat requirements	Open woodlands-grasslands, browse availability[a]	Open woodland, shrub-savanna, browse availability[h]

Sources: a=This study, b=Kingdon (1982a), c=Prater (1971), d=Schaller (1967), e=Hillman (1979), f=Jarman(1974), g=Hofmann(1973), h=Pienaar (1974)

The social organisation in Eland is comparable to the Nilgai (Table 11.3). The composition of the groups is flexible and constantly changing in both species. The only social unit is formed between a female and her calf and possibly between young calf while in nursery groups. Adult bulls remain solitary for the greater part of the year but may form breeding herds during the rut. Jarman (1974) concluded that group formation was mainly the result of predation pressure in open areas, and that the maximum size of groups was controlled by food dispersion and availability. The adult Eland and Nilgai are both relatively immune to all predation whereas the female and calf find security in large groups.

The feeding behaviour of Eland and Nilgai are quite similar. Like Nilgai, the Eland are predominantly browsers on leaves and fruits of shrubs and trees but may consume grasses during the wet season. Hillman (1979) found that the tree+shrub, herb and grass layers contributed 85%, 4% and 11% in the diet of Eland in the dry season and 30%, 8% and 62% in the wet season respectively. The present study on Nilgai indicate that the contribution of tree+shrub and grass layers in the diet of Nilgai is 84% and 16% in the dry season and 74% and 26% in the wet season (Table 3.1). Hofmann (1973) classified Eland as the seasonally and regionally adapted intermediate feeders preferring forbs, shrubs and tree foliage and Hofmann (1985) has placed Nilgai in the intermediate/mixed feeder category. Western (1975) found that Eland were water-independent species in the Amboseli National Park. Taylor and Lyman (1967) suggested that an increase in browsing in the dry season increases the pre-formed water intake. Results from the present study show that surface water availability is not a limiting factor in the distribution of Nilgai as is the

case with both Sambar and Chital (Table 9.3). Thus on the basis of the similar ecological requirements of Nilgai and Eland we can say that they probably represent good ecological equivalents.

11.3.4 CONCLUSION

The above review illustrates some of the striking similarities in ecology and behaviour of unrelated species occuring in different zoogeographical regions of the world. Sambar, an Asian cervid shows a lot of ecological similarities with the African bovid Greater Kudu. They occupy similar niches and utilize the habitat as browsers. Chital, another cervid exhibits similarities with African antelope, Impala. They show a number of similarities in morphology, behaviour and feeding and utilize the habitat as grazers. Nilgai, a Boselaphine antelope may probably have some distinct phylogenetic affinity with the Eland, a tragelaphine antelope. Nevertheless, they show remarkable similarity in morphology, behaviour and feeding styles. Both are opportunistic feeders of browse and grass. It would be interesting to look for the presence of ecological equivalents of all the ungulate species occuring in Asia and Africa in order to understand the relationship between the array of habitat conditions and the range of adaptation in the species occuring in these two different biogeographical regions. However, as Karr and James (1975) have pointed out that one-to-one convergence of all species, producing ecological equivalents in different geographical areas, cannot be demonstrated. Many species cannot be matched on a one-on-one basis because of phylogenetic correlates of morphological characters or variation in structural aspects of communities related to history. As an example (*op cit.*) say that variation

in the availability of certain kinds of food resources may produce mosaic patterns in the distribution of ecological and morphological equivalents. Clearly, competitive mechanisms must impose very different selection pressures that cause divergence.

What does the existence of ecological equivalents tell us? Arthur (1987) has provided an answer. First and most obviously, it tells us that geographical barriers are of considerable importance in evolution. Given no barriers and free dispersal, there would presumably be no ecological equivalents. Second, it tells us that (within limits) convergent evolution can fashion organisms to perform a similar task regardless of the phylogenetic starting point. Finally, it tells us that given some 'ecological opportunity' and sufficient evolutionary time, something will evolve to utilize it. To this we may add that there are not infinite number of solutions to utilize the diversity in habitats and that in similar ecological situations, species develop similar adaptations, irrespective of their phylogenetic history.

11.4 MANAGEMENT IMPLICATIONS

The management of living resources in protected areas requires an understanding of the ecological principles, including an appreciation of the ecological processes operating in a protected area, and the acceptance of the concept that protected area management is a specialized form of land use (Mackinnon and Mackinnon, 1986). The National Parks in India are generally small (average size *ca.* 250 km^2), isolated and either directly or indirectly under human historic influence.

Management prescriptions and techniques that are appropriate for large protected areas can often be disastrous for small ones. For the reasons mentioned above, the National Parks in India need to be intensively managed and the passive approach of 'benign neglect', advocated by Walker (1989) may prove to be detrimental to the conservation-management objectives in these areas. The management of small sized National Parks in India requires that we must know more about the species and their interactions if the management is to become effective (see Soule and Simberloff, 1986).

The results obtained in this study have several management implications. Once the habitat requirements of the species are determined, management of habitats for the species becomes critically important. Water and grassland management are important for the grazing herbivores, as has been discussed in Chapters Six and Seven. The management strategy to be adopted is intimately linked with the specific objectives of management of an area. The classic example of the management of meadows in Kanha National Park for the three grassland species, *viz.* Barasingha, Chital and Blackbuck discussed in Section 8.2 shows that the overall conservation status of a species must have an over-riding influence on the management strategy to be adopted. In order to save the highly endangered Barasingha populations it is imperative that the excessive grazing pressure on the meadows should be reduced, perhaps even by selectively culling Chital populations, which form more than 95% of the grassland herbivore biomass. The complex habitat management problem in Kanha National Park relating to vegetation

succession, fire management and herbivore dynamics amply demonstrates that the natural world is not static; hence we must be either reconciled to change or attempt to correct and guide change by management intervention. The removal of anthropogenic forces which had co-evolved with the ecosystem, have now accelerated the natural successional processes. These forces, in the form of scattered human settlements in the Park, had checked the invasion of woody species through their annual burning practices. In other words, they helped to create the diversity of habitats by maintaining grassland-mosaics in areas, where climax vegetation is Sal forest. Active management is now necessary and a 'hands off' preservationist policy is not possible, if the critically endangered species Barasingha is to be saved from extinction.

