Ecology and Management of Lion and Ungulate Habitats in Gir

Thesis
submitted to the
Saurashtra University

For the degree of
Doctor of Philosophy

in
Wildlife Science

Diwakar Sharma

Wildlife Institute of India
Post Box # 18, Chandrabani, Dehra Dun - 248 001
&
Department of Biosciences, Saurashtra University
Rajkot - 360 005

APRIL 1995

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

I have great pleasure in forwarding the thesis of ***Mr. Diwakar Sharma*** *titled* ***"Ecology and Management of Lion and Ungulate Habitats in Gir"*** *for the award of the degree of* ***Doctor of Philosophy*** *in* ***Wildlife Science****. The thesis embodies original findings and interpretation of facts. This research was carried out by Diwakar Sharma under my supervision. This research has neither formed the basis for the award of any degree in the past, nor is it submitted for any other degree at present.*

Dr. A.J.T. Johnsingh
Guiding Teacher
Wildlife Institute of India

Sh. S.K. Mukherjee
Director
Wildlife Institute of India

Forwarded through :

Head
Department of Biosciences
Saurashtra University
Rajkot - 360 005.

Post Box No. 18, Chandrabani, Dehradun - 248 001. India
EPABX: 620912 to 620915; Fax: 0135-620217; Gram: WILDLIFE

Dedicated to my Mother

CONTENTS

Chapter - 7 CONCLUSIONS AND RECOMMENDATIONS

Acknowledgement

The successful completion of this project, particularly the field work had been possible only due to the extensive support and co-operation provided to me by various institutions.

Mr. H.S. Panwar, former Director, Wildlife Institute of India, strongly supported the project and had always been a source of immense support regarding logistics. His visits to the field were of great use in stimulating discussions necessary for formulating the project objectives.

I am thankful to the Gujarat Forest Department for permitting me to carry out the study in Gir and providing the logistics required. Without this support the study could not have been accomplished.

I am indebted to Dr. A.J.T. Johnsingh, my Ph. D. supervisor and the investigator of the project from 1992-1995, for his guidance, support and inspiring field trips. I am also thankful to him for providing me a photograph of a Gir riverine habitat.

Dr. S.N. Prasad, the first investigator of the project (1991-1992) initiated this study and played a vital role in finalizing methodology for major components of the study.

Prof. Y.D. Singh, Head, Department of Biosciences and, Mr. V. Vijay Kumar, faculty, Suarashtra University Rajkot are acknowledged for rendering help pertaining to my Ph.D. registration which saved considerable of amount my time which otherwise would have been spent travelling to and staying in Rajkot. In Rajkot, the enjoyable hospitality of Mr. V. Vijay Kumar and his family is kindly acknowledged.

I am thankful to Mr. H.A. Vaishnav, former Principal Chief Conservator of Forests; Mr. R.L. Java (now, Principal Chief Conservator of Forests), Mr. D.M. Naik, Mr. S.K. Sinha (both Chief Conservators of Forests, (wildlife) at different periods), Mr. R.V. Asari (Conservator of Forests, (Wildlife), Junagadh Circle), Mr. S.C. Pant and S. J.P. Vasava (both Deputy Conservator of Forests at different periods, East Gir division) for their unfailing support and help during this study.

Mr. B.J. Pathak, DCF and Mr. Shyamal Tikedar, DCF, shared me their knowledge about the management of Gir.

Words can not expess the help, company and warm hospitality provided by Mr. Shyamal Tikedar, Deputy Conservator of Forests (DCF)and his wife Smt. Lata Tikedar. Away from home, they gave me a home.

Mr. N.V. Kataria, (DCF), was very helpful to me whenever I approached him with some problems. I am grateful to him for all the efforts he made for the smooth running of this project. The help and hospitality from his family are worth mentioning.

Being alone in the field can sometimes be very boring. There was a time I longed for a lively company which I found in Pranav G. Trivedi. His six months study on pea fowl for his M.Sc. (Wildlife Science) in Gir brought a vigour in me.

I am grateful to the Soil Chemistry Department, Gujarat Agricultural University (GAU), Junagadh for doing chemical analysis of soil samples collected from Gir.

Mr. P.P. Rawal, Zoo Manager, Sakkarbagh Zoo provided all his support in setting the exclosures for grass productivity and soil analysis. Dr. Ismail Dhruj from GAU, Junagadh played a vital role from getting the PC repaired and getting the soil analysis done.

Back at WII, Dr. Y.V. Jhala and Dr. S.P. Goyal helped me solve the problem of measuring and calculating browse production and utilization using twig method. I am thankful to Dr. Ajith Kumar and Mr. Qamar Qureshi for helping me with statistics.

I am thankful to Mr. Ajay Sharma for doing physical texture analysis of soils.

I acknowledge the help rendered by Sh Rajesh Thapa and Mr. L.N. Sharma in using computer programmes for analyses. Mr. Sukumar always helped in time of LAN/PC problems. Mr. B. Desai was helpful in printing this manuscript. Mr. Shanmugam helped with drawings on AUTOCAD.

Mr. P.L Saklani, from herbarium section and my friends Neel Gogate and C.P. Kala took pains to check the scientific names of plants. I thank them for the help. Mr. Bivash Pandav is acknowledged for assisting in data entry.

During the final phase of writing, friends at hostel, Ms. Divya Mudappa, Ms. Nima Manjrekar and Charu Dutt Mishra were of great help in finishing the work in time. In spite of being busy with their own work they helped me with data entry, drawings and reading the drafts. I am grateful to them for easing my work load.

I acknowledge the assistance and information provided by my field assistants Dhana Laxman Gadhavi, Karasan Nanji and Mohmmad Juma. Their experience of working with different researchers and their knowledge of Gir were of immense use to me. Along with them I am also grateful to Satish Raval, and dirvers Mohammad, Ibrahim, Rajjak and Ahemad for helping in field work for long hours for several consecutive days without complaints. Their enthusiasm was always a great source of support in doing field work even under hostile field conditions.

I also acknowledge the support and co-operation of the staff of Gir. During the three years period the staff at Sasan, Dhari, Chhodavadi, Jasadhar and Bhimchas were of great use in hard times.

Friends at Veraval and Ahemdabad supported me during three years' stay in field. Narsimhan and his wife Priya, Somnath and Shailesh were very hospitable and helpful at Veraval. In Ahemdabad, the warm hospitality and assistance from Manoj Dholakia and his parents; Padmaraj Jadeja, Ram Kumar and Prajit Kapoor made my stay and work in Ahemdabad trouble free. I am very grateful to all of them for this.

Support and co-operation of my father, sisters and brother have been invaluable in accomplishing this research. All these years they silently facilitated this research by keeping the family problems away from me.

Finally, I am grateful to my wife Anita, who not only often suffered in solitude but also helped me in this research in various ways from counting ungulates from vehicle (she turned out to be very efficient in spotting animals), data entry, soil sample collection and soil analysis.

Diwakar Sharma

IMPACT OF MANAGEMENT PRACTICES ON LION AND UNGULATE HABITAT IN GIR PROTECTED AREA.

SUMMARY

A study on the impacts of management practices on lion and ungulate habitat was conducted in Gir Protected Area (PA) from June 1991 to July 1994. The Gir PA includes Gir Wildlife Sanctuary and National Park. It is situated between 20° 55' to 21° 20'N and 70° 25' to 71° 15' E in the Southern part of Kathiawar peninsula in western Gujarat. Gir PA (hereafter Gir) is located about 60km South of Junagadh. The area which was 3,107 sq km in 1877 (Joshi 1976) has been presently reduced to 1,412 sq km, of which about 259 sq km is national nark. The terrain is hilly, altitude ranging from about 100m above mean sea level to the highest of 528m above mean sea level. The hills run in all directions, have moderate slopes, and constitute the important catchment for Kathiawar peninsula. The rocks are volcanic in origin, consisting of Deccan traps and are the oldest exposed rocks in Gir (Patel, 1992). As many as seven types of soils are categorized based on their colours (Munsell colour chart) ranging from dark yellowish brown to very dark greyish Brown (Pandit *et al.* 1992.).

The climate is semi-arid with three distinct seasons. Summer (March-mid June), monsoon (mid June - mid October) and winter (late October to February). Gir has dry deciduous forest - 5A/C1b (Champion & Seth 1968). In eastern Gir *Anogeissus pendula* replaces *Tectona grandis* but the vegetation is dominated by thorny species such as *Acacia* and *Zizyphus*.

Gir is the last refuge of the wild Asiatic lions (*Panthera leo persica*) and long term conservation of the Asiatic lion is an overriding management objective of Gir. In order to improve habitat conditions in Gir, the park authorities, over the last 20-25 years have made some management interventions such as relocation of some

maldharis (local graziers), reduction in livestock grazing (specially migrant livestock during the rainy season) and fire control. These measures have led to vegetational recovery and increase in wild ungulate and lion populations.

Understanding this vegetational recovery was thought to be crucial to determine the extent of management intervention required. It also needed to be determined if the trend (especially in the western Gir) was toward a higher woody proportion both at shrub and tree levels, and whether this in long term would adversely affect the distribution and abundance of ungulates, and therefore, group hunting by the lions, their pride size and territoriality.

The objectives of the study were:

1. to investigate the impact of *maldharis* on vegetation;
2. to investigate the habitat utilization by ungulates; and
3. to find out the impact of management practices such as use of fire, creation of water holes, grass harvesting, *maldhari* relocation and creating of national park).

The vegetation study was conducted in 211 plots of 20m X 20m each. Vegetation data included counts and measurement of trees, seedling, shrubs. Status of trees and seedlings in terms of lopped, cut, dead or intact was recorded to study the effect of climate and anthropogenic factors. Data on environmental variables i.e. slope and soil parameters (pH, electrical conductivity, potash, phosphorus, organic carbon, texture, moisture and water retaining capacity and colour) was collected to study their impact on vegetation distribution.

Habitat utilization by ungulates was investigated through direct and indirect evidence. Indirect evidence included pellet group count and browse consumption. Pellets groups of chital (*Cervus axis*), sambar (*Cervus unicolor*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella gazella*), chowsingha (*Tetracerus quadricornis*) and wildpig (*Sus scrofa*) were counted from ten 10m X 2m belt transects in and around 100 vegetation plots. Direct count of ungulates was carried out using vehicle transects at twelve routes all over Gir in the summers of 1992, 1993 and 1994. Data on cover and animal evidence was collected in summer (April-May) and winter (December-January) of 1991, 1992, and 1993.

Browse consumption by ungulates was estimated on trial for few major browse species. The browse production and consumption was estimated through diameter-weight relationship based on linear regression.

Habitat factors included were cover at 0.5m, 1.0m and 1.75m height, canopy, tree species diversity, browse availability, grass cover, leaf litter, distance from *nes*, distance from water, slope and grazing by livestock. Cover was measured from five, fixed 1m X 1m quadrats in initially selected 100 vegetation plots. Relationship of vegetation associations with environmental factors and ungulate abundance with habitat factors were investigated through multivariate analysis.

Fifteen vegetation associations were categorized based on two way indicator species (TWINSPAN) computer programme. These were:

1. *Acacia catechu - Zizyphus nummularia - Aristida adscensionis*;
2. *Apluda mutica - Themeda quadrivalvis - Sehima nervosum*;
3. *Anogeissus latifolia - Acacia catechu - Terminalia crenulata*;
4. *Anogeissus latifolia - Acacia catechu*;
5. *Acacia spp. - Zizyphus mauritiana*;
6. *Zizyphus mauritiana*;
7. *Acacia nilotica - Zizyphus mauritiana*;
8. *Tectona grandis - Acacia catechu - Zizyphus mauritiana*;
9. *Tectona grandis - Acacia catechu - Terminalia crenulata*;
10. *Tectona grandis*;
11. *Acacia catechu - Lannea coromandelica - Boswellia serrata*;
12. *Tectona grandis - Acacia spp. - Wrightia tinctoria*;
13. *Tectona grandis* mixed;
14. Mixed and

15. *Syzygium rubicundum - Pongamia pinnata* associations.

Tree density and diversity were all maximum in Mixed association while seedling density and shrub volume were maximum in *Syzygium rubicundum - Pongamia pinnata* association.

Soil pH, moisture and potash were important environmental factors which determined the vegetation distribution (Canonical correspondence analysis-CANOCO; P=.05). However, different vegetation associations were governed by various environmental variables separately and just one or a combitaion of some variables could not explain the distribution of vegetation associations.

Twelve habitat types were classified based on similarity in vegetation associations and TWINSPAN analysis. These habitats were given a simple name and a name that represented the habitats. The following twelve habitats were categorized:

1. Scrubland
2. Savanna
3. *Anogeissus - Acacia - Terminalia*
4. *Anogeissus - Acacia*
5. Thorn forest
6. *Teak - Acacia - Zizyphus*
7. Teak forest
8. *Teak - Acacia - Boswellia*
9. *Teak - Acacia - Wrightia*
10. Teak mixed
11. Mixed forest
12. Riverine

Mixed habitat was more diverse while riverine was most dense in terms of cover. Thorn forest provided maximum browse to the ungulates. Chital (*Cervus* *axis*) showed high use of Thorn forest habitat while sambar (*Cervus unicolor*) used more Mixed, Riverine and Teak - *Acacia* - *Zizyphus* habitat. Data on other ungulates was not sufficient for statistical analysis. CANOCO showed that disturbance governed the wild ungulate abundance in summer while ground cover and human disturbance were decisive factors in winter. Sambar and nilgai were away from disturbance while chital could afford disturbance in both summer and winter. Chinkara was observed mostly in the east Gir, a place with conditions like savanna and with more disturbance.

Impacts of management practices was investigated in vegetation plots and pellet transects, and comparison of data at varying distances from *nes* and water points, from national park and wildlife sanctuary, from burnt and unburnt areas and from harvested and unharvested localities.

Relocation of *maldharis* resulted in vegetation succession and the late seral stages were more preferred by ungulates. Impact of current *neses* was severe only upto 500m. Water points and vegetation around these influenced the distribution and abundance of ungulates. More evidence of chital which could afford human disturbance were found near water point with relatively open vegetation while that of sambar were 1-2km away from water points. Fire lines resulted in better grass production without dramatic changes in vegetation. Grass harvested areas produced more grass than unharvested ones. The impact of creating the national park, which is largely a hilly tract, is negligible on vegetation and sambar. Chital seemed to avoid the national park area.

List of Figures

List of Tables

List of Plates

List of Abbreviations Used

Short form	-	Vegetation association
AZA		- *Acacia catechu* - *Zizyphus nummularia* - *Aristida adscensionis*
ATS		- *Apluda mutica* - *Themeda quadtivalvis* - *Sehima nervosum*
AnATr		- *Anogeissus* - *Acacia* - *Terminalia*
AnA		- *Anogeissus* - *Acacia*
A sp		- *Acacia spp.* - *Zizyphus mauritiana*
Zm		- *Zizyphus mauritiana*
AZ		- *Acacia nilotica* - *Zizyphus mauritiana*
TAZ		- *Tectona grandis* - *Acacia catechu* - *Zizyphus mauritiana*
TaTr		- *Tectona grandis* - *Acàcia catechu* - *Terminalia crenulata*
Tg		- *Tectona grandis*
TALB		- *Tectona grandis* - *Acacia catechu* - *Lannea coromandelica* - *Boswellia serrata*
TAWr		- *Tectona grandis* - *Acacia catechu* - *Wrightia tinctoria*
TM		- *Tectona grandis* -
M		- Mixed
Riv		- *Syzygium rubicundum* - *Pongamia pinnata*

Short form	-	Habitat type
Scr		- Scrubland
Svn		- Savanna
AnATr		- *Anogeissus* - *Acacia* - *Terminalia*
AnA		- *Anogeissus* - *Acacia*
Th		- Thorn forest
TAZ		- Teak - *Acacia* - *Zizyphus*
TF		- Teak forest
TAB		- Teak - *Acacia* - *Boswellia*
TAWr		- Teak - *Acacia* - *Wrightia*
TM		- Teak mixed
M		- Mixed
R		- Riverine

Chapter 1.

INTRODUCTION

1.1. GENERAL

Habitat in its simplest term is defined as 'the locality, site and particular type of local environment occupied by an organism' (Lincoln *et al.* 1982). It is a place where an animal or plant finds the required arrangement of food, cover, and water to meet its biological needs.

An effective management of habitat based on the study of various habitat parameters and the requirements of animals is yet to begin in India. Needless to say, such a management practice requires the knowledge of both vegetation and biology of the animal species concerned.

A habitat has four primary components i.e. food, cover, water and space (Giles 1978). Food availability in a habitat is one of the most important factors deciding habitat utilization by an animal. Cover includes vegetation or other shelter giving structures that may provide an animal refuge against inclement weather, and predators/enemies, e.g. refuge cover, ambush cover, escape cover, and breeding cover.

Importance of water varies from one species to another. Sambar being a cervid is more water dependent than chinkara, an antelope. Use of a habitat is preferred if water is available along with forage. A habitat free from predation (including by humans) and human induced disturbances is preferred to one which have all forms of predation and disturbance.

Space is required for the procurement of food, water, cover and mate. The need and amount of space also vary among different species. Some protect their space in the forms of well defined territories (e.g. lion - *Panthera leo persica,* and lek by adult black buck - *Antelope cervicapra* males) while others such as chital (*Cervus axis*) and sambar (*Cervus unicolor*) do not have such territories.

1.2. VEGETATION ECOLOGY

Vegetation has threefold importance in habitat ecology and management. Firstly, it physically represents the ecosystem. Secondly, it forms the base of trophic pyramid. Thirdly, it acts as part of the habitat where animals spend most or part of their life.

Although vegetation, as part of habitat, represents an ecosystem and forms the basis of food and cover for animals, there are other habitat factors such as water and terrain which are equally important. Importance of these factors for different animals varies based on their physiological and behavioural requirement.

Vegetation is one aspect of the habitat which can be manipulated to reach certain management objectives. Understanding vegetation involves studies on physiology, synecology, phenology, productivity and temporal succession. This includes classification and ordination of plant communities and their relationships with environments.

Plant community concepts started in the beginning of this century from Clements (1916, 1928) with his organismic approach and Gleason (1917, 1926 & 1939) with his individualistic approach. Clements' view was that plant communities can be easily recognized, defined and these repeat with regularity. Various species comprising the communities are like organs of animal body. Gleason believed that plant species respond individually to the variation in environmental factors. Since environmental factors vary in space and time, the combination of plant species found at any point on earth was unique. This difference in the opinion still continues as some plant ecologists classifying vegetation believe in Clements' approach and others in Gleason's.

Present views of plant community are that vegetation distribution of a particular region is mosaic and one vegetation type grades into other through ecotones (Whittaker 1953, Whittaker & Levin 1977). It is based on the argument that broadly similar conditions in terms of environmental factors and biotic pressures occur over considerable areas. With the repetition of the factors, the vegetation is also repeated, like similar fragments within a mosaic.

Concepts of temporal succession originated because of seasonal dynamism in plant communities. Again Clements (1916) pioneered the ideas of succession and climax. It is of profound importance that management understands the principles of succession developed by ecologists. Effective habitat management is closely related to the understanding of vegetation changes in relation to both natural forces (cyclone, climate changes) and anthropogenic forces (like livestock grazing, water development and protection).

1.3. LARGE MAMMAL ECOLOGY

Adequate knowledge of biology of the concerned species is important for the better management of habitat. This knowledge includes feeding, reproductive and social habits of the concerned mammals. It is only recently that quantitative methods have been used to study these aspects (Joslin 1973, Berwick 1974, Johnsingh 1982, Khan *et al.* 1990, Sukumar 1990, Johnsingh & Sankar 1991, Mathur 1991, Ravi Chellam 1993). Before this it was natural history observations (e.g. Schaller 1967) that guided the biologists. In the following paragraphs the information available on the three ungulates in Gir is synthesized. Only those parameters that are relevant for the report are covered.

1.3.1. Chital

Chital or spotted deer (*Cervus axis*) is a widely distributed deer in India. It occurs from dry and moist deciduous forests to Mangroves of Sunderbans. It is generally an edge species preferring mosaic of grasslands and forests (Schaller 1967, Daniel 1994) and is observed in open area.

Chital is a medium-sized deer with average weight of 40-45kg. It is social animal and occurs in small groups or herds depending upon season. Herd size is influenced by the availability food and water (Schaller 1967). Comparatively large herds (more than 250 animals) of chital were seen during summer in Shigawada reservoir in Gir. This reservoir provided tender grass and water. There were many occasions when large herds (about 90 animals) of chital were seen around water in summer, as also has been reported from Sariska (Chakrabarty 1993). It is a generalist feeder (Rodgers 1988, Johnsingh & Sankar 1991).

1.3.2. Sambar

Sambar (*Cervus unicolor*) is the most widely distributed deer in India. It is found in dry and moist deciduous to evergreen forests, and pine and oak forest of the Himalayas even upto 4000m as seen in Kedarnath Musk deer Sanctuary. It is the largest deer in Southeast Asia with full grown stags weighing upto 320kg (Prater 1980). It prefers dense forests (Ables & Ramsey 1974, Prater 1980). This animal is solitary or occurs in small groups (Schaller 1967, Prater 1980). Compared to chital, sambar is a less generalist feeder (Johnsingh & Sankar 1991, Khan *et al.* 1994).

1.3.3. Nilgai

Nilgai or blue bull (*Boselaphus tragocamelus*) once occurred widely from the base of the Himalayas to Mysore (Prater 1980). It avoids dense forest and prefers scrubland dotted with trees (Daniel 1994). It is a rather 'ungainly animal(s) somewhat horse-like in build..' and the bulls can weigh upto 288kg (Prater 1980). It is categorized as a browser (Khan *et al.* 1990)

1.4. ANIMAL-HABITAT ECOLOGY

Each vegetation community and its successional stages create a unique set of habitat. Animal communities in these vegetation types are also considered to be a part of those habitat because of their effect on each other (Giles 1978).

Vegetation in our protected areas exists in a number of successional and structural conditions due to the influence of natural and anthropogenic factors. Because of their different successional stages the animals depending upon them are also different. For example chital has been considered a species of open forest or edge, sambar of mature and dense forests and nilgai of early successional stages i.e. open scrubland (Daniel 1994). It is clear that habitat management involves a thorough knowledge of both the vegetation and animal ecology.

1.5. MANAGEMENT HISTORY OF GIR

The management history of Gir forest is described by Joshi (1976) and is summarized below from this source. The first effort towards protection/conservation of Gir forest dates back to 1906 when the Nawab of Junagadh took steps to preserve this forest. Subsequently a boundary was demarcated in 1913 encompassing about 1,500 sq. km.

The forest was being managed by Revenue Department from 1878-1914 and one could cut timber in any manner on payment basis. From 1915-1934, teak (*Tectona grandis*) was harvested under coppice with standard system with 30 years rotation. Teak is reported to form 80% of the crop in west Gir, while east Gir had thorny species and grasslands. From 1935 to 1954 a clear felling system with the exclusion of fruit trees was adopted. This resulted in deterioration of forest on poor and hilly areas where clear felling is ecologically unsuitable. This practice lacked cleaning and thinning operation resulting in dense vegetation due to coppicing. From 1965 to 1972 five different working classes were developed for forest management. Rotation period was increased to 40 years for superior teak and 30 years for inferior one. Even crop from scrubland was harvested at 20 year rotation and 5% plantation was suggested in scrubland. These workings were not strictly followed. Hence, plantations failed and vegetation could not be thinned.

The first documented effort towards wildlife management is that of animal census on water holes in May 1974. An area of 140 sq. km was declared national park in 1975 and subsequently all *maldharis* were shifted outside from this area. The national park was areas was increased to 259 sq km. later. The working plan by Joshi (1976) is also the first one in which importance was given to conservation of the Asiatic lion and habitat management. Five working categories for the wildlife sanctuary and national park were suggested in it. These working categories included habitat improvement, watershed conservation, grassland (grass harvesting), plantation and recreation. Of these habitat improvement and plantation work did not succeed much as is evident from the pits for plantation in which seedling/sapling died.

1.6. NEED FOR THIS STUDY

Presently, the Gir is the only refuge of the Asiatic lions (*Panthera leo persica*) in its range. This implies that long term conservation of the Asiatic lion will remain an overriding management objective of Gir. The park authorities, over the last 20-25 years, have made some management interventions such as relocation of *maldharis* (local graziers), reduction in livestock grazing (specially migrant livestock during the rainy season) and fire control in order to improve habitat conditions in Gir. These measures have led to vegetational recovery and increase in wild ungulate and lion populations. The wild ungulate number has increased from about 5,500 in 1973 (Joslin 1984) to about 35,000 in 1990 (Khan *et al.* 1990). The lion population also has increased as per five yearly counts conducted by the park authorities (Ravi Chellam & Johnsingh 1993).

The remaining *maldhari* settlements (locally called *nes*) show vegetational degradation and soil erosion which gradually decline along a radial gradient from the *nes*. Similar degradation is obvious in bordering areas as well as around settlements within Gir. Since in many regions of Gir PA such *neses* settlements and peripheral areas occur in juxtaposition, the degradation is not only a cause of serious concern for wildlife management but equally for the sustainability of the traditional cattle raising, specially the way of the maldhari lifestyle. There is evidence (Abdi 1993) to suggest that each group of maldharis earlier had two or three *nes* sites which were rotationally used. With the growth in the number of maldharis and hence in the number of *neses* and the expansion of the forest settlements, the option of rotation of *nes* sites does not exist any more. The use of one locality for long time has led to over-utilization of resources in the immediate vicinity of *neses*, and degradation of that area.

On the other hand a comparison of recently relocated (1988-89) and earlier relocated (early 1970's) *nes* sites suggests patterns of vegetational recovery. Understanding this vegetational recovery was thought to be crucial to determine the extent of management intervention required.

It also needed to be determined if the trend (especially in the western Gir) was toward a higher woody proportion both at shrub and tree levels, and whether this in long term would adversely affect the distribution and abundance of ungulates, and therefore, group hunting by the lions, their pride size and territoriality. This possibility may not arise in the eastern Gir which has sparse vegetation owing to heavy livestock grazing, thin soil and less rainfall. If grazing is controlled, the eastern Gir perhaps has greater potential to become a typical scrub-savanna habitat as compared to the trend in western Gir towards a denser dry deciduous forest (with much of the biomass locked as wood).

Habitat of Gir has been studied in the past, but in different contexts and using different methods. Studies conducted by Berwick (1974) and Khan *et al.* (1990) had vegetation component. Berwick classified habitat types subjectively. That was the first attempt to categorize the habitat/vegetation. Before this the work done by Santapau and Raizada (1956) was limited to listing the flora.

Khan *et al.* (1990) classified the habitat of Gir using quantitative and modern analytical techniques (TWINSPAN programme). They increased the number of habitat types to 11 as against 4 by Berwick. But Khan *et al.* (1990) identified a tree and/or shrub based on its height and not on its life form. Hence, larger individuals of the same species were categorized as trees and smaller individuals as shrub based on height. In this study shrubs were the caespitose (multi-stemmed or bunched) species 0.5-5m tall (Mueller-Dombois & Ellenberg 1974).

1.7. OBJECTIVES

Above considerations suggested that a long term study was required to assess the changes in habitat due to various management practices. This study aimed at investigating the effects of past management practices on lion and ungulate habitats in Gir and also to suggest the type of habitat manipulation required.

The study had the following broad objectives:

1. To assess the impact of the *maldharis*, their cattle, and relocation of *neses* on (i) regeneration, (ii) recruitment and (iii) productivity of tree, shrub and herb layers.

2. To quantify habitat utilization by ungulates through indirect/direct evidence in strata identified in objective (1).

3. To evaluate the role of the following management practices on vegetation and ungulates:

a) fire as a potential management tool (by way of early controlled burning).

b) grass harvesting as one of the potential eco-development measures to supply fodder to villagers and to mitigate livestock grazing, and investigate the effect of grass harvesting on ungulates.

c) water holes on ungulates abundance.

d) relocation of *nes* sites and monitoring the resulting vegetational recovery.

The work was centred around the following hypotheses:

1. The past relocation of *neses* with the concomitant decrease in the cattle pressures and increase in fire protection have enhanced vegetation density (biological hypothesis).

2. The rate of succession of vegetation on similar soil and terrain with similar water regime differs with the status of protection afforded from livestock (biological hypothesis).

3. Localities unaffected by heavy livestock grazing are avoided by chital, an edge species but preferred by sambar, an animal of dense cover (biological hypothesis).

4. Sambar and chital which are water dependent are found near water (biological hypothesis).

5. Grass harvesting does not affect habitat utilization by ungulates (null hypothesis).

1.8. ORGANIZATION OF THE THESIS

This thesis is composed of seven chapters. The following chapter describes the study area in the context of topography, geology, anthropogenic pressures, and past research works in Gir. The aim is to emphasize the features that have direct or indirect impact on vegetation. The third chapter presents the general methods and analyses adopted in this research. The fourth chapter describes the vegetation types based on modern classification and ordination techniques. The edaphic and terrain factors are described in detail along with the structure of vegetation at various levels.

The fifth chapter is on habitat utilization by ungulates. This describes in detail the habitat utilization by chital and sambar only. Data for other ungulates was relatively meagre but enough in case of nilgai and chinkara to conduct multivariate analysis. Vegetational and physiographic factors that could affect the habitat utilization by these four ungulate species are described in this chapter. The sixth chapter discusses the impact of various management practices on vegetation and animals and revolves around programmes like relocation of maldharis, grass harvesting, water hole management, and fire line creation.

The seventh and final chapter concludes about the findings of the study on impact of management actions and gives specific recommendations.

Chapter 2

STUDY AREA

2.1. GENERAL

The Gir Protected Area (PA) includes Gir Wildlife Sanctuary and National Park and is situated between 20° 55' to 21° 20'N and 70° 25' to 71° 15' E in the Southern part of Kathiawar peninsula in western Gujarat. It forms most of what is called the Gir forest or the Gir Conservation Unit (GCU). GCU includes the recently formed Chachai-Pania wildlife sanctuary (39 sq. km) at the northern boundary of Gir PA, and the satellite reserved forests (most of them grasslands). Gir PA (hereafter Gir) is located about 60km South of Junagadh. The area which was 3,107 sq km in 1877 (Joshi 1976) has been presently reduced to 1,412 sq km, of which about 259 sq km is national nark. The national park starts three km from Sasan in the west and ends one km short to Banej in the east. In the north it touches almost the middle of Gir from Chhodia upto Kankai, and protruding further in the north to Sap *nes* in north-east of Kankai, and in the south its boundary from Khokhra-II runs parallel to that of wildlife sanctuary boundary through Janwadla (Fig 2.1). Gir has a maximum aerial length of about 80km (W-E) and the maximum width of about 45km (N-S). The boundaries of Gir wildlife sanctuary are described by Patel (1992).

2.2. TOPOGRAPHY AND DRAINAGE

The terrain is hilly, altitude ranging from about 100m above mean sea level (near Jamwala at the southern boundary) to the highest of 528m above mean sea level (Nandiwela hill near Jasadhar in east Gir). The highest hill adjacent to Gir is Sarkala (648m above mean sea level) in the north. The hills run in all directions and have moderate slopes. The terrain includes plateaus such as Vanasali and Jhinjudi in the national park area, and plains such as Karadapan, Janwadla, Dabhala and Jasadhar. The physiography is intersected by seasonal streams locally called in Gir as *Chhel/Sel.*

The hills of Gir constitute the important catchment for Kathiawar peninsula. The major rivers that originate in Gir are Raval[1] (constituted by Jamri and Raval), Singawada (formed by Adak and Singawada), Machundari (formed by Dhramania and Machundari), Hiren, Jatardi, and Popatdi. Of these the first four have been dammed. Except Popatdi which flows north-westward, others flow either southward or south-eastward. This has made the surroundings of Gir, particularly the southern fringe, the most irrigated and productive agricultural tract in Saurashtra peninsula. Even after average monsoon all these rivers contain only pools of water in summer. At present none of the rivers in Gir can be stated as perennial. The Hiren River is perennial only upto about 10km from Kamleshwar Dam (Hiren Dam I).

2.3. GEOLOGY and SOILS

The rocks on hills are volcanic in origin, consisting of Deccan traps and are the oldest exposed rocks in Gir (Patel, 1992). The Deccan trap rocks in the south-west Gir are overlain by miliolite limestone upto a height of 200m. The miliolite limestone is overlain by alluvial soils. The basalt are traversed by Dikes (Dikes - flat tubular bodies which emerge as a result of filling of magma in the vertical and inclined fissures in the earth's crest; Ershov *et al.* 1988) throughout Gir, as is evident due to their emergence on the surface (Patel, 1992).

As many as seven types of soils are categorized based on their colours (Munsell colour chart) ranging from dark yellowish brown to very dark greyish Brown (Pandit *et al.* 1992.). For simplicity, these can be regrouped as alluvial (dark yellowish brown, strong brown or dark brown) red, (dark reddish brown to dark brown) sandy, (dark greyish brown) and black cotton soil (dark brown, very dark brown to very dark greyish brown). The plain & gentle slopes, mainly in the south-west regions of Gir have alluvial soil. Their water holding capacity is less than black soil. Their depth is upto 1m.

---

[1]IMPORTANT: The names of rivers, hills and places and their position are based on Survey of India maps of 1964 survey.

Red soils, all over Gir, occur on hill slopes. Because of their rocky and sandy nature they have poor water holding capacity. Black soils occur on the lower hills, lower parts of high hills and in the valleys. Their depth may be upto 2-3m. These soils have a property of swelling up when wet and retaining water for long periods.

Sandy soil is formed by the depositions along rivers and their tributaries. These are rich in organic matter. The sand content in these soil is very high (63 - 93%) compared to silt and clay. These are alkaline in nature (pH 7.05 to 8.25) (Pandit *et al.* 1992).

2.4. CLIMATE

The climate is semi-arid with three distinct seasons. Summer (March-mid June), Monsoon (mid June - mid October) and winter (late October to Feb.)

The minimum temperature recorded over the years is 4 °C in December and the maximum rises to 45 °C in May-June. The humidity is maximum in monsoon (98) and minimum in summer (24). Most of the rainfall occurs in the months of July, August and September (Fig. 2.2). Average rainfall in Gir is estimated to be about 800mm/year. West Gir receives higher rainfall (about 1000mm/year) than east Gir (about 600mm/year). There is large variation in the annual rainfall. Drought occurs once in 4-5 years and the frequency of drought has increased recently (Patel 1992).

2.5. VEGETATION

Gir has dry deciduous forest - 5A/C1b (Champion & Seth 1968). In eastern Gir *Anogeissus pendula* replaces *Tectona grandis* but the vegetation is dominated by thorny species such as *Acacia* and *Zizyphus*. Puri *et al.* (1989) have classified Gir vegetation similar to *Tectona grandis-Holorrhena antidysenterica* communities. Khan *et al.* (1990) classified Gir vegetation into 11 habitat types.

2.6. MAMMALS

Asiatic lion (*Panthera leo persica*) is the flagship species and management inputs are directed for its conservation. Other carnivores include leopard (*Panthera pardus*), striped hyena (*Hyena hyena*), jungle cat (*Felis chaus*), and rusty spotted cat (*Felis rubiginosa*). Major herbivores in Gir which are also the wild prey base of lion and leopard include sambar (*Cervus unicolor*), chital (*Cervus axis*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella gazella*), chowsingha (*Tetracerus quadricornis*), wild pig (*Sus scrofa*) and langur (*Presbytis entellus*). Other small herbivores are Indian hare (*Lepus nigricollis*) and Indian crested porcupine (*Hystrix indica*).

2.7. PEOPLE

All of the Gir, barring national park is inhabited by *maldharis* about 60 *neses* (hamlets) containing 360 families, about 2550 people and 10,000-12,000 livestock. A *nes* may contain 1 - 10. The huts are made up of branches of *Helicteres isora*, *Syzygium spp.* and *Butea monosperma* supported by teak and bamboo. The roof is thatched with grass, *Syzygium spp.* and *Butea* leaves. In some cases the roof is made up of earthen tiles or tin sheets.

The *maldharis* keep buffaloes and facilitate their feeding by lopping palatable trees during the pinch period in summer. The buffaloes are protected against large carnivores by constructing 1-2m wide and about 1.5m high thorn fence all around. The thorn fence is mainly composed of *Zizyphus spp.* and *Acacia spp.* Sometimes *Capparis sepiaria* and *Carissa carandas* are also used.

The buffalo milk is sold either as such or in the form of clarified butter. After population increase and the resultant forest shrinkage the *maldharis* have given up their nomadic lifestyle. At present they are settled in one place and shift to other places (permanently or temporary) only at the times of fodder and water shortages. One such massive shift took place in 1993-94 when fodder shortage was observed due to less and prolonged rainfall (latter decayed fast much of the grass produced) coupled with extensive forest fires in summer which led to declined grass availability.

In addition to the *neses*, there are 14 forest settlement villages on the periphery of Gir barring two (Jambuthala and Timberva) which are inside. These settlement villages were established before declaring Gir a protected area. The 556 families of these villages consist of about 4,800 people and 4,250 livestock (Pathak *et al.* 1994). The main occupation of the villagers is farming.

Gir is surrounded by about 75 villages within 6km from boundary with a total population of about 80,000 people. There are 206 villages with 1,60,000 people and 1,00,000 livestock within 10km from the boundary. The biotic pressures as a result can be estimated by these figures which also indicate that Gir is more or less an island.

2.8. VISITORS

Gir receives three kinds of visitors. First visit Gir for seeing lions. There number is about 30,000 per annum and most of them visit during three periods i.e. Oct-Nov (Diwali vacation), Dec-Jan (X-mas vacation), and May-Jun (summer vacation). Secondly, there are travellers passing through Gir via three state highways namely, Sasan-Visavadar (12km in Gir), Kodinar-Dhari (29km), and Una-Dhari (22km). Regulations are, however, maintained on the traffic in one way or the other. There is a 12km long metre gauge railway in Gir from Sasan to Kansia along which six trains pass through daily, four of them being powered by steam locomotives.

Third and perhaps the most harmful category of visitors is that of pilgrims visiting Kamleshwar, Kankai, Patla-Mahadev, Banej and Tulsishyam temples. There is a constant danger from the temple authorities due to their ambitious plans to expand their infrastructure and, because they can get support from people to achieve this. The annual average number of such visitors is estimated to be about 1,00,000 (Pathak *et al.* 1994), most of them coming during festival times.