Monitoring, i.e. keeping track of things in time through measurements taken in a time-series, is an important requisite for management of living resources. Monitoring also helps to understand the ecological relationships between different components of an ecosystem. For example, how variation in rainfall affects primary production and what influence does it ultimately have on animal distribution and abundance. The present study has laid down the basic framework of an ecological monitoring programme in a wildlife reserve. The compartment approach adopted in the study has been useful in gathering baseline ecological information on habitats and species. As indicated earlier, these compartments can serve as 'ecological bench-marks' for monitoring. The forest compartments can also provide a basis for ecological inventory, point referencing, statistical sampling and for spatial analyses of habitat and animal distribution-abundance information. A wildlife compartment

history form (see Appendix VIII) has been devised by making appropriate modifications in the existing forest compartment form in order to incorporate data gathering on features important for managing the wildlife species. The compartments can be surveyed on the basis of the methodology described in this study and the information can be collated on these forms. One-fourth of the compartments can be selected and surveyed every 2.5 years so that a ten year cycle can be adopted for monitoring ecological changes occuring in the habitats. This cycle would also coincide with the present ten year duration prescribed for a management plan of an area. Trends in animal abundance, a crucial feature for the wildlife manager, can also be effectively monitored through these compartment enumerations on a regular basis to yield reliable estimates of population structure, compared to the present system of having 1-3 days annual census operation. All this information can be used to build up a database through which both the wildlife decision makers at the federal and state levels as well as the field manager can analyse the trends of ecosystem components in order to make rational land use plans.

The study has shown that the modern line transect sampling method is an efficient technique for estimating the population of ungulates in National Parks. The motorcycle-based transect method which has been successfully used in estimating Chital and Nilgai populations can probably be extended to estimate other woodland-grassland species such as Four-horned antelope, Chinkara and Blackbuck. For forest ungulates like Sambar and Gaur, foot transects would have to be used to obtain reliable results. Similarly, it has been demonstrated that the 'toe-point

transect' method may be used to obtain rapid ecological information on the ground and aerial cover. The method is robust, reliable and efficient in providing a broad ecological description of the habitat conditions in an area. More studies are needed to study the observer bias on the rapid methods. However, it has to emphasized that the ecological information so gathered is at a coarse level and will have to be fine-tuned by other precise vegetation analyses methods for specific decision making processes. Further, it must also be pointed out that large-scale monitoring is not a very potent way of answering specific biological questions. As ecological hypothesis testing needs data, the rapid ecological methods demonstrated in this study may be utilized for collection of large number of data sets relatively quickly.

Most of the wildlife areas in India have human settlements within their legal boundaries. These settlements often have deleterious effect on the animal distribution and abundance has been demonstrated in this study. Sambar and Chital generally avoid areas where human settlements occur whereas Nilgai appears to be more tolerant. The pattern of disturbance from these settlements is not uniform and depends upon a large number of factors such as their size, location, occupation, livestock numbers as well as the wildlife species occuring around these settlements. In addition, the study has shown that the physical and other biotic pressures on sites may also modify the impacts of a human settlement on the abundance of wild ungulates. Mathur (1991) showed that the ecological impacts of livestock grazing vary with the wild ungulate species and that these impacts can be minimized by adopting appropriate management strategies. Homewood and Rodgers (1987) challenged the conventional

wisdom of equating pastoralist regimes with overgrazing in East Africa and stressed the need to adopt objective methods, both ecological and socio-economic, in investigating individual cases of pastoralist induced overgrazing. It is, therefore, apparent that a blanket removal of all these settlements from the Park boundaries cannot be suggested. Instead, there is a need to conduct more socio-economic studies of the human settlements in order to quantify their dependance on the habitat and also to devise means for preventing or at least reducing this dependance by providing viable alternatives. Only those settlements whose relocation would result in release of prime habitat for wildlife should be taken up for rehabilitation. The future success of wildlife conservation in India is greatly dependent on the awareness and contribution from the people living in and around the protected areas.

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APPENDIX I Climatic water balance computation for Tadoda National Park (1969-1984). Calculation are after Thornthwaite & Mather (1957). Concept of Water Status (WS) has been given by Pandeya, S. C. (1977). Except T and I all the values are in mm.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
T ^{0}C	22.1	25.2	29.5	33.6	35.8	32.2	28.2	27.4	27.8	27.0	23.5	20.8	-
I	9.49	11.57	14.69	17.89	19.69	16.78	13.72	13.14	13.43	12.85	10.41	8.66	162.32
UPE	71.25	102.6	163.7	189.0	206.7	193.1	171.0	159.8	149.9	138.0	86.49	59.22	-
PE	71	103	164	189	207	193	171	160	150	138	86	59	1691
P	12	15	9	14	19	170	300	376	176	59	11	52	1213
P-PE	-59	-88	-155	-175	-188	-23	129	216	26	-79	-75	-7	-
St	109	81	48	27	14	13	300	300	228	175	136	132	-
ΔSt	-23	-28	-33	-21	-13	-1	287	0	-72	-53	-39	-4	-
AE	35	43	42	35	32	171	171	160	150	112	50	56	1057
D	36	60	122	154	175	22	0	0	0	26	36	3	634
S	0	0	0	0	0	0	129	216	0	0	0	0	345
WS	50	-7	-107	-148	-174	70	429	516	254	96	61	125	1165

T=Temperature in ^{0}C; I=Heat index; UPE=Unadjusted Potential Evapotranspiration; PE=Potential Evapotranspiration; P=Precipitation; St=Soil water storage; ΔSt=Change in soil water storage; AE=Actual Evapotranspiration; D=Water Deficit; S=Water Surplus; WS=Water Status (P-PE + St).

APPENDIX II Climatic water balance computation for Sariska National Park (1969-1984). Calculation are after Thornthwaite & Mather (1957). Concept of Water Status (WS) has been given by Pandeya, S. C. (1977). Except T and I all the values are in mm.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
T ^{0}C	14.9	17.1	23.6	30.5	33.7	34.3	30.7	29.3	29.0	26.6	20.9	16.3	-
I	5.22	6.44	10.48	15.45	17.97	18.46	15.61	14.54	14.32	12.56	8.72	5.98	145.75
UPE	19.32	26.40	95.79	176.5	208.8	207.0	194.7	176.2	159.1	133.6	59.40	24.3	-
PE	19	26	96	176	209	207	195	176	159	134	59	24	1480
P	12	13	6	11	29	70	238	224	152	7	4	4	770
P-PE	-7	-13	-90	-165	-180	-137	43	48	-7	-127	-55	-20	-
St	53	51	35	18	9	5	150	150	124	74	59	54	-
ΔSt	-1	-3	-15	-17	-10	-3	205	-4	-84	-49	-15	-4	-
AE	13	15	22	28	38	74	195	176	278	57	20	8	924
D	6	11	74	148	171	133	0	0	119	77	39	16	794
S	0	0	0	0	0	0	43	48	0	0	0	0	91
WS	46	38	-55	-147	-171	-132	193	198	117	-53	4	34	72

T=Temperature in ^{0}C; I=Heat index; UPE=Unadjusted Potential Evapotranspiration; PE=Potential Evapotranspiration; P=Precipitation; St=Soil water storage; ΔSt=Change in soil water storage; AE=Actual Evapotranspiration; D=Water Deficit; S=Water Surplus; WS=Water Status (P-PE + St).

APPENDIX III Climatic water balance computation for Kanha National Park (1969-1984). Calculation are after Thornthwaite & Mather (1957). Concept of Water Status (WS) has been given by Pandeya, S. C. (1977). Except T and I all the values are in mm.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
T ^{0}C	17.1	19.6	24.0	29.2	32.5	31.1	26.9	26.2	26.4	24.5	20.4	16.8	-
I	6.44	7.91	10.75	14.47	17.01	15.92	12.56	12.28	12.42	11.09	8.41	6.26	135.5
UPE	37.9	54.0	103.9	151.3	165.3	151.1	129.7	129.3	135.0	114.4	69.3	38.2	-
PE	38	54	104	151	165	151	130	129	135	114	69	38	1278
P	32	36	18	7	11	200	358	437	187	54	23	12	1375
P-PE	-6	-18	-86	-144	-154	49	228	308	52	-60	-46	-26	-
St	189	176	133	82	49	98	300	300	300	245	210	192	-
ΔSt	-3	-10	-43	-51	-33	49	202	0	0	-55	-35	-18	-
AE	35	46	61	58	44	151	130	129	135	109	58	30	986
D	3	8	43	93	121	0	0	0	0	5	11	8	292
S	0	0	0	0	0	0	26	308	52	0	0	0	386
WS	183	158	47	-62	-105	147	528	608	352	185	164	166	2371

T=Temperature in ^{0}C; I=Heat index; UPE=Unadjusted Potential Evapotranspiration; PE=Potential Evapotranspiration; P=Precipitation; St=Soil water storage; ΔSt=Change in soil water storage; AE=Actual Evapotranspiration; D=Water Deficit; S=Water Surplus; WS=Water Status (P-PE + St).

Appendix IV Mean density (Y), number of sightings (NS), standard error (SeY) of mean density and 95% confidence limits of the three ungulate species in different habitat types and the overall study area (OSA) in Tadoba National ParK obtained from motorcycle based transects. The unit of density are no/km^2. Habitat types are described in the text.

	Habitat types					
Sambar						
Summer	Teak	Teak-Bamb	MMDF	Misc-Bamb	Grlan	OSA
Y	9.92	13.96	2.70	7.02	7.34	8.19
SeY	1.19	1.65	0.19	0.70	1.16	0.56
NS	32	32	30	34	20	148
95%t	2.43	3.36	0.40	1.43	2.37	1.12
Winter						
Y	8.12	11.41	3.00	8.53	5.23	7.26
SeY	0.76	1.06	0.17	0.48	1.29	0.44
NS	35	34	32	32	13	146
95%t	1.56	2.17	0.36	0.98	2.63	0.87
Combined						
Y	9.02	12.69	2.85	7.78	6.29	7.72
SeY	0.71	0.98	0.13	0.43	0.87	0.35
NS	67	66	62	66	33	294
95%t	1.42	1.97	0.26	0.86	1.74	0.70
Chital						
Summer						
Y	32.6	22.8	15.9	24.3	29.8	25.14
SeY	6.29	4.16	3.62	5.12	7.30	2.46
NS	45	40	55	60	21	221
95%t	12.8	8.50	7.38	10.4	14.9	4.85
Winter						
Y	23.7	18.1	12.3	21.0	27.7	20.60
SeY	3.21	1.80	1.60	1.57	3.81	1.21
NS	45	41	49	53	26	214
95%	6.56	3.67	3.27	3.21	7.77	2.39
Combined						
Y	28.1	20.5	14.1	22.7	28.7	22.87
SeY	3.55	2.27	1.97	2.66	4.09	1.37
NS	90	81	104	113	47	435
95%	7.09	4.54	3.95	5.32	8.17	2.70
Nilgai						
Summer						
Y	4.50	4.60	12.1	4.91	10.4	7.32
SeY	0.47	0.68	2.60	0.48	1.43	0.67
NS	26	24	32	32	27	141
95%	0.97	1.40	5.31	0.99	2.92	1.32
Winter						
Y	3.26	3.46	9.26	3.76	7.83	5.51
SeY	0.79	0.67	0.86	0.28	1.11	0.40
NS	14	21	32	31	22	120
95%	1.61	1.38	1.76	0.57	2.27	0.79
Combined						
Y	3.88	4.03	10.7	4.33	9.13	6.42
SeY	0.46	0.48	1.37	0.28	0.91	0.39
NS	40	45	64	63	49	261
95%	0.93	0.96	2.74	0.57	1.83	0.77