2.9. RESEARCH INPUTS

Gir has a long history of research and the studies conducted so far include both the animal and plant component of Gir. Some of the vegetation studies are mere compilation (Santapau and Raizada 1954, 1956), and productivity of a few tree species in parts of Gir (Habibullah 1983, Rao 1983). Hodd (1969) provides information about effect of ungulates on grass community.

Studies on animals include observation on lion by Dharmakumarsinhji and Wynter-Blyth (1951) and Dharmakumarsinhji (1968). Joslin (1973) studied the behaviour and ecology of lions and Berwick (1974) investigated the habitat utilization by and feeding behaviour of ungulate community in Gir. The latter two studies mention that a number of biotic factors like livestock, human settlements and fuelwood collection have a significant impact on the vegetation. Other studies include that of Sinha (1987) on general descriptive ecology of the Gir.

Patel (1992) carried out the first intensive study on the geology of Gir including the quantification of mineral composition of soil and water. According to him Gir is comprised of vast tracts of lava flows. He has attempted to establish the relationship among geomorphology, soils, water and, vegetation and has suggested methods for storing and harvesting water.

The Wildlife Institute of India has recently carried out four studies: ecology of ungulates, the predation and ranging patterns of lions, lion-human conflicts, and habitat selection by pea fowls. The first study has concluded that heavy cattle grazing results in adverse effect on wild ungulates in the sanctuary portion as a result of disturbance, immediate resource suppression and long term changes in vegetation (Khan *et al.* 1990). This study concluded that these changes could severely affect long term conservation of the lions. The second study suggests that lion seems to be indifferent to the vegetation density while hunting (Ravi Chellam, 1993). In the third study Saberwal *et al.* (1994) investigated the reasons behind lion-human conflicts. The fourth observed that water, food, predator avoidance, and topography are the important parameters in habitat selection by peafowl, *Pavo cristatus* (Trivedi 1993). He recorded high peafowl abundance near water and in less dense vegetation with low grass height.

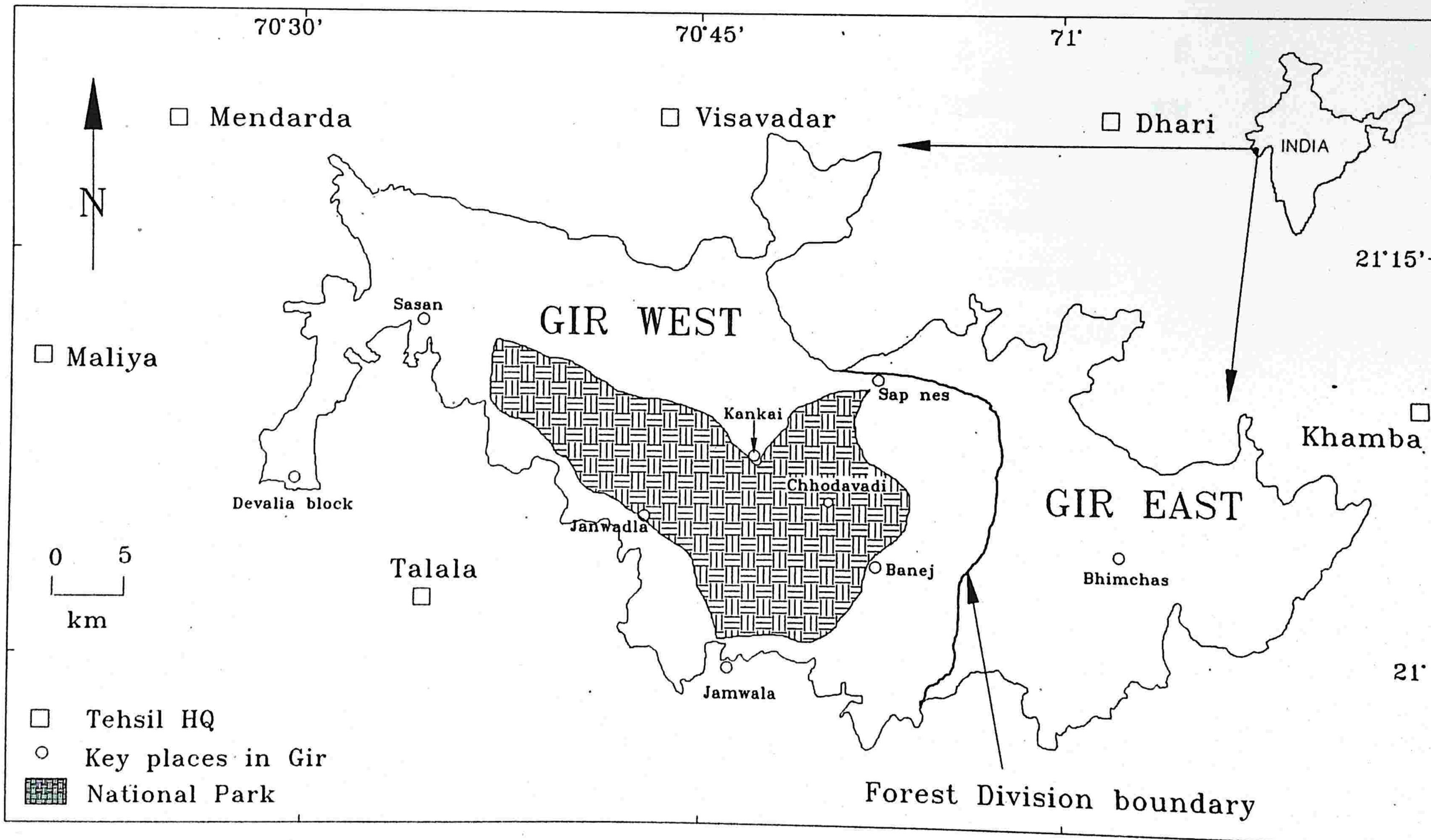


Fig. 2.1. Gir PA showing national park and administrative division of west and east Gir wildlife sanctuary.

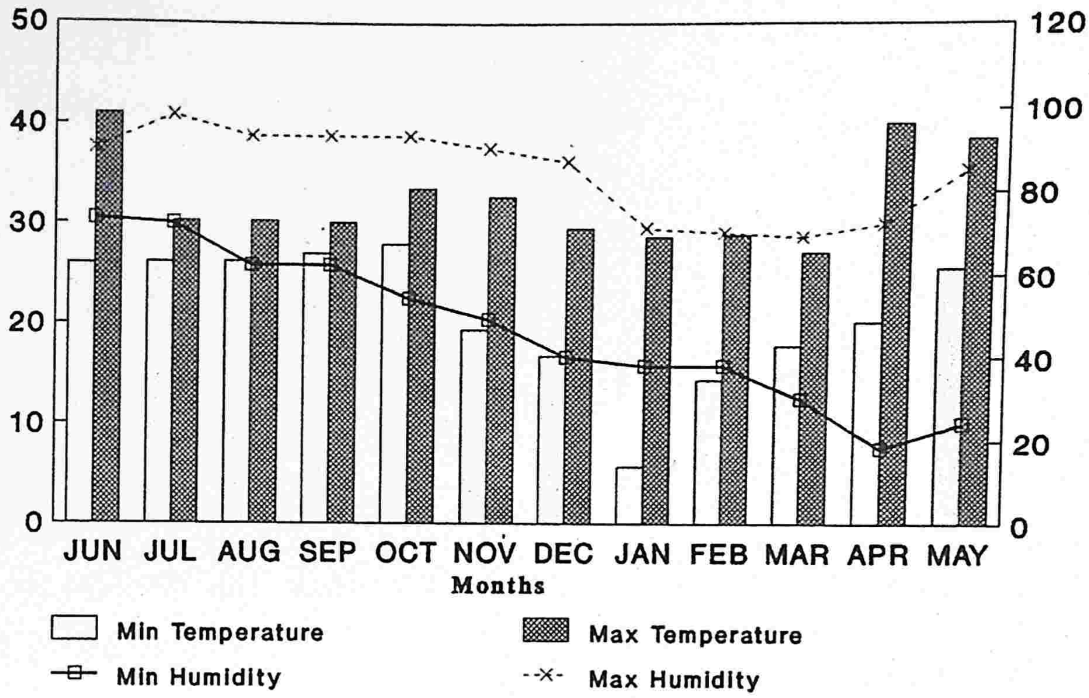


Fig. 2.2. Minimum and maximum temperature and humidity in Gir from June 1993 to May 1994.

Chapter 3

METHODS

Field work was carried out from June 1991 to July 1994. Except for three weeks in September 1991, 1992 and 1993; two weeks in December 1991 and 1992, and three weeks in February 1992 all time was spent in the field. Methods were evolved according to the objectives of the study, and the time, material and man-power available.

3.1. SELECTION OF STUDY SITES

A total of 211 study sites, each 20m X 20m, were selected during three sampling phases (Fig 3.1). Nested plot technique (Mueller-Dombois & Ellenberg 1974) was used for determining the minimum area of vegetation plot required for the tree, shrub and seedling data.

In the first phase, sampling was done systematically to select old *nes* sites based on forest records revealing evacuation time of the *nes* and the administrative division in which the *nes* was situated, followed by a survey in March-April 1991. Since it was not feasible to study all the sixty evacuated *neses*, fourteen were selected for intensive study using stratified sampling (stratification based on the period of evacuation). Of these five each were in sanctuary west and east, and four in the national park. A current *nes* with no other such *nes* nearby was also selected in west Gir for this study.

The second phase of sampling was done to study the impact of *nes* at varying distances on vegetation, and for vegetation types. The impact of *nes* on the surrounding vegetation at varying distances from *nes* was studied in plots selected through stratified random sampling. The stratification was based on the period of evacuation and distance from a *nes*. Around a *nes* the plots were selected randomly from the 1:50000 scale Survey of India Map. This included dropping 15 pebbles, each about 2-3mm in size, from 50cm height above the evacuated *nes* position on the map and taking into account only the four nearest to the position on map. Choosing the nearest ones ensured that the disturbance due to a current *nes* ,if nearby, was the minimum and effect of evacuated *nes* pronounced. Once in that area, the exact location of the plot was chosen 500 paces away in a direction indicated by the second-hand of a wrist-watch. A total of 60 study sites were selected around evacuated *neses*. This was followed by study site selection along rivers, on hills, in thorny vegetation, in seasonal streams, in savanna and teak forest. All of these were visually distinct vegetation types and 25 study sites were selected.

The hundred sites (15+60+25) selected in these two phases were studied intensively for vegetation and ungulate pellet count data.

The third phase of sampling was to select sites to acquire the minimum sample size for a vegetation type based on running mean method (Mueller-Dombois & Ellenberg 1974). Species included for the running mean methods were decided based on abundance of various species in each vegetation type. For instance, for Teak forest only *Tectona grandis* trees were taken into account while for mixed forest the individuals of all species were included. Third phase sampling was based on the preliminary vegetation map (about 1:50000 scale) prepared by Diwakar Sharma (unpubl.) from aerial photographs of 1984 and ground surveys. Pebbles of 2-3mm of thrown on this map and those falling in required vegetation type were taken in account and their position was recorded with respect to stream, river, hill and name of the locality. For every vegetation type the selection started close to Sasan (base camp) resulting in overall more sampling near it.

3.2. ENVIRONMENTAL FACTORS

Data on environmental factors was collected to study their influence on tree species and vegetation types. Environmental data included factors that could influence vegetation types. These were slope and soil parameters (colour, texture, moisture, water retaining capacity, pH, Electrical conductivity, potash, phosphorus and organic carbon). Data was collected from 113 plots after the total plots (211) were grouped in vegetation categories. Of these the hundred plots were from intensive study sites (selected in first two phases) and 13 more were selected to represent minimum of five plots from some vegetation types. This is because these vegetation types had relatively few intensive study sites than others. Once the plots were grouped and listed (in same order as they were selected) according to vegetation types, site were chosen randomly from the list for environmental data collection.

3.2.1. Slope Measurement

Slope was measured using a modified protractor ('D') having a pendulum at the centre. The straight side of the 'D' was aligned with the slope to be measured. The reading to which the pendulum pointed was recorded as the angle of the slope. The slope was classified into categories: 'level-almost level' (0-1°), 'gentle' (2-5°), 'moderate' (5-10°), 'moderately steep' (10-18°), 'steep' (18-30°) and 'very steep' (30-40°) (Young 1972) .

3.2.2. Soil Parameters

Soil samples were taken from a depth of 15cm. The samples were collected in February 1994. Each soil sample from a pit was thoroughly mixed and a core sample of about 400g was collected in polythene bags which were sealed and brought back to the field laboratory the same day. From every sample, 200g was kept in a paper bag and dried in an oven for 72 hours at 80 °C. The deference in wet and dry weights gave the moisture content. Soil colours were determined using the Munsell Colour Chart (1954).

The analysis for pH, electrical conductivity, phosphorus, potash and organic carbon was carried out by the Soil Testing Laboratory of Gujarat Agriculture University, Junagadh.

Soil texture was determined by analysing particle size distribution or mechanical analysis of soils (Dewis 1984). For this a 50g oven dried (at 105 °C for 24 hours) sample was passed through ASTM sieve number 10 (2mm mesh size) to separate coarse. Subsequent sieve numbers 20 (0.85mm), 40 (0.42mm), 60 (0.25mm), 120 (0.12mm), and 350 (0.005mm) separated particles of different sizes on washing the samples through the sieve with water.

Since clay is negligible in the soils of Gir (Pandit *et al.* 1992, Patel 1992), the minimum sieve size used (350) was sufficient to separate fine silt (particle slightly bigger than clay) from other particles (Zonn 1986).

3.3. VEGETATION PARAMETERS

3.3.1. Density

Individuals of all trees (woody plants with a straight bole and with girth more than 20cm at breast height (1.3m) and shrubs (woody plants without clear stem and with profuse branching near the ground - Mueller-Dombois & Ellenberg 1974, p 474) were counted in the 20m X 20m vegetation plots. Seedlings/saplings (woody plants with straight bole and with GBH ≤20cm) were recorded only in 10m X 10m plot as found from nested plot technique (Mueller-Dombois & Ellenberg 1974). Other data on trees and seedling included the status (lopped, cut, dead or alive) and coppicing.

3.3.2. Status

Status (lopped, cut, dead or alive) provides a good estimate of the level of disturbance in an area and also the environmental conditions. Dead was if the individual lacked green leaves during monsoon and/or the bark was peeling off the stem; cut was if an individual was cut from the main stem at height of about 1m; lopped was if only the branches of an individual were cut and, intact was if none of the above happened.

3.3.3. Coppicing

A tree species was recorded as coppiced if multiple stems emerged from the ground. In the case of seedlings it was confirmed by digging the ground and finding out whether multiple stems erupted from a single root. Another coppicing noticed was the growth of a tree/seedling from a dead tree.

3.3.4. Cover Estimation

Cover (grass/herb, shrub and canopy) was estimated from five fixed 1m X 1m quadrats. Vertical grass/herb and shrub cover at three height levels (0.5m, 1.0m and 1:75m) from the ground was measured using a modified cover density board - a 40cm X 20cm wide check-board with 32 squares. The measurement was based on the obstruction of vision (Wight 1930). For this the check-board was held by a person 15m away at 0.5m, 1.0m, and 1.75m height and observed from five fixed 1m X 1m quadrats in 100 vegetation plots. The number of check-board squares visible were counted. Larger distances resulted in generally low visibility and shorter distance in high in all vegetation types. Fifteen meter distance provided acceptable results for all vegetation types. Obstruction of vision was calculated by subtracting the visible squares from total squares and converting into percentages. The obstruction provided the estimates of cover at three heights.

Since shrub density alone does not provide a good estimate of shrub cover, shrub volume was taken as another variable. Shrub volume was calculated from data on length, height and depth of individual shrubs.

Canopy cover was measured from the quadrats using a spherical densiometer. It is a grided convex mirror with 24 grids each having four equidistant dots which were marked temporarily. The densiometer was held at elbow height and the number of dots covered by the leaves were counted. These numbers were converted into percentages.

3.4. UNGULATE HABITAT UTILIZATION

Ungulate habitat utilization was studied by counting pellet groups in and around 100 vegetation plots selected in first two phases of sampling, and through vehicle transects in the months of May and June of 1992, 1993 and 1994. Data on habitat utilization was collected for chital, sambar, nilgai, chinkara, chowsingha and wild pig. Both, sightings and pellet groups of chowsingha and wild pig, however, were too few for analysis and drawing conclusions. Pellets of different ungulates were distinguished based on shape and size.

3.5. TEMPORAL VARIATION

Temporal variations in cover values was studied in summers (April to May) of 1991, 1992 and 1993, and winters (December to mid-January) of 1991-92, 1992-93 and 1993-94. This data was not collected during monsoon (June-September) as this season has abundant cover, food and water every where in Gir. In this study the emphasis was to find out the habitat utilization in winter and summer.

3.6. ANALYSIS

The analysis of the pooled data was based basically on the difference among groups of vegetation, varying distances from *nes* and water, and between national park and wildlife sanctuary, and seasons. Therefore, pooled data from all the study sites was used for each of these analysis, e.g. sites selected for vegetation types were used also to study the impact of *nes* at varying distances and vice-versa.

The selection of sample number based on running mean method (Mueller-Dombois & Ellenberg 1974) resulted in unequal sample size. The large within group variation than between groups variation made most of the data unfit for parametric statistical analysis particularly parametric Analysis of Variance (Bartlett-Box test for homogeneity of variance - Sokal & Rohlf 1981). Hence, non-parametric statistical analysis was mostly used. Statistical analysis of the data was done using SPSS/PC (Marija 1990). To test the significance of variation among different vegetation associations, habitat types, and varying *neses* from disturbance and water, Kruskal-

Wallis test was used (more than two independent samples). The difference in two seasons or groups was tested using Mann-Whitney statistics (two independent samples). In cases where data was fit for parametric analysis of two groups t-test was done.

Vegetation and habitat classification was done using TWINSPAN (Hill 1979). The relationship of vegetation with environmental factors and that of animals with habitat factors was determined using CANOCO (ter Braak 1988). The significance of these relationships was tested using Monte Carlo permutation test available in CANOCO.

3.7. SUMMARY

Data on vegetation and environmental variables were collected to study the relationship between the two and determine which of the variables governed vegetation distribution. Environmental variables included soil texture, soil nutrients, soil moisture and slope. Habitat utilization by ungulates was investigated through pellet count and vehicle transects. Temporal variation in habitat utilization by ungulates was studied for summer and winter. Data analysis mainly involved non-parametric statistics, and few multivariate techniques.

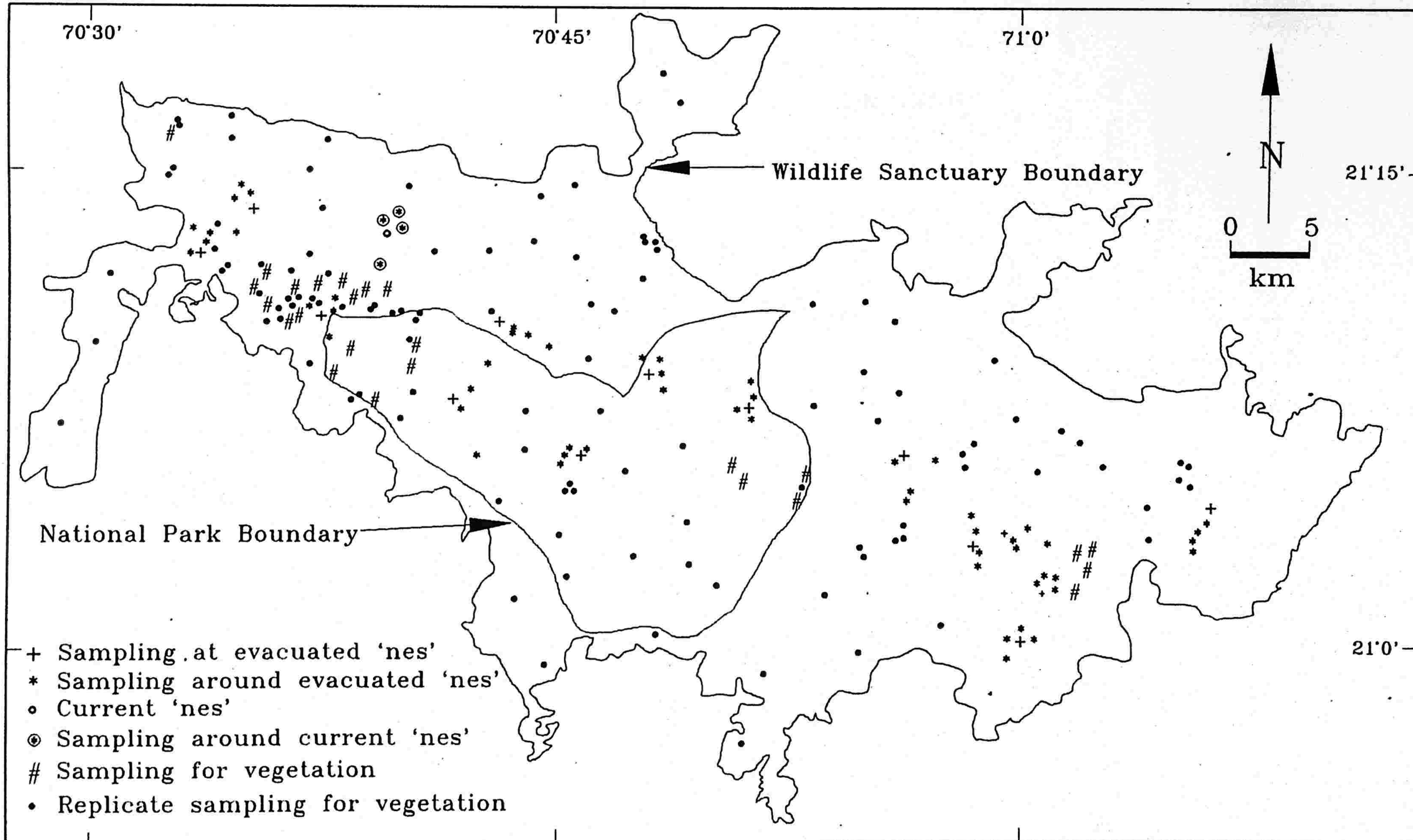


Fig. 3.1. Locations of sampling done in three phases (1–+; 2–* & #; 3–•) for study in Gir.

Chapter 4

VEGETATION STRUCTURE AND CLASSIFICATION

4.1. INTRODUCTION

The study of plant communities and their relationship with environmental factors is important in devising successful management strategies. There are many situations where vegetation study can be among top priorities of management. These include recognition and definition of different vegetation communities, study of relationship between vegetation and environmental variables and study of vegetation as a habitat for animals.

In this regard synecologists have been of extreme use for protected area management by providing the classification of vegetation. Now the sophisticated multivariate analysis techniques (Hill 1979, ter Braak 1988) provide new insights into vegetation classification, ordination and its relationship with environmental factors.

This chapter describes the vegetation types and some vegetation characteristics in detail. The relationship of the vegetation with environmental variables are studied using multivariate analysis. The environmental variables are not described separately. In the text the vegetation characteristics are not only merged for every vegetation association but are also compared separately and presented in the form of table and/or figures for their easier comparison among vegetation associations. The scientific names of plants are based on Champion & Seth (1968) and Bennet (1987).

4.2. METHODS

4.2(a). Field Methods

Vegetation data was collected in 211 plots of 20m X 20m each (Fig 4.1). Size of the vegetation plot was decided based on the nested plot technique (Mueller-Dombois & Ellenberg 1974). This involved working out an area of 5 X 5 sq. m and recording all species present in it. The sample area was then enlarged twice the original size, then to four and eight times. The additionally occurring species were listed. The sample area was increased till the addition of new species to the list became very few (2-3% of the list).

Of the 211 plots, 100 were intensively studied for trees, seedling/sapling, shrubs and ground layer enumeration and cover data. Ground cover data included the species and number of ephemeral herbs/shrubs/grasses. In the remaining 111 plots data only on the tree density and status was collected (see 3.1 for more detail).

Shrub cover was measured in two ways. Firstly, the shrubs were enumerated species-wise and their density calculated; secondly, length, depth and height of all the shrub species in a plot were recorded. The dimensions were later used to calculate the shrub volume.

Environmental data was collected from 113 location all over Gir. All of these location were in vegetation plots. The selection procedures is explained in 3.2. This included soil parameters (pH, electrical conductivity, potash. phosphorus, organic carbon, moisture, water retaining capacity, texture and colour) and slope (slope of hill and vegetation plot).

4.2(b). Analysis

Vegetation classification involved three steps - Important Value Index (IVI) calculation, manual classification, and TWINSPAN (Hill 1979) analysis. The IVI calculation was based on the relative density, relative dominance in basal area and relative frequency of species. Manual classification was based on Braun-Blanquet's floristic association system (Mueller-Dombois & Ellenberg 1974).

After spending about 18 months in the field and knowing the vegetation composition, analysing the data manually and through IVI calculation, the input parameters in TWINSPAN were changed from defaults to get the best possible results. The use of TWINSPAN for this data started when 96 vegetation plots had been selected and it continued till the end. The changes in TWINSPAN outputs resulting from varied input parameters, and increasing number of plots were studied carefully. The following input parameters were opted for the final analysis in TWINSPAN.

The pseudospecies cut levels for abundance were chosen as:

0	-
1-5%	1
6-25%	2
26-35%	3
36-66%	4
>66%	5

instead of default 0, 1-2%, 3-5%, 6-10% and 11-20% cut levels to reflect typical value of species abundance in Gir. A pseudospecies is quantitative equivalent of a differential species (one with a clear ecological preference) e.g. for species *Zizyphus nummularia*, pseudospecies *Zizyphus nummularia*2 means *Zizyphus nummularia* with 6-25% abundance. The presence of differential species can be used to identify particular environmental conditions. 'The idea of differential species in essentially qualitative..' (Hill 1979) and hence pseudospecies is used for quantitative data.

A weightage of 2 was given to the highest pseudospecies cut level and all the other cut levels were given a weightage of 1. The level of division was decided to bring into attention the species with high abundance (>66%) and help identifying the associations with dominance of such species.

Canonical Correspondence Analysis (ter Braak, 1988) was done to determine the relationship between environmental factors and the vegetation association and the plant species. Monte Carlo permutation tests were used to determine whether the canonical axes were significantly related to environmental variables.

Diversity measurements are seen an indicators of the well being of ecological systems (Magurran 1988). An ecosystem with more diversity is supposed to be better than others. That is why in spite of considerable debate about its measurement diversity has been a central theme in ecology. Considering this following diversity indices were measured in this study.

Species diversity in a vegetation association was measured by widely used Shannon-Wiener index (Pielou 1975, Magurran 1988), i.e.

$$H'=-\sum p_i \log p_i$$

where:

H' = Shannon Wiener diversity index

p_i = Proportion of i^{th} species in a community.

Species richness was calculated using the Menhinick index (Magurran 1988).

$$R=S/\sqrt{N}$$

where,

R = Species richness

S = number of species in a community

N = number of individuals of all species in a community.

Species evenness (i.e. species with equal or virtually equal abundance) was calculated through index J (Magurran 1988)

$$J=H'/\log S$$

where:

J = Evenness index

S = Total number of species in a community

Distribution pattern of species was calculated using variance to mean ratio (Pielou 1977). The mean and variance of species per plot was calculated from the number of individuals of a species in all the vegetation plots. If variance to mean ratio was less than 1 the distribution is random, if equal to one, it is uniform, and if the ratio is more than one the distribution is clumped.

Non-parametric Kruskal-Wallis ANOVA was applied to determine the statistical significance of the differences in various factors among the vegetation types. Non-parametric statistics had to be used because of data being not uniformly distributed, unequal sample sizes in different groups and high within group variation than between group variation as shown by test for homogeneity of variance (Bartlett-Box F test - One Way Analysis of Variance at $p<0.05$).

4.3. RESULTS

4.3.1. Vegetation Classification

TWINSPAN analysis resulted in fifteen major vegetation associations in Gir. Table 4.1 shows the classification of vegetation associations and species by TWINSPAN and Fig. 4.2 presents this graphically with eigen values and indicator species at each division. A list of plant species recorded in vegetation plots is given in Appendix 1. In Table 4.1 species "*Zizy nummularia*" is good differential species and its presence only in the left side of division (upper part) is strongly indicative of relatively drier conditions. Similarly, the species "*Car carandas*" is another good differential species on the right side of the division (bottom part) and is indicative of relatively moist conditions. The vegetation associations are described below in the same order as in Table 4.1. All the vegetation associations, except two, contain two or more species in the nomenclature hence justifying the name 'associations'. In two vegetation associations one species comprised more than 75% of vegetation, and there was no other species always occurred with it.

Quantitative results are presented in the form of mean±SE (standard error of mean at 95% confidence interval) followed by n i.e. sample number.

4.3.1.1. ***Acacia catechu - Zizyphus nummularia - Aristida adscensionis* (AZA) association:** This association occurred as an early seral stage after heavy disturbance (grazing). The localities where this association occurred soil was brown to dark brown, thin layered, and the bed rock was exposed at certain places. The terrain was undulating and the slope was gentle to steep. There was no upper canopy. The scanty understorey was composed of *Acacia catechu, Acacia nilotica, Acacia leucophloea* and *Zizyphus mauritiana*. These occurred occasionally and did not form more than 25% of the association. The shrub species encountered were *Capparis sepiaria* and *Zizyphus nummularia*. Ground layer mostly consisted of *Aristida adscensionis* and *Cassia tora*. Mean tree density was 280±60 trees per hectare (n=11) and seedling density was observed to be 1233±357 individuals per hectare (n=6). Mean diversity and evenness were 1.4±0.11 and 0.76±0.04 respectively. The average shrub density was 291±66.3 clumps/ha. The average shrub volume was measured to be 985±146 cu. m/ha.

4.3.1.2. ***Apluda mutica - Themeda quadrivalvis - Sehima nervosum* (ATS) association:** This association was dominated by grasses and was observed in localities which were burnt regularly, had shallow soils (<30 cm), and at gentle to steep slopes or hill tops. The soil colours were brown, dark brown, dark reddish brown and dark reddish grey. On gentle slopes with brown to dark brown soils the upper canopy occasionally had *Tectona grandis* and *Terminalia crenulata*. Understorey had scattered *Acacia spp.*, *Zizyphus mauritiana* and *Bauhinia racemosa*. In the ground layer, mostly *Apluda mutica*, *Themeda quadrivalvis*, *Sehima nervosum* and *Heteropogon contortus* grasses and *Neurocanthus sphaerostachys* (an ephemeral stick shrub) were found. If the soil was red brown, and the locality was heavily grazed, *Aristida adscensionis* dominated with patches of *Heteropogon contortus*. Under growth (shrub layer) was composed of scanty *Capparis sepiaria*, *Carissa carandas* and *Zizyphus nummularia* all of which did not always occur together.

Mean tree and seedling densities observed were 195±31/ha (n=7) and 2550±851/ha (n=6) respectively. Species diversity and species evenness were 1.42±0.15 and 0.71±0.06. The average shrub density and shrub volume were 15±5 clumps/ha and 17±16 cu. m/ha respectively.

There were localities where *Heteropogon contortus* occurred upto 25% and other associates was *Sehima nervosum.*

4.3.1.3. ***Anogeissus latifolia* - *Acacia spp* - *Terminalia crenulata* (AnATr) association:** This association was confined to undulating terrain with gentle to moderately steep slopes of east Gir. The soils were brown, reddish brown, dark reddish brown and very dark greyish brown. Other associates were *Dichrostachys cinerea, Flacourtia indica, Bauhinia racemosa* and *Boswellia serrata* (on red soils). The upper canopy had stunted *Terminalia crenulata.* All the other trees formed the understorey. Undergrowth sometimes had *Capparis sepiaria, Carissa carandas* and *Zizyphus nummularia.* The ground layer had patches of *Neurocanthus sphaerostachys.* The composition of most of the co-associates was not more than 25%. *Anogeissus latifolia, Acacia spp.* and *Terminalia crenulata* usually formed about 10% to 35%, although, *Anogeissus latifolia* reached about 66% in few cases. The mean tree and seedling densities were 361±103 (n=7) and 433±88 (n=3). The species diversity and evenness were calculated to be 1.87±0.13 and 0.91±0.02. The mean shrub density and shrub volume were 158±58/ha and 685±533 cu. m/ha.

4.3.1.4. ***Anogeissus latifolia* - *Acacia catechu* (AnA) association:** This was found at the undulating terrain with gentle to moderate slopes in east Gir. Soils were yellowish brown, reddish brown and dark reddish brown. *Anogeissus latifolia* composed about 25% to 66% of the vegetation and rest was shared by various *Acacia spp.*. Other understorey tree species were *Wrightia tinctoria, Grewia tiliaefolia,* and *Catunaregam uliginosa. Zizyphus nummularia* was recorded in the undergrowth. The ground layer had *Neurocanthus sphaerostachys.* The mean tree and seedling densities were 488±64/ha (n=6) and 1075±269/ha (n=4). The mean diversity and evenness values were 1.46±0.12 and 0.77±0.03 respectively. Average shrub density was 31±12.5/ha and average shrub volume was 104±89 cu. m/ha.

4.3.1.5. *Acacia spp - Zizyphus mauritiana* (A sp) association: This association comprising mainly thorny species covered a wide range of soil types in Gir. It occurred on level to moderately steep slopes. The soil colour types were yellowish red, dark yellowish brown, brown, dark brown and very dark greyish brown. Sometimes, *Acacia spp.* dominated the association. Occurrence of upper canopy species was rare. Except in cases where *Acacia spp.* dominated the community, this association was observed mostly in the vicinity of *neses*. *Zizyphus nummularia*, *Capparis sepiaria* and *Carissa carandas* were found in the undergrowth, but they did not occur together. The ground layer had *Achyranthus aspera, Neurocanthus sphaerostachys* and *Cassia tora*. This and the following two associations were seral stages about 20 years after the evacuation of *nes*. The mean tree and seedling densities were found to be 295±30/ha (n=34) and 1258±329/ha (n=19) respectively. The mean species diversity was 1.32±0.06 and mean species evenness was 0.83±0.02. The average shrub density and shrub volume were 57±33/ha and 623±369 cu. m/ha.

4.3.1.6. *Zizyphus mauritiana* (Zm) association: This association was observed at few places in Gir where soil was brown or very dark brown, shallow (less than 30 cm) and where the locality was heavily disturbed in past. It was restricted to gentle slopes. Upper canopy was absent and *Zizyphus mauritiana* composed almost 100% of the understorey. Undergrowth had occasional *Capparis sepiaria*. The ground layer was composed of clumps of *Neurocanthus sphaerostachys*. The mean tree density was 325±101/ha (n=3) and mean seedling density 2867±1875/ha (n=3). The mean species diversity and species evenness were calculated to be 0.67±0.13 and 0.69±0.05 respectively. The average shrub density and volume were 25±8/ha and 94±71 cu. m/ha.

4.3.1.7. *Acacia nilotica - Zizyphus mauritiana* (AZ) association: This was a very restricted association observed at very gentle to moderate slopes. It occurred at dark brown and very dark greyish brown soils, mostly in the vicinity of rivers. The undergrowth was composed of *Capparis sepiaria*. The ground layer had *Cassia tora* and *Achyranthus aspera*. The mean tree density was 131±40/ha (n=4) and seedling density 4800/ha. The average species diversity was 0.77±0.16 and the mean species evenness 0.77±0.17. The average shrub density and shrub volume was 225/ha and 76 cu. m/ha.

4.3.1.8. *Tectona grandis - Acacia catechu - Zizyphus mauritiana* (TAZ) association: This association occurred on brown, dark reddish brown, dark brown, dark reddish grey and very dark greyish brown soils on very gentle to moderate slopes in west Gir. The upper canopy was consisted of *Tectona grandis*. *Acacia catechu* and *Zizyphus mauritiana* were dominant in understorey. The other co-associates were *Acacia leucophloea*, *Acacia nilotica*, *Bauhinia racemosa* and *Wrightia tinctoria*. Undergrowth had scattered *Carissa carandas*, *Capparis sepiaria*, and *Zizyphus oenoplia*. Ground layer consisted of *Neurocanthus sphaerostachys*, sometimes *Achyranthus aspera*, *Apluda mutica*, *Heteropogon contortus* and *Themeda quadrivalvis*. The tree and seedling densities were found to be 388±61/ha (n=15) and 1775±536/ha (n=8) respectively. The species diversity and species evenness were calculated to be 1.2±0.07 and 0.80±0.04 respectively. The average shrub density was 28±8/ha and shrub volume was calculated to be 697±376 cu. m/ha.

4.3.1.9. *Tectona grandis - Acacia catechu - Terminalia crenulata* (TATr) association: This association occurred on the gentle to moderate slopes in west Gir where the soil was dark reddish brown and dark brown. *Tectona grandis* and *Terminalia crenulata* formed the upper canopy. The understorey was mainly composed of *Acacia catechu* and occasionally *Acacia ferruginea*. The other co-associates were *Acacia nilotica* and *Flacourtia indica*. Undergrowth consisted of *Capparis sepiaria* and, ground layer was composed of *Apluda mutica*, *Themeda quadrivalvis*, and *Neurocanthus sphaerostachys*. The tree density was 390±33/ha (n=17) and seedling density 1513±368/ha (n=8). The species diversity and species evenness were 1.53±0.07 and 0.78±0.03 respectively in this association. The shrub density was 5±1/ha and the volume 9±9 cu. m/ha.

4.3.1.10. *Tectona grandis* (Tg) association: It occurred on very gentle to steep slopes with dark yellowish and dark reddish brown to dark brown soils in west Gir. *Tectona grandis* formed 67% to 100% of the vegetation. The understorey was sparse and was formed of *Acacia spp.*, *Catunaregam spinosa* and *Wrightia tinctoria*. Undergrowth and ground layer were poor. Undergrowth had *Capparis sepiaria*. Ground layer was occasionally formed of *Apluda mutica*, and clumps of *Neurocanthus sphaerostachys*. The tree density was recorded to be 428±75 (n=15) and seedling density 1688±169 (n=8). The species diversity and evenness were calculated as 0.75±0.09 and 0.57±0.04 respectively. The shrub density and volume were 3.6 clumps/ha and 2.3±2.3 cu. m/ha respectively.