Appendix V Mean density (Y), number of sightings (NS), standard error (SeY) of mean density and 95% confidence limits of the three ungulate species in different habitat types and the overall study area (OSA) in Sariska National Park obtained from motorcycle based transects. The unit of density are no/km^2. Habitat types are described in the text.

Sambar	Habitat types				
Summer	Anog.	Anog.Mix	Bosw.Mix	MTDF	OSA
Y	8.03	6.60	4.96	1.93	5.38
SeY	1.57	1.03	0.95	0.21	0.56
NS	20	26	20	32	98
95%t	3.20	2.10	1.94	0.43	1.11
Winter					
Y	9.74	4.09	3.26	2.70	4.95
SeY	1.14	0.36	0.32	0.30	0.40
NS	28	30	26	27	111
95%t	2.33	0.74	0.66	0.62	0.79
Combined					
Y	8.89	5.34	4.11	2.31	5.16
SeY	0.97	0.56	0.51	0.19	0.34
NS	48	56	46	59	209
95%t	1.94	1.13	1.02	0.38	0.67
Chital					
Summer					
Y	7.33	15.1	8.86	12.3	10.96
SeY	1.84	2.50	2.12	1.88	1.07
NS	15	32	22	60	129
95%t	3.77	5.11	4.32	3.83	2.12
Winter					
Y	5.62	11.2	10.0	9.32	9.04
SeY	1.91	1.47	1.18	1.63	0.83
NS	19	32	32	66	149
95%	1.91	1.47	1.18	1.63	0.83
Combined					
Y	6.47	13.1	9.48	10.8	10.00
SeY	1.03	1.31	1.09	1.03	0.57
NS	34	64	54	126	278
95%	2.06	2.63	2.18	2.06	1.14
Nilgai					
Summer					
Y	5.31	14.9	6.21	23.1	12.40
SeY	1.24	2.62	1.43	2.74	1.23
NS	16	28	21	68	133
95%	2.54	5.34	2.91	5.60	2.43
Winter					
Y	3.82	10.3	8.09	17.2	9.83
SeY	1.45	1.54	1.06	2.66	1.20
NS	16	32	32	67	147
95%	1.45	1.54	1.06	2.66	1.20
Combined					
Y	4.57	12.5	7.15	20.1	11.11
SeY	0.71	1.38	0.76	1.55	0.69
NS	32	60	53	135	280
95%	1.43	2.77	1.52	3.10	1.35

Appendix VI Mean density (Y), number of sightings (NS), standard error (SeY) of mean density and 95% confidence limits of the three ungulate species in different habitat types and the overall study area (OSA) in Kanha National Park. obtained from motorcycle based transects. The unit of density are no/km^2. Habitat types are described in the text. *=species does not occur.

Sambar	Habitat types					
Summer	Sal	Sal Mix.Bamb	MMDF	Misc.Mix.Bamb	Grlan	OSA
Y	3.92	4.64	3.00	3.38	2.82	3.55
SeY	0.78	1.04	0.14	0.38	0.56	0.29
NS	22	20	32	30	20	124
95%t	0.78	1.04	0.14	0.38	0.56	0.29
Winter						
Y	4.63	5.51	1.92	5.06	4.06	4.24
SeY	0.56	0.60	0.39	0.45	0.46	0.24
NS	26	25	17	35	27	130
95%t	1.15	1.23	0.81	0.93	0.93	0.48
Combined						
Y	4.28	5.03	2.46	4.22	3.44	3.89
SeY	0.47	0.60	0.22	0.31	0.37	0.19
NS	48	45	49	65	47	254
95%t	0.95	1.20	0.44	0.63	0.74	0.37
Chital						
Summer						
Y	8.09	15.3	3.84	9.73	104.0	28.17
SeY	1.44	2.55	0.77	1.91	14.3	4.19
NS	25	47	26	74	94	266
95%t	2.94	5.20	1.58	3.90	29.2	8.29
Winter						
Y	5.68	11.4	3.53	11.1	88.4	24.05
SeY	0.78	1.06	0.52	1.05	6.30	2.89
NS	24	32	22	57	103	238
95%	1.61	2.17	1.07	2.15	12.8	5.67
Combined						
Y	6.88	13.3	3.69	10.4	96.6	26.11
SeY	0.83	1.39	0.46	1.08	7.83	2.54
NS	49	79	48	131	197	504
95%	1.65	2.78	0.93	2.17	15.6	5.00
Nilgai						
Summer						
Y	*	*	3.06	*	2.68	2.87
SeY	*	*	0.50	*	0.49	0.35
NS	*	*	24	*	20	44
95%	*	*	1.03	*	1.00	0.70
Winter						
Y	*	*	1.91	*	2.12	2.01
SeY	*	*	0.56	*	0.37	0.23
NS	*	*	21	*	20	41
95%	*	*	0.56	*	0.75	0.46
Combined						
Y	*	*	2.49	*	2.40	2.44
SeY	*	*	0.29	*	0.30	0.21
NS	*	*	45	*	40	85
95%	*	*	0.59	*	0.61	0.42

Appendix VII Mean density(Y), standard error (SeY) of mean density, number of sightings (NS) and 95% confidence limits of the three ungulate species in different study areas obtained from foot transects. The units of density are no/km^2.

Study area	Species	Season	Y	SeY	NS	95%t
Tadoba	Sambar	Summer	9.87	0.80	25	1.66
		Winter	11.3	0.91	24	1.88
		Combined	10.5	0.61	49	1.23
	Chital	Summer	20.7	1.39	25	2.87
		Winter	16.7	1.06	25	2.18
		Combined	18.7	0.91	50	1.83
	Nilgai	Summer	6.17	0.50	24	1.03
		Winter	7.86	0.38	25	0.79
		Combined	7.01	0.33	49	1.83
Sariska	Sambar	Summer	8.53	0.67	22	1.40
		Winter	7.69	0.80	20	1.66
		Combined	8.11	0.52	42	1.05
	Chital	Summer	9.60	0.65	22	1.35
		Winter	8.34	1.21	18	2.51
		Combined	8.97	0.68	40	1.38
	Nilgai	Summer	11.5	1.14	22	2.39
		Winter	12.7	1.19	22	2.49
		Combined	12.1	0.82	44	1.66
Kanha	Sambar	Summer	5.98	0.84	21	1.73
		Winter	6.83	0.83	22	1.71
		Combined	6.40	0.59	44	1.18
	Chital	Summer	23.1	1.85	30	3.79
		Winter	20.2	1.08	30	2.22
		Combined	21.6	1.08	60	2.16
	Nilgai	Summer	3.87	1.54	4	3.56
		Winter	3.42	1.18	5	2.74
		Combined	3.64	0.94	9	2.00

Appendix VIII

WILDLIFE COMPARTMENT HISTORY FORM

.....

NAME OF THE PROTECTED AREA:

NAME OF THE BLOCK: COMPARTMENT NUMBER:

AREA IN HECTARES: DATE:

.....

1. LOCATION:

2. BOUNDARIES:
   A) NORTH
   B) SOUTH
   C) EAST
   D) WEST

2a. STATUS OF BOUNDARIES:

3. PERMANENT FEATURES:

4. TOPOGRAPHICAL FEATURES:
   (Give altitudinal variation, aspect and slope)

5. GEOLOGY AND ROCK:

6. SOIL:
   (Give type, texture, colour, depth, humus and drainage)

7. VEGETATION (Champion and Seth Category):

	Top Canopy	Middle Canopy	Shrub Layer	Grasses
A). Dominant spp.				
B). Other spp.				
C). Average Height				
D). Density				

8a. REGENERATION OF KEY SPECIES:

Name of Species	Natural Regeneration		Artificial Regeneration
	Seedling	Coppice	

8b. STATE WHETHER ALL AGE CLASSES ARE REPRESENTED:

8c. STATE WHETHER REGENERATION IS ADEQUATE TO RESTOCK THE AREA:

9. PLANTATIONS: Yes No

Name of Species	Year of Plantation	Young/Mature	Average Density & Height

10. WATER AVAILABILITY:

A). SOURCES:	None		Artificial	Natural
B). SEASONAL AVAILABILITY	July-Sept	July-Dec	July-March	July-June
C). TYPE:	SEEPAGE	STREAM	RIVER	OTHERS

11. SALT LICKS: None Artificial Natural

12. WEEDS: Yes No
Species Low Medium High

13. LOPPING:
None Low Medium High

14. GRAZING:
None Low Medium High

15. FUELWOOD REMOVAL:
None Low Medium High

16. ILLICIT CUTTING:
None Low Medium High

17. MINOR FOREST PRODUCE COLLECTION:

Name of the produce	Time of collection	Extent of collection

18. FIRE INCIDENCE: Yes No
Time period Low Medium High

19. SOIL EROSION: (Give Type and Extent)

20. WILDLIFE USE:

A). Name of the species:

B). Relative abundance of each species:

Species	Rare	Occasional	Common	Abundant

C). Presence of indirect evidences:
(Pugmarks, Dung, Pellets, Antler rubbing, wallows)

D). Presence of species-specific habitat:
(Nests, Dens, Snags, Caves, Cliffs, Talus)

21. HUMAN SETTLEMENTS: Yes No

Name Number of dweliings

<10 10-25 25-50 >50

22. GRAZING CAMPS: Yes No

Name Number of cattle units

23. ANY OTHER INFORMATION OF SPECIAL INTEREST:

ECOLOGICAL IMPACTS OF LIVESTOCK GRAZING ON WILD UNGULATES IN SARISKA NATIONAL PARK,INDIA

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ABSTRACT

The competition for resources between domestic livestock and wild ungulates and its resolution is a matter of great concern to wildlife, range and livestock managers. Grazing effects and interspecific interactions not only influence the dynamic process of population regulation in wild ungulates but also modify the potentially fragile animal habitat relationships. The paper aims to describe the ecological impacts of livestock grazing on three wild ungulate species Sambar (***Cervus unicolor***), Chital (***Axis axis***) and Nilgai (***Boselaphus tragocamelus***) in a wildlife protected area located in the semi-arid region of northern India. Although the Wildlife Protection Act prohibits the presence of human settlements and domestic livestock inside wildlife areas yet they continue to exist due to a large number of socio-economic considerations. The study provides quantitative data to show how the construction of a dry rubble wall around the human settlements by the park management has led to a significant reduction in the livestock grazing impacts on the prime wildlife areas. The paper also describes a modified point-intercept method for measuring the changes in ground cover as a result of continuous grazing and discusses its significance in the rapid evaluation and monitoring of habitat quality. Comparisons have been made in the abundance of wild ungulate populations between similar, adjacent grazed and ungrazed areas in order to determine the factors influencing the habitat selection by the wild ungulates. The implications of the study in the management of an area shared by both wildlife and domestic stock are discussed.