4.3.1.11. *Tectona grandis* - *Acacia catechu* - *Lannea coromandelica* - *Boswellia serrata* (TALB) association: The upper canopy species occasionally consisted of *Tectona grandis*, *Lannea coromandelica* and *Terminalia crenulata*. Understorey was dominated by *Acacia catechu* and *Wrightia tinctoria*. *Boswellia serrata* was the only upper canopy species restricted to this type of association on gentle to steep slopes with very thin or negligible layer of soil which were yellowish brown, dark yellowish brown, dark brown, very dark greyish brown, dark reddish grey in colour. The soil type was morum and in many cases the weathered bed rock was exposed. The association mostly occurred on the southern aspects of hill slopes. The other associated species were *Soyamida febrifuga* and *Sterculia urens*. The undergrowth was composed of *Capparis sepiaria* and *Carissa carandas*. Ground layer had clumps of *Neurocanthus sphaerostachys* and *Heteropogon contortus*. The average tree and seedling densities were 565±56/ha (n=13) and 900±204/ha (n=4) respectively. The species diversity and species evenness were found to be 1.83±0.07 and 0.83±0.03 respectively. The mean shrub density was 44/ha and the mean shrub volume 516±516 cu. m/ha.

4.3.1.12. ***Tectona grandis - Acacia spp - Wrightia tinctoria* (TAWr) association:** This association was present in the moist localities on yellowish red, dark reddish brown, dark brown, dark reddish grey and very dark greyish brown soils with basalt boulders. It was mostly at the base of the hills with level to steep slopes. *Tectona grandis* sometimes composed the major part of the association. *Wrightia tinctoria* was the next dominant, although, it formed a part of the understorey. Rest of the vegetation had *Lannea coromandelica*, *Acacia catechu*, *Acacia leucophloea*, *Acacia nilotica*, and *Zizyphus mauritiana*. The undergrowth was composed of *Capparis sepiaria*, *Helicteres isora* and, occasional *Carissa carandas* and *Zizyphus oenoplia*. Ground layer was formed of *Neurocanthus sphaerostachys*. The average tree and seedling densities were 646±51/ha (n=26) and 1240±428/ha (n=10) respectively. The species diversity and species evenness were 1.53±0.05 and 0.74±0.02 respectively. The mean shrub density was 35±15.5/ha and mean shrub volume 125±75 cu. m/ha.

4.3.1.13. ***Tectona grandis* mixed (TM) association:** This association was observed in moist areas with yellowish red, dark yellowish brown, reddish brown, dark reddish brown, dark brown, very dark brown, and very dark greyish brown soils. The slopes ranged from level to moderately steep. *Tectona grandis* formed more than 25% of the association, followed by *Wrightia tinctoria*. Other species in this association were *Diospyros melanoxylon* in the upper canopy and *Emblica officinalis*, *Bauhinia racemosa*, *Zizyphus mauritiana*, *Acacia catechu* and *Grewia tiliaefolia*, all in the understorey. Undergrowth was formed mainly of *Helicteres isora* and *Carissa carandas*. Ground layer was poor with occasional *Neurocanthus sphaerostachys* and *Cassia tora*. The average tree density was 697±60/ha (n=32) and the average seedling density 1500±269/ha (n=13). The average species diversity and species evenness were 1.72±0.06 and 0.79±0.02 respectively. The average shrub density was 90±36/ha and the volume 454±235/ha.

4.3.1.14. Mixed (M) association: This association was observed at dark reddish brown, dark brown, and very dark greyish brown soils in narrow valleys and along seasonal streams (both resulting in moist conditions). This association occurred on almost level to moderately steep slopes. *Tectona grandis, Diospyros melanoxylon, Garuga pinnata, Gmelina arborea* and *Mallotus phillipensis* formed the upper canopy. The understorey was composed of *Catunaregam spp., Zizyphus xylopyrus, Wrightia tinctoria* and *Manilkara hexandra.* Undergrowth had *Capparis sepiaria* and *Helicteres isora.* The latter in some places formed a thick layer. Thickets of *Carissa carandas* became more common and sometimes abundant. Ground layer consisted of *Cassia tora* and *Barleria prionitis.* In east Gir *Tectona grandis* was absent. The average tree density was 739±113/ha (n=9) and seedling density 3433±970/ha (n=6). This association had maximum average species diversity of 2.15±0.25, and average species evenness was 0.80±0.08. The average shrub density and volume were 295±110 and 6567±3066 cu. m/ha respectively.

4.3.1.15. *Syzygium rubicundum - Pongamia pinnata* (SP) association: This association formed a narrow belt along the rivers throughout Gir on moderate to moderately steep slopes. It occurred on very dark greyish brown and black soils. *Syzygium rubicundum, Syzygium cumini, Pongamia pinnata, Mitragyna parvifolia* and *Tamarindus indica* formed the upper canopy. Understorey consisted of *Manilkara hexandra* and *Ixora arborea.* Undergrowth was formed of *Capparis sepiaria* and extensive thickets of *Carissa carandas* which were impenetrable in most places. Ground cover had patches of *Barleria prionitis.* The average tree density was 489±123/ha (n=7) and the average seedling density was the highest of all associations, i.e. 6500±422/ha (n=5). The species diversity and species evenness were 1.47±0.24 and 0.69±0.08 respectively. The shrub density and shrub volume were 280±89/ha and 10846±5291 respectively.

It is noteworthy that there were some species which had wide distribution, although their abundance varied. These were *Bauhinia racemosa, Wrightia tinctoria, Diospyros melanoxylon, Lannea coromandelica, Zizyphus mauritiana, Acacia* spp. and *Capparis sepiaria.* These were mostly present in every vegetation association.

Classification of pooled data from 211 vegetation plots all over Gir is shown in Fig. 4.2. The classification is upto maximum of level 6 (division at eigen values .259, .273, .313 and .427). In many cases the divisions upto level 6 provided same groups as at level 4 or 5, and in others the groups at level 6 were small (with less than 5 plots). In such cases only the divisions at higher level was considered and are presented. This is important to note that at every level the heterogeneity was comparatively more in east Gir (cluster on the right hand side from first division) than in west.

In moving from left to right, the vegetation classification showed that there is a general decline in moisture. For instance, SP (*Syzygium rubicundum - Pongamia pinnata*), M (Mixed), TM (*Tectona grandis* mixed) associations occurred in areas with more moisture while those on the right hand side were found in drier areas. The species list at every division consists of the indicator species for that division. Fig. 4.2 also indicates that the number of misclassifications, particularly for grass species (*Apluda mutica, Themeda quadrivalvis*), were high, e.g. *Apluda mutica, Zizyphus mauritiana* and *Acacia nilotica* were the indicator species of more than one group at different levels and occurred both at positive and negative side of the division.

4.3.2. Vegetation Ordination

The CANOCO results (Fig 4.3, eigen value - axis 1=.34, axis 2=.28) indicated unclarity in many vegetation associations. This ordination reveals that *Acacia spp. - Zizyphus mauritiana, Tectona grandis - Acacia catechu - Terminalia crenulata* associations do not stand clear and cluster near the centre. Distinct clusters were formed only by *Acacia catechu - Zizyphus nummularia - Aristida adscensionis, Acacia nilotica - Zizyphus mauritiana, Zizyphus mauritiana, Tectona grandis, Acacia catechu - Lannea coromandelica - Boswellia serrata* and *Tectona grandis - Acacia catechu - Wrightia tinctoria* associations. The figure also shows the broad spectrum of environmental factors in many vegetation types.

Axis 1 in Fig. 4.3 separated associations based on pH and axis 2 separated vegetation associations roughly on the basis of soil moisture and potash. The correlation between axis 1 and pH was -.95 while that between soil moisture and potash was 0.59 and 0.42 respectively. These two axes, however, explained only 36% of the variation in vegetation associations. Monte Carlo permutation tests for axis 1 eigen value revealed that all these factors were sufficient to explain the variation at $p <.05$ level.

Most of these factors independently accounted for the distribution of a few vegetation associations. The *Acacia catechu - Zizyphus nummularia - Aristida adscensionis*, *Apluda mutica - Themeda quadrivalvis - Sehima nervosum*, *Acacia nilotica - Zizyphus mauritiana*, *Zizyphus mauritiana* and *Acacia spp. - Zizyphus mauritiana* associations were related by less soil moisture, fine sandy and silty soils. *Tectona grandis -Acacia catechu - Zizyphus mauritiana* was associated with sandy soils and weakly with soil moisture. *Tectona grandis*, Mixed and *Syzygium rubicundum - Pongamia pinnata* associations were influenced by medium sandy soils and moisture in increasing order. *Anogeissus latifolia - Acacia catechu*, *Anogeissus latifolia - Acacia catechu - Terminalia crenulata*, *Acacia catechu - Lannea coromandelica - Boswellia serrata* and *Tectona grandis* mixed associations were mainly governed by undulating to hilly terrain.

4.3.3. Vegetation Density

4.3.3.1. Tree and Seedling/Sapling Density

Maximum tree density was found in a plot in *Tectona grandis - Acacia catechu - Wrightia tinctoria* vegetation plot while minimum was in *Acacia catechu - Zizyphus nummularia - Aristida adscensionis*, *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* and *Tectona grandis* associations (Table 4.2). Maximum average tree density was observed in Mixed association and minimum in *Acacia nilotica - Zizyphus mauritiana* and *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* association (Fig. 4.4). The overall variation in average tree density among vegetation associations was significant (K-W χ^2=72.27, P<0.001, n=210).

Maximum seedling/sapling density was in a SP association plot (10100/ha) followed by M while minimum was in a vegetation plot in A sp association (100/ha) (Table 4.2). Average seedling density was maximum in *Syzygium rubicundum - Pongamia pinnata* association and minimum in *Anogeissus latifolia - Acacia catechu - Terminalia crenulata* association (K-W χ^2=33.66, P<0.01, n=104).

4.3.3.2. Shrub Density and Volume

Maximum shrub density (825/ha) was in a plot in M association and minimum (0/ha) in at least one plot each in the eight associations (Table 4.3). Average shrub density was maximum in Mixed and *Acacia catechu - Zizyphus nummularia - Aristida adscensionis* associations and minimum in *Tectona grandis* and *Tectona grandis - Acacia catechu - Terminalia crenulata* associations (Fig. 4.5). The overall difference was significant (K-W χ^2=24.42, P<0.05, n=99).

Maximum shrub volume (30312.7 cu. m/ha) was in a plot in SP association and minimum (0 cu. m/ha) in eight associations (Table 4.3). Average shrub volume, however, was significantly more in *Syzygium rubicundum - Pongamia pinnata* and Mixed associations, and was minimum in *Tectona grandis* and *Tectona grandis - Acacia catechu - Terminalia crenulata* associations. The over all difference was significant (Fig. 4.5) (K-W χ^2=38.44, P<0.001, n=99).

4.3.4. Tree Distribution

The distribution of most of the tree species turned out to be clumped. Those which were randomly or uniformly distributed, were very few in number. The extent of clumping can be estimated by the magnitude by which the distribution pattern increased from 1 (Table 4.4). The most clumped species were *Wrightia tinctoria, Syzygium rubicundum* and *Anogeissus latifolia* followed by *Tectona grandis* and *Screbera swietenioides.*

4.3.5. Extent of Coppicing

Among vegetation associations, maximum tree coppicing (71.4%) was in *Acacia catechu - Zizyphus nummularia - Aristida adscensionis* and minimum in *Acacia nilotica* (0%) and *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* (2%) associations (Fig. 4.6). Maximum average percentage tree coppicing was observed in *Tectona grandis - Acacia catechu - Terminalia crenulata* association followed by *Tectona grandis*, *Tectona grandis - Acacia catechu - Zizyphus mauritiana*, and *Zizyphus mauritiana* associations, while minimum average percentage was recorded in *Acacia nilotica* and *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* associations. The variation in average coppicing was significant (K-W χ^2=35.5, P<0.01, n=105).

Trends in seedling coppicing in the vegetation associations were different from tree coppicing. The maximum coppicing was in *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* (93.3%) and minimum in *Acacia nilotica - Zizyphus mauritiana* (2.0%) association. Maximum average percentage seedling coppicing (Fig 4.6) was in *Anogeissus latifolia - Acacia catechu* association and minimum average percentage again in the *Acacia nilotica - Zizyphus mauritiana* association. The overall variation, however, was not significant at P<0.05.

The extent of average coppicing when analyzed for major species revealed that it was maximum in *Bauhinia racemosa* and minimum in *Acacia catechu* (Table 4.5). The overall variation was significant (K-W χ^2=27.4, p<.01, n=766).

Among species, maximum coppicing in seedling was 100% in *Bauhinia racemosa*, *Wrightia tinctoria* and *Zizyphus mauritiana* in few vegetation plots, and minimum 0% in all the species. Maximum average coppicing was in *Tectona grandis* and *Wrightia tinctoria* and minimum in *Terminalia crenulata* (Table 4.5). The overall difference in average seedling coppicing was highly significant (K-W χ^2=50.7, p<0.001, n=312).

4.3.6. Tree and Seedling Mortality

Among vegetation associations, average tree mortality was highest in *Tectona grandis* and least in *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* association. The average seedling mortality was observed to be greatest in *Syzygium rubicundum - Pongamia pinnata* association and least in *Zizyphus mauritiana* association (Fig. 4.7).

Among species, average tree mortality was maximum in *Terminalia crenulata* and minimum in *Wrightia tinctoria.* Average seedling mortality was highest in *Acacia catechu* and minimum in *Acacia nilotica* (Table 4.6). The overall difference in the average tree and seedling mortality were significant (K-W χ^2=90.6, p<.001, and K-W χ^2=22.0, p<.01 respectively)

4.3.7. Diversity Indices

Maximum tree diversity (2.92) was in a plot in M (Table 4.7) and minimum in *Tectona grandis* (0.1) association (a plantation). Average tree species diversity was maximum in mixed association and minimum in *Zizyphus mauritiana, Acacia nilotica - Zizyphus mauritiana* and *Tectona grandis* associations (Fig. 4.8). The overall variation in tree species diversity was significant (K-W χ^2=92.41, p<.001, n=210).

Maximum tree species richness was in a plot (3.07) in M association and minimum in *Tectona grandis* (.39) (Table 4.8). Average species richness showed trend (Fig. 4.8) very similar to diversity and the overall variation was significant (K-W χ^2=85.77, p<.001, n=210).

Maximum species evenness was in a plot each in *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* and *Tectona grandis - Acacia catechu - Zizyphus mauritiana* (1.0) and minimum in M association (Table 4.7). Average species evenness was maximum in *Anogeissus latifolia - Acacia catechu - Terminalia* *crenulata* and minimum in *Zizyphus mauritiana* and *Tectona grandis* associations. The overall variation was significant (K-W χ^2=44.00, p<.001, n=210).

4.4. DISCUSSION

4.4.1. Vegetation Classification and Ordination

TWINSPAN (Hill 1979) in spite of some limitations is the best available computer programme for classification of species and samples simultaneously. The programme presents the results in a comprehensive two way table. The limitation arise due to its format and the options for analysis. Its limitations in calculations are described in Hill (1979), Greg-Smith (1983), Causton (1988) and Kent & Coker (1992).

In the present case the problems were faced in deciding the pseudospecies (Hill 1979, Kent & Coker 1992) cut levels and the weightage given to them. Even small variations here led to large changes in the output. These problems were sorted out partially by conducting the Braun-Blanquet manual classification with initial 96 vegetation plots (Mueller-Dombois & Ellenberg 1974) and calculation of Important Value Index (IVI) also helped. Both of these provided hints towards the nature and classification of vegetation in Gir. IVI calculations together with field observations suggested that the default pseudospecies cut level (0 2 5 10 20) would not be useful since in 20% of the plots, single species composed more than 66% of the vegetation and 75% plots had species which composed more than 35% of the vegetation.

The vegetation was classified and named based on association concept. This involves communities 'of definite floristic composition, uniform physiognomy and when occurring on uniform habitat conditions', based on the definition of the International Botanical Congress in Brussels in 1910 (Mueller-Dombois & Ellenberg 1974). The criteria of uniform habitat conditions was not fulfilled, as is apparent from the vegetation descriptions, since most of the vegetation associations occurred on various types of habitat. Furthermore, many habitat conditions were common for different vegetation associations. Except this, the association concept at this stage provides best information about Gir vegetation.

A dendrogram of the vegetation classification scaled according to eigen values could not be produced because it turned out to be too complicated to interpret. The first division occurred at an eigen value of 0.440 while most of the subsequent divisions were at higher eigen values leading to complexities in the dendrogram. Instead, a simple unscaled dendrogram served the purpose of presenting the vegetation association with eigen values and indicator species at every division (Fig. 4.2). This method of presentation has been used elsewhere (Forbes 1994). The first eigen values indicated that overall Gir vegetation is homogenous, while at association levels there is heterogeneity. Furthermore, west Gir is less heterogenous than east Gir. This becomes clear from the fact that about 70% of area in Gir is dominated by *Tectona grandis* and its associations, all of which are in west Gir.

It is evident that some of the vegetation associations described above are poorly separated (Fig 4.2 and 4.3). The number of misclassifications (same species occurring at negative and positive side of, and at different divisions) is large, indicating that the vegetation classification is not very accurate. This is also confirmed by the distance between samples within associations which were larger than those between neighbouring associations (Fig. 4.3). It also shows that there were no clear cut boundaries between vegetation associations.

4.4.2. Tree and Seedling Density

It becomes evident that site factors have played an important role in determining the vegetation types in Gir. That is why the well known observation of inverse relationship between canopy and ground cover (Skarpe 1992, Vetaas 1992) does not hold true here. For instance the *Syzygium rubicundum - Pongamia pinnata* association supported largest seedling density, shrub density and volume because of high moisture content in soils. Also it has tree species like *Syzygium rubicundum*, and shrub, *Carissa carandas* which were gregarious in nature.

Tree density seemed to be often characteristics of vegetation associations. Hence, *Acacia catechu - Zizyphus nummularia - Aristida adscensionis* and *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* associations had generally low tree density. In *Acacia* spp. - *Zizyphus mauritiana, Zizyphus mauritiana* and *Acacia nilotica - Zizyphus mauritiana* associations the trees were evenly distributed and the inter-tree distances were relatively large. This larger distance between individuals may be a result of low tree density at least in *Acacia nilotica - Zizyphus mauritiana* association. Most of the localities with this association were the site of *nes* in past and hence the soil conditions were comparatively poor.

Better soil moisture and shade in *Syzygium rubicundum - Pongamia pinnata* association led to better seed germination and hence high seedling/sapling density. But as seedling/sapling grew the lack of space caused high mortality which accounts for comparatively low tree density in this association. Other association that attracted attention was *Anogeissus latifolia - Acacia catechu - Terminalia crenulata* due to lowest seedling/sapling density. In this case hilly terrain, nutrient poor shallow soils, livestock grazing and low rainfall acted synergetically and formed poorest conditions for seed germination.

The shrub cover which should have been a characteristics of *Acacia catechu - Zizyphus nummularia - Aristida adscensionis* association fails to be so. The largest shrub volume was observed in *Syzygium rubicundum - Pongamia pinnata* association due to *Carissa carandas* - a gregarious shrub. *Carissa carandas* was recorded in moist localities and *Capparis sepiaria* was a generalist. Such positive interaction between tree and herb/shrub vegetation has been found by Weltzin & Coughenour (1990) also.

The density estimates of this study are not comparable with Berwick (1974) and Khan *et al.* (1990) because former presented the density only for browse (any woody browse) species while the latter reported the density of trees and shrub based on height and not on life form of species. Therefore, the only study left for comparison is that of Trivedi (1993) who calculated tree density in major habitat types. There is some discrepancy in the density estimates of Trivedi's and the present studies. This difference is due to intensive sampling along transects by Trivedi (1993). These transects were selected in vegetation types based on the preliminary vegetation map prepared by Diwakar Sharma (unpubl.). On the other hand the sampling in the present study was done in three phases all over Gir and vegetation classification was done using TWINSPAN which categorized vegetation based on abundance of species. Therefore, large variation in density has resulted in this study, reflecting the actual variation on ground.

4.4.3. Tree Distribution

It is well accepted fact that natural distribution of plants is clumped and not random as was believed earlier. The pattern of tree species in Gir is no exception to this as indicated by results that the distribution of most of the species is highly clumped. There has been another study in a dry deciduous forest (Hubbell 1979) showing that adult trees were clumped. But Hubbell recorded more clumping in the rarer species unlike in this case where rarer species were randomly or uniformly distributed.

4.4.4. Tree/Seedling Mortality and Coppicing

Results suggest that environmental factors play an important role in tree/seedling mortality. Tree/seedling mortality also depends on the species resistance to environmental changes (Swaine 1992, Crawford 1989). This is the reason why *Acacia catechu*, *Acacia senegal* and *Terminalia crenulata* suffered largest mortality. Although, *Acacia senegal* was observed on rich black cotton soils, it could not survive the drought from 1985-1987 and many trees died and quickly decayed (Khan *et al.* 1994). Similarly, *Terminalia crenulata* suffered heavy mortality due to drought (Khan *et al.* 1994) and also because it occurred on slopes with thin soil. Most of the dead trees of *Terminalia crenulata* and *Acacia catechu* were found at thin red brown and brown soils. The important role of soils in tree survival has also been observed in Sariska Tiger Reserve where more porcupine induced tree mortality was observed at degraded red brown soils (Sharma and Prasad 1991).

High rate of tree coppicing was noticed in species and localities in which large scale cutting occurred in the past. That is why *Tectona grandis* trees which were cut in millions by Gujarat State Forest Department after the cyclones of 1982 and 1984 coppiced profusely. The reason for coppicing is partial death of seedling/sapling due to fire and browsing. Most of the species with high rate of coppicing were browse species.

4.5. SUMMARY

Vegetation classification have identified fifteen major associations in Gir PA. Both TWINSPAN and CANOCO analysis showed that the associations were not clearly defined. TWINSPAN produced two way table in which both the species and vegetation plots were positioned in increasing order of moisture from left to right and from top to bottom. Soil pH was represented by axis 1 while potash and soil moisture were roughly represented by axis 2. The environmental variables were sufficient at P=.05 level to explain the variation in the distribution of vegetation associations. Tree mortality and coppicing was a combined effect of edaphic and climatic factors, and the practices carried out in Gir in the past. Tree dispersion of most species was clumped.

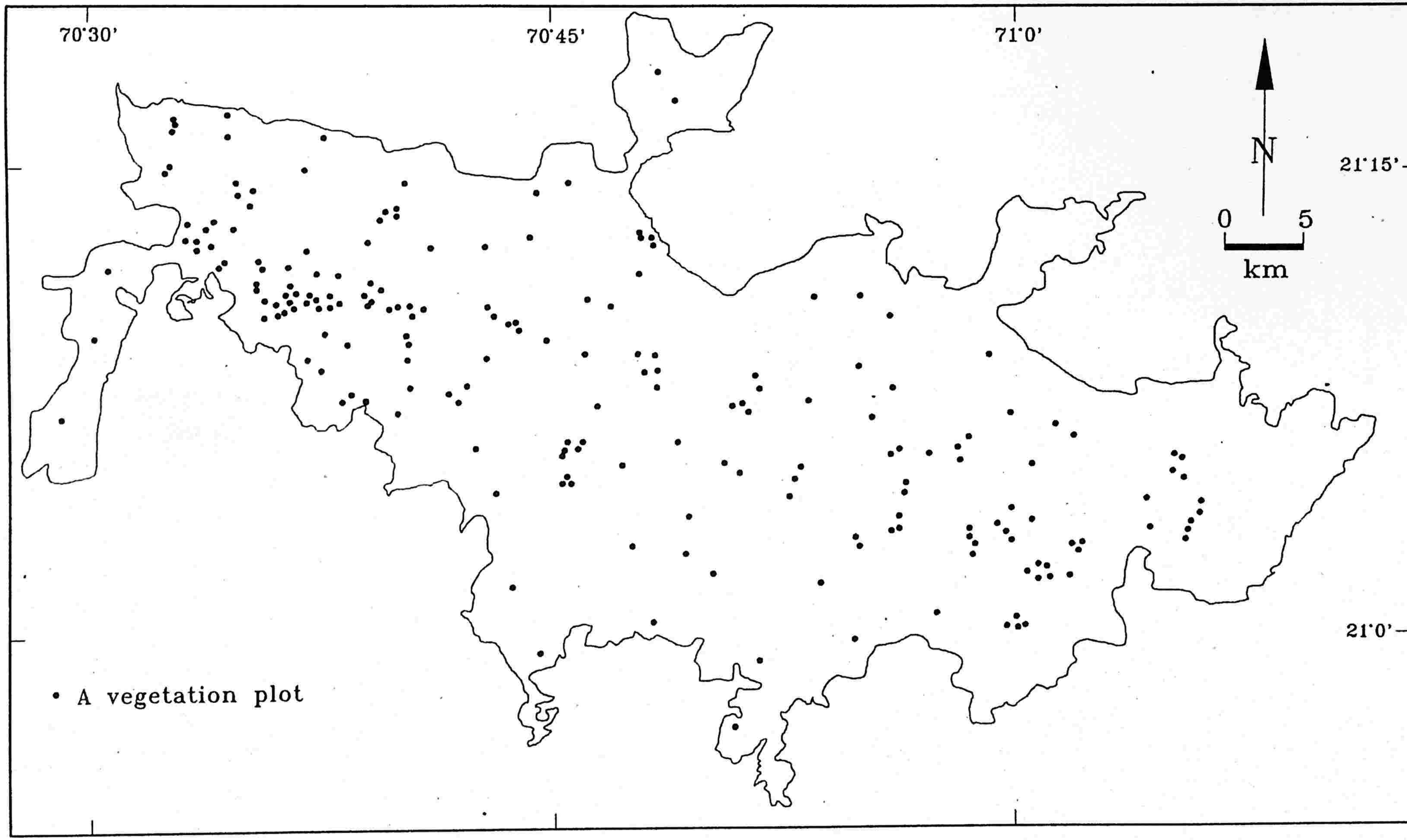


Fig. 4.1 Vegeatation plots in Gir.

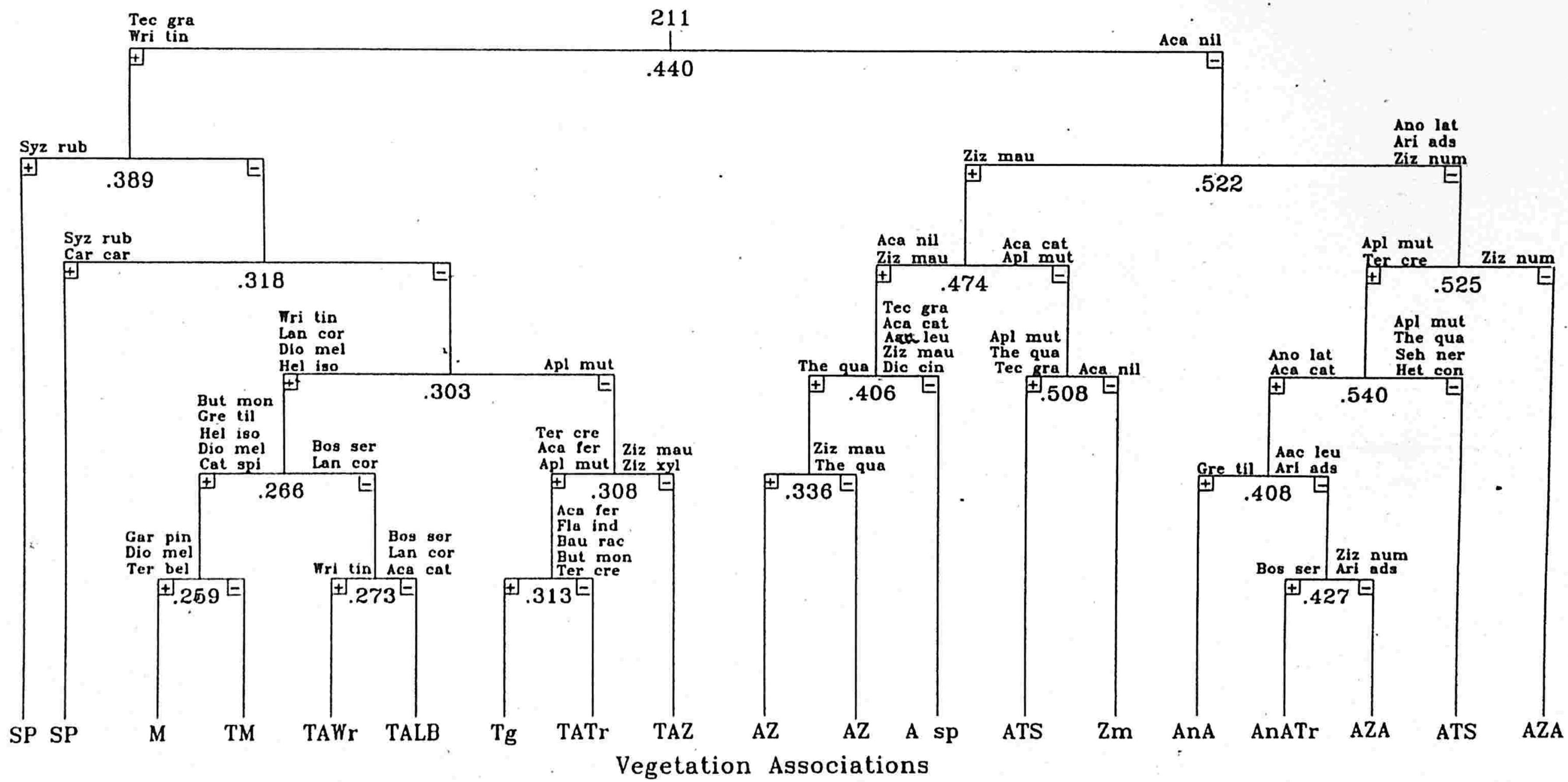


Fig. 4.2. Dendrogram of Gir vegetation classification based on TWINSPAN (Hill 1979). Numbers below each division are eigen values. Indicator species are also shown at each division.

Aca cat = *Acacia catechu*
Aca fer = *Acacia ferruginea*
Aca leu = *Acacia leucophloea*
Aca nil = *Acacia nilotica*
Ano lat = *Anogeissus latifolia*
Apl mut = *Apluda mutica*
Ari ads = *Aristida adscensionis*
Bau rac = *Bauhinia racemosa*
But mon = *Buteá monosperma*
Bos ser = *Boswellia serrata*
Car car = *Carissa carandas*
Cat spi = *Catunaregam spinosa*
Dic cin = *Dichrostachys cinerea*
Dio mel = *Diospyros melanoxylon*
Fla ind = *Flacourtia indica*
Gar pin = *Garuga pinnata*
Gre til = *Grewia tiliaefolia*
Hel iso = *Helicteres isora*
Het con = *Heteropogon contortus*
Lan cor = *Lannea coromandelica*
Seh ner = *Sehima nervosum*
Syz rub = *Syzygium rubicundum*
Tec gra = *Tectona grandis*
Ter bel = *Terminalia bellerica*
Ter cre = *Terminalia crenulata*
The qua = *Themeda quadrivalvis*
Wri tin = *Wrightia tinctoria*
Ziz mau = *Zizyphus mauritiana*
Ziz num = *Zizyphus nummularia*
Ziz xyl = *Zizyphus xylopyrus*

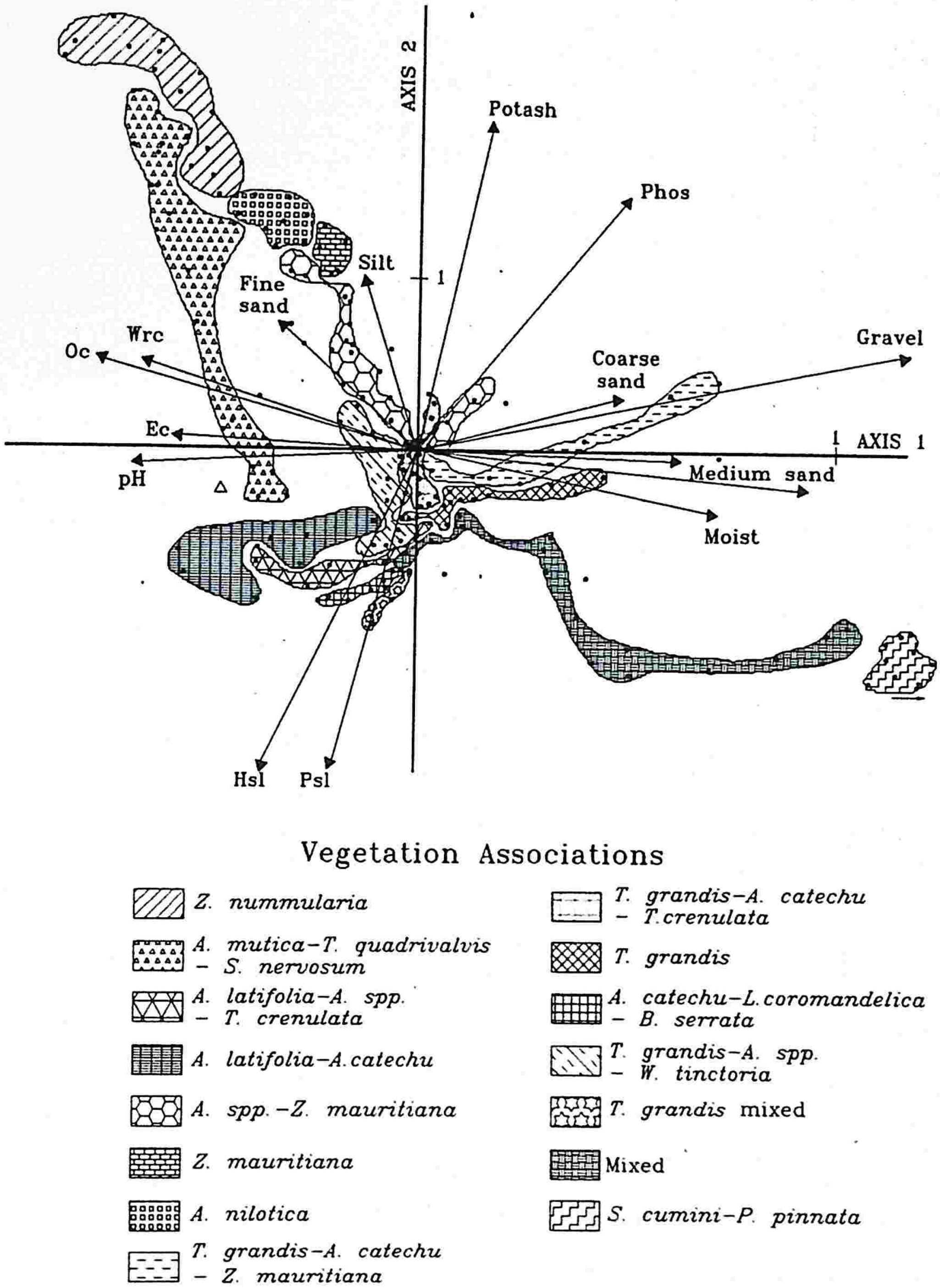


Fig. 4.3. Ordination diagram based on canonical correspondence analysis (CANOCO) of Gir vegetation with respect to five variables; soil texture (gravel, sandy and silty), soil moisture (Moist), water retaining capacity of soil (Wrc), soil nutrients (Potash, Phos, Ec, pH and Oc), and slope (Hsl and Psl). Dots represent the vegetation plots.

Other abbreviations are:

Phos – phosphorus; EC – electrical conductivity; OC – organic carbon; Hsl – hill slope; Psl – slope of vegetation plot location.

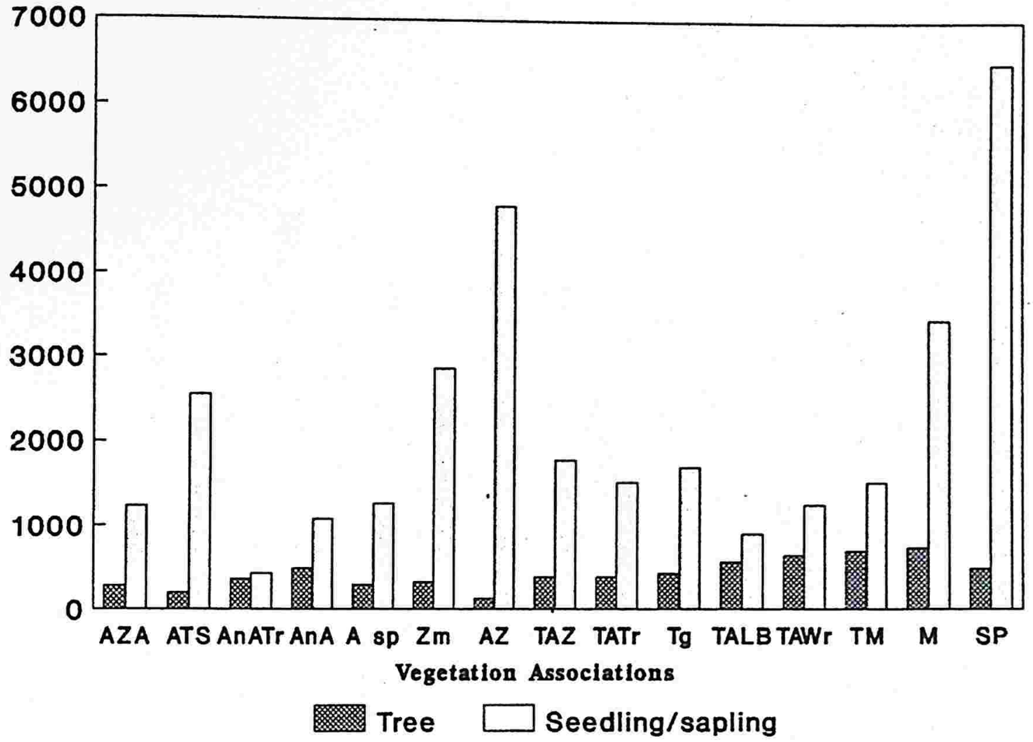


Fig. 4.4. Average tree and seedling/sapling density (number/ha) in vegetation associations in Gir.