KEY WORDS Human settlements, rubble wall, toe-point transect, habitat selection, Sambar, Chital, Nilgai.

ECOLOGICAL IMPACTS OF LIVESTOCK GRAZING ON WILD UNGULATES IN SARISKA NATIONAL PARK, INDIA

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INTRODUCTION

Brown (1971) remarked that one of the most serious threats facing natural vegetation or wildlife is not so much hunting, whether illegal or legal, as the destruction of habitat by Man - either directly, or indirectly through his domestic animals. Smith (1977) stated that livestock grazing is the single most important factor limiting wildlife production in the USA. Although these statements amply reflect the existence of an inherent competition between domestic livestock and wildlife yet few studies have been attempted to understand the pattern of this interaction from the ecological standpoint. The livestock-wild ungulate interaction may manifest itself in many forms as the rangeland and wildlife environments are never static and also because the impacts could be direct or indirect. Moreover, little effort has been made by the range and wildlife managers towards findings ways to mitigate these impacts.

A network of wildlife protected areas (PA) comprising national parks and wildlife sanctuaries has been established in India (Rodgers and Panwar, 1988). Although the Wildlife Protection Act (Anon., 1972) prohibits human settlements, cattle camps and grazing inside the national parks but in practice this is not the case in many of these areas. Rehabilitation schemes for shifting settlements from inside the national parks have not achieved the desired level of success due to a large number of conflicting socio-economic and political considerations. The wildlife manager has to often devise strategies for the conservation management of wildlife species taking into account the competition for sharing of the forage and water resources with the domestic livestock present in ever increasing numbers.

The three ungulate species Sambar (***Cervus unicolor***), Chital (***Axis axis***) both belonging to Cervidae and Nilgai (***Boselaphus tragocamelus***), a member of the bovidae, together contribute nearly 94% to the total wild ungulate biomass in the study area. They form the major prey base for the Tiger (***Panthera tigris***) and thus their population dynamics has a considerable significance for the park management. The objectives of the present study were: 1) to determine the ecological impacts of livestock grazing on three wild ungulate species Sambar, Chital and Nilgai 2) to demonstrate the use of a rapid method for monitoring changes in the ground cover condition as a result of livestock grazing and 3) to evaluate the efficacy of the management input of construction of dry rubble wall around human settlements to mitigate the livestock grazing impacts.

In 1986, the park management constructed dry rubble walls 1.5 m high at a very low cost around the periphery of the human settlements occuring in Sariska valley to prevent the domestic livestock from grazing in the prime wildlife habitats. Although the wall is not 100% livestock proof yet it has been able to contain the impacts of livestock grazing in prime wildlife areas. The present study evaluates the efficacy of one such wall constructed around Haripura village.

STUDY AREA

The study was carried out in Sariska National Park (298 km^{-2}) located at a distance of 198 km from Delhi and 108 km from Jaipur, in the civil district of Alwar, Rajasthan. It lies between 27^0 18' to 27^0 26' North latitudes and 76^0 21' to 76^0 29' East longitudes. The highly dissected topography of Sariska consists typically of steep sided rocky plateaus divided by narrow valleys. The area is occupied by the pre-cambrian rocks of the Delhi and Aravalli systems and comprise of quartzite, conglomerates, grits, limestone, granite and schists. The soil is sandy to sandy-loam, shallow and covered with boulders. Sariska has a sub-tropical climate characterized by a distinct summer and winter, small monsoon period and a short spring. The mean annual rainfall is 755 mm (range 478-1164 mm) and mainly occurs during monsoon period from July to September. Champion and Seth (1968) have classified the vegetation types of Sariska as Tropical Dry Deciduous (TDD) and Tropical Thorn Forest (TTF). The forest varies greatly in composition and quality depending on the geological and soil formation on which they occur. The major habitat

types in Sariska along with their relative proportions, canopy status, dominant tree and shrub species are shown in Table 1.

11 human settlements and grazing camps having a human population of 2000 and a cattle population of approximately 3500 (Sharma and Arya, 1981) exist in the study area In addition, a human population of up to around 250,000 and a cattle population of nearly 100,000 cow units occupy the periphery areas outside the study area (Anon., 1989). The national park is virtually an ecological island under constant pressure from the human and cattle population. The human settlements have occupied the alluvial open areas in the valleys and the two large plateaus, Kiraska and Kankwari, which are about 5 km in width. These are pastoralist settlements with traditional occupance and were granted some grazing concessions by the forest department in 1947, much before the area was declared as a wildlife reserve. They mostly keep domestic cows, buffalo, cows and goats and earn their livelihood by selling milk and milk products.

METHODS

I estimated the ground cover and monitored the changes in its composition in order to evaluate the direct impacts of grazing . The ground cover was estimated by using a modification of the Point-Intercept Method (Mueller-Dombois & Ellenberg, 1974). The modified method called "Toe-point transect" is a rapid method for the systematic sampling of cover along a straight line. The cover categories to be estimated were defined as bare ground, small rocks (3-8 cm in diameter), litter (any organic material, including dead annuals and perennials), grass and

dung (cow, buffalo, sheep or goats). A fine notch is made on the toe of one shoe and 'hits' are recorded on every alternate step as the pacer (observer) walks along the transect. A 'hit' consists of the ground cover material covered by an imaginary, non dimensional point located at the tip of the pacer's toe. The hits are recorded in different categories (bare, rock, litter, etc.) in separate columns on the data sheet. A hit is termed a 'basal hit' if it occurs directly upon the trunk or stem of a plant species or a 'canopy hit' if it occurs under a plant species (Sale & Berkmueller, 1988). A canopy hit occurs whenever the canopy (leaves and branches) of a plant would intercept a drop of rain falling toward the 'hit point', or in other words, where a line originating perpendicularly from the point intersects the canopy.