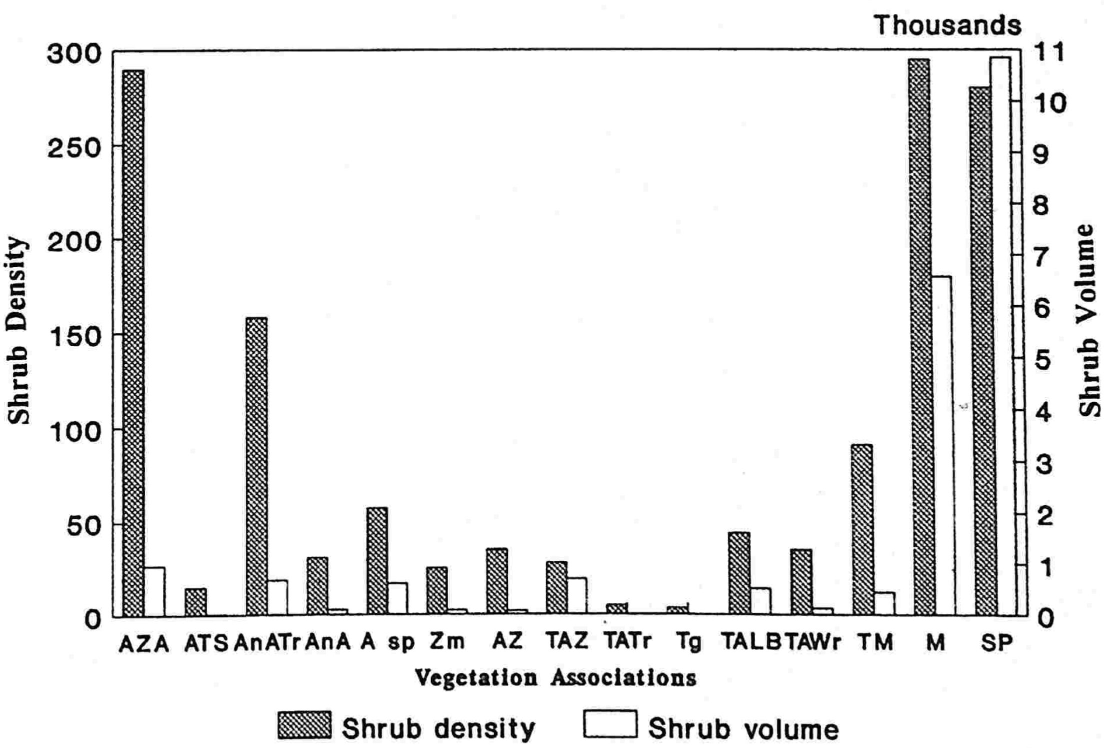


Fig. 4.5. Average shrub density (number/ha) and volume (cu. m/ha) in vegetation associations in Gir.

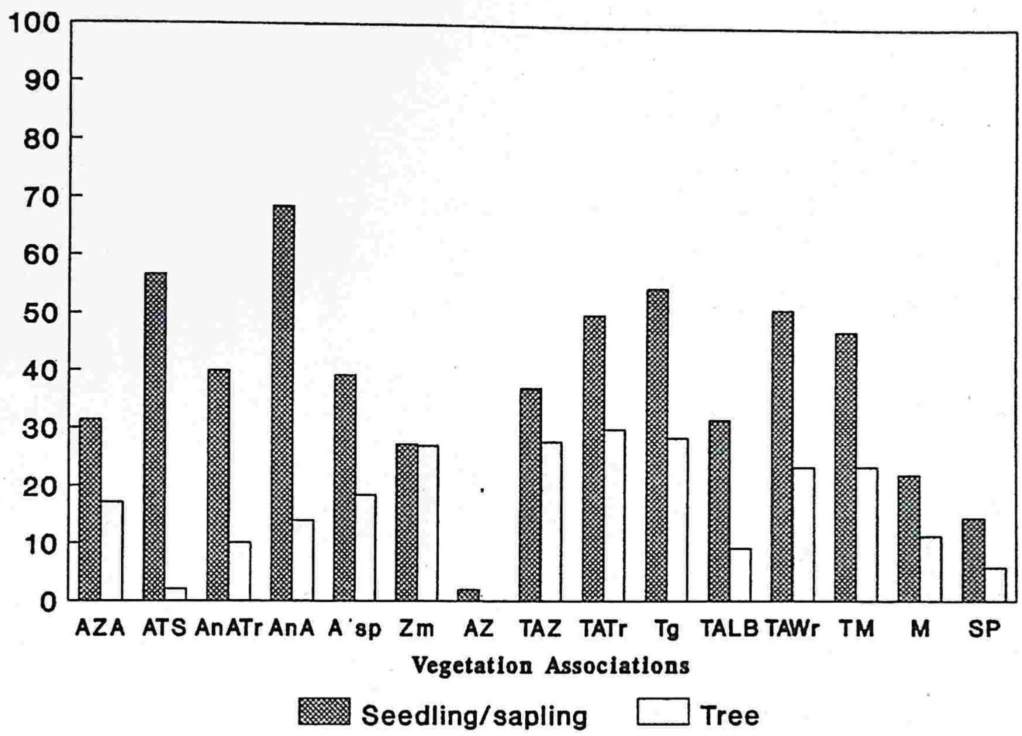


Fig. 4.6. Percentage of tree and seedling/sapling coppicing in vegetation associations in Gir.

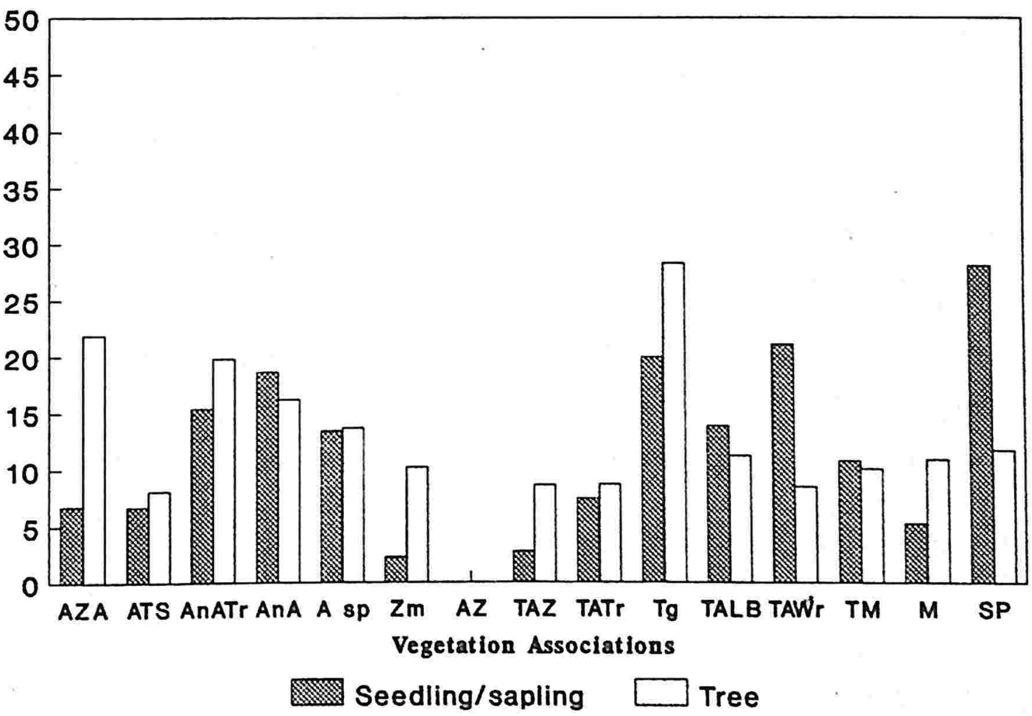


Fig. 4.7. Percentage of tree and seedling/sapling mortality in vegetation associations in Gir.

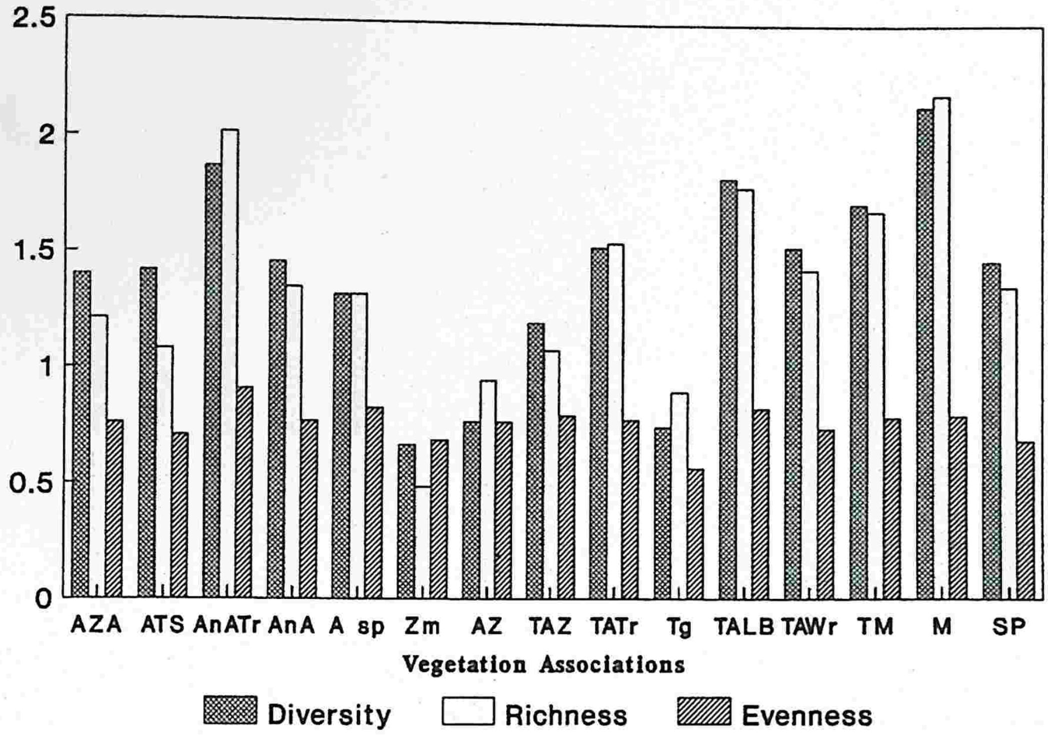


Fig. 4.8. Average diversity indices for tree species in vegetation associations in Gir.

Table 4.1. Species composition with their abundance in vegetation associatons in Gir.

SPECIES	RANGE OF ABUNDANCE[‡] OF SPECIES IN VEGETATION ASSOCIATIONS[‡]														
	AZA	ATS	AnATr	AnA	A sp	Zm	AZ	TAZ	TATr	Tg	TALB	TAW	TM	M	SP
Term crenulata	0-2	0-2	2-4	–	0-2	–	–	–	0-4	0-2	0-2	0-2	0-2	0-2	–
Ehre laevis	–	–	–	–	0-2	–	–	–	–	–	–	0-1	0-1	–	0-1
Bala aegyptiaca	–	–	–	0-2	–	0-2	–	–	–	–	0-2	0-2	0-2	–	–
Acac catechu	0-2	0-4	0-2	1-3	0-5	–	–	0-4	0-4	0-2	2-4	0-4	0-2	0-2	–
Acac senegal	0-2	0-1	0-2	–	0-2	–	–	0-1	–	–	–	–	0-1	0-1	–
Acac leucophloea	0-3	0-3	0-2	0-1	0-3	–	–	0-3	0-2	0-2	0-2	0-2	0-1	0-2	–
Them quadrivalvis	–	0-4	0-1	–	–	–	0-2	–	0-2	0-1	–	0-2	–	–	–
Cass auriculata	0-2	–	–	–	–	–	–	–	–	–	–	0-1	0-1	–	–
Dich annulatum	–	–	0-2	–	–	–	–	–	0-2	–	–	–	0-1	–	–
Aplu mutica	0-2	0-4	0-2	0-1	0-3	–	0-2	0-2	0-2	0-2	–	0-4	0-1	–	–
Zizy nummularia	2-5	0-1	–	–	–	–	–	–	–	–	–	–	–	–	–
Mori oleiflora	–	–	–	0-2	–	–	–	–	–	–	–	–	–	–	–
Capp sepiaria	0-2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hete contortos	–	0-2	0-2	–	–	–	–	–	0-1	–	–	–	–	–	–
Anog latifolia	0-4	0-2	2-4	3-4	–	–	–	–	–	–	0-4	–	0-1	0-2	–
Aris adscenscinis	0-2	0-4	0-2	–	–	–	–	–	–	–	–	0-2	–	–	–
Sehi nervosum	0-1	0-3	0-2	–	–	–	–	–	0-1	–	–	–	–	–	–
Catu uliginosa	–	0-2	–	–	0-1	–	–	–	–	–	0-1	–	–	–	–
Acac nilotica	0-1	0-2	0-3	0-2	0-4	–	4-5	0-2	–	0-2	–	0-2	0-2	0-2	–
Zizy mauritiana	0-2	–	–	0-1	0-4	5	0-3	1-4	0-2	–	0-2	0-2	0-2	0-1	0-2
Dich cinerea	0-1	–	0-2	0-1	0-2	–	–	0-1	0-2	–	0-2	0-2	0-1	–	–
Adin cordifolia	–	–	–	–	–	–	–	–	–	–	–	0-1	0-1	–	0-2
Soya febrifuga	–	–	0-2	0-2	–	–	–	–	–	–	0-2	0-1	0-1	0-1	–
Flac indica	0-1	0-1	0-2	0-1	–	–	–	–	0-2	–	0-1	0-2	0-1	–	–
Zizy oenoplea	0-1	–	–	–	0-2	–	–	–	–	0-1	0-1	0-1	0-1	0-1	–
Bauh racemosa	0-1	0-2	0-2	–	0-2	–	–	0-2	0-2	–	0-2	0-2	0-2	0-2	0-2
Cass fistula	–	–	0-2	–	–	–	–	–	–	–	–	0-2	0-1	0-1	–
Bute monosperma	–	0-1	0-3	–	0-2	–	–	0-1	0-2	–	–	–	0-2	0-2	–
Bomb ceiba	–	–	0-1	–	–	–	–	–	0-1	–	–	–	0-1	–	–
Mori tinctoria	0-1	0-1	0-2	–	–	–	–	–	0-1	0-2	0-1	0-2	0-1	0-2	0-2
Zizy xylopyrus	–	–	–	–	0-2	–	–	0-2	–	–	–	0-1	0-1	0-1	–
Tect grandis	–	0-4	–	–	0-4	0-2	0-3	3-5	3-5	5	0-4	2-4	2-4	0-3	0-2
Embl officinalis	0-1	0-2	–	–	–	–	0-3	–	0-2	0-2	0-2	0-2	0-2	0-1	–
Acac ferruginea	0-1	0-1	0-1	0-1 0-4	–	–	–	0-4	0-2	0-2	0-1	0-2	–	–	
Catu spinosa	–	0-2	–	–	–	–	–	0-2	–	–	0-2	0-1	0-1	0-2	0-1
Scre swietenioides	–	–	–	0-2	–	–	–	–	–	–	0-1	–	0-2	0-3	–
Grew tiliaefolia	–	–	–	0-2	–	–	–	0-2	0-2	–	0-2	0-1	0-2	0-2	0-2
Dios melanoxylon	0-1	–	0-2	0-1	0-2	–	–	–	–	0-2	0-2	0-2	0-2	0-3	0-2
Lann coromandelica	–	0-1	–	0-1	0-2	–	–	–	0-2	0-2	1-2	0-2	0-2	0-2	0-1
Bosw serrata	–	0-1	–	0-1	–	–	–	–	0-2	0-1	1-3	0-2	–	0-1	–
Ster urens	–	–	–	0-1	–	–	–	–	0-2	–	0-2	0-1	0-1	–	–
Pter marsupium	–	–	–	0-1	–	–	–	–	–	–	0-4	–	0-1	0-2	–
Wrig tinctoria	–	0-2	–	0-2	–	–	–	0-1	0-2	0-2	0-1	1-4	1-4	0-3	0-3
Hyme excelsum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Eryt variegata	–	–	–	–	–	–	–	–	–	–	0-2	0-1	–	–	–
Dalb latifolia	–	–	–	–	–	–	–	–	–	–	0-2	0-2	0-1	–	–
Tama troupii	–	–	–	–	–	–	–	–	–	–	–	–	0-1	0-1	–
Holo integrifolia	–	–	–	–	–	–	–	–	–	–	0-1	0-2	–	0-2	–

Contd..

Table 4.1 contd.

SPECIES	RANGE OF ABUNDANCE* OF SPECIES IN VEGETATION ASSOCIATIONS#														
	AZA	ATS	AnATr	AnA	A sp	Zm	AZ	TAZ	TATr	Tg	TALB	TAW	TM	M	SP
Gmel arborea	-	-	-	-	-	-	-	-	-	-	-	-	0-1	-	-
Malo philipensis	-	-	-	-	-	-	-	-	-	-	-	-	-	0-2	-
Case elliptica	-	-	-	-	-	-	-	-	-	-	-	-	-	0-1	-
Schl oleosa	-	-	-	-	-	-	-	-	-	-	-	0-1	0-1	0-2	-
Mili tomentosa	-	-	-	-	-	-	-	-	-	-	-	0-2	0-2	0-1	0-1
Mani hexandra	-	-	-	-	-	-	-	-	0-2	-	0-2	-	-	0-1	-
Heli isora	-	-	-	0-1	-	-	-	-	-	-	-	0-1	0-2	0-2	0-1
Ficu religiosa	-	-	-	-	-	-	-	-	-	-	-	-	0-2	-	-
Albi odoratissima	-	-	-	-	-	-	-	-	0-2	-	-	-	0-1	-	-
Arto heterophyllus	-	-	-	-	-	-	-	-	0-2	-	0-1	-	-	-	-
Hola antidysenterica	-	-	-	-	0-2	-	-	0-2	-	0-2	-	0-2	0-2	0-2	-
Eryt colorata	-	-	-	-	-	-	-	-	0-2	0-1	-	-	0-1	0-2	-
Pani psilopodium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Garu pinnata	-	-	-	-	-	-	-	-	-	-	-	0-2	0-1	0-2	0-2
Aegl marmelos	-	-	-	-	-	-	-	-	-	0-1	-	0-2	0-2	0-2	0-2
Sapi emarginata	-	-	-	-	-	-	-	-	-	-	-	0-1	0-2	-	0-1
Term belerica	-	-	-	-	-	-	-	-	-	-	-	0-1	0-2	0-2	0-2
Ficu racemosa	-	-	-	-	-	-	-	-	-	-	-	-	0-2	0-2	0-1
Brid retusa	-	-	-	-	-	-	-	-	-	-	-	-	0-1	0-1	0-1
Alan latifolium	-	-	-	-	-	-	-	-	-	-	-	-	0-1	0-1	0-1
Tama indica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0-2
Syzy rubicundum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0-4
Mitr parvifolia	-	-	-	-	-	-	-	0-2	-	0-1	0-2	-	0-2	0-3	0-2
Ixor arborea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0-2
Syzy cumini	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0-2
Pong pinnata	-	-	-	-	-	-	-	-	-	-	-	-	-	0-1	0-4
Cari carandus	-	-	-	-	-	-	-	-	-	-	-	-	0-2	0-2	2-4

- Vegetation associations: AZA = *A. catechu - Z. nummularia - A. adscensionis*; ATS = *Apluda mutica - Themeda quadrivalvis - Sehima nervosum*; AnATr = *Anogeissus latifolia -Acacia spp - Terminalia crenulata*; AnA = *Anogeissus latifolia - Acacia catechu*; A sp = *Acacia spp - Zizyphus mauritiana*; Zm = *Zizyphus mauritiana*; AZ = *Acacia nilotica - Zizyphus mauritiana*; TAZ = *Tectona grandis - Acacia catechu - Zizyphus mauritiana*; TATr = *Tectona grandis - Acacia catechu - Terminalia crenulata*; Tg = *Tectona grandis*; TALB = *Tectona grandis - Acacia catechu - Lannea coromandelica - Boswellia serrata*; TAWr = *Tectona grandis - Acacia spp - Wrightia tinctoria*; TM = *Tectona grandis* mixed; M = Mixed; SP = *Syzygium rubicundum - Pongamia pinnata*

* - Abundance scale: 0 & - = NIL; 1 = 1-5%; 2 = 6-25%; 3 = 26-35%; 4 = 36-66%; 5 = >66%

Table 4.2. Tree and seedling/sapling density (number/hectare) in different vegetation associations in Gir.

VEGETATION ASSOCIATION	TREE DENSITY			SEEDLING/SAPLING DENSITY		
	MEAN	MIN	MAX	MEAN	MIN	MAX
AZA	279.5	25	550	1233.3	200	2800
ATS	195.4	25	400	2550.0	200	6300
AnATr	360.7	150	950	433.3	300	600
AnA	487.5	350	700	1075.0	400	1600
A sp	294.8	50	825	1257.9	100	6100
Zm	325.0	200	525	2866.7	700	6600
AZ	131.2	75	250	4800.0	4800	4800
TAZ	388.3	75	850	1775.0	300	4200
TATr	389.7	125	575	1512.5	400	3200
Tg	428.3	25	1050	1687.5	1000	2600
TALB	565.4	300	925	900.0	400	1400
TAWr	646.1	225	1450	1240.0	400	4900
TM	696.9	100	1275	1500.0	300	3600
M	738.9	150	1075	3433.3	1200	7500
SP	489.3	100	1075	6500.0	2400	10100
TOTAL	464.8	25	1450	1865.4	100	10100
SIGNIF.	***			***		

*** p< .001

Table 4.3. Shrub density (number/hectare) and volume (cu. m/hectare) in different vegetation associations in Gir.

VEGETATION ASSOCIATION	SHRUB DENSITY			SHRUB VOLUME		
	MEAN	MIN	MAX	MEAN	MIN	MAX
AZA	290.6	75	575	985.4	19.3	2885.0
ATS	14.8	0	50	16.9	0	79.8
AnATr	158.3	50	250	685.1	115.2	1751.6
AnA	31.2	0	75	104.8	0	371.9
A sp	57.4	0	625	623.1	0	4656.4
Zm	25.0	0	50	94.0	0	232.9
AZ	225.0	225	225	76.9	76.9	76.9
TAZ	28.1	0	75	696.7	0	2500.0
TATr	5.0	0	25	9.4	0	46.9
Tg	3.6	0	25	2.3	0	16.0
TALB	43.7	0	175	515.8	0	2063.5
TAWr	35.0	0	200	124.8	0	579.0
TM	90.4	0	525	454.3	0	2549.0
M	295.0	0	825	6567.5	0	17004.1
SP	280.0	50	600	10845.9	1060.9	30312.7
TOTAL	95.20	0	600	1131.9	0	30312.7
SIGNIF.	*			***		

* p<.05, *** p< .001

Table 4.4. Distribution pattern and contribution of tree species in Gir vegetation.

SPECIES	MEAN	VARIANCE	DISPERSION PATTERN	%
Acacia catechu	1.649	6.82	4.14	9.16
Acacia ferruginea	.345	1.33	3.85	1.80
Acacia leucophloea	.601	.97	1.61	3.36
Acacia nilotica	.796	3.68	4.63	4.20
Acacia senegal	.066	.10	1.51	.35
Adina cordifolia	.028	.05	1.98	.15
Aegle marmelos	.113	.31	2.73	.59
Alangium latifolium	.014	.01	.99	.07
Albizzia odoritissima	.009	.00	.99	.05
Anogeissus latifolia	.748	7.56	10.10	3.90
Balanites aegyptiaca	.085	.28	3.37	.44
Bauhinia purpurea	.431	.91	2.11	2.35
Bombax ceiba	.028	.03	1.31	.15
Boswellia serrata	.317	.87	2.75	1.68
Bridelia retusa	.014	.01	.99	.07
Butea monosperma	.222	.53	2.40	1.28
Cassia fistula	.047	.07	1.56	.25
Dalbergia latifolia	.014	.01	.99	.07
Dichrostachys cinerea	.127	.18	1.47	.69
Diospyros melanoxylon	.398	1.60	4.02	2.35
Ehretia laevis	.042	.05	1.18	.22
Emblica officinalis	.165	.28	1.69	.86
Erythrina variegata	.042	.14	3.41	.22
Ficus bengalensis	.004	.00	1.00	.02
Ficus racemosa	.004	.00	1.00	.02
Ficus religiosa	.023	.02	.98	.12
Ficus amplissima	.018	.01	.98	.10
Flacourtia indica	.104	.19	1.90	.57
Garuga pinnata	.132	.42	3.23	.69
Gmelina arborea	.009	.00	.99	.05
Grewia tiliaefolia	.369	.88	2.38	1.93
Contd......				

Table 4.4 contd..

SPECIES	MEAN	VARIANCE	DISPERSION PATTERN	%
Holorrhena antidysenterica	.161	.48	3.02	.84
Holoptelea integrifolia	.023	.02	.98	.15
Hymenodictyon excelsum	.004	.00	1.00	.02
Ixora arborea	.018	.02	1.48	.10
Lannea coromandelica	.289	.64	2.22	1.53
Manilkara hexandra	.004	.00	1.00	.02
Miliusa tomentosa	.071	.12	1.73	.37
Mitragyna parvifolia	.075	.16	2.18	.40
Morinda tinctoria	.104	.14	1.35	.59
Moringa oleiflora	.014	.02	1.66	.07
Pongamia pinnata	.037	.07	1.97	.20
Pterocarpus marsupium	.042	.06	1.40	.22
Sapindus emarginatas	.018	.02	1.48	.10
Schleichera oleosa	.028	.05	1.98	.15
Screbera swietenioides	.109	.76	7.01	.57
Soyamida fabrifuga	.075	.11	1.55	.40
Sterculia urens	.047	.06	1.35	.25
Syzygium cumini	.004	.00	1.00	.02
Syzygium rubicundum	.161	1.64	10.18	.84
Tamarindus indica	.014	.02	1.66	.07
Tamarix troupii	.018	.01	.98	.10
Tectona grandis	5.729	47.92	8.36	31.28
Terminalia belerica	.047	.07	1.56	.25
Terminalia crenulata	.582	2.12	3.63	3.11
Wrightia tinctoria	2.132	22.09	10.36	11.16
Catunaregum spinosa	.132	.23	1.80	.69
catunaregum uliginosa	.028	.02	.97	.15
Zizyphus mauritiana	1.388	5.83	4.20	7.48
Zizyphus xylopyrus	.075	.08	1.17	.44
Zizyphus Oenoplia	.042	.04	.96	.22

Table 4.5. Tree and seedling/sapling coppicing in major species in Gir PA.

SPECIES	PERCENTAGE COPPICING	
	TREE	SEEDLING/SAPLING
Acacia catechu	4.97	7.79
Acacia leucophloea	4.95	9.80
Acacia nilotica	5.55	11.12
Anogeissus latifolia	8.82	29.22
Bauhinia racemosa	16.26	21.93
Diopyros melanoxylon	8.64	15.67
Tectona grandis	10.56	43.17
Terminalia crenulata	3.67	4.17
Wrightia tinctoria	5.55	32.88
Zizyphus mauritiana	9.26	35.31
TOTAL	7.90	25.38
SIGNIF.	**	***

** p<.01, *** p<.001

Table 4.6. Tree and seedling/sapling mortality in major species in Gir PA.

SPECIES	PERCENTAGE MORTALITY	
	TREE	SEEDLING/SAPLING
Acacia catechu	20.30	25.86
Acacia leucophloea	9.57	10.87
Acacia nilotica	11.99	4.76
Anogeissus latifolia	9.55	10.50
Bauhinia racemosa	4.61	13.10
Diopyros melanoxylon	5.50	.79
Tectona grandis	8.84	15.77
Terminalia crenulata	41.50	22.92
Wrightia tinctoria	2.63	13.73
Zizyphus mauritiana	3.63	16.74
TOTAL	11.54	14.34
SIGNIF.	***	**

** P<.01, p<.001

Table 4.7. Tree species diversity and evenness in vegetation associations in Gir.

VEGETATION ASSOCIATION	DIVERSITY			EVENNESS		
	MEAN	MIN	MAX	MEAN	MIN	MAX
AZA	1.40	.90	2.03	.76	.57	.92
ATS	1.42	.46	1.96	.71	.33	1.00
AnATr	1.87	1.36	2.24	.91	.84	.97
AnA	1.46	1.12	1.95	.77	.62	.85
A sp	1.32	.64	1.80	.83	.52	.98
Zm	.67	.42	.86	.69	.61	.78
AZ	.77	.35	1.04	.77	.25	.97
TAZ	1.20	.64	1.59	.80	.56	1.00
TATr	1.53	.96	2.04	.78	.55	.64
Tg	.75	.10	1.29	.57	.35	.72
TALB	1.83	1.46	2.33	.82	.63	.95
TAWr	1.53	1.19	2.15	.74	.55	.95
TM	1.72	.91	2.11	.79	.60	.98
M	2.15	.31	2.92	.80	.17	.92
SP	1.47	.73	2.45	.69	.41	.91
TOTAL	1.46	.10	2.92	.77	.17	1.00
SIGNIF.	***			***		

*** p<.001

Table 4.8. Tree species richness in vegetation associations in Gir.

VEGETATION ASSOCIATION	RICHNESS		
	MEAN	MIN	MAX
AZA	1.21	.54	1.90
ATS	1.08	.59	1.73
AnATr	2.02	1.58	2.67
AnA	1.35	.96	1.80
A sp	1.32	.66	2.07
Zm	.49	.35	.67
AZ	.95	.55	1.50
TAZ	1.08	.49	1.73
TATr	1.55	.86	2.35
Tg	.90	.39	1.51
TALB	1.79	1.40	2.27
TAWr	1.43	.93	2.00
TM	1.69	.76	2.53
M	2.20	.58	3.07
SP	1.36	.55	2.14
TOTAL	1.42	.35	3.07
SIGNIF.	***		

*** p<.001

Chapter 5

HABITAT UTILIZATION BY UNGULATES

5.1. INTRODUCTION

The knowledge of habitat utilization by animals helps in managing the distribution and abundance of concerned species by manipulating some of the habitat factors. To gain this knowledge, information about the biology of animals and their behaviour, and the use of habitat by them is required. Recent studies conducted in Gir and elsewhere (Joslin 1973, Berwick 1974, Khan *et al.* 1990, Chakrabarty 1991, Bhujanga Rao 1991, Johnsingh & Sankar 1991, Mathur 1991, Ravi Chellam 1993) provide knowledge about the behaviour of and habitat utilization by lion and some of the ungulates. Various other studies conducted have reported the variation in habitat utilization by animals within (De & Spillett 1966, Ben-Shahar 1990) and between seasons (Bhujanga Rao 1991, Pratt *et al.* 1986).

This study is different from the others (in Gir) regarding the methods adopted (compared to Khan *et al.* 1990) and time elapsed (Berwick 1974). Habitat utilization study by Khan *et al.* (1990) included vehicle transect in summer and winter, and extent (qualitative) of use of plant species by chital (*Cervus axis*), sambar (*Cervus unicolor*) and nilgai (*Boselaphus tragocamelus*). This study investigated the habitat utilization quantitatively through direct observation and pellet count of ungulates, and browse consumption in habitat types.

This chapter presents methods and results of habitat utilization by chital, sambar, nilgai and chinkara (*Gazella gazella*). Nilgai and chinkara data was not sufficient to analyze separately. Therefore, data of these two species are used only in multivariate analysis and presented here. The chapter, although presents the results on different aspects separately, it discusses them together. The term habitat is used for the vegetation association (modified in some cases) only.

5.2. METHODS

5.2(a). Field Methods

5.2.1. Habitat Types

Habitat types were classified based on the structure and composition of vegetation associations. Assistance of TWINSPAN two way table (Table 4.1) was taken to regroup the vegetation plots into habitat types. The regrouping involved knowledge from field about the availability of food, cover and terrain features in those habitat types. Vegetation associations (identified by TWINSPAN) similar in food and cover values, and terrain features were merged into a single habitat types. Most of the habitat types were the same as vegetation associations (Table 5.1), although the nomenclature of habitat types was made simple by using common/generic names of the dominant tree species (e.g. *Anogeissus* - *Acacia*). In cases where the habitat type was a combination of certain vegetation associations, a name that did not represent a species, was used (e.g. Thorn forest) and in others, a name that provided more information about the habitat (Riverine).

5.2.2. Cover Measurements

Cover was estimated through a cover density board (3.3.4.) at five fixed locations in 100 stands. Cover was recorded in summer (May) and in winter (mid December-mid January). Similarly canopy cover was recorded using a Spherical Densiometer at five fixed locations, and four replicates were taken at each location in each season.

In each and adjacent to each of the 100 vegetation plots, five fixed 1 X 1 sq. m quadrats were placed at 20m intervals to record data on ground cover, shrub cover, canopy cover and leaf litter and grass (see 3.3.4.). Both leaf litter and grass were visually estimated in terms of percentage area covered by these.

5.2.3. Habitat Utilization by Ungulates

Habitat utilization by ungulates was investigated by direct and indirect evidence. Direct observations included vehicle transect on twelve routes adequately covering the different areas all over Gir. Indirect evidence included:

1. leaf litter consumption
2. browse consumption (use)
3. pellet group count

5.2.4. Leaf Litter Consumption

As a pilot study leaf litter productivity and consumption for some the browsed tree and shrub species (*Bauhinia racemosa, Helicteres isora, Terminalia crenulata, Wrightia tinctoria, Zizyphus mauritiana*) were estimated in 0.5m X 0.5m exclosures in disturbed and undisturbed areas in 1993-1994. Twenty exclosures (four for each species) were kept under the browse tree and shrub species in different areas in east and west Gir at the beginning of leaf fall (January 1st week). These were protected from grazing. The dry weight of the leaves accumulated in exclosures and at varying distances from *nes* and water points (minimum tree three samples each from seven habitats both in national park and wildlife sanctuary) was calculated. The accumulated leaf litter was collected and weighed in May 1994. This exercise could not be conducted for *Acacia* spp. because it was difficult and time consuming to collect the leaves of these trees. Furthermore, as this exercise progressed there was confirmation only about the consumption of *Zizyphus mauritiana* leaf litter by wild ungulates. Therefore, other species were not included in the results.

5.2.5. Browse Estimation

Plant browse production and consumption were estimated for the dominant and palatable (to wild ungulates) tree and shrub species as a pilot study. The browse trees and shrub species were classified based on literature (Khan *et al.* 1990) and observations in field. Browse productivity and consumption for tree and shrub species was estimated using a diameter-weight regression (Ruyle *et al.* 1983). Current year twigs of browse species were clipped from the base of their origin (bad scar) between October and December. These twigs were cut into 5cm long pieces, their diameter measured (to the nearest of 0.01mm) at the end towards origin. These were then weighed to the nearest 0.001g. Both the fresh and the oven dried (80°C for 36 hours) weights of the twigs with leaves were measured.

On the other hand, diameter of the current year browsed twigs of three species (*Acacia nilotica*, *Bauhinia racemosa* and *Wrightia tinctoria*) were measured between October and December, and between October and April for *Capparis sepiaria* as this was evergreen and browsed throughout the year. Five twigs each from 3-5 individuals of these species in different areas were sampled. The weight of browsed portion was calculated using the equation from regression analysis.

In addition the browsed and unbrowsed twigs were counted for one preferred tree (*Bauhinia racemosa*) and shrub species (*Capparis sepiaria*) (Khan *et al.* 1990) in three habitats to estimate the availability and consumption from the tree/shrub by ungulates. These habitats showed comparatively more sign of ungulates during preliminary analysis. The percentage of browse consumed with respect to total produced and available was calculated from these counts. The number of twigs present upto 2m height from ground were considered to be available to the ungulates.

The other category of browse estimated was the percentage of trees/shrubs providing browse to wild ungulates. Percentage was calculated as number of forage trees/shrubs divided by total trees/shrubs in a vegetation plot. A species was categorized as browse based on field observations and literature (Khan *et al.* 1991, Khan 1994).

5.2.6. Pellet Count

Pellets of chital, sambar, nilgai, chinkara, chowsingha and dung of wild pig were counted in 10m X 2m belt transects and then removed. This are was thoroughly searched and if required was cleared off the grass and leaf litter to increase the search efficiency. There were 10 such transects in 100 stands (Fig 5.1). This exercise was done in winter (December-January) and summer (May-June).

5.2.7. Direct Observations

Direct evidence included observations on animals in the summers of 1992-1994. Summer being a season with paucity of water and cover was critical and hence was chosen for data collection. The animals were observed in the morning (630-830hrs), noon (1200-1400hrs) and evening (1700-1900hrs). The data collection was done by four observers on a jeep traversing 360km roads in west and east wildlife sanctuary and, national park (Fig 5.2). For every observation, data on ungulate species, group size, vegetation type, terrain and distance from water and *nes* were recorded.

5.2(b). Analysis

The significance of variation in the overall habitat utilization was tested using non-parametric Kruskal-Wallis χ^2 test at $p<.05$ (Sokal & Rohlf 1981). The seasonal variation in habitat utilization was tested with Mann-Whitney test at $p<.05$ level. The relationship between the diameter and weight of browse was determined through linear regression assuming that the weight of twigs was linearly related to the diameter. The correlation was tested through analysis of variance (F) (Ruyle *et al.* 1983) at $p<.05$ level. Since the existence of a significant F by itself does not assure that diameter can usefully predict weight of a twig, coefficient of multiple determinant or correlation coefficient (r^2) was used for this purpose.

Canonical correspondence analysis (CANOCO) (ter Braak 1988) was conducted to determine the relationship between environmental factors and ungulate species. The following environmental variables (habitat factors) were considered:

1. COVER - cover at 0.5m, 1.0m and 1.75m height, canopy cover, grass cover, and leaf litter,
2. DIVERSITY - species diversity, and evenness,
3. DISTANCE FROM *nes*,

4. DISTANCE FROM WATER, and
5. BROWSE AVAILABILITY in habitat types

Monte Carlo permutation test (ter Braak 1988) was used to determine whether the first canonical axis was significant and that the environmental variables sufficient to explain the variation in ungulate distribution.

5.3. RESULTS

The habitats are described below with their features. These features/parameters are also presented separately for their easy comparison among habitat types. The results are presented in the form mean±standard error of mean at 95% confidence level. The results of statistical tests are in the form of - name of the test, calculated value, significance level and sample number.

5.3.1. Habitat types

The habitat types and the corresponding vegetation associations are given in Table 5.1. The twelve habitat types are described below.

5.3.1.1. Scrubland: This habitat type corresponded to *Acacia catechu - Zizyphus nummularia - Aristida adscensionis* association (Plate 1). It had an abundance of the shrub *Zizyphus nummularia* whose leaves and fruits provided forage. The shrub height was generally not more than a metre. The average cover at 0.5m height was 63.7%±6.1% (n=40) in winter and it declined to 40.6%±3.5% (n=120) in summer. The average cover at 1.0m height was 38.6%±6.0% in winter and reduced to 13.4%±2.2% in summer. Canopy cover in winter and summer was 14.3%±2.7% and 1.8%±0.3 respectively. About 72% of all the tree and shrubs were available as browse.

5.3.1.2. Savanna: This habitat type was the same as *Apluda mutica - Themeda quadrivalvis - Sehima nervosum* association (Plate 2). It had scattered trees of *Acacia spp.* characteristics of savanna (Bourlier & Heady 1983). The grasses provided fodder to wild ungulates during monsoon (Khan 1994). The scattered trees provided very less canopy cover. The grasses provided thick cover in winter especially at 0.5m height. The fodder value for wild ungulates after monsoon was not much (Khan 1994). The cover at 0.5m height was 72.1%±6.4% (n=35) in winter and 18.9%±3.3% (n=70) in summer. The cover at 1.0m height in winter was 32.1%±6.2% and it decreased to 10.4%±2.5% in summer. Similarly cover at 1.75m height in winter was 23.0%±5.8% and reduced to 12.8%±3.0 in summer. The canopy cover did not change much from 9.3%±2.7% in winter to 5%±1.7% in summer. Here, 19% of the trees/shrubs belonged to browse.

5.3.1.3. *Anogeissus - Acacia - Terminalia*: This habitat type was same as the vegetation association in east Gir (Plate 3). The vegetation was open due to low rainfall and nutrient poor soils. This habitat type occurred on undulating topography with gravel. Shrub and ground cover were generally not very good. Species that provided browse included *Acacia spp.*, *Zizyphus mauritiana*, *Terminalia crenulata* and occasional Capparis sepiaria. The cover at 0.5m height was 62.9±9.1% (n=15) in winter and 34.8±5.8% (n=45) in summer. The cover at 1.0m height decreased from 15.2±7.0 in winter to 11.0±3.6% in summer. The cover at 1.75m height varied form 18.7±7.1% in winter to 14.6±4.2% in summer. The canopy cover declined from 16.8±4.5% in winter to 9.1±2.0% in summer. This habitat had 39% trees and shrubs as browse.

5.3.1.4. *Anogeissus - Acacia*: It was restricted at the lower parts of hills or in the valleys with better moisture conditions (Plate 4). The cover at field and shrub level was good. The change in cover was quite large between summer and winter. In this habitat also the low tree density and poor growth due to low rainfall and nutrient poor soils resulted in less cover. *Acacia spp.*, *Zizyphus mauritiana*, *Zizyphus nummularia*, *Bauhinia racemosa*, *Catunaregam spp.* and *Capparis sepiaria* constituted the browse available to animals. The mean cover at 0.5m height was 46.9±2.6% in winter (n=260) and it reduced to 29.7±2.4% in summer (n=230). The cover at 1.0m height was 22.6±2.0% and 10.3±1.3% in winter and summer respectively. The cover at 1.75m height was 28.2±2.1% in winter and reduced to 12.3±1.4% in summer. The canopy cover decreased to less than half from 15.6±1.2% in winter to 6.5±0.7% in summer. The amount of browse available here was 29%.

5.3.1.5. Thorn forest: This habitat type included three vegetation associations namely, *Acacia spp. - Zizyphus mauritiana*, *Zizyphus mauritiana* and *Acacia nilotica - Zizyphus mauritiana* (Plate 5). Its characteristics were thorny species all of which were preferred browse (Khan 1994). Quite often this habitat was found in proximity to water. Most of the tree species (e.g. *Acacia spp. Bauhinia racemosa*, *Zizyphus mauritiana*, and *Dichrostachys cinerea*) found in this habitat offered good browse throughout the year in forms of leaves, pods and/or fruits. The cover at 0.5m height decreased from 54.7±8.9% in winter (n=20) to 30.±4.5% in summer. The cover at 1.0m height changed from 25.8±7.8 in winter to 8.6±2.4% in summer. Similarly, the cover at 1.75m height decreased from 36.9±6.8 to 9.5±2.5 in summer. The canopy cover was estimated to be 22.1±3.7 in winter and it decreased to 4.9±0.8% in summer. This habitat had the maximum i.e. 76% browse available.

5.3.1.6. *Teak - Acacia - Zizyphus*: This habitat was comprised of the *Tectona grandis - Acacia catechu - Zizyphus mauritiana* and *Tectona grandis - Acacia catechu - Terminalia crenulata* associations (Plate 6). This habitat was often in better moisture conditions than all the above. Common forage trees included *Acacia spp., Zizyphus mauritiana* and *Bauhinia racemosa*. Other browse species with less abundance were *Capparis sepiaria, Catunaregam spp., Emblica officinalis, Flacourtia indica* and *Balanites aegyptiaca*. The mean cover at 0.5m height was 55.7±2.7% in winter (n=205) and 25.2±5.0% in summer (n=112). The cover at 1.0m height decreased from 22.9±2.1% in winter to 8.1±1.8% in summer. The cover at 1.75m height was 26.9±2.4% in winter to 11.5±2.0% in summer. The canopy cover also declined from 19.3±1.5% in winter to 8.1±1.0% in summer. In this around 32% of the tree/shrubs provided browse.

5.3.1.7. Teak forest: This habitat type corresponded to the *Tectona grandis* association (Plate 7) and provided the least quantity of forage to ungulates since most of it was composed of *Tectona grandis*. Browse was available only from occasional *Acacia spp.*, *Zizyphus mauritiana*, *Bauhinia racemosa* and *Catunaregam spp.* The average cover at 0.5m height was 59.6±3.9% in winter (n=105) and reduced to half in summer (28.2±5.0%, n=65). The cover at 1.0m height decreased drastically from 26.3±3.3% in winter to 4.6±1.5% in summer. The average cover at 1.75m height in winter was 20.2±2.7% and it reduced to about one third, i.e. 7.3±1.8% in summer. Similarly, the canopy cover decreased to one third from 15.9±1.5% in winter to 5.8±0.6% in summer. This habitat type had the least (11%) browse available.

5.3.1.8. *Teak - Acacia - Boswellia*: This habitat type was the same as *Acacia catechu - Lannea coromandelica - Boswellia serrata* association and present mostly on hilly terrain (Plate 8). The average cover at 0.5m height was largest in this habitat type in both winter and in summer. The reason for this was the hilly terrain which many times obstructed the vision at this level. Otherwise, this habitat had less vegetation due to thin layer of soil which was quite often interspersed with exposed bed rock. The browse species present were *Acacia catechu*, *Soyamida febrifuga* and *Wrightia tinctoria*. Cover at 0.5m height was 78.1±5.4% (n=20) and it decreased to half (40.6±4.8%) in summer (n=60). The average cover at 1.0m height was 24.7±3.7% in winter and decreased little to 17.0±3.7% in summer. The cover at 1.75m height reduced to almost half from 35.1±7.7% in winter to 19.6±3.7% in summer. The canopy cover was 26.5±3.9% in winter and 11.9±1.7% in summer. This habitat type had 34% of the trees and shrubs as browse.

5.3.1.9. *Teak - Acacia - Wrightia*: This habitat was at the lower parts of the hills with boulders (Plate 9). The browse species were *Acacia catechu*, *Flacourtia indica*, *Wrightia tinctoria*, *Balanites aegyptiaca*, *Grewia tilaefolia*, *Catunaregam spp.*. *Zizyphus mauritiana*, *Capparis sepiaria*, *Helicteres isora*. The average cover at 0.5m height declined from 56.6±3.5% in winter (n=145) to 19.1±3.1% in summer (n=100). The cover at 1.0m height changed from 21.2±2.6% in winter to 13.6±2.7%, cover at

1.75m height from 23.7±2.7% to 14.8±2.7% in summer. The canopy cover reduced from 22.9±1.8% in winter to 9.1±1.4% in summer. About 20% of the trees and shrubs were available as browse here.

5.3.1.10. Teak mixed: This habitat type was in moist localities in the valleys on nutrient rich soils (Plate 10). Some of the species like *Butea monosperma* and *Diospyros melanoxylon* provided good canopy cover in summer. Browse species present in this habitat were *Acacia spp.*, *Zizyphus mauritiana*, *Grewia tilaefolia*, *Wrightia tinctoria*, *Diospyros melanoxylon*, *Capparis sepiaria*, *Carissa carandas*, and *Helicteres isora*. High density and volume of *Carissa carandas* and relatively high density of *Helicteres isora* accounted for more cover at ground and shrub levels. The cover at 0.5m height was 69.5±2.6% in winter (n=175) and 25.9±2.9% in summer (n=135). The cover at 1.0m height decreased to half from 29.2±2.5% in winter to 12.4±2.0% in summer. The cover at 1.75m height declined more than half from 24.0±2.8% in winter to 14.0±1.9% in summer. The average canopy cover was 22.6±1.5% and 10.1±1.0% in winter and summer respectively. In this habitat 28% of the species were available as browse.

5.3.1.11. Mixed forest: This and the riverine (5.3.1.12) were the densest habitat types in both summer and winter (Plate 11). This was the most diverse too. It occurred on and around seasonal streams in relatively undisturbed areas. Forage species present here were *Zizyphus oenoplia*, *Acacia spp.*, *Barlaria prionitis*, *Holoptelia integrifolia*, *Terminalia bellerica*, *Wrightia tinctoria*, *Carissa carandas* and *Helicteres isora*. The cover at 0.5m height in this habitat type was 68.9±5.3% in winter (n=50) and changed little to 59.4±4.2% in summer (n=90). The cover at 1.0m height changed more from 53.2±5.2% in winter to 34.8±3.9% in summer. The average cover at 1.75m height was reduced to almost half from 54.1±5.3% in winter to 30.7±3.8% in summer. The average canopy cover also reduced to half from 42.2±4.3% to 22.7±2.6% in summer. This habitat provided 33% of trees and shrubs as browse.

5.3.1.12. Riverine: This habitat type corresponded to *Syzygium rubicundum - Pongamia pinnata* vegetation association (Plate 12). It was restricted along rivers and had more cover value at all the three levels, more moisture, and proximity to water. *Mitragyna parvifolia, Terminalia bellerica, Syzygium rubicundum, Ixora arborea, Zizyphus oenoplia* and *Carissa carandas* provided browse to the wild ungulates. The average cover at 0.5m height decreased from 68.4±5.1% in winter (n=50) to 43.3±7.7% in summer (n=30). The cover at 1.0m height decreased from 48.5±5.8% to 34.5±7.5%, and cover at 1.75m height from 51.9±5.7% in winter to 38.3±7.6% in summer. The change in average canopy cover was little, from 58.8±3.9% in winter to 46.3±5.8% in summer. Here, 31% of the tree/shrubs were available as browse.

5.3.2. Cover Availability

Cover availability at various height from ground ranged from 0% to 100% in at least one plot in each vegetation association. Hence, the minimum and maximum values are not tabulated and any variation from this trend is mentioned in the text.

5.3.2.1. Cover at 0.5m height

The minimum average cover during summer was in Savanna and Teak - *Acacia - Wrightia* habitats and maximum in Mixed forest (Fig. 5.3). The overall difference among the habitats was highly significant (K-W χ^2=109.54, p<.001). The average cover during winter was minimum in Thorn forest and maximum in Teak - *Acacia - Boswellia*. The overall deference in average cover was significant in winter too (K-W χ^2=46.24, p<.001). The average cover at this height was significantly more in winter than in summer in all the habitats except M (Table 5.2). Overall cover at this height decreased significantly during summer (M-W Z=15.29, p<.001, n=2240) in Gir.

5.3.2.2. Cover at 1.0m height

The maximum percentage cover in summer at this height was only 62.5% in the Teak forest which also had the least average cover. The maximum average in summer was in Mixed forest and Riverine habitats (Fig. 5.4). The overall variation was significant both in summer (K-W χ^2=84.22, p<.001) and winter (K-W χ^2=58.76, p<.001). Except *Anogeissus - Acacia - Terminalia*, Teak - *Acacia - Boswellia* and Riverine, there was significantly more cover in winter as compared to summer (Table 5.3). The overall change from winter to summer in cover at this height was significant (M-W Z=10.46, p<.001, n=2240).

5.3.2.3. Cover at 1.75m Height

At this height Teak forest had only 62.5% cover in summer and 93.8% in winter. Teak forest also had the minimum and Riverine the maximum average cover in summer while in winter *Anogeissus - Acacia - Terminalia* had the minimum and Mixed forest habitat the maximum average cover at this height (Fig. 5.5). In both the seasons the overall variation in average cover was significant (K-W χ^2=60.83, p<.001 in summer; and K-W χ^2=59.53, p<.001 in winter). There was an overall significant decline in the cover at this height from winter to summer (M-W Z=10.31, p<.001). Among various habitats there was significant decline in cover at this height in summer (Table 5.4). The exception to this were Savanna, *Anogeissus - Acacia - Terminalia*, Teak - *Acacia - Boswellia* and Riverine.

5.3.2.4. Canopy Cover

The average minimum percentage canopy cover during summer was in Scrubland and maximum in Riverine (Fig. 5.6). The overall variation in average canopy cover was significant (K-W χ^2=220.67, p<.001).

The average percentage canopy cover during winter was least in Savanna and maximum in Riverine habitat. The overall variation between habitat types was significant (K-W χ^2=146.90, p<.001). The overall canopy cover in Gir in winter was significantly more than in summer (M-W Z=14.72, p<.001). Among habitats except Savanna, *Anogeissus - Acacia - Terminalia* and Riverine, the decline in average percentage canopy cover in summer was significant (Table 5.5).

5.3.3. Browse Availability and Consumption

5.3.3.1. Browse Availability

A list of browse trees available in Gir is given in Appendix II. The range of percentage browse trees/shrubs available and their density in each habitat type is given in table 5.6. Maximum percentage of browse tree species were available in Thorn forest and Scrubland habitats (Fig. 5.7). On the other hand, minimum browse trees were present in Teak forest and Savanna. The overall variation in the availability of browse trees was significant (K-W χ^2=90.89, p<0.001, n=93).

Maximum density of browse plants was in a case of scrubland and minimum was in savanna and Teak forest (Table 5.6). Maximum average browse plant density was in scrubland and minimum average in Teak Forest. The overall difference in average browse density was significant K-W χ^2=32.89, p<0.001, n=93).

5.3.3.2. Consumption

Leaf Litter Consumption: Fig. 5.8 provides the details of *Zizyphus mauritiana* leaf litter consumption by wild ungulates in the various habitat types. Consumption of leaf litter was maximum in Thorn forest and minimum in Teak forest. In all the habitats the amount of leaf litter consumed was more near water (upto 200m and no livestock) than away from it (WLS).

Browse consumption: Regression equations and their functions are presented in Fig 5.9, 5.10 and 5.11. Highly significant F values were found which indicated that the twig weight and diameter are linearly related. The correlation between the diameter and cumulative dry weight of the twig changed from one species to another. Table 5.7 provides information about correlation and coefficient of multiple determinant (percentage variation explained) by cumulative weight for six common browse species in Gir. The maximum variation was explained in *Acacia nilotica*, in which the correlation was also maximum. The least correlation and variation explained was in case of *Zizyphus mauritiana* and *Capparis sepiaria*. The correlation was significant (p<.001) in all the cases.

Measurements of browsed twig diameter showed that there was significant difference (Table 5.8) in the size of twig consumed among four species - *Acacia nilotica, Bauhinia racemosa, Capparis sepiaria* and *Wrightia tinctoria* (one way ANOVA F= 7.4, p<.001). The diameter of browsed twigs on *Bauhinia racemosa* and *Wrightia tinctoria* were significantly larger than that of *Capparis sepiaria* (Scheffe's Multiple Range Test, P<.05).

Table 5.9 provides a summary of the average dry weight consumed per twig for the four species. It is evident that there was difference in the weight of twig consumed among the four species. The statistical results were the same as in above para.

On a average 30% of the available browse was consumed by ungulates (Table 5.10). The percentage of browse consumed of the total produced was very less (about 3%) for tree species (*Bauhinia racemosa*) compared to shrub species (*Capparis sepiaria*) in which 14.5 to 21% browse was consumed. The maximum average percentage browse consumed of the available was from *Capparis sepiaria* in Teak mixed habitat and minimum from *B. racemosa* in same habitat. It was also seen that less browse was consumed from *Capparis sepiaria* in a habitat in the national park than in the wildlife sanctuary.

5.3.4. Habitat Utilization by Ungulates

Habitat utilization described in this section is for chital and sambar. Data from pellet count is pooled according to the habitat types and is presented in the form of density i.e. average number of pellet groups/hectare for every habitat. The data from direct observations of animals along roads is modified and presented as average number of animal groups sighted per habitat.

5.3.4.1. Habitat utilization by chital

Pellet groups: The range of pellet group density found in various habitats is given in Table 5.11. The average pellet group density was maximum (Fig. 5.12a) in

Riverine habitat (310±11 groups/ha, n=87) and, minimum in Mixed (130±13/ha, n=28) and Teak forest (130±11/ha, n=48) in summer. The overall difference in pellet group density was significant (K-W χ^2=77.17, p<.001, n=969). In winter the Thorn forest had maximum average pellet group density (310±18/ha, n=227) and the minimum was recorded from Scrubland (120±6/ha, n=38). The overall deference in winter was significant (K-W χ^2=64.13, p<.001, n=834). Seasonal variation in the pellet group density was significant in Scrubland (M-W Z=4.21, p<.001, n=125), Teak Mixed (M-W Z=2.05, p<.05, n=225) and Riverine (M-W Z=2.42, p<.05, n=49) habitats (Table 5.11).

Direct observations: The minimum and maximum range along with the average number of chital group sighting in different habitats is given in Table 5.13. The average chital group sighted (Fig. 5.12b) was maximum in morning/evening hours in Thorn forest (7.8±1.07, n=50) and in *Anogeissus* - *Acacia* habitat in noon hours (8.30±1.12, n=26 respectively). There were no sightings in *Anogeissus* - *Acacia* - *Terminalia* habitat. Next minimum sightings were in Teak - *Acacia* -*Wrightia* both in the morning/evening and noon hours (2.7±0.88, n=3; and 2.3±0.7, n=3 respectively). Generally very few groups were sighted in Savanna, Teak - *Acacia* - *Boswellia* and Teak - *Acacia* - *Wrightia* habitats. The overall variation in average group size sighted in various habitat types was significant both in morning/evening (K-W χ^2=16.13, p<.05, n=38) and noon hours (K-W χ^2=28.95, p<.001, n=141). There was no significant difference in any habitat utilization between morning/evening and noon hours.

In general chital evidence showed greater habitat utilization in Thorn forest and Riverine habitats than others. On the other hand evidence in hilly habitats (Teak - *Acacia* - *Boswellia*, Teak - *Acacia* - *Wrightia*, *Anogeissus* - *Acacia* - *Terminalia* and Teak - *Acacia* -*Wrightia*) and Teak forest indicated relatively little use by this species.

5.3.4.2. Habitat utilization by sambar

Pellet Groups: The range of pellet group density in various habitats is provided in Table 5.13. There was little but statistically significant variation (K-W χ^2=21.65, p<.05, n=476) in the average group density in different habitats in summer. Maximum average group size was in the Mixed forest habitat (75±5.5/ha) (Fig. 5.13a). In winter the maximum average pellet group density was in Mixed forest habitat (170±15/ha, n=33) and in Teak forest (85±9.5/ha, n=38). The overall variation in winter was significant (χ^2=23.15, p<.05, n=386). The seasonal variation in the average pellet group was not statistically significant in any habitat type (Table 5.13).

Direct Observation: The range of sambar group sightings in different habitats during morning/evening and noon hours in given in Table 5.14. Sambar sightings in general were very poor compared to chital. In three habitat types there were no sighting in morning/evening hours and this list increased to eight during noon hours. In most of the habitat types the sightings were one or two with a maximum of five in Teak - *Acacia* - *Zizyphus* during morning/evening hours, as also during noon hours (Fig. 5.13b). The variation in average group size in various habitat types was insignificant statistically.

Sambar pellet group density indicated more use of mixed habitat than other and its sightings were too less to conclude.

5.3.5. Relationship Between Ungulates and Habitat factors

Among the twelve habitat variables, species diversity and richness, and cover at 1.0m and 1.75m height were strongly associated. Therefore, cover at 1.75m was dropped from further analysis by CANOCO. Species richness was not included because species diversity is the mostly used one (Kent & Coker 1991).

The two CANOCO axes accounted for 90.1% variance in species and environment in summer and for 89.5% variance in winter. The eigen value of first axis was 0.074 and that of second axis was 0.038 for summer data. For winter data these eigen values were 0.101 and 0.048 for the first two axes.

During summer the distance from *nes* (measure of disturbance) was presented by first axis which separated disturbed areas on left side from the undisturbed ones on right side (Fig 5.14). The separation was not perfect and the weighted correlation between distance from *nes* and axis 1 was 0.75. The other variable associated with axis 1 was grass cover (0.51 correlation). The correlation of any variable with axis 2 was very poor and the maximum was between percentage browse availability and axis 2 (0.40).

In summer sambar and nilgai were in undisturbed areas while chital and chinkara were in disturbed areas (Fig. 5.14). This relationship, however, is not significant for chital and sambar as these occupy positions near the centre. The Monte Carlo permutation test (ter Braak 1988) conducted for the first axis eigen value (P=.65) showed that this axis does not significantly account for the variation in ungulate distribution in summer in Gir.

In winter grass cover was associated with axis 1 (weighted correlation =0.65), and Distance from *nes* (0.72) and cover at 0.5m height (0.53) with axis 2. This means more nilgai evidence were found in undisturbed areas with high grass cover. More sambar evidence were found in undisturbed areas with low grass cover but its position near the centre indicates its weak relationship. Chital evidence were more in disturbed area with less grass cover, but the relationship is poor because of its position near the centre. The position of chinkara indicates its preference for undisturbed areas with less grass cover.

5.4. DISCUSSION

In the last chapter the vegetation classification has been discussed. Since the habitat types were derived from these associations, the results of habitat classification are not being discussed here.

Cover data suggests that variation in cover at all the three levels was due to habitat types which in turn were affected by edaphic factors. Hence, cover values at all the levels were more in Mixed and Riverine habitats because these habitats were in localities with more humus and soil moisture (see 4.3).

Browse (leaf letter) consumption turns out to be a function of browse availability in habitats. More leaf litter was consumed in habitats with more plants available as browse. More leaf litter consumption near water points show that habitats providing food and water are preferred by ungulates. Twigs even of large diameter were consumed is case of species with tender twigs such as *Bauhinia racemosa* and *Wrightia tinctoria* compared to those with harder twigs (e.g. *Acacia nilotica* and *Capparis sepiaria)*. However, the measurement of hardness is subjective and based only on the efforts required in clipping the twigs. *Bauhinia racemosa* and *Wrightia tinctoria* also provided more forage per bite (due to larger leaves) than the other two.

Habitat utilization by ungulates shows discrepancy in pellet groups and direct observations. Habitat utilization as indicated by the pellet groups varies less compared to the results of direct observations. This discrepancy was less in the case of chital.

The chital pellet groups and animal sightings were more in habitats with high browse availability (Fig. 5.16a and 5.16b). Chital sightings were more in the habitats in which more *Zizyphus mauritiana* leaf litter was consumed. Another factor which led to the variation in pellet groups and direct observations was the hilly terrain. There was no chital sighting in *Anogeissus -Acacia - Terminalia* and relatively few sightings in *Teak - Acacia -Boswellia* and *Teal - Acacia - Wrightia* habitats, all of which were associated with hilly terrain. Pellet groups, on the other hand did not vary much among these habitat types. This suggests that chital used hilly terrain only as passage or for yarding (on small hills with flat top) at night.

Large differences were observed in pellet groups and sightings of sambar. This crepuscular animal was seen more in habitats with more canopy cover, water and away from human disturbance (Fig. 5.17a and 5.17b). It did not show any relationship with browse availability. The pellet groups were almost uniformly distributed among the habitats. This discrepancy in sambar sightings and pellet groups suggests that these animals took shelter under some dense trees (e.g. *Butea monosperma*) away from human disturbance during day time but used all the habitats almost uniformly at night when human disturbance was the least. Pellet distribution also indicated that cover is not very important for sambar at night.

CANOCO results suggest that in general habitat utilization by ungulates seems to be controlled by disturbance and cover. The extent of these factors varied in winter and summer. The reasons for variation in habitat utilization in both summer and winter are described below.

If animal distribution is related with each environmental factor (Fig. 5.14) it is seen that in summer sambar distribution is associated with cover (grass cover, cover at 0.5m and 1.0m height). This preference of sambar for dense cover has been observed by Ables & Ramsey (1974). When its negative relationship with grazing and, positive relationship with cover at 0.5m and 1.0m height, and grass cover (all indicators of less human disturbance) is viewed, its becomes evident that it keeps away from human disturbance. Avoidance of disturbed areas has also been observed in Rajaji national park (Bhatnagar 1991). Since most of the water points in Gir are near *neses* sambar avails these water facilities at night and/or dusk and dawn hours, the time of least human activity. The difference in the pattern of habitat utilization between day and night supports this. This difference in habitat utilization at different periods of the day has been reported by Pratt *et at.* (1986). Sambar also seems not to bother about high browse availability areas unlike elsewhere when it preferred areas with high browse (Bhatnagar 1991). This may be due to two reasons. First, because livestock frequents such areas (see grazing and browse in similar direction), and second, because of solitary habits and selective feeding, unlike chital it is not dependent on areas of more browse availability.

Sambar distribution was very weakly associated with slope in summer while its weak negative relationship with slope in summer indicates that this animal used more valleys than hill slopes or tops for most of its activities. This is because in summer when the grass is utilized from nearby areas the livestock grazes farther away in areas with more browse. The *maldharis* lop the trees in valleys, creating disturbance and pushing sambar to relatively undisturbed hill slopes during the day.

In summer chital evidence decreased on increasing distance from water and human settlements which reveal that it can afford to be near human settlements. Being a gregarious animal it searches for localities with relatively high browse availability. In winter when water is not a limiting factor, chital was still maximum in disturbed areas near *nes* and in areas with high browse availability even if it was grazed. Its association with slope and water was almost neutral in winter, but in summer it was negatively (weak) associated with slope. This animal is reported to be found in areas having edge of grasslands and forests (Prater 1980, Daniel 1994) because grass forms relatively large part of its diet (Johnsingh & Sankar 1991). Its position on ordination diagram may support this, but stronger evidence that there were more signs of this animal in disturbed areas is noteworthy. The high abundance of chital in disturbed areas may also be due to less ground and shrub cover in such areas. This is also supported by the data that thorn forest which not only provided highest percentage of browse but also had less ground and shrub cover, generally had more chital evidence and sightings. The avoidance of areas with dense cover may be the reason for comparatively less observations in mixed and riverine habitats in Gir, as has been observed in Rajaji national park (Bhat 1993). The dense cover in these two habitats provides good ambush cover to lion (Ravi Chellam 1993) and leopard, making chital wary of these habitats.

Nilgai which is reported to be water independent and preferring scrubland (Chakrabarty 1991, Bohra *et at.* 1992, Daniel 1994) was associated with undisturbed areas with more grass in winter. Its relationship with water is not clear. In both the seasons it was away from areas of disturbance which has not been reported earlier. This conclusion is supported by my observations of nilgai in some areas. In Devalia Safari Park within Gir (a 4 sq. km area enclosed by 4m high chain-link fence) which provides safety to the animals, one can observe nilgai very closely. On the other hand flight distance is much more in Gir and nilgai were seen away from human settlements. This indicates harassment to these animals in one way or other.

Chinkara was both water and cover independent during summer and winter as has been reported elsewhere (Prater 1980, Bohra *et al.* 1992, Daniel 1994). It was mostly observed in east Gir which generally had less dense cover.

5.5. SUMMARY

Twelve habitat types were classified based on similarity in vegetation associations and TWINSPAN analysis. Habitat utilization by the wild ungulates in Gir was determined by collecting quantitative data on ungulates and habitat factors. The methods used for investigating the habitat utilization included both the traditional (comparing evidence among habitat types) and modern (CANOCO) techniques. Mixed habitat was more diverse while riverine was most dense in terms of cover. Thorn forest provided maximum browse to the ungulates. Chital (*Cervus axis*) showed high use of Thorn forest habitat while sambar (*Cervus unicolor*) used more Mixed, Riverine and Teak - *Acacia* - *Zizyphus* habitat. Data on other ungulates was not sufficient for statistical analysis. The habitat variables used to study the ungulate abundance could not significantly explain the variation in ungulate distribution and abundance. Multivariate analysis showed that habitat utilization was governed by cover and disturbance. In summer disturbance determined ungulate abundance in different areas while in winter disturbance along with cover seemed to be decisive. Sambar and nilgai were away from disturbance while chital could afford disturbance in both summer and winter. Chinkara was observed mostly in the east Gir, a place with conditions like savanna and with more disturbance.

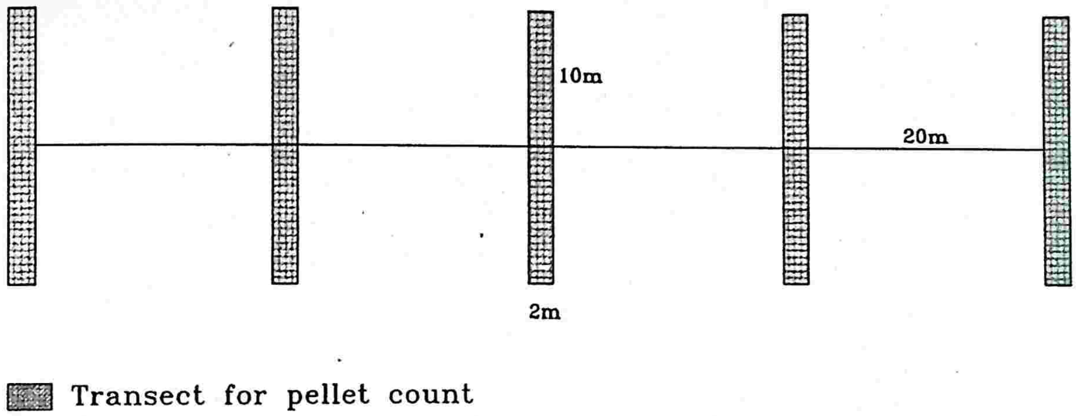


Fig. 5.1. Design of transects used for ungulate pellet groups count in summer and winter.

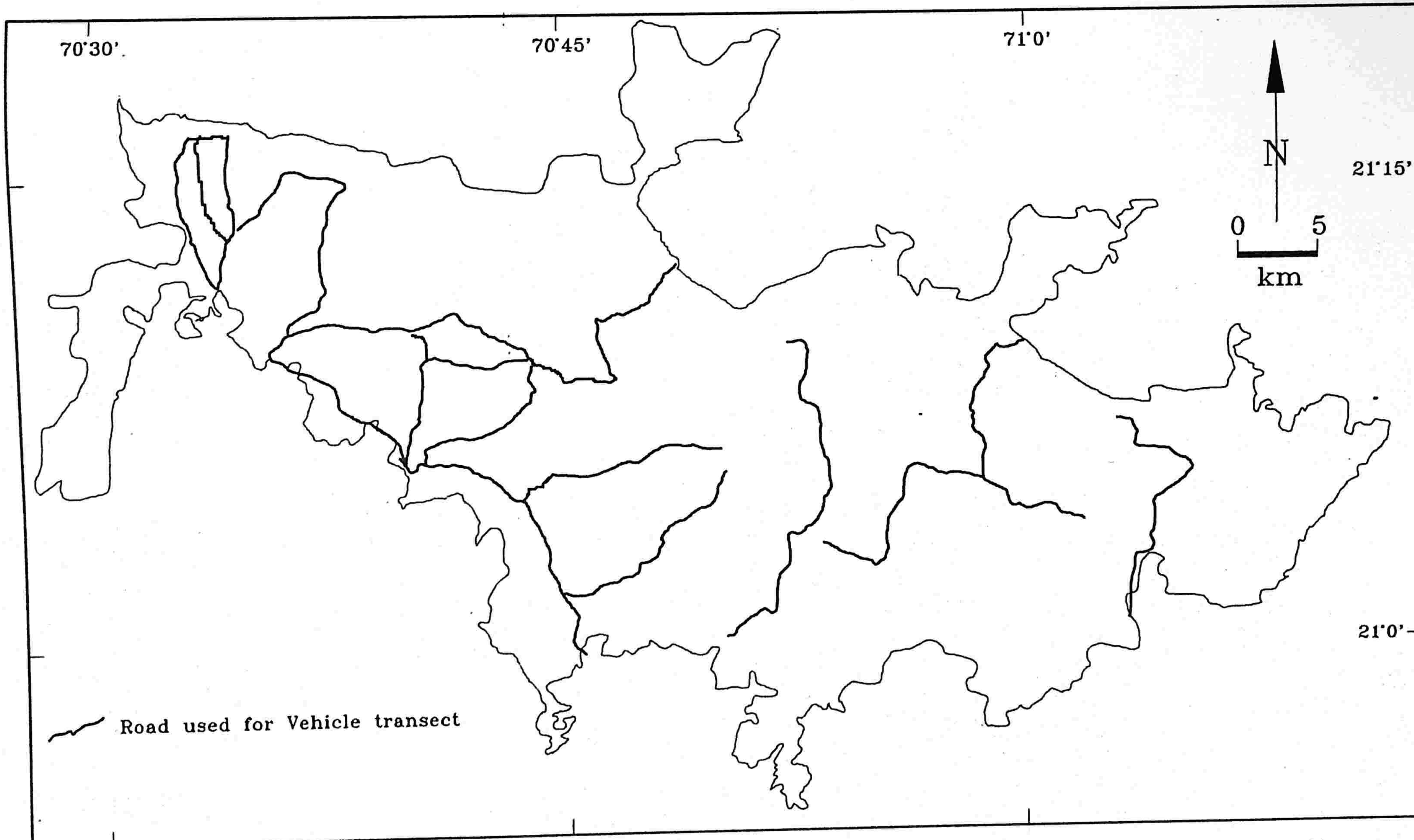


Fig. 5.2. Road network used for vehicle transects in the summers of 1992, 1993 and 1994 in Gir.

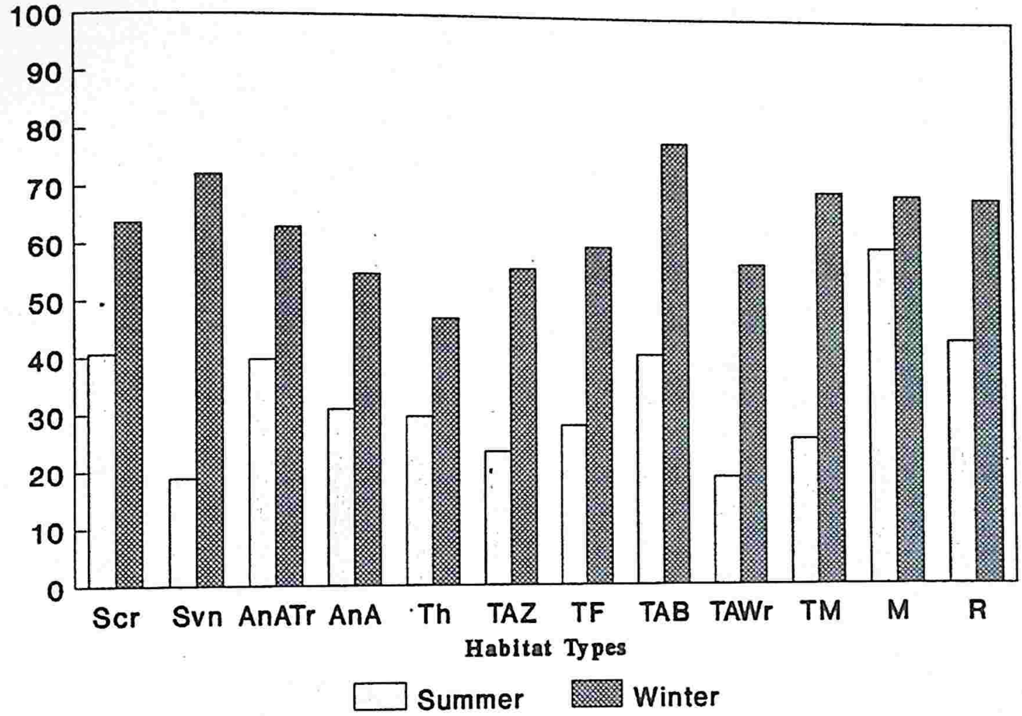


Fig. 5.3. Average percentage cover at 0.5m height in different habitats in summer and winter in Gir.