10 separate transects, each comprising 200 paces and thus providing 100 'points' per transect, were walked in areas inside the rubble wall (i.e areas open to livestock grazing). Similarly, 10 transects were walked in areas lying within 1 km outside the wall (i.e areas close to grazing). In all, 2000 points were tallied in different cover categories. Grass height was also recorded, to the nearest centimeter, whenever a grass was hit.

The study area has an extensive network of roads and the sampling of the ungulate populations was done using Motorcycle based transects following the road strip sampling technique (Hirst, 1969). Transects were run in each habitat type of the study area every morning (0600-0800 hrs) and evening (1600-1800 hrs) and the number of Sambar, Chital and Nilgai groups observed were recorded. In order to determine the preference or avoidance of the ungulate species for the different habitat

types in the study area a test concerning proportions, based on the normal approximation to the binomial distribution (Bhattacharya & Johnson, 1977) was used:

$$Z = \frac{p - p_0}{\sqrt{p_0(1 - p_0)/n}}$$

where n is the total number of independent animal observations, p the proportion of observation made in each habitat type, and p_0 the proportion of each habitat type within the study area. To avoid problems of sample interdependence, solitary animals as well as herds were all treated as independent observation. The Z statistic can be used to indicate the degree of preference or avoidance for the different habitat types. Field work was carried out in the dry season (April-June, 1988) .

RESULTS AND DISCUSSION

The composition of the ground cover inside and outside the rubble wall is given in Table 2. The percentages of bare soil and cattle dung are quite high in areas open to livestock grazing i.e inside the wall whereas the percentages of grass and litter are quite low. Dung is an indicator of the cattle activity in an area and bare soil is probably the consequence of the movement and trampling action of the cattle, once the vegetation has been grazed completely. The low grass height (0.9 ± 0.08 cm) inside the

wall compared to grass height (4.91 ± 0.66 cm) outside the wall shows that grazing pressure is, as expected quite high inside. Table 3 shows the means, standard error of the mean and 95% confidence limits of the various categories of ground cover inside and outside the wall. I used paired Student-'t' (two-tailed) test (Armitage and Berry, 1988) to determine whether the means differed significantly in the two situations. A significant difference in the means would indicate that the wall was successful in keeping the livestock out from the prime wildlife habitats. Excepting the amount of rock, there was a significant difference ($p<0.001$) in the amount of bare soil, dung, grass and litter in the areas closed to livestock grazing probably as a result of the construction of the rubble wall. Grass cover and grass height was significantly higher in areas barred to livestock while the amount of cattle dung and bare soil was significantly lower. The amount of grass available i.e forage volume was calculated by multiplying the mean grass height with the cover value. The forage volume in areas open to grazing was 0.0004 m^3/m^2 whereas in areas closed to grazing it was 0.0103 m^3/m^2 In other words, the areas protected from livestock grazing had nearly 26 times more grass than areas which were open to grazing. As the data was gathered during the dry season when forage resources become very limited, these results are of great significance for management . A very significant amount of grass is available in the valley areas where the impact of livestock grazing have been controlled due to construction of the rubble walls around human settlements. The Sariska valley is also the site for very high dry season concentration of the ungulate species around the waterholes. The concentration of animals around the waterholes increases the grazing pressure in the valleys and the vegetation shows signs of overgrazing. If the amount of forage

available to the wild ungulates can be enhanced as has been shown above, the carrying capacity of the Sariska valley would be be considerably enhanced. One of the major cause of the large scale mortality of Sambar and Chital in the Sariska valley during the summers of 1988 was the severe depletion of forage resources.

The three ungulate species exhibit a great degree of selectivity for the different habitat types in Sariska (Table 4). Their preference/avoidance for the habitat types is graphically represented by Fig.1. Sambar, a forest ungulate species, prefers densely wooded slopes covered with ANOG (Anogeissus pendula) and avoids the Miscellaneous (MISC) habitats with an open canopy and a high level of disturbance from human settlements and livestock grazing. Chital, a species of the 'edge', prefers the woodland habitat interspersed between the dense Anogeissus pendula forest and the miscellaneous forest dominated by Acacias and other thorn forest species. Nilgai, a tragelaphine antelope, is not highly dependent on water and prefers open miscellaneous habitats dominated by shrubs and characterized by the presence of human settlements and livestock grazing. The human settlements probably make the habitat conditions optimal for Nilgai by keeping the canopy open by maintaining a heavy lopping pressure on the tree layer. The three ungulate species react differently to the ecological impact occuring in the habitat as a result of livestock grazing. Sambar appears largely intolerant, Chital moderately intolerant and Nilgai apparently thrives in habitat where cattle also occur. This difference in the response pattern may be explained on the basis of the feeding strategies adopted by these species. Nilgai, being an opportunistic feeder and independent of frequent water requirements,

consumes a large proportion (nearly 70%) of browse material in its diet and therefore faces little competition from domestic livestock for forage and water. Chital is predominantly a grazer and is highly dependent on the availability of water. It is a very adaptable species (Krishnan, 1972) and is able to seasonally increase the proportion of browse to nearly 48% in order to reduce dietary overlap with domestic cattle. Sambar, though has little dietary overlap with the domestic cattle which are coarse grazers but faces competition from goats for the browse material. During the continuous period of drought in 1988 it was observed in Sariska that the local pastoralist community had exchanged their buffalo for goats which are not dependent on grass and water and for whom they could provide the browse material by lopping the top branches of trees and shrubs. This type of adaptive strategy has been described by Hjort (1976) as prevalent among some of the pastorialist communities in Africa. Sambar requires water for drinking as well as wallowing and avoids sharing of water sources with livestock and its abundance is reduced greatly in habitats where cattle are present.