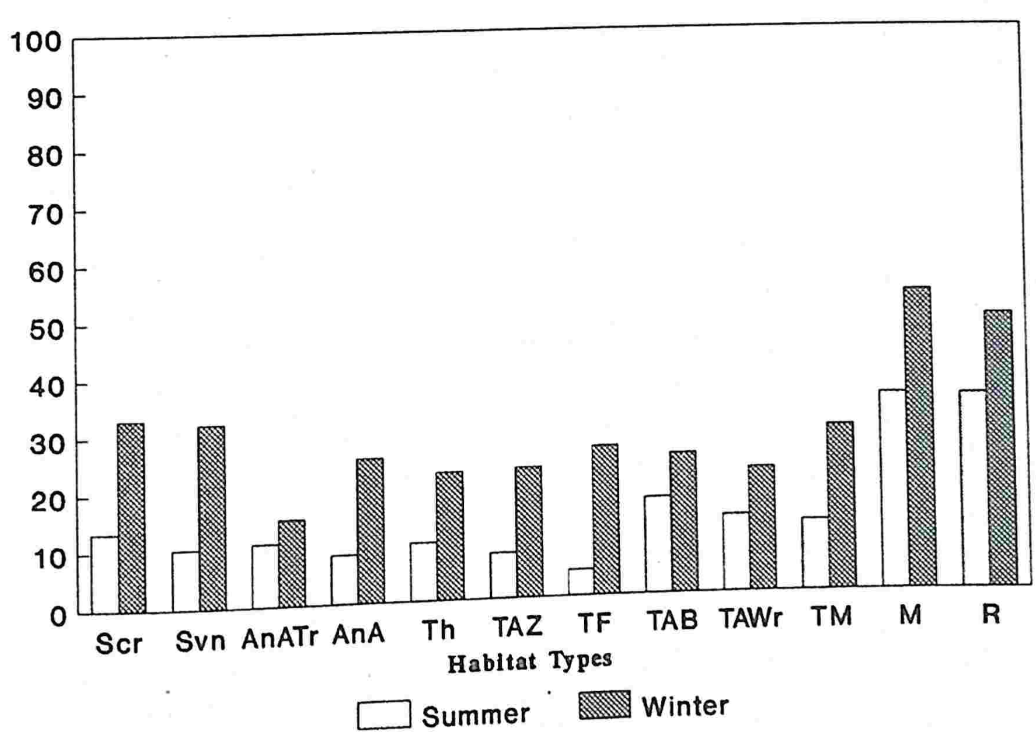


Fig. 5.4. Average percentage cover at 1.0m height in different habitats in summer and winter in Gir.

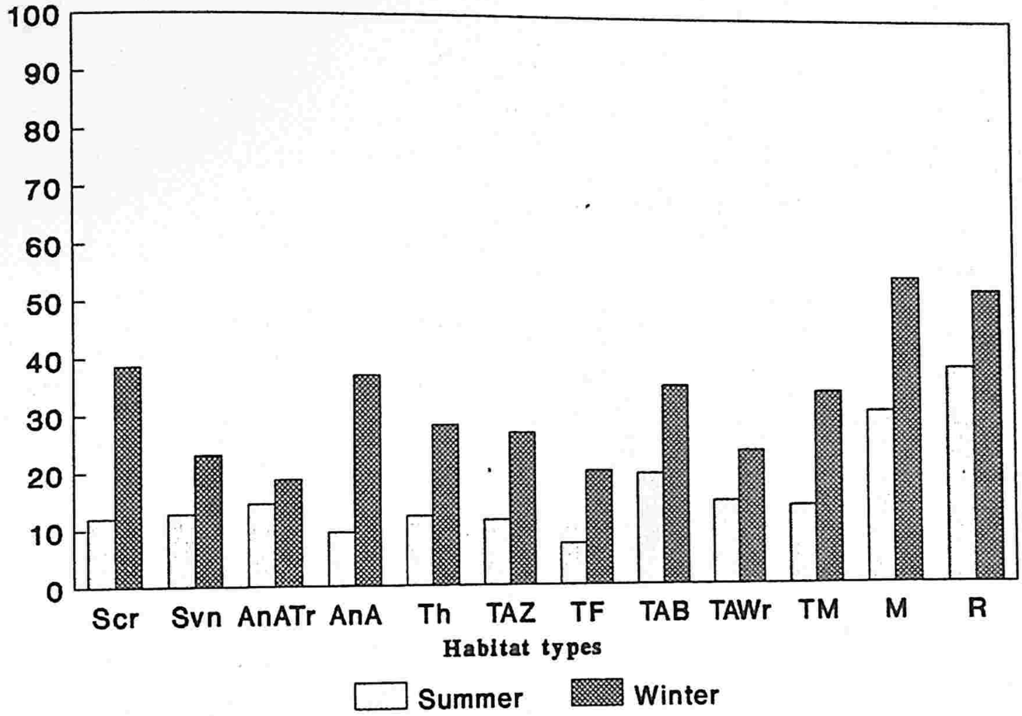


Fig 5.5. Average percentage cover at 1.75m height in habitat types in summer and winter in Gir.

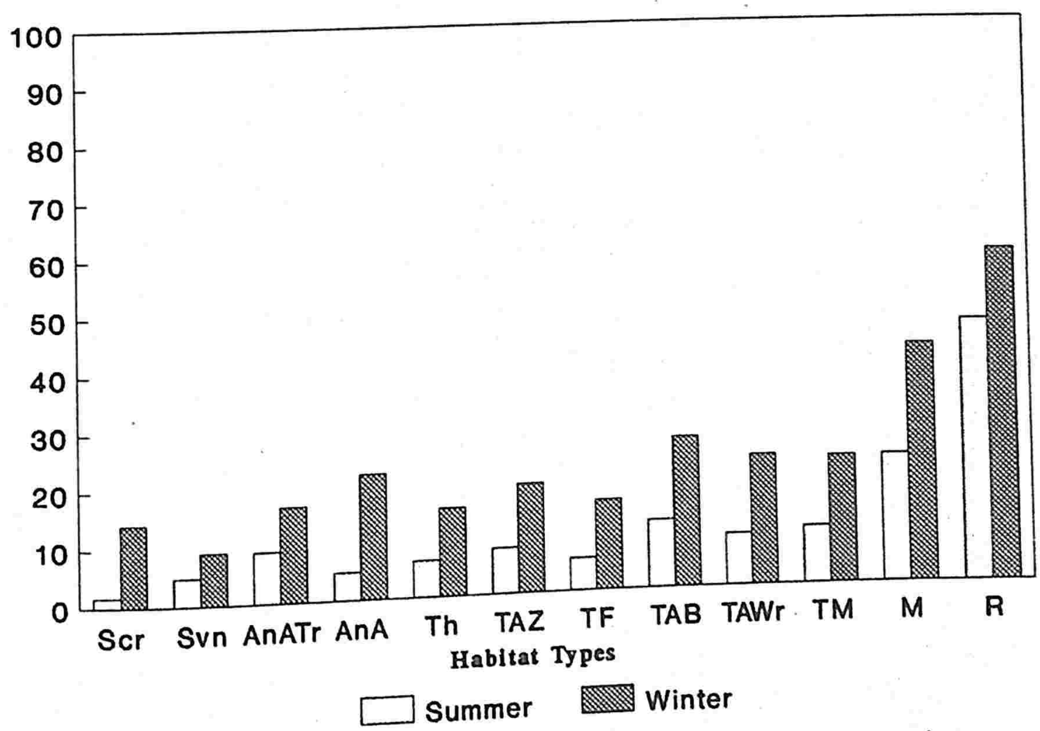


Fig. 5.6. Average percentage canopy cover in different habitats in summer and winter in Gir.

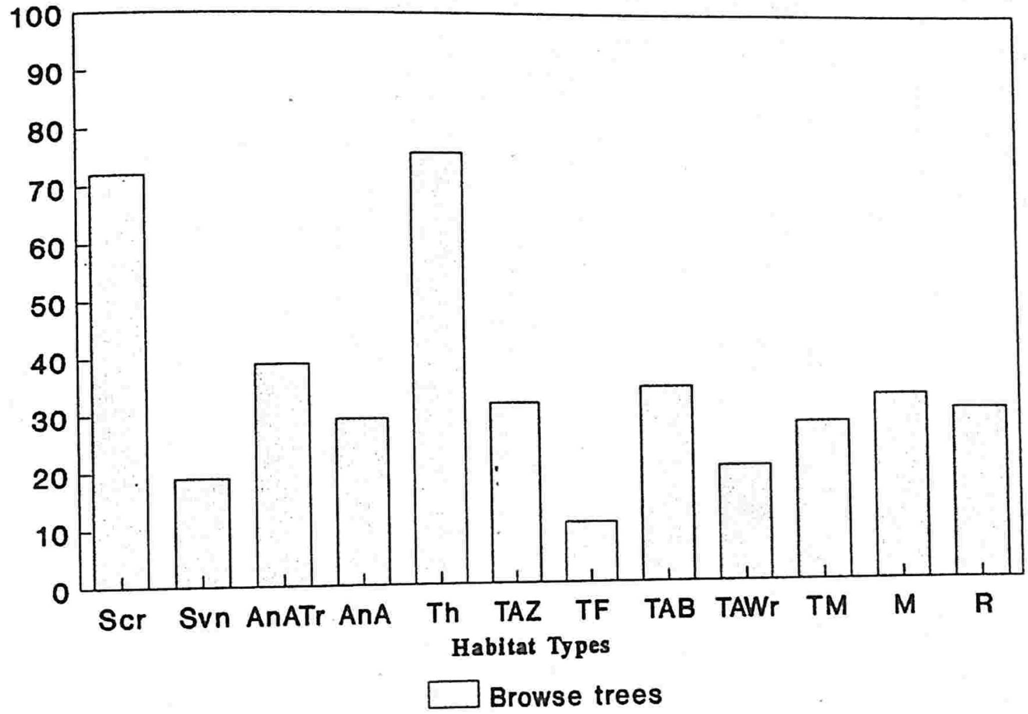


Fig. 5.7. Percentage of browse trees available in habitat types in Gir.

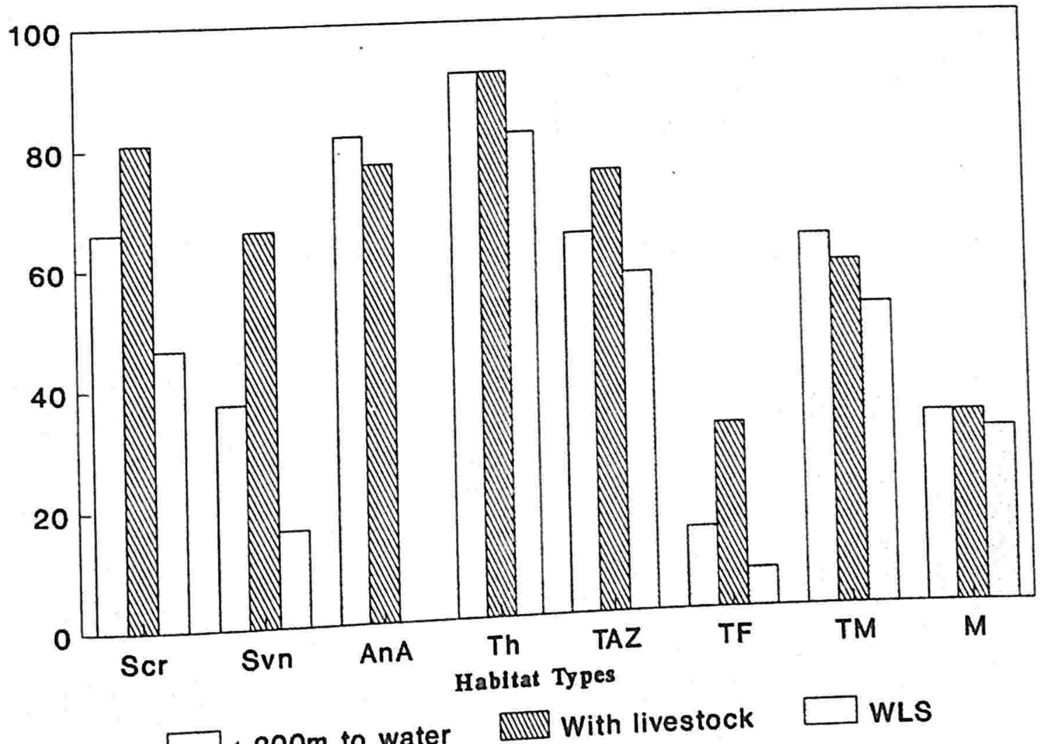
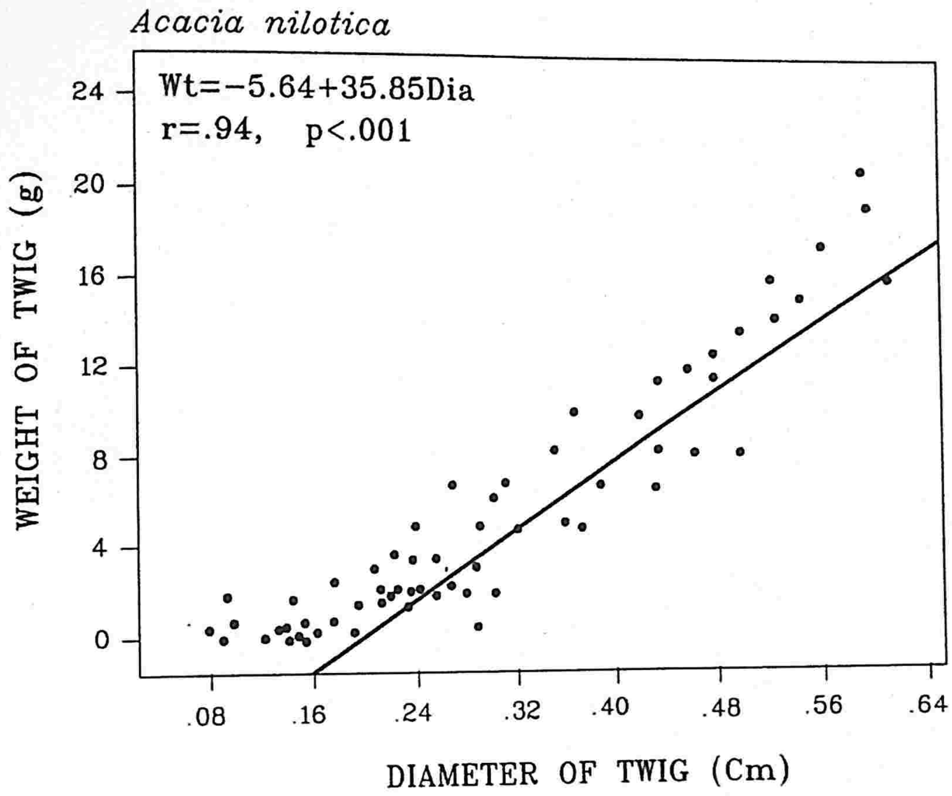


Fig. 5.8. Percentage of *Zizyphus mauritiana* leaf litter consumed by wild ungulates in different habitats and conditions in Gir.



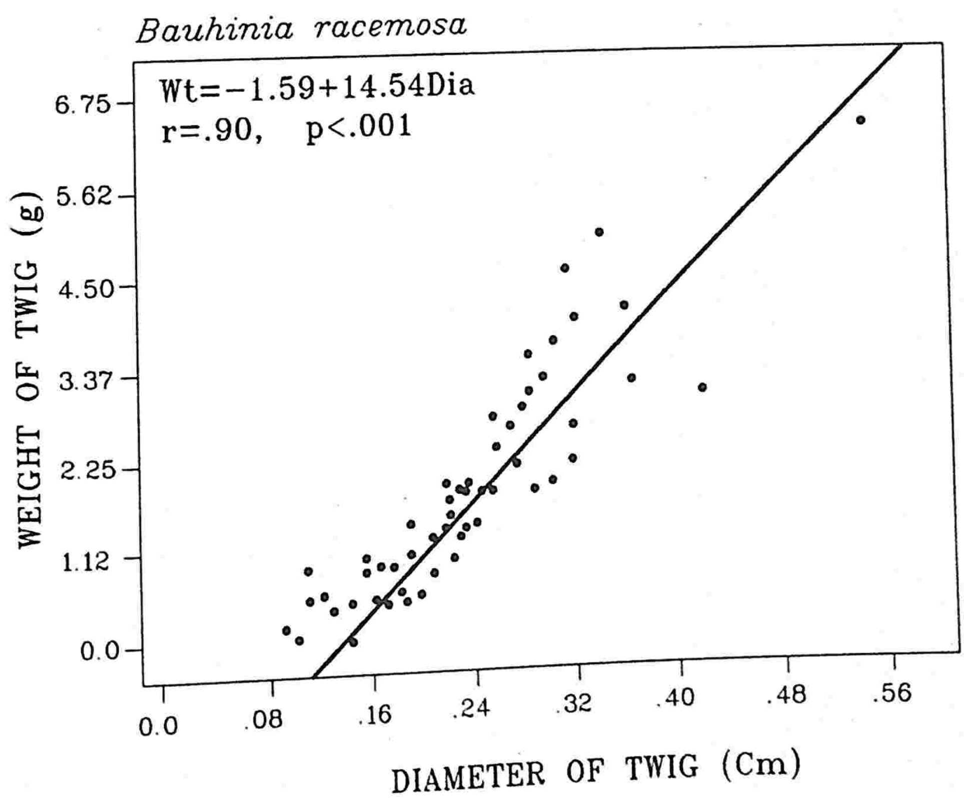
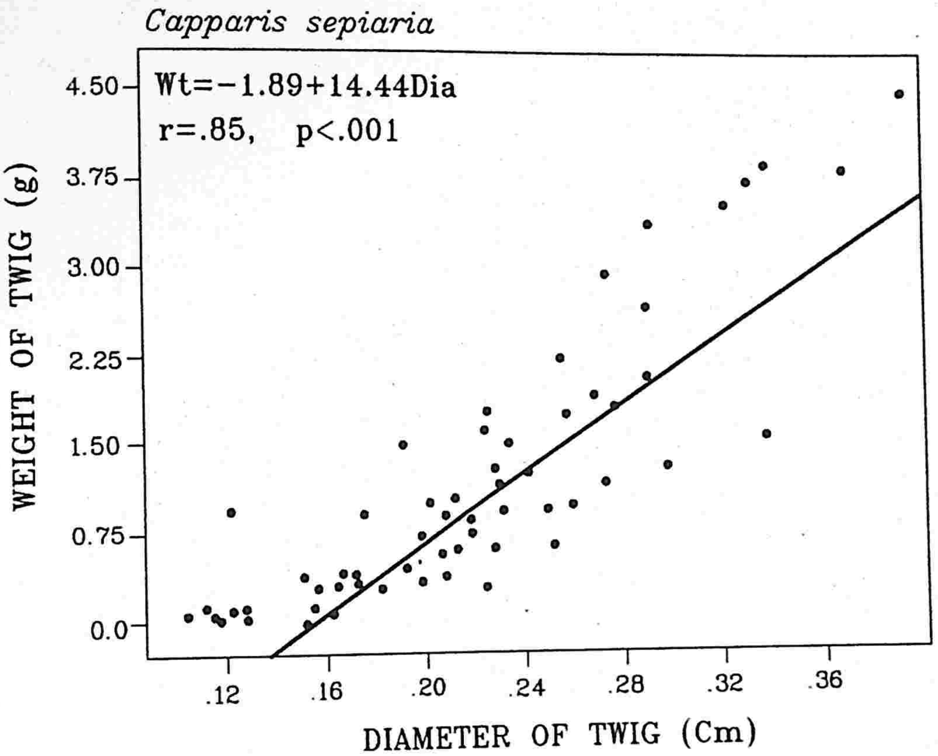


Fig. 5.9. Regression of cumulative weight of twigs on diameter for *A. nilotica* and *B. racemosa*.



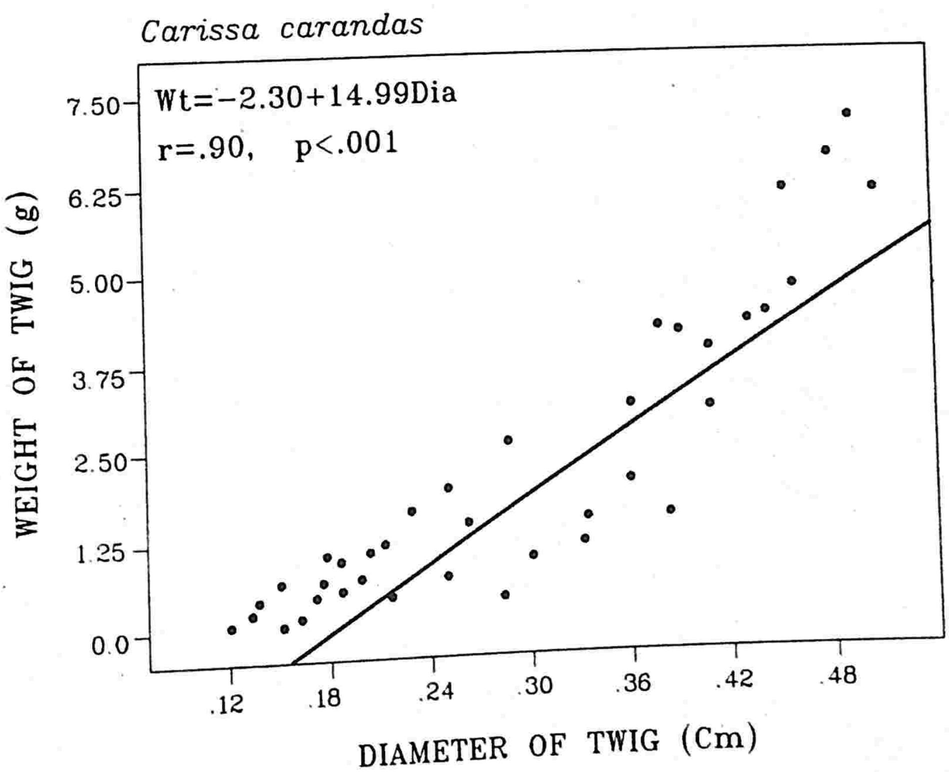
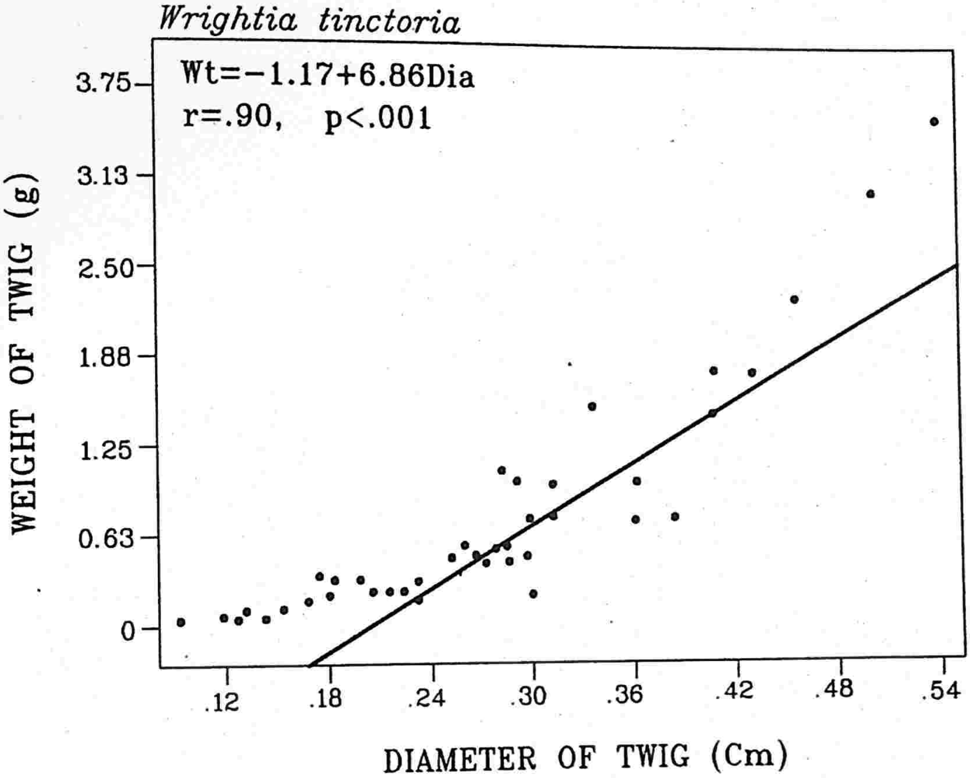


Fig. 5.10. Regression of cumulative weight of twigs on diameter for *C. sepiaria* and *C. carandus*



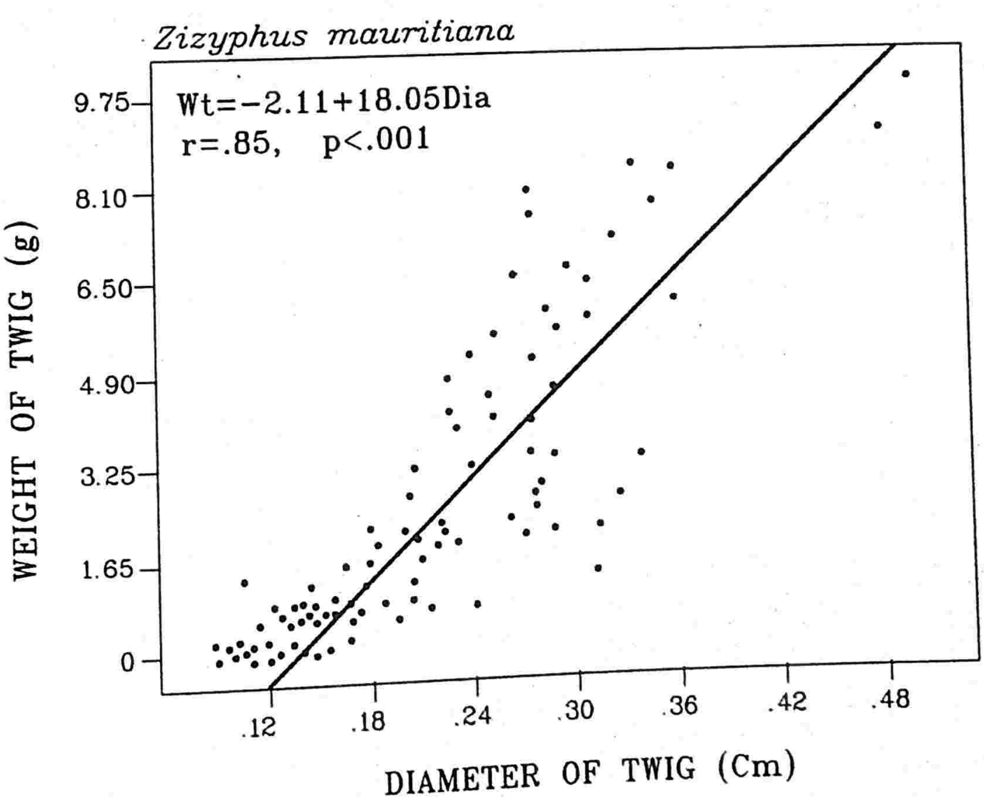


Fig. 5.11. Regression of cumulative weight of twigs on diameter for *W. tinctoria* and *Z. mauritiana*.

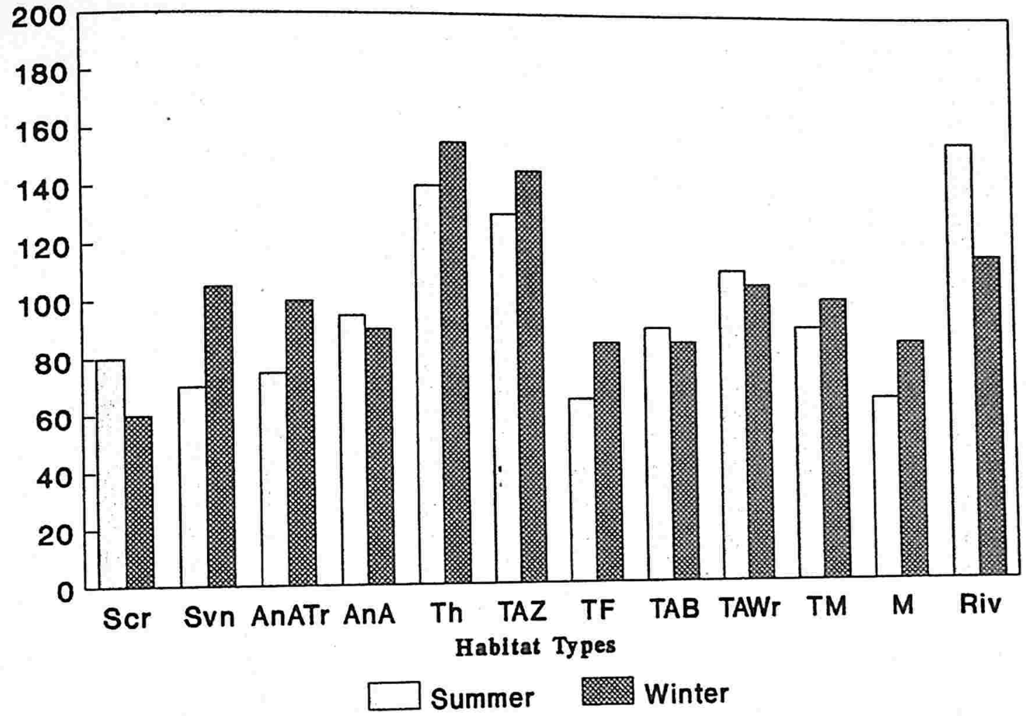


Fig. 5.12a. Average chital pellet group density (number/ha) in different habitats in summer and winter in Gir.

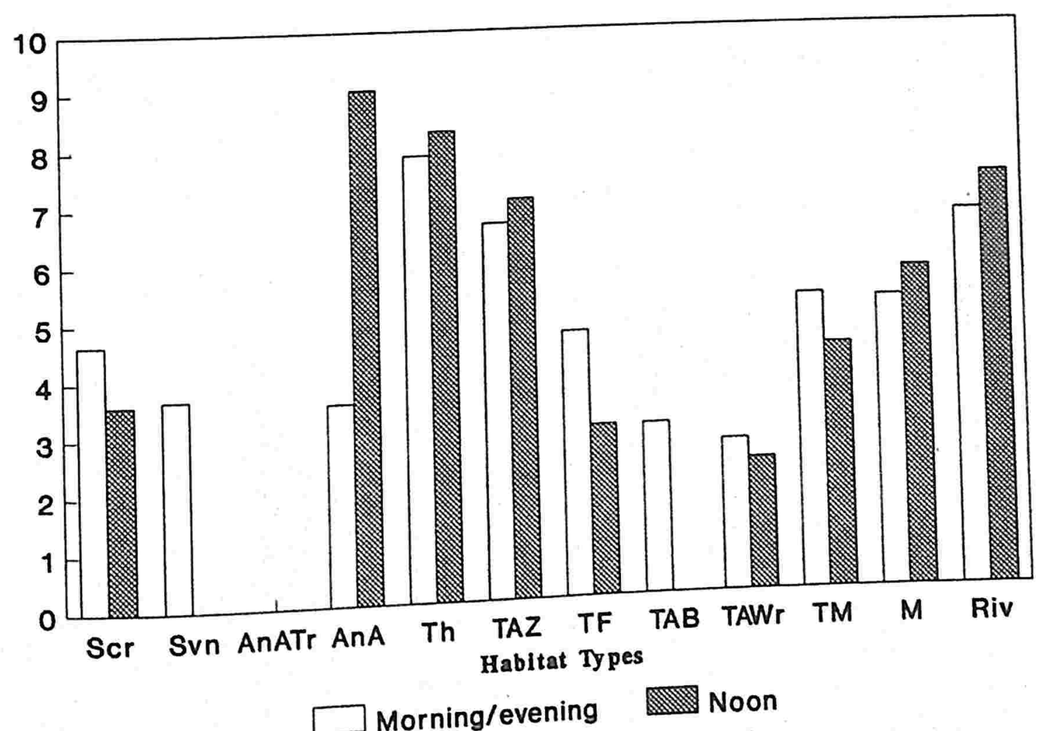


Fig. 5.12b. Average size of chital groups sighted in different habitats in Gir in morning/evening and noon hours.

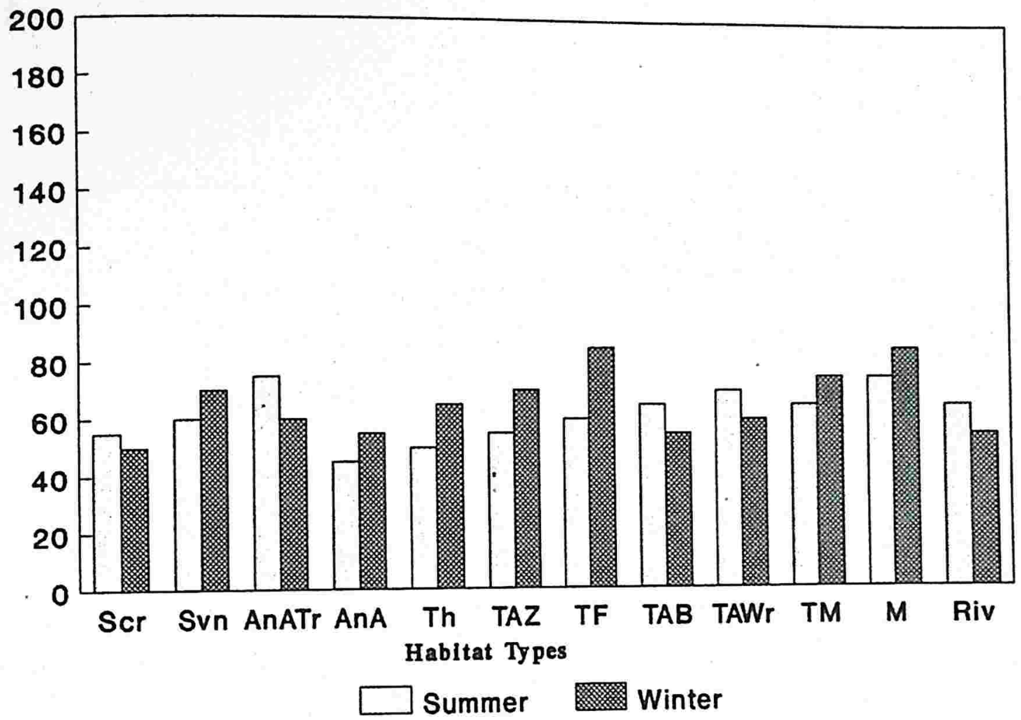


Fig. 5.13a. Average sambar pellet group density (number/ha) in different habitats in summer and winter in Gir.

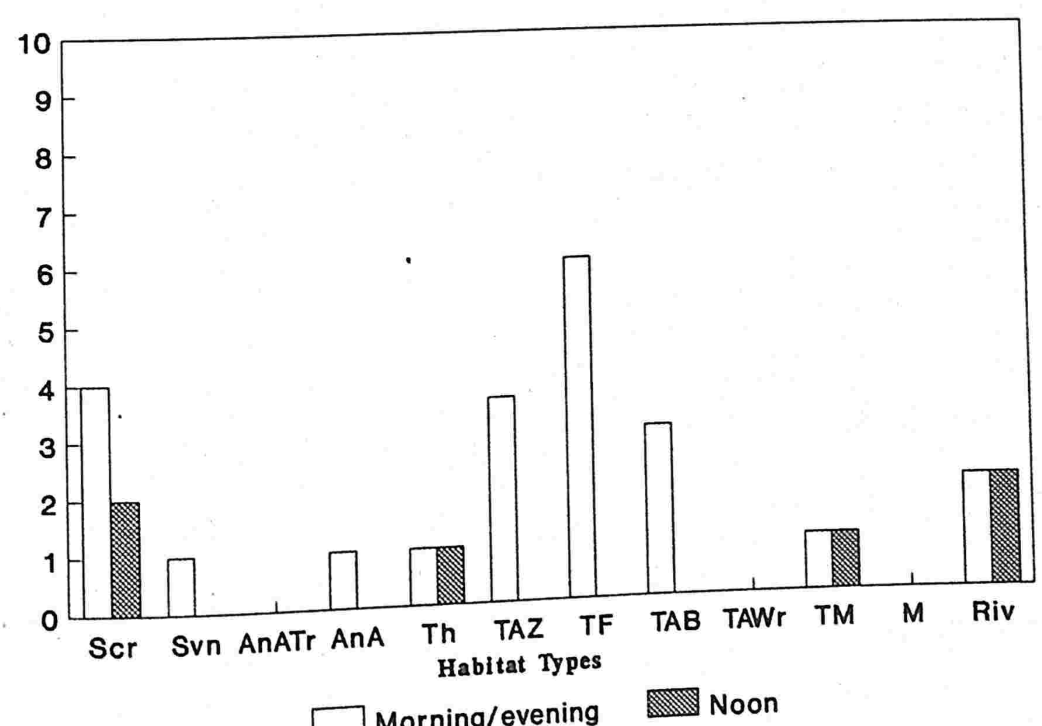


Fig. 5.13b. Average size of sambar groups sighted in different habitats in Gir in morning/evening and noon hours.

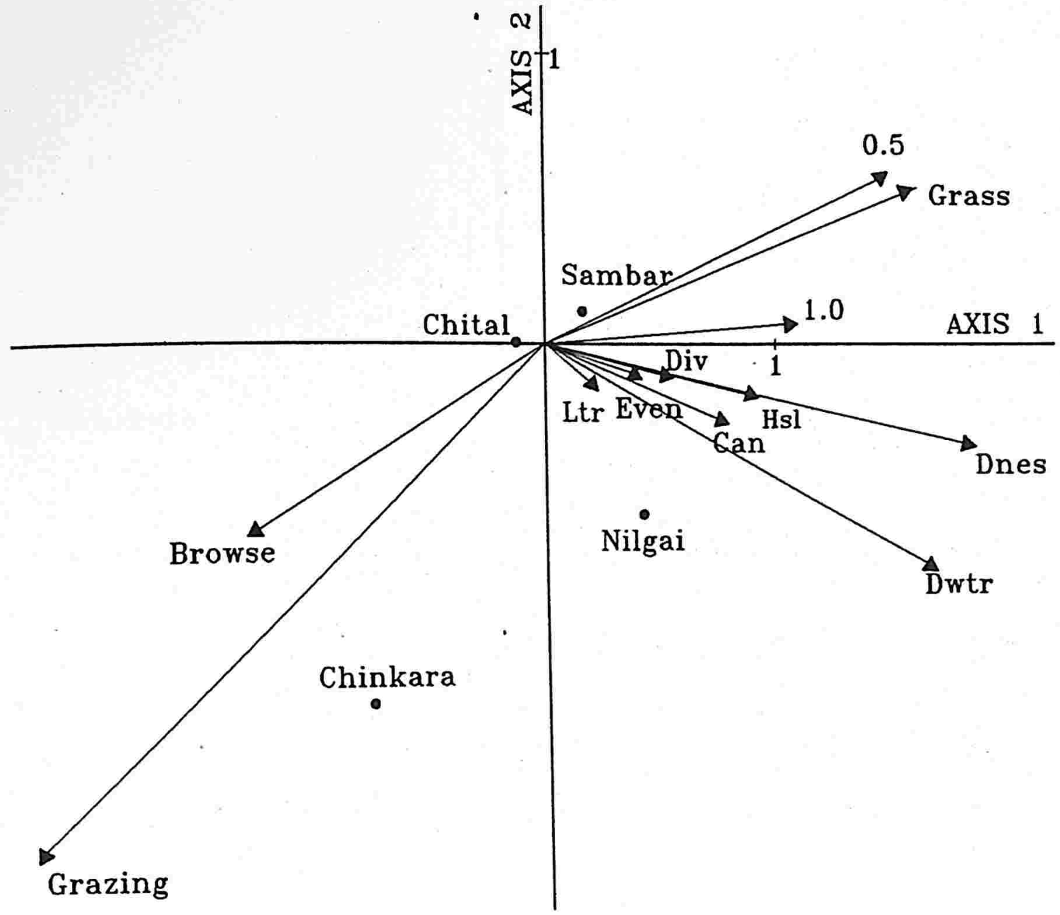


Fig. 5.14. Ordination diagram based on canonical correspondence analysis (CANOCO) of major ungulates in Gir with respect to seven quantitative environmental variables in summer; cover (0.5m, 1.0m, 1.75m, grass, Ltr and Can), diversity (Div and Even), percentage browse availability (Browse), distance from 'nes' (Dnes), distance from water (Dwtr), slope (Hsl) and grazing.

Other abbreviations are:
0.5m - cover at 0.5m height; 1.0m - cover at 1.0m height; 1.75m - cover at 1.75m height; Can - canopy cover; Ltr - Leaf litter; Div - tree diversity; Even - tree species evenness.

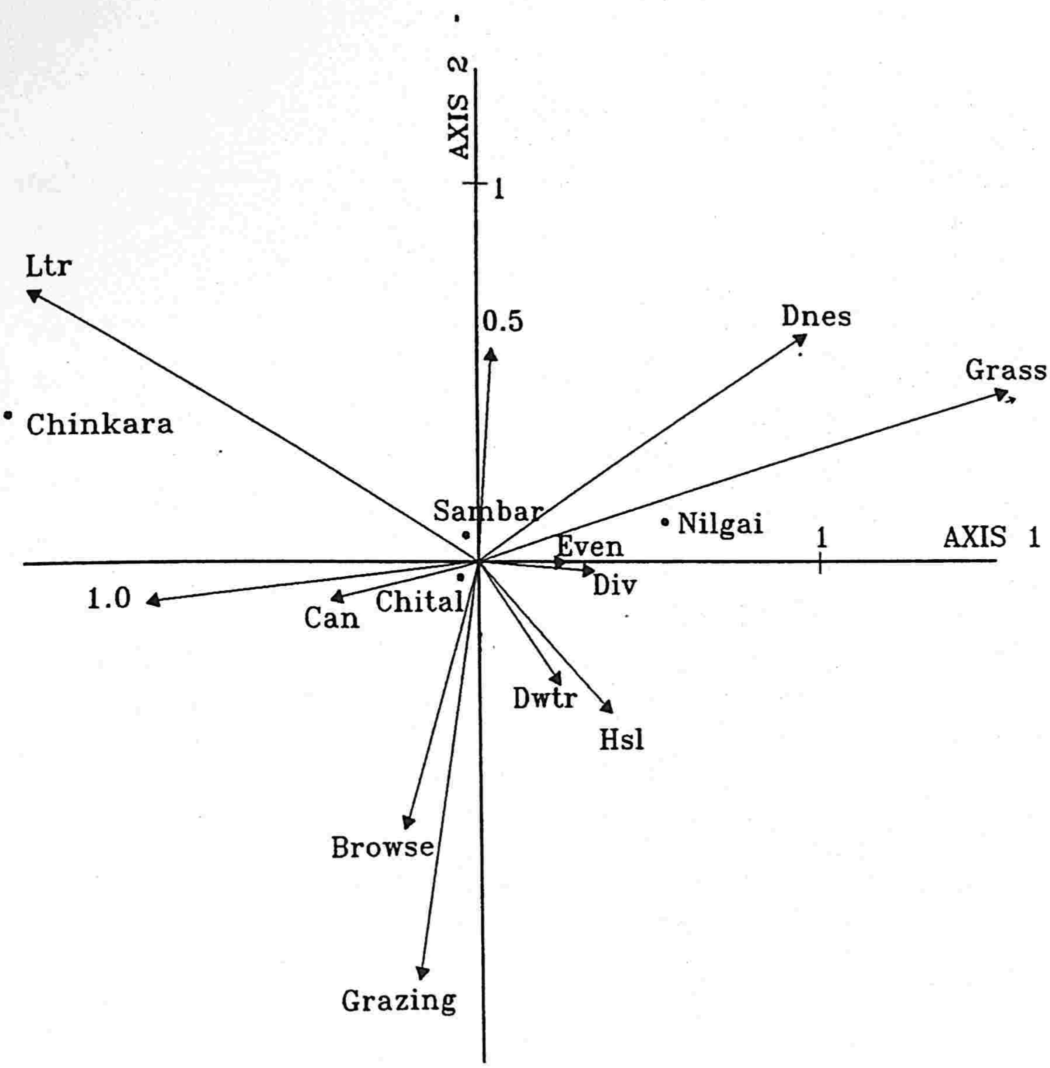


Fig. 5.15. Ordination diagram based on canonical correspondence analysis (CANOCO) of major ungulates in Gir with respect to seven quantitative environmental variables in winter; cover (0.5m, 1.0m, 1.75m, grass, Ltr and and Can), diversity (Div and Even), distance from 'nes' (Dnes), distance from water (Dwtr), slope (Hsl), percentage browse availability (Browse) and grazing.

Other abbreviations are:
0.5m - cover at 0.5m height; 1.0m - cover at 1.0m height; 1.75m - cover at 1.75m height; Can - canopy Ltr - Leaf litter; Div - tree diversity; Even - tree species evenness.

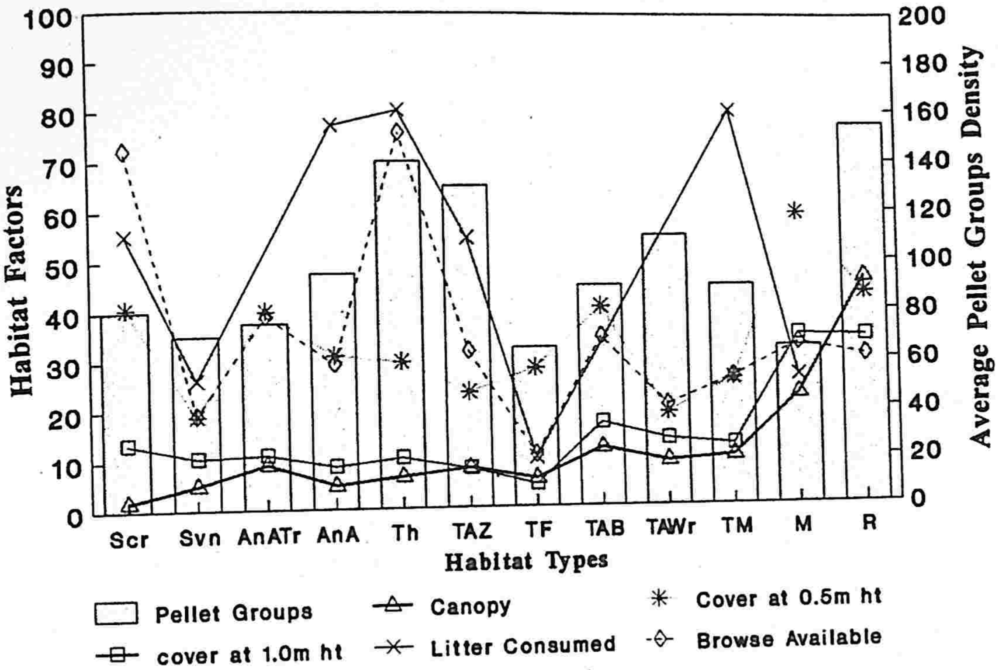


Fig. 5.16a. **Relationship of chital pellet groups with habitat factors in summer. The habitat factors and their symbols are the same in this and Fig. 5.16b.**

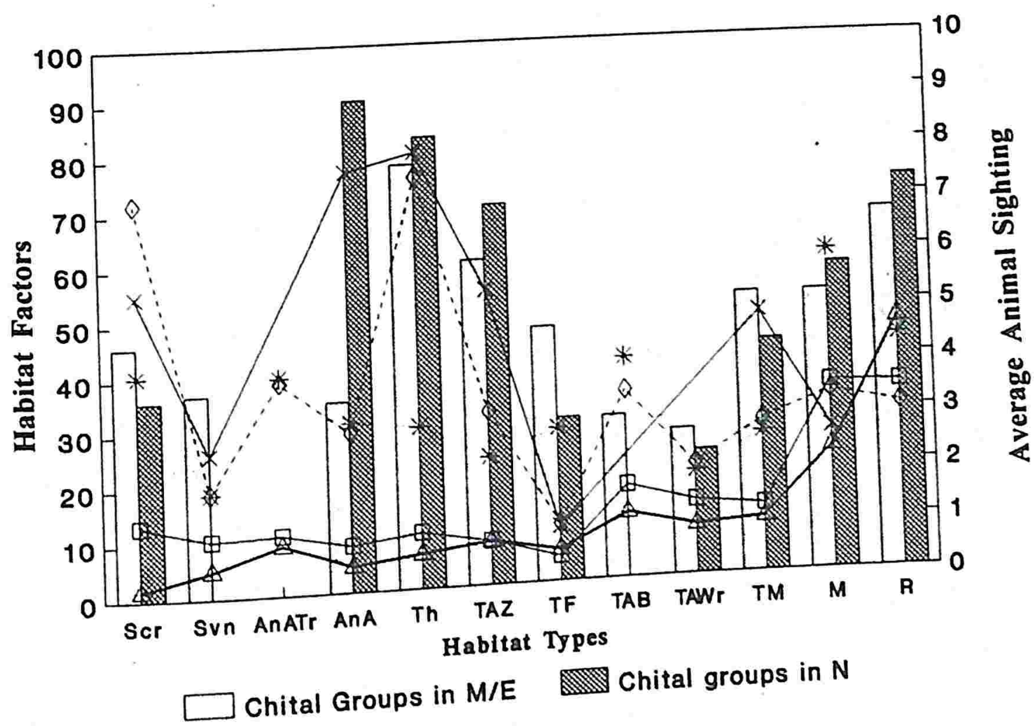


Fig. 5.16b. **Relationship of chital sightings in morning/evening (M/E) and noon (N) with habitat factors in summer.**

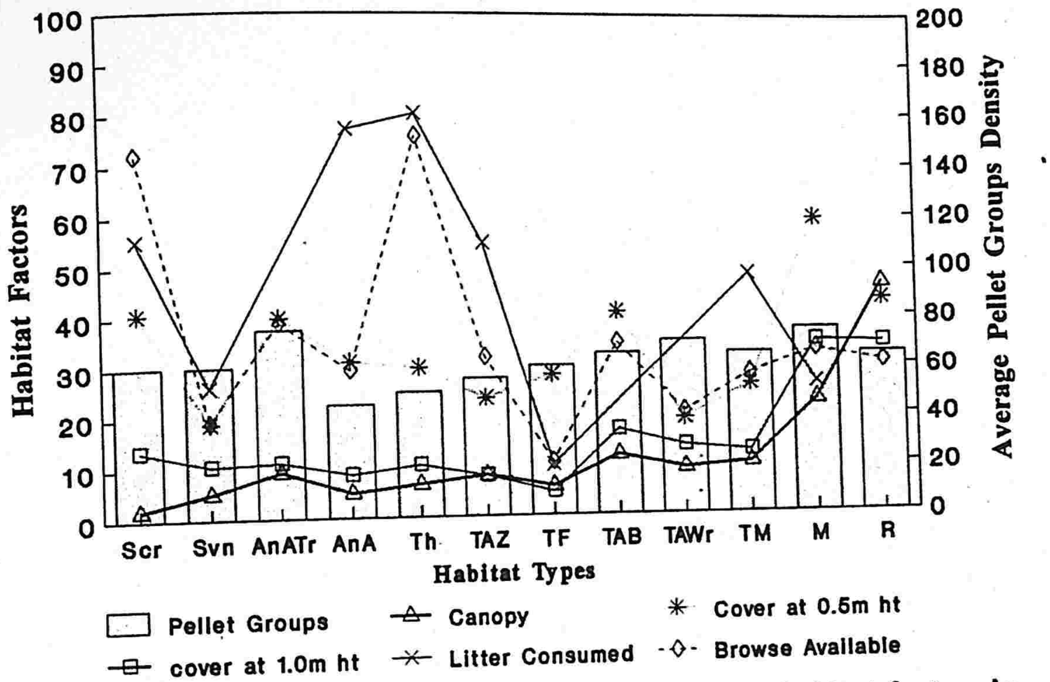


Fig. 5.17a. Relationship of sambar pellet groups with habitat factors in summer. The habitat factors and their symbols are the same in this and Fig. 5.17b.

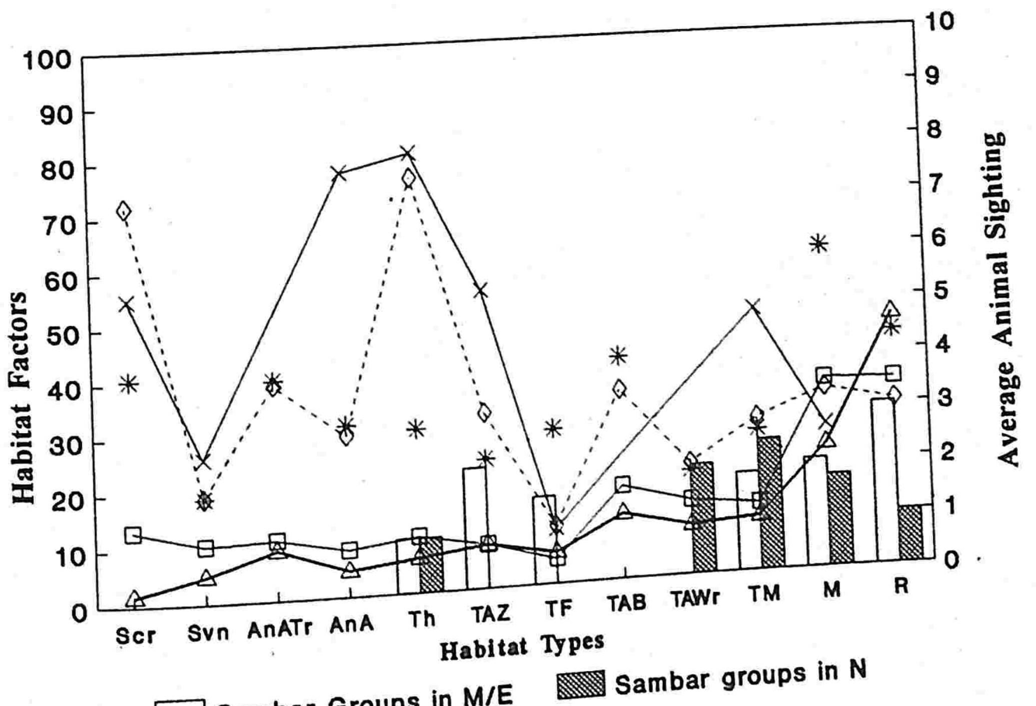


Fig. 5.17b. Relationship of sambar sightings in morning/evening (M/N) and noon (N) with habitat factors in summer.

Table 5.1. Vegetation associations that comprised the habitats.

HABITAT TYPES	VEGETATION ASSOCIATIONS
Scrubland	*A. catechu - Z. nummularia - A. adscensionis*
Savanna	*A. mutica-T. quadrivalvis-S. nervosum*
Anogeissus-Acacia-Terminalia	*A. latifolia-A. catechu-T. crenulata*
Anogeissus-Acacia	*A. latifolia-A. catechu*
Thorn	*A.* spp.-*Z. mauritiana*
	Z. mauritiana
	A. nilotica - Z. mauritiana
Teak-*Acacia-Zizyphus*	*T. grandis-A. catechu-Z. mauritiana*
	T. grandis-A. catechu-T. crenulata
Teak forest	*T. grandis*
Teak-*Acacia-Boswellia*	*A. catechu-L. coromandelica-B. serrata*
Teak-*Acacia-Wrightia*	*T. grandis-A.catechu-W. tinctoria*
Teak mixed	*T. grandis* mixed
Mixed	Mixed
Riverine	*S. cumini-P. pinnata*

Table 5.2. Percentage of cover thickness observed at 0.5 m height in habitat types during summer and winter seasons.

HABITAT TYPES	SUMMER	WINTER	BETWEEN SEASONS (M-W TEST)	
	MEAN±SE	MEAN±SE	Z VALUE	SIGNIFICANCE
Scr	40.6±3.6	63.7±6.2	2.96	**
Svn	18.9±3.3	72.1±6.4	6.67	***
AnATr	39.8±5.8	62.9±9.1	2.28	*
AnA	31.0±4.6	54.7±9.0	2.32	*
Th	29.7±4.4	46.9±2.6	4.83	***
TAZ	23.5±3.1	55.8±2.7	7.01	***
TF	28.2±5.0	59.6±3.9	4.55	***
TAB	40.6±4.9	78.1±5.4	3.66	***
TAWr	19.1±3.1	56.6±3.5	6.81	***
TM	25.9±2.9	69.5±2.6	9.59	***
M	59.4±4.2	68.9±5.3		
Riv	43.3±7.7	68.4±5.1	2.15	*
TOTAL	31.9±1.1	58.8±1.2	15.29	***
SIGNIF.	***	***		

* =p<0.05 ** =p<0.01 *** =p<0.001

Table 5.3. Percentage of cover thickness observed at 1.00 m height in habitat types during summer and winter seasons.

HABITAT TYPES	SUMMER	WINTER	BETWEEN SEASONS (M-W TEST)	
	MEAN±SE	MEAN±SE	Z VALUE	SIGNIFICANCE
Scr	13.4±2.2	33.1±5.9	3.11	**
Svn	10.4±2.5	32.1±6.2	3.45	***
AnATr	11.0±3.7	15.2±7.0		
AnA	8.6±2.4	25.5±7.7	2.94	**
Th	10.3±1.3	22.6±2.0	3.46	***
TAZ	8.0±1.8	22.9±2.1	5.10	***
TF	4.6±1.5	26.3±3.3	5.39	***
TAB	17.0±3.7	24.7±7.3		
TAWr	13.6±2.7	21.9±2.6	2.81	**
TM	12.4±2.0	29.2±2.5	5.41	***
M	34.8±4.0	53.3±5.2	2.53	*
Riv	34.5±7.5	48.5±5.8		
TOTAL	13.5±0.8	27.1±1.0	10.46	***
SIGNIF.	***	***		

* =p<0.05 ** =p<0.01 *** =p<0.001

Table 5.4. Percentage of cover thickness observed at 1.75 m height in habitat types during summer and winter seasons.

HABITAT TYPES	SUMMER	WINTER	BETWEEN SEASONS (M-W TEST)	
	MEAN±SE	MEAN±SE	Z VALUE	SIGNIFICANCE
Scr	12.0±1.8	38.6±6.0	3.87	***
Svn	12.8±3.0	23.0±5.8		
AnATr	14.6±4.2	18.8±7.1		
AnA	9.5±2.5	36.9±6.8	3.57	***
Th	12.3±1.5	28.2±2.1	4.97	***
TAZ	11.5±2.1	26.9±2.4	3.76	***
TF	7.4±1.8	20.2±2.7	2.97	**
TAB	19.6±3.7	35.2±7.7		
TAWr	14.8±2.7	23.7±2.7	2.62	**
TM	14.0±1.9	34.0±2.8	4.92	***
M	30.7±3.8	54.1±5.3	3.03	**
Riv	38.3±7.6	51.9±5.7		
TOTAL	14.9±0.8	30.1±1.1	10.31	***
SIGNIF.	***	***		

** =p<0.01 *** =p<0.001

Table 5.5. Percentage of canopy cover observed in habitat types during summer and winter seasons.

HABITAT TYPES	SUMMER	WINTER	BETWEEN SEASONS (M-W TEST)	
	MEAN±SE	MEAN±SE	Z VALUE	SIGNIFICANCE
Scr	1.8±0.3	14.3±2.7	5.78	***
Svn	5.0±1.7	9.3±2.7	1.55	
AnATr	9.1±2.0	16.8±4.5	1.81	
AnA	4.9±0.8	22.2±3.7	4.65	***
Th	6.5±0.7	15.6±1.2	5.29	***
TAZ	8.1±1.0	19.3±1.5	4.08	***
TF	5.8±0.6	15.9±1.5	4.72	***
TAB	11.9±1.7	26.6±3.9	3.70	***
TAWr	9.1±1.4	22.9±1.8	5.67	***
TM	10.1±1.0	22.6±1.5	5.81	***
M	22.7±2.6	42.2±4.3	3.59	***
Riv	46.4±5.8	58.8±3.9		
TOTAL	9.4±0.8	21.6±0.7	14.79	***
SIGNIF.	***	***		

*** p<0.001

Table 5.6. Percentage and density of browse species available in different habitat types.

HABITAT TYPES	BROWSE SPECIES					
	PERCENTAGE			DENSITY (NO./HA)		
	MEAN	MIN	MAX	MEAN	MIN	MAX
Scr	72.09	37.93	85.71	643.75	275.0	1525.0
Svn	19.02	4.54	35.00	115.00	25.0	225.0
AnATr	38.97	23.81	50.00	208.33	150.0	250.0
AnA	29.24	14.29	53.85	187.50	100.0	350.0
Th	75.66	9.52	100.00	386.25	75.0	750.0
TAZ	31.27	10.00	74.36	246.15	75.0	725.0
TF	10.63	2.44	23.26	106.25	25.0	250.0
TAB	34.54	10.53	73.38	325.00	175.0	525.0
TAWr	20.48	2.22	51.85	250.00	125.0	425.0
TM	28.19	4.65	75.00	275.00	150.0	500.0
M	33.03	10.53	50.82	341.67	75.0	775.0
Riv	30.56	14.29	45.00	218.75	150.0	300.0
TOTAL		2.22	100.00	306.18	25.0	1525.0
SIGNIF	***			***		

*** p<.001

Table 5.7. Correlation between diameter and cumulative dry weight of the twigs of major browse species in Gir.

SPECIES	CORRELATION	VARIATION EXPLAINED	SIGNIFICACE LEVEL
A. nilotica	.940	88%	***
B. racemosa	.903	81%	***
C. sepiaria	.853	73%	***
C. carandus	.899	81%	***
W. tinctoria	.899	81%	***
Z. mauritiana	.854	73%	***

*** p<.001

Table 5.8. Average diameter and difference among species upto which the twig of four browse species was consumed by ungualtes in Gir.

AVERAGE DIAMETER (cm)	SPECIES	*Capparis sepiaria*
0.1719	*Capparis sepiaria*	
0.1925	*Acaica nilotica*	
0.2280	*Wrightia tinctoria*	*
0.2399	*Bauhinia racemosa*	*

* significantly different at p<.05.

Table 5.9. Mean browse consumed from twigs of some plants species in Gir. The weight is calculated from diameter of the browsed twigs using regression equations.

SPECIES	BROWSE CONSUMED (g)	
	n	MEAN±SE
Acacia nilotica	18	2.43±.074
Bauhinia racemosa	16	2.19±.038
Capparis sepiaria	22	1.00±.025
Wrightia tinctoria	22	.56±.013

Table 5.10. Browse consumption in relation to the production and availability from branches of two forage species in Gir.

SPECIES	HABITAT TYPE	PERCENTAGE CONSUMPTION OF	
		PRODUCTION	CONSUMPTION
B. racemosa	Th (WLS)	2.93	33.44
	TM (WLS)	3.36	26.31
C. sepiaria	TAZ (WLS)	14.48	33.68
	TM (WLS)	21.05	39.66
	TM (NP)	15.93	27.02

(WLS) = in wildlife sanctuary

(NP) = in national park.

Table 5.11. Chital Pellet group density (number/ha) in various habitat types during summer and winter in Gir.

HABITAT TYPES	SUMMER			WINTER			BETWEEN SEASONS SIGNIF.
	MEAN	MIN	MAX	MEAN	MIN	MAX	
Scr	80	50	400	60	50	100	***
Svn	70	0	250	105	50	300	
AnATr	75	50	250	100	50	250	
AnA	95	50	500	90	50	200	
Th	140	50	1150	155	50	700	
TAZ	130	50	1050	145	50	650	
TF	65	50	250	85	50	300	
TAB	90	50	350	85	50	200	
TAWr	110	50	700	105	50	500	*
TM	90	50	400	100	50	550	
M	65	50	200	85	50	250	*
Riv	155	50	400	115	50	250	
TOTAL	110	0	1150	120	50	700	***
WITHIN SEASONS SIGNIF.	***			***			

* =p<0.05 *** =p<0.001

Table 5.12. Chital groups in habitat types during morning/evening and noon hrs.

HABITAT TYPES	MORNING/EVENING			NOON		
	MEAN	MIN	MAX	MEAN	MIN	MAX
Scr	4.6	0.0	21.0	3.6	0.0	13.0
Svn	3.7	3.0	4.0	n.d		
AnATr	n.d			n.d		
AnA	3.5	2.0	5.0	9.0	7.0	11.0
Th	7.8	1.0	33.0	8.3	1.0	26.0
TAZ	6.6	1.0	31.0	7.0	1.0	19.0
TF	4.7	1.0	24.0	3.0	1.0	6.0
TAB	3.0	0.0	5.0	n.d		0.0
TAWr	2.7	1.0	4.0	2.3	1.0	3.0
TM	5.2	1.0	26.0	4.3	1.0	19.0
M	5.2	1.0	18.0	5.7	1.0	16.0
Riv	6.7	1.0	34.0	7.3	1.0	20.0
TOTAL	5.9	0.0	34.0	5.8	0.0	26.0
AMONG HABITAT SIGNIF.				***		

n.d. - NO DATA, *** $p<0.001$

Table 5.13. Average sambar pellet group density (number/ha) in various habitat types during summer and winter in Gir.

HABITAT TYPES	SUMMER			WINTER		
	MEAN	MIN	MAX	MEAN	MIN	MAX
Scr	55	50	100	50	50	50
Svn	60	50	100	70	50	100
AnATr	75	50	200	60	50	100
AnA	45	50	100	55	50	100
Th	50	50	200	65	50	250
TAZ	55	50	450	70	50	250
TF	60	50	500	85	50	300
TAB	65	50	150	55	50	100
TAWr	70	50	400	60	50	250
TM	65	50	300	75	50	200
M	75	50	300	85	50	200
Riv	65	50	250	55	50	100
TOTAL	60	50	500	70	50	300
WITHIN SEASON SIGNIF.	*			*		

* $p<0.05$

Table 5.14. Sambar groups in habitat types during morning/evening and noon hours.

HABITAT TYPES	MORNING/EVENING			NOON		
	MEAN	MIN	MAX	MEAN	MIN	MAX
Scr	n.d			n.d		
Svn	n.d			n.d		
AnATr	n.d			n.d		
AnA	n.d			n.d		
Th	1.0	1.0	1.0	1.0	1.0	1.0
TAZ	2.2	1.0	5.0	n.d		
TF	1.6	1.0	2.0	n.d		
TAB	n.d			n.d		
TAWr	n.d			2.0	2.0	2.0
TM	1.8	1.0	7.0	2.4	1.0	7.0
M	2.0	2.0	2.0	1.7	1.0	2.0
Riv	3.8	1.0	9.0	1.0	1.0	1.0
TOTAL	2.1	1.0	9.0	1.8	1.0	7.0

n.d. - NO DATA

Plate 1. Scrubland habitat.

Plate 2. Savanna habitat.

Plate 3. Anogeissus-Acacia-Terminalia habitat.

Plate 4. Anogeissus-Acacia habitat.

Plate 5. Thorn forest habitat.

Plate 6. Teak-Acacia-Zizyphus habitat.

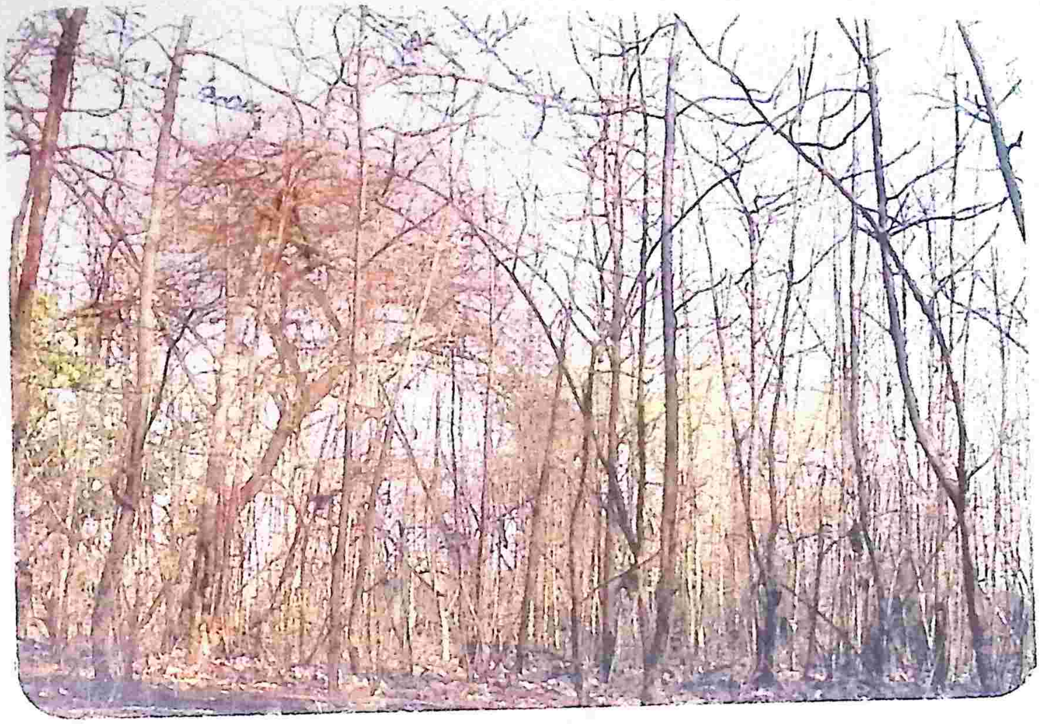


Plate 7. Teak Forest habitat.

Plate 8. Teak-Acacia-Boswellia habitat.

Plate 9. Teak-Acacia-Wrightia habitat.

Plate 10. Teak mixed habitat.

Plate 11. Mixed habitat.

Plate 12. Riverine habitat.

Chapter 6

IMPACT OF MANAGEMENT PRACTICES

6.1. INTRODUCTION

The impact of the following management practices on vegetation and ungulates was evaluated:

1. *Maldharis*
2. Fire
3. Grass harvesting
4. Water Management
5. Creating of National Park.

1. There was a large scale relocation of *maldharis* from the national park by the Gujarat State Forest Department in the early 1970s. Otherwise also the *maldharis* shift from one place to another within Gir depending upon resource availability. After they vacate a locality there is rapid vegetation succession. One of the objective of the study was to assess the rate and direction of such succession. The biological hypothesis, based on various degrees of land use, was that the vegetation at evacuated localities was significantly different from the nearby relatively undisturbed vegetation.

2. With accumulated leaf litter in areas protected for several years, accidental fires (in summer) cause considerable damage. This raised the question of whether controlled burning can be a management tool. Fire lines are created every year in Gir and this may have caused a change in vegetation and its utilization by ungulates. The objective was to assess the changes in vegetation along the fire lines and the utilization of fire lines by ungulates. The biological hypothesis set to test this was that vegetation in fire lines differed significantly from the unburnt areas and hence was used differently by the ungulates.

3. Grass is harvested from various localities in Gir for distribution outside during periods of fodder scarcity. The objective was to assess the potential for grass harvesting as an eco-development measure and its effect on wild ungulates. Since most of the ungulates (sambar, nilgai, chinkara, chowsingha) in Gir are browsers, and others (chital) do not feed much on grass which is mature from January onwards (Khan 1994), it was hypothesised that mature grass harvesting (in December-January) does not affect utilization of the habitats by ungulates.

4. Being a dry deciduous forest in a semi-arid region, water is a critical habitat factor. Depending upon rainfall in the previous year, there is water shortage from late February to late April (excluding drought year in which water shortage is from December). During this period water is supplied artificially by filling iron/cement troughs by tanker or siphoning out water from wells. The objective was to study the utilization of water points by ungulates and their impact on vegetation. The biological hypothesis was that ungulate density was significantly higher near water points.

5. An area of 259 sq. km was declared national park in 1972 and subsequently all the *maldhari* settlements were removed from this area. After that there has been negligible human interference within in the national park. The objective was to investigate the effects of protection on vegetation and ungulates. A hypothesis was set that the national park has better (denser and much more diverse) vegetation and greater animal abundance than the wildlife sanctuary.

This chapter describes the methods used and results obtained in investigating the impacts of management practices on vegetation and ungulates. Basic principles behind plot selection were the same as mentioned in the previous chapters. Methods for determining the grass productivity under different practices are described under the impact of grass harvesting while the results are included under the respective management practice.

6.2. METHODS

6.2(a). Field Methods

6.2.1. Impact of *Maldharis*

The vegetation succession, its rate and its effect on ungulates was studied through vegetation plots selected at varying distances from *neses* evacuated at different time (3, 5, 8, 12, 15, 25, and >25 years before 1991) and the existing ones. The vegetation plots were laid randomly at varying distances of upto 8km from a *nes*. Data on vegetation composition, density, cover, grass, leaf litter and animal evidence were collected in these plots. Buffaloes of five *neses* were followed for a period of one week each to study their grazing range, and lopping by *maldharis*. The impact was categorized based on the intensity of grazing and other associated disturbances. Species eaten by the buffaloes and lopped by *maldharis* were also recorded. Cover and animal evidence data were later grouped into seven categories, i.e. 0.0-0.5km, 0.5-1.0km, 1.0-2.0km, 2.0-3.0km, 3.0-4.5km, 4.5-6.0km and >6.0km from disturbance while effect of lopping and cutting was categorized only in first six groups.

6.2.2. Impact of Fire

The effect of fire lines on vegetation was studied by comparing the data (tree and seedling density and composition) from vegetation plots in and outside fire lines and in other localities with regular fires. Fire lines in Gir are maintained every year in the form of 30m wide strip on either side of all roads.

6.2.3. Impact of Grass Harvesting

Impact of grass harvesting on grass productivity was determined through controlled plots as described below. Its impact on ungulate abundance was studied by counting ungulate pellet groups in harvested and unharvested localities, keeping other habitat factors constant. For ungulate pellet count a locality near the river (about 800m away) was selected. Locality near river was chosen in anticipation that more ungulates use the area, thus increasing sample number.

Grass productivity was measured in eight localities. Four of these were in the western part of the wildlife sanctuary, two in the national park and two in the eastern part of the wildlife sanctuary. These localities were selected based on the vegetation types and management (administrative) divisions. In each of these locality a control area (exclosure) of 5m X 5m was set up. This control area was protected against all disturbances using 2.5m high chain-link fence.

Grass productivity in undisturbed area, livestock grazed area and burnt area was compared with that of the control area. Grass was harvested from these areas at each locality at six week intervals during the growing season (monsoon). Six weeks were sufficient for grass to grow back after the previous harvest, a conclusion based upon field trials. Grass was cut from three 0.5m X 0.5m quadrats in each area. A quadrat made of thick wire was thrown randomly three times each in control, grazed and burnt area, and grass was harvested at ground level. On many occasions some herbs and ephemeral shrubs were cut along with the grass. Hence, the harvested samples were sorted out for grasses and were weighed after oven-drying at 80°C for 24 hours. The productivity was calculated and extrapolated as kg/ha.

6.2.4. Impact of Water Management

Effect of water on animals was investigated through transects (see 5.2.6) at varying distances from water sources. Animal pellet groups were counted and removed in summer and winter from those transects. The data was later grouped into six categories, i.e. 0.0-0.1km, 0.1-0.5km, 0.5-1.0km, 1.0-2.0km, 2.0-3.0km and 3.0-5.0km from water point.

6.2.5. Impact of Creating National Park

Impact of creating the national park was investigated by comparing various vegetation parameters and animal abundance in wildlife sanctuary and national park. Impact of grazing was studied by visually estimating the quantity of grass and leaf litter in 1m X 1m quadrats, canopy cover, cover thickness at 0.5m, 1m and 1.75m, tree and seedling density, and wild ungulate evidence in the 100 vegetation plots all over Gir (see 3.1 for more detail).

6.2(b). Analysis

Different seral communities of vegetation were categorized using TWINSPAN (Hill 1979), which also classified species occurrences at different seral stages. The options chosen for TWINSPAN were the same as described in 4.2(b). The significance of different cover values and animal abundance at various distances from *nes* and water was tested through non-parametric Kruskal-Wallis one-way ANOVA. The same was tested for national park and wildlife sanctuary using Mann-Whitney statistics. Wherever the assumptions of parametric statistics were met, T-test was used (Sokal & Rohlf 1981).

6.3. RESULTS

Vegetation parameters and animal abundance results are presented according to the management practices. The quantities are presented in the form mean±standard error of mean at 95% confidence level. Statistical results are given in order - name of the test, its value, significance level and sample number.

6.3.1. Impact of *Maldharis*

6.3.1.1. Vegetation Succession

Vegetation succession at a site after relocation of a *nes* from there, started with the *Apluda mutica - Themeda quadrivalvis -Sehima nervosum* association (Table 6.1). However, *Sehima nervosum* was negligible or absent from areas sampled. At this stage there were very few tree species and these were present even before the relocations. Shrubs like *Zizyphus nummularia* was abundant in localities evacuated more than five years ago. This succession resulted in thorny vegetation with species like *Acacia nilotica* and *Zizyphus mauritiana* after 9 years. This situation continued even upto 25 years after relocation of *nes*. It is after this that the surrounding vegetation started encroaching the evacuated *nes* site. The number of species increased from ten in the first four years to 21 in more than 25 years after evacuation. The number of tree species and the rate of succession differed based on edaphic factors. Although not tested statistically (there was no such option in TWINSPAN), the different vegetation composition at different intervals after evacuations lead to acceptance of the hypothesis that vegetation associations at evacuated *nes* localities was different from surrounding ones. The surrounding vegetation was similar to or denser than the one after 25 years of evacuation.