CONCLUSION

The evaluation and interpretation of livestock grazing impacts on wild ungulates is often very complex and generalizations are difficult to make. This study shows that the impacts vary with the ungulate species; Nilgai has no adverse impact due to cattle presence while Sambar and Chital numbers decline in habitats where livestock grazing is intense. However, even the apparent coexistence of Nilgai with livestock cannot be assumed as evidence of a compatible relationship or that negative impacts will not

occur in future. The study demonstrates that the construction of a rubble wall has been successful in reducing the livestock grazing impacts in the prime wildlife areas as evidenced by the massive increase in the grass forage volume. This success, however, depends on the ability of the management to prevent the breaching of the walls. During the period of drought there is an increased temptation on part of the pastoralists to breach the wall and push the cattle outside leading to a conflict with park authorities. Nevertheless, the pastoralists have come to accept the presence of the wall and are willing to contain their acitivities around the settlements in preference to the possibility of being evicted from areas, where their cattle have free ranged for a very long time and perhaps now cannot adapt to stall feeding measures. Moreover, the construction of the wall shows a willingness on the part of management to devise strategies to mitigate the impact of livestock grazing in wildlife areas even though it can only be termed as an adhoc measure to be adopted till such time when the schemes to rehabilitate human settlements and grazing camps become operational or the pastoralist communities agree to control human and stock numbers and not spread their activities in other areas of the park.

The toe-point transect method can be rapidly applied to situations where one has to compare and monitor the changes in the habitat occuring as a result of management actions e.g. monitoring the grass cover or height around a waterhole to quantify the impact of grazing on vegetation. It needs very little formal training to use and can be adopted by both range as well as wildlife managers to monitor extensive areas and build up large data sets to base the management decisions.

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Table 1 The major habitat types in Sariska National Park, canopy status and dominant tree and shrub species

Habitat type	Area (Km^2)	Top storey	Under storey	Dominant tree species	Dominant shrub species
Anogeissus (ANOG)	28.3	Dense	Sparse	Anogeissus pendula	Adhatoda vasica Grevia flavescens
Anogeissus Mix (ANOGMX)	83.4	Medium	Medium	Anogeissus pendula Acacia leucophloea	Grewia flavescens Nyctanthes arbor-tristis
Boswellia Mix (BOSWMX)	70.0	Medium	Medium	Boswellia serrata Lannea coromandelica	Fluggea leucopyrus Indigofera crassiodes
Miscellaneous (MISC)	116.3	Sparse	Dense	Acacia leucophloea Ziziphus mauritiana	Capparis spp. Grewia spp.

Table 2 The composition of ground cover inside and outside the rubble wall expressed as the Percentage of Hits on shoe notch

Transect Number	Inside the wall % Hits of					Transect Number	Outside the wall % Hits of				
	Bare	Rock	Dung	Grass	Litter		Bare	Rock	Dung	Grass	Litter
1	34	12	37	3	14	11	16	18	15	18	33
2	30	13	40	5	12	12	20	18	13	22	27
3	29	16	30	6	19	13	17	22	17	26	18
4	24	19	33	2	22	14	13	18	14	20	35
5	30	17	35	3	15	15	22	16	16	24	22
6	33	13	39	1	14	16	19	21	18	17	25
7	25	19	35	8	13	17	24	17	20	22	17
8	35	15	31	5	14	18	21	15	19	23	22
9	40	19	33	2	6	19	20	19	21	18	22
10	29	21	35	9	6	20	19	15	18	20	28

Table 3 Means(expressed as %), standard errors, 95% confidence limits of various categories comprising the ground cover and the results of Student-t test. *** P<0.001, * P=not significant

Cover category	Inside the wall			Outside the wall			Statistical significance
	Means	S.E.	95%t	Means	S.E.	95%t	
Bare soil	30.9	1.51	3.41	19.1	0.99	2.25	***
Rock	16.4	0.98	2.22	17.9	0.74	1.67	*
Dung	34.8	1.02	2.31	17.1	0.82	1.86	***
Grass	4.4	0.85	1.91	21.0	0.92	2.08	***
Litter	13.5	1.57	3.54	24.9	1.88	4.25	***
Grass Ht. (cm.)	0.9	0.04	0.08	4.91	0.29	0.66	***

Table 4 Proportion of the three wild ungulate species observed in different habitat types compared with the proportion of area covered by each habitat type in Sariska National Park.

Species	Habitat types			
	Anog	AnogMx	BoswMx	Misc
Sambar (N=184)				
Observed proportion of Sambar	0.18	0.39	0.20	0.22
Proportion of area	0.10	0.28	0.19	0.39
Z-value	3.63	8.87	0.34	-4.39
P-value	<0.01	<0.01	0.36	<0.01
Chital (N=448)				
Observed proportion of Chital	0.06	0.36	0.13	0.44
Proportion of are	0.10	0.28	0.19	0.39
Z-value	-2.83	3.77	-3.24	2.01
P-value	<0.01	<0.01	<0.01	0.02
Nilgai (N=693)				
Observed proportion of Nilgai	0.03	0.23	0.07	0.65
Proportion of are	0.10	0.28	0.19	0.39
Z-value	-6.19	-2.94	-8.0	14.05
P-value	<0.01	<0.01	<0.01	<0.01

Fig 1 The relationship between habitat type and the Z-Statistic for the three ungulate species in Sariska National Park. Positive Z-values show the degree of attraction to a given habitat type and negative Z-values indicate avoidance