6.3.1.2. Tree and Seedling/Sapling Density

AT and around the current *neses* the average seedling/sapling density was minimum near the *nes* and increased upto 0.5-1.0km, and did not change significantly after that (Fig. 6.1). The overall difference was not significant.

On the other hand, at the evacuated *nes* sites the average tree density was maximum at sites vacated 9-25 years before 1991 and minimum in sites vacated 5-8 years before 1991 (Fig. 6.2). But seedling density generally decreased with time after *nes* evacuation.

6.3.1.3. Tree Cutting and Lopping

The range of percentage tree lopped and cut in plots at varying distances from current *nes* is given in Table 6.2. Average percentage of trees lopped was maximum upto 1km from the *nes* and decreased after that (Fig. 6.3). The overall variation was, however, significant only at $p<0.1$ (K-W $\chi^2=9.40$, n=72). On the other hand, average percentage of tree cutting was maximum farthest away from a *nes*, followed by distances of 0.5-1.0km. The overall variation was not significant.

6.3.1.4. Cover

The changes in cover values at various heights and canopy were measured at varying distances from current *neses* only and the results are given in Tables 6.3-6.6 in the form - mean±SE (standard error of mean at 95% confidence interval), and Fig. 6.4-6.5. The minimum and maximum cover values in at least one vegetation plot under any management practice was 0 and 100% respectively and hence is not presented in tables. The statistical results are given as - name of the test, its value and significant level. The sample number in summer was 1115 and in winter 1075 for every cover category.

Average grass cover in summer was least nearest to the *nes* and largest farthest away (Fig. 6.4a) but there was no clear pattern. The overall difference in average grass cover was significant in summer (K-W χ^2=37.28, p<.001). In winter again the minimum grass cover was nearest to the *nes* (Fig. 4.4b) and maximum farthest away. There was no trend in between. The overall difference was significant in winter too (K-W χ^2=71.82, p<0.001).

Average leaf litter and canopy cover was maximum near a *nes* and minimum at 0.5-1km distance (Fig. 6.4a). The ranges for canopy cover in summer and winter in a plot at varying distances from current *nes* are Given in Table 6.3. The overall difference was statistically significant for both leaf litter and canopy cover in summer (K-W χ^2=84.37, p<.001 and K-W χ^2=38.37, p<.001 respectively). During winter (Fig 4.4b) the maximum leaf litter was 4.5-6km from *nes* and minimum 3-4.5km away. The canopy cover was maximum nearest the *nes* and minimum 3-4.5km away. The overall difference in leaf litter and canopy cover was significant during winter (K-W χ^2=28.03, p<0.001 and K-W χ^2=38.37, p<0.001 respectively).

Average percentage cover at 0.5m, 1.0m and 1.75m height during summer (Fig. 6.5a) was maximum at 0-0.5km distance, and minimum at 0.5-1km from *nes* for 0.5 and 1.0m height but at >6km distance for 1.75m height. The overall variation was significant only for 1.0m and 1.75m height (K-W χ^2=18.89, p<.01 and K-W χ^2=15.59, p<.05) during summer. The ranges for cover at various heights in a plot at varying distance from current *nes* during summer and winter is given in tables 6.4-6.6.

During winter (Fig. 4.5b) the maximum cover at 0.5m height was at >6km distance from *nes* and minimum 0.5-1.0km away. The cover at 1.0m height was maximum 4.5-6km away and minimum 0.5-1.0km. The cover at 1.75m height was maximum 4.5-6km and minimum >6km away from *nes*. The over difference at all the three heights in winter was significant (K-W χ^2=148.67, p<0.001, K-W χ^2=20.44, p<0.01 and K-W χ^2=33.69, p<.001 respectively).

6.3.1.5. Ungulate Distribution

The variation in ungulate distribution is described in relation to the current *nes* only.

Chital

Pellet groups: The minimum pellet group density found in summer was 0/ha in a plot at >6.0km distance from the *nes* and maximum was 1150/ha groups at 1.0-3.0km from the *nes* (Table 6.7). Average pellet group density was largest within 0-0.5km and minimum was within 3-4.5km from the 'nes' (Fig. 6.6a). The overall variation in the average pellet group density was significant (K-W χ^2=41.58, p<0.001, n=969).

During winter there was not much variation in the maximum number of pellet group density recorded upto 3km from the *nes* after which the number declined to half. The minimum groups size observed was one (Table 6.7). The average pellet group density was largest nearest to the *nes* and it inconsistently decreased with increase in distance from *nes* (Fig. 6.6a). The overall variation in the average group size was significant (K-W χ^2=56.1, p<0.001, n=834). Significantly more chital pellet groups were observed in summer at 0-0.5km (M-W Z=3.35, p<.001), 3-4.5km (M-W Z=2.12, p<.05) and >6km (M-W Z=2.58, p<.01) distances from *nes* than in winter (Table 6.7).

Direct Observations: Maximum percentage of chital sightings in morning/evening hours were 1-3km away from a *nes* (together forming 50.2%) followed by 3-4.5km distance (15.2%). The least number of sightings were at distance of 4.5-6km (Fig. 6.6b).

During noon hours also the maximum sightings were 1-3km away from *nes* (49.6%).

Sambar

Pellet Groups: The minimum pellet group density found in summer was 50/ha in any plot and maximum was 500/ha at >6.0km from the *nes* (Table 6.8). Average sambar pellet group density in summer was minimum nearest a *nes*. The average pellet group density was more or less consistent as the distance increased from a *nes* (Fig. 6.7a). The overall variation was not significant.

During winter there was not much variation in the maximum number of pellet group density recorded. The minimum group density observed was 50/ha (Table 6.8). The largest average group density in winter was nearest to a *nes*. The minimum average was 4.5-6km away from a *nes* (Fig. 6.7a). The overall variation in sambar pellet group density was significant (K-W χ^2=16.06, p<.05, n=386). There were significantly more sambar pellet group density at >4.5-6.0km (M-W Z=2.79, p<.01) distance in summer than in winter (Table 6.8).

Direct Observations: No sambar was sighted within 1km from a *nes* both in morning/evening and noon hours. The maximum sightings were at >6km from a *nes* in morning/evening hours. During noon the number of sightings at various distances was the same (Fig. 6.7b).

6.3.2. Impact of Fire

6.3.2.1. Vegetation

The vegetation in regularly burnt area was different from nearby unburnt areas (Table 6.9). TWINSPAN demarcated these two groups clearly. It is also shown in the Table 6.9 that grasses *Sehima nervosum*, *Themeda quadrivalvis* and *Apluda mutica*, and trees *Butea monosperma* and *Acacia ferruginea* were more abundant and/or more frequent in burnt areas. Species like *Acacia catechu* and *Tectona grandis* were found both in burnt and unburnt localities but their abundance was more in unburnt areas. There were many species which were found only in unburnt areas. The overall number of species was higher (24) in unburnt area compared to burnt ones (14).

Sixteen species in seedling/sapling category were encountered in unburnt areas compared to nine in burnt ones. Seedlings/saplings of *Balanites aegyptiaca, Acacia catechu* and *Acacia nilotica* were more abundant and frequent in burnt areas while those of *Tectona grandis, Wrightia tinctoria, Grewia tiliaefolia* and *Bauhinia racemosa* were more in unburnt areas.

Based on these results the hypothesis that fire leads to different vegetation associations is accepted.

Tree density (Table 6.10) in burnt areas was different from unburnt areas but there was no trend. A large variation in tree density in different localities was observed. Seedling/sapling density was more in unburnt areas. The small data set could not be tested for statistical significance.

Grass production, on an average, was more in regularly burnt areas than others in five localities (Fig. 6.8). The difference was significant only between burnt (1546kg/ha) and grazed (by livestock and/or wild ungulates) (1005kg/ha) areas ($T=2.74$, $df=142$, $p<.01$).

6.3.2.2. Ungulates

The impact of fire on ungulates could not be determined because the area under regular fire was not wide enough as total width was only 30m on either side of the roads. This small width, if affected the habitat utilization by ungulates would go unnoticed since the near by area would show the similar evidence (pellet groups). Data on browse and grazing evidence could not be collected.

6.3.3. Impact of Grass Harvesting

Grass productivity in previously harvested areas was greater (1701±179kg/ha) than in unharvested (protected/exclosed) areas (377±240kg/ha) (Fig. 6.8). The difference in grass production between the two areas was significant ($T=6.76$, $df=18$, $p<.001$). Animal (chital) evidence did not vary significantly between harvested (n=39) and unharvested areas (n=33).

6.3.4. Impact of Water Management

6.3.4.1. Ungulates

Chital

Pellet groups: The maximum density of chital pellet groups observed in summer was 1150/ha in plots at 0.0-.5km distance and minimum was 0/ha in a plot 0-0.1km from water (Table 6.11). The maximum average chital pellet group density (Fig. 6.9a) was found within 0.1km from water point (220±30, n=68). The overall variation in average pellet groups at varying distances from water was significant (K-W $\chi^2=45.65$, $p<0.001$, $n=969$).

In winter the maximum pellet density observed was 700/ha at 0.5-1.0km from water and minimum was 50/ha (Table 6.11). The average pellet group density was largest nearest a water point and decreased with distance (Fig 6.9a). The overall variation in mean pellet group density was significant (K-W $\chi^2=57.28$, $p<0.001$, $n=834$). Pellet group density at 0.1-0.5km and 1-2km from water in summer was higher than in winter (M-W $Z=-2.99$, $p<.01$ and 1-2km (M-W $Z=-2.11$, $p<.05$ respectively).

Direct Observations: Direct observations did not compare with results from the pellet group study. Maximum percentage of chital sightings were between 1-2km from water followed by 0.5-1km and 0.-0.5km during morning/evening hours (Fig. 6.9b). No chital were sighted at a distance of 3-5km from a water point. During noon hours no chital were at 3-5km from water point and the maximum was at 0.1-

0.5km from water. However, overall variation between chital sightings during both morning/evening and noon hours was not statistically significant.

Sambar

Pellet groups: Maximum sambar pellet density in summer (500/ha) was 3-5km from water and minimum was 50/ha (Table 6.12). In winter the maximum density was 300/ha at 0.1-0.5km distance from water and minimum was 50/ha in at least case at any distance (Table 6.12). Average sambar pellet group density indicated almost uniform distribution from water points both in winter (n=476) and summer (n=386) (Fig. 6.10a). The overall variation was not significant. Comparison of summer and winter shows (Table 6.12) that there were significantly less pellet group density in summer than in winter at 3-5km distance from water (M-W Z=2.57, $p<.001$, n=57).

Direct Observations: Maximum percentage sightings of sambar in morning/evening hours were between 1-2km from water and no animal was seen beyond 3km (Fig. 6.10b). During noon, animals were observed only upto 2km from water point. Even then there was no sighting of sambar at 3-5km from water point.

The results from chital pellet evidence led to the acceptance of the biological hypothesis that there were more animals near water sources. The hypothesis is rejected in case of sambar.

6.3.5. Impact of Creating National Park

6.3.5.1. Vegetation

Tree and Seedling Density: Both, average tree and average seedling/sapling densities were higher in national park than in wildlife sanctuary (Fig. 6.11). However, the difference was significant only in case of tree density (M-W Z=2.20, $p<0.05$, n=209).

Diversity Indices: There was not much variation in the diversity indices between national park and wildlife sanctuary (Fig. 6.12). Tree species diversity was slightly more in the national park, species richness equal in both and evenness was more in the wildlife sanctuary. The differences were not statistically significant.

Cover Values: Average cover at 0.5m height in summer (Fig. 6.13a) was almost equal in national park and wildlife sanctuary. However, in winter (Fig. 6.13b) this cover was significantly more in national park than in wildlife sanctuary (M-W Z=9.9, $p<0.001$).

Average cover at 1.0m height in summer was significantly more in wildlife sanctuary than in national park (M-W Z=2.04, $p<0.05$). However, in winter this cover was almost equal in national park and wildlife sanctuary.

Average cover at 1.75m was more in wildlife sanctuary than in national park both in summer (M-W Z=3.48, $P<0.001$) and winter (M-W Z=4.35, $p<0.001$).

Canopy cover was more in national park compared to wildlife sanctuary in summer (M-W Z=3.13, $p<0.01$) but less in winter (M-W Z=3.90, $p<0.001$).

Leaf Litter consumption: Leaf litter consumption among vegetation types was less in national park than in wildlife sanctuary (Fig. 6.14). The data could not be tested for statistical significance due to insufficient samples.

6.3.5.2. Ungulate Abundance

Significantly less average chital pellet group density (Fig. 6.15) was recorded in national park compared to wildlife sanctuary both in the summer (M-W Z=4.63, $p<0.001$) and winter (M-W Z=5.77, $P<0.001$).

Sambar pellet group density on average were marginally more in national park (Fig. 6.15) than in wildlife sanctuary in summer, while in winter the average number of pellet groups observed in both the management units did nor vary significantly.

Most of the above results, particularly the statistically significant ones led to the rejection of the hypothesis that national park had better vegetation and animal values than wildlife sanctuary.

6.4. DISCUSSION

Maximum percentage of trees were lopped nearest the *nes* (within 0.5km). Cutting evidence (tree stumps) were less nearest a *nes* than at >6km distance. This may be due to two reasons; firstly, *maldharis* prefer to make huts at relatively hard and elevated ground to avoid slush in rains; secondly, increased human activities would have led to removal of stump to ground and eventually to its covering with mud and livestock dung, hence making it unnoticeable. Low tree density nearest a *nes* was a result both hard ground (less regeneration) and tree cutting. Trees are cut to make huts. Thorny species like *Acacia spp.* and *Zizyphus spp.* are lopped to make a fence around the house for protection from predators. Fodder trees are lopped to feed calves. The low seedling/sapling density near a *nes* may be as a result of trampling and over-utilization as recorded elsewhere (Putman *et al.* 1989). The high rate of seed germination soon after *nes* evacuation supports this. This also suggests that the impact of *maldharis* and their livestock is temporary and seed germination takes place in the early stages of succession.

Cover values turn out to be affected by environmental factors like soil moisture and vegetation features such as tree species, and are not affected much by disturbance. For example, most of the *maldhari neses* are in the vicinity of the Riverine habitat which has maximum cover at all the levels. Hence, the impact of *maldharis* is unnoticeable. The absence of any trend on increasing distance from *nes* also supports that cover in Gir is strongly related to vegetation than disturbance. In other words the variation in cover values among habitats is more that at varying distance from *neses*.

Most of the management practices seem to have less impact on vegetation than the environmental factors themselves (see 4.3.2., 4.3.3. and 5.3.2). Presence and relocation of *maldharis* resulted in changes in vegetation, but only within 500m radius from a *nes* and, the resulting vegetation associations combined with availability of water (Leythold 1977) within 1km favoured chital. This is supported by more than average herd size and pellet groups density observed in Thorn forest habitat (see 5.3.4.1.).

Relocation of *maldharis* has benefited chital and sambar only in terms of vegetation associations that succeeded, and associated factors (like forage, cover). The relocation had negative effects also, such as the non-availability of water in semi-natural situations that had previously been developed and used by *maldharis*. These water points are preferred by animals to those in the form of metallic troughs which limit the ways of approach. This is indicated both by pellet evidence and direct sightings of chital. Sambar pellet evidence and sightings were not comparable, because of habits of this animal. Sambar is a crepuscular animal (Prater 1980, Chakrabarty 1991) and visited these water points during late evening and early morning when human disturbance was least as has been observed in case of habitat utilization by the Indian crested porcupine (Sharma & Prasad 1992). The difference in the use of resources by species with different habits has been reported by Leythold (1977). This explains the low variation in pellets of sambar observed at various distance from the *nes*. During the day, however, they maintained a minimum distance of about 1km from *nes* and were mostly seen in Riverine habitat.

It becomes important to manage water points and vegetation around them in an attempt to manage wild animal distribution and abundance. Negligible animal evidence were recorded at water points with thick ground and shrub cover compared to water points having sparse vegetation upto 20-25m around it. Thick vegetation not only reduces the number of approaches but also provides ambush cover to predators, thus making ungulates suspicious (Leythold 1977). Hence, if a water point is in semi-natural situation, the vegetation around it should not be allowed to become thick at ground and shrub level. Patel (1992) suggests the types of water points that should be created based on the topography of the place. The impact of wild animals presence on vegetation near water was not quantified because there was no visible difference in vegetation composition and density at varying distances from a water point. There are, however, studies in areas with mega-herbivores that report changes in vegetation after creation of water points (e.g. Weir 1971).

Controlled grazing by livestock does not seem to adversely affect grass production. In areas where grazing occurred in the previous year as well as during the monsoon of the year of data collection, the grass production was only 30% of that in the control area in cases of pressure from 2-3 *neses* or from a village (e.g. category 2 in Th in east in Fig. 6.8). However, if grazing pressure was only from one *nes* the grass productivity was more than 50% of that in the control area (e.g. category 2 in TAZ, TM in west in Fig. 6.8). The productivity in grazed areas could be measured because buffaloes left grass about 5cm in height, which could be harvested to ground level. Elsewhere also the controlled grazing is reported to be beneficial for grasses (Strange 1980, Vickery (1984). Hence, controlled grazing should be allowed in Gir.

Grass harvesting did not lead to negative effects on vegetation and animals in Gir. Therefore, it is suggested to harvest grass on a rotational basis from potential areas even within the national park. Otherwise, the old grass stock hampers fresh growth. Harvesting and burning if finished by the end of January may increase grass productivity as indicated by the results of this study and elsewhere (Vickery 1984). Low fires after grass harvesting are unlikely to affect the canopy but will be good for grasses (Trapnell 1959), although this effect is likely to vary according to habitat (Granger 1984).

Fire lines, as such, have not changed vegetation largely. Since the intensity of fire in fire lines is low, it caused more effect at the ground level, and therefore on the seedling/sapling stage resulting in relatively low tree density in many cases. It is at the seedling stage that fire resistant species showed better performance and, therefore, dominated in regularly burnt areas. Such change in species composition in regularly burnt and unburnt areas has also been recorded by Johnsingh (1986).

Fire showed both positive and negative effect on vegetation in Gir. In localities where accidental fires were frequent, like Chotikyala (Chhodavadi(a), (b) and (c) in Table 6.3) near Banej in central Gir, the vegetation is less dense in areas outside fire lines (but affected by frequent accidental and intense fires) than inside. This is because there was negligible fuel left after fire lines creation and this eliminated the possibility of accidental fires. Otherwise there was no clear difference in vegetation density. This double impact of fire has been observed by various other studies (Trapnell 1959, Chandler *et al.* 1983, Yeaton 1988, Swaine 1992).

Creation of national park was a result of the reports that vegetation of Gir was degrading under *maldhari* pressure and wild ungulates are facing competition from livestock (Hodd 1969, Joslin 1973, 1984, Berwick 1974, 1976). Twenty years after national park declaration, the results do not support the idea that national park creation would lead to more cover and wild animal values. Species diversity is marginally more in national park than wildlife sanctuary, and this should be monitored in future. While the changes after stopping (over)grazing has been evident in shorter duration elsewhere (Putman *et al.* 1989, Backeus *et al.* 1994), here such changes might not be apparent due to differences in terrain and water in the national park and wildlife sanctuary. The national park terrain is more hilly than the wildlife sanctuary as is evident from SPOT data (NRSA 1992). This hilly terrain can only support sparse cover. The low cover at 0.5m height in the wildlife sanctuary is due to trampling by livestock which has not affected the wild ungulate population as is evident by significantly more chital and relatively less sambar evidence in wildlife sanctuary than those in national park. Less chital evidence and sightings in national park may also be due to the hilly terrain of national park which is not preferred by this animal. The low amount of leaf litter consumed by wild ungulates in the national park compared to that in the wildlife sanctuary with no livestock grazing, also supports the finding that there were more wild ungulates in wildlife sanctuary than in the national park.

6.5. SUMMARY

Impact of *maldhari* relocation has been mixed on ungulates. If water was still available in semi-natural way, the vegetation succession has been preferred by the ungulates and not otherwise. Grass harvesting does not effect ungulates adversely. Availability of water has governed chital and sambar distribution. Chital was found to be less disturbance sensitive compared to sambar which maintained distance from water if it was disturbed. Regular fires along fire lines have not affected tree cover largely but have promoted grass production. Accidental fires, on the other hand, have led to sparse tree cover and more grass cover. Creating of national park has not shown large changes in vegetation and ungulate distribution and abundance.

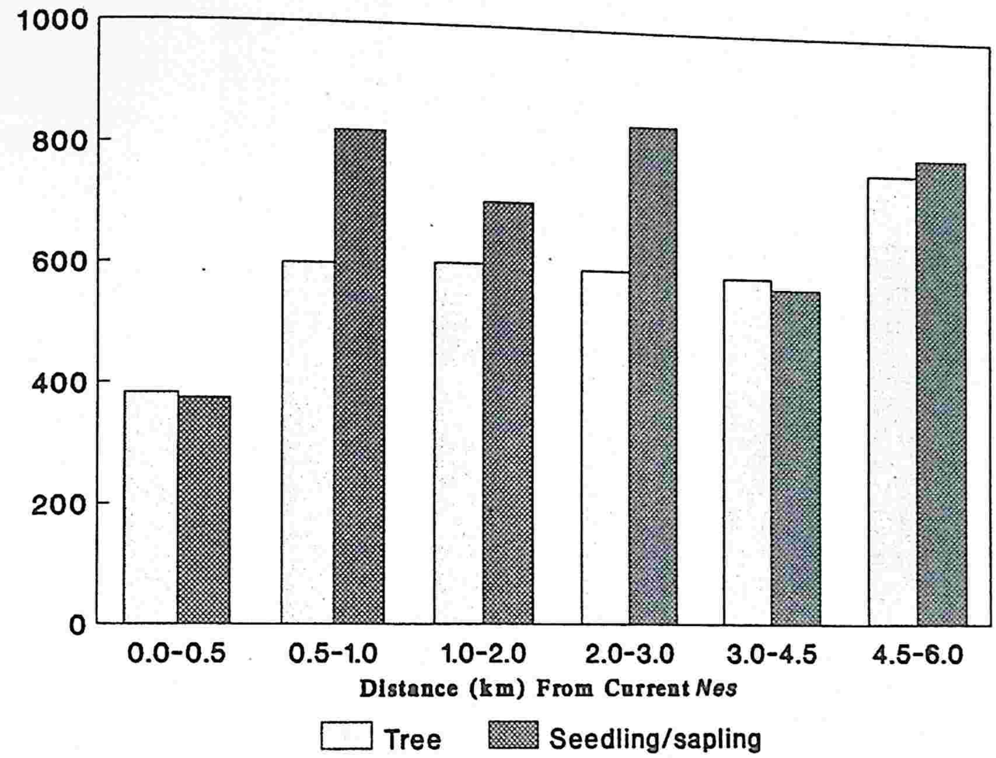


Fig. 6.1. Average tree and seedling/sapling density (number/ha) in relation to distance from current *nes* in Gir.

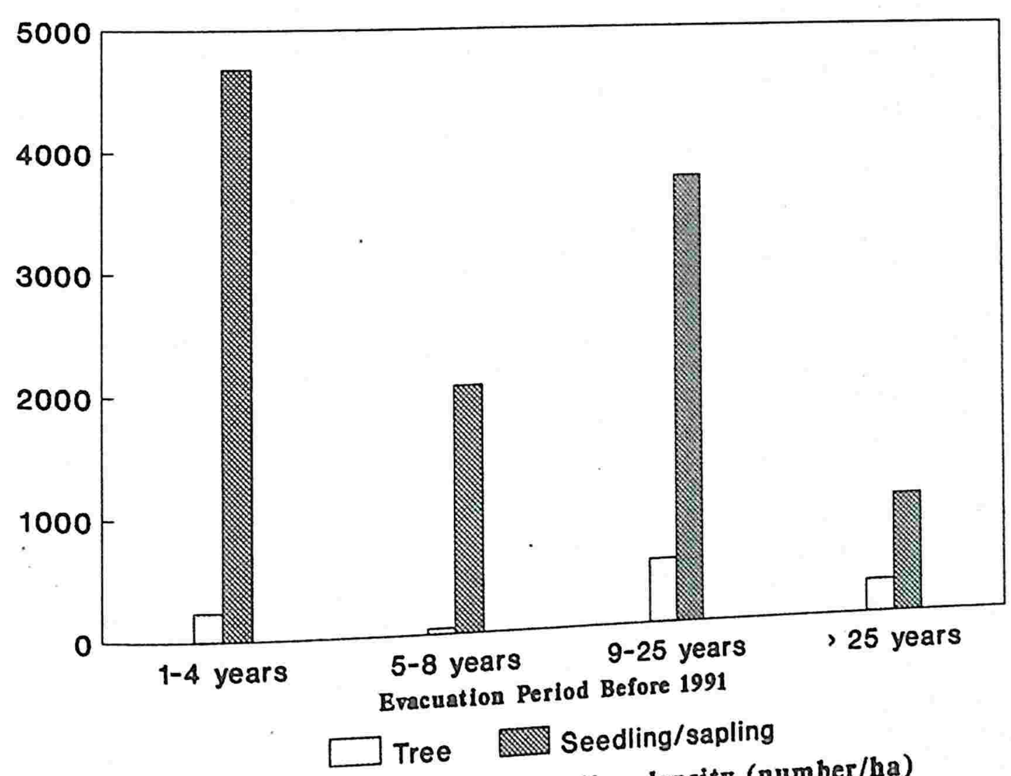


Fig. 6.2. Average tree and seedling/sapling density (number/ha) in 'nes' sites evacuated at different periods in the past.

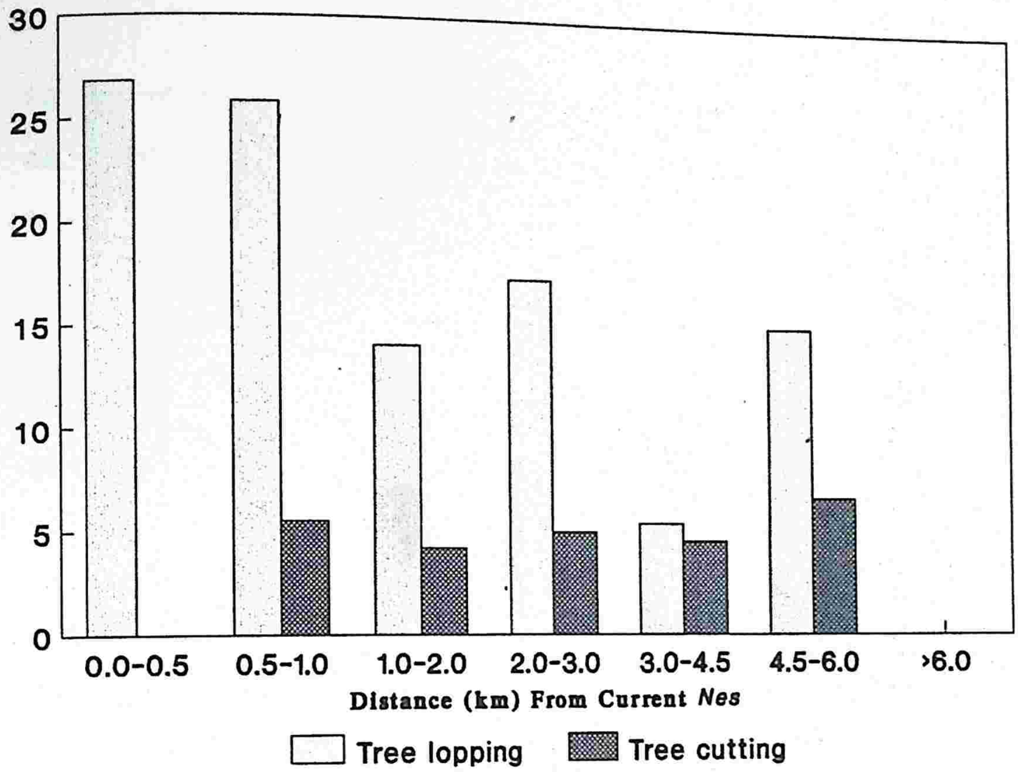


Fig. 6.3. Average percentage tree lopping and cutting in relation to distance from current *nes* in Gir.

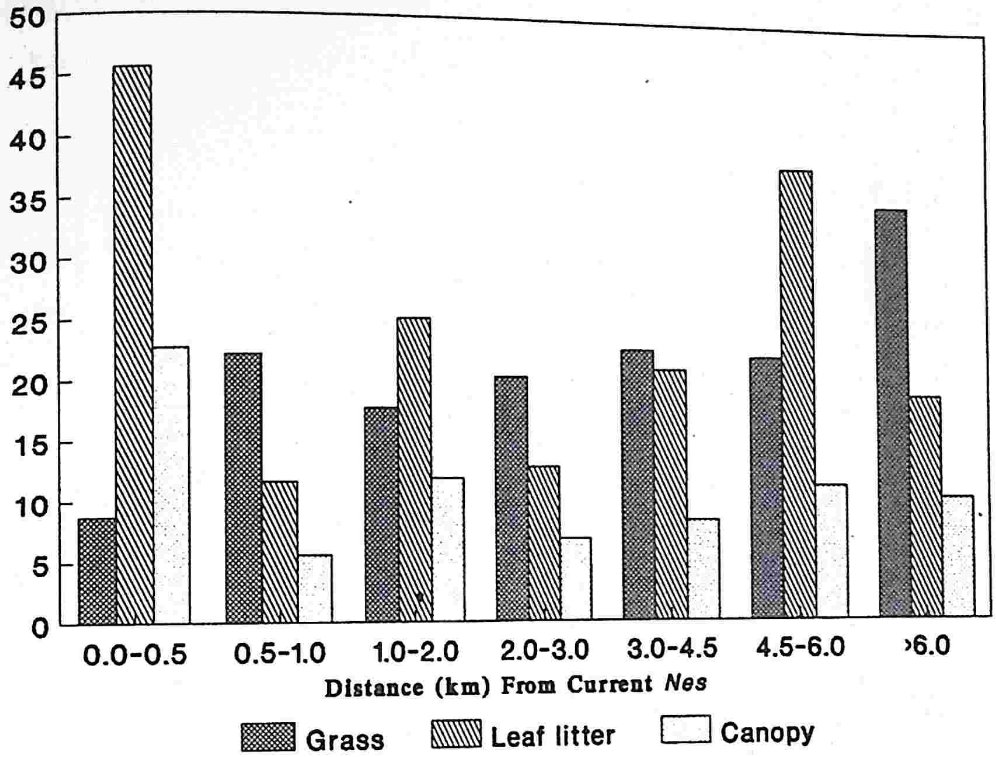


Fig. 6.4a. Average percentage of grass, leaf litter and canopy cover in relation to distance from current *nes* in Gir during summer.

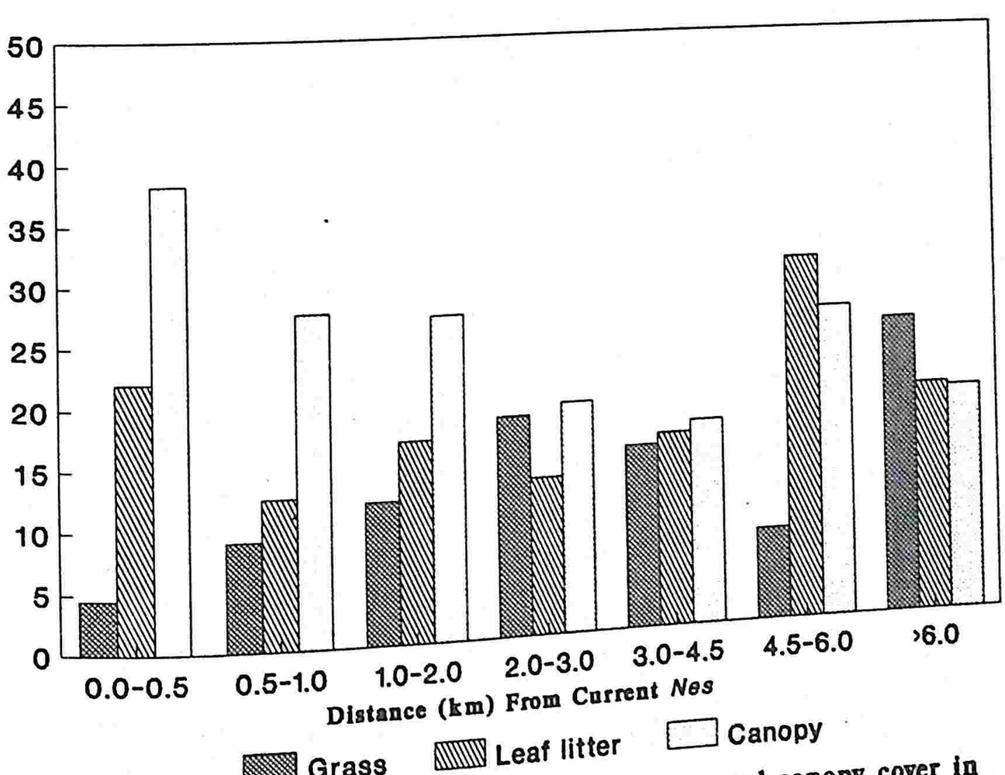


Fig. 6.4b. Average percentage of grass, leaf litter and canopy cover in relation to distance from current *nes* in Gir during winter.

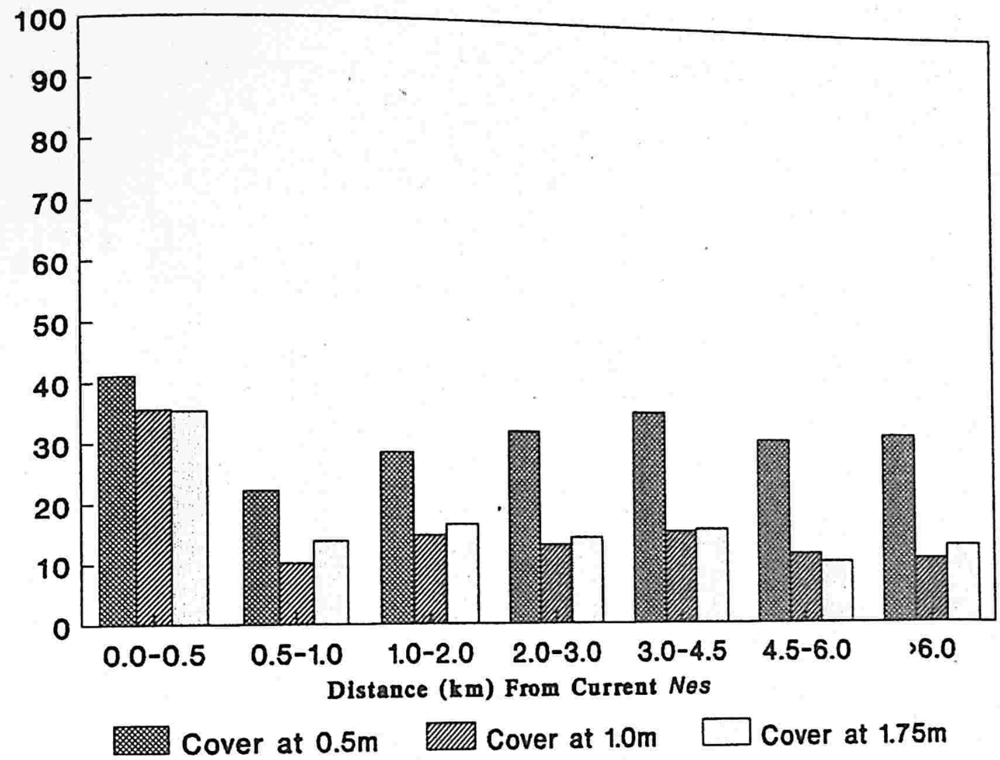


Fig. 6.5a. Average percentage cover values at three heights in relation to distance from current *nes* in Gir during summer.

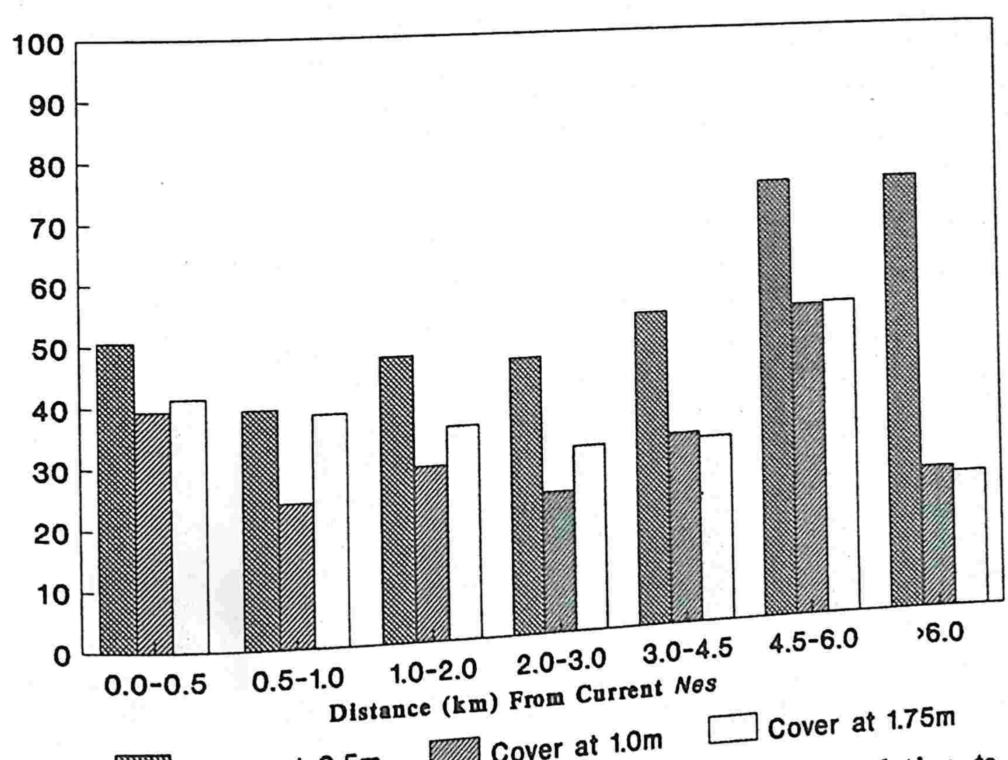


Fig. 6.5b. Average percentage cover values at three heights in relation to distance from current *nes* in Gir during winter.

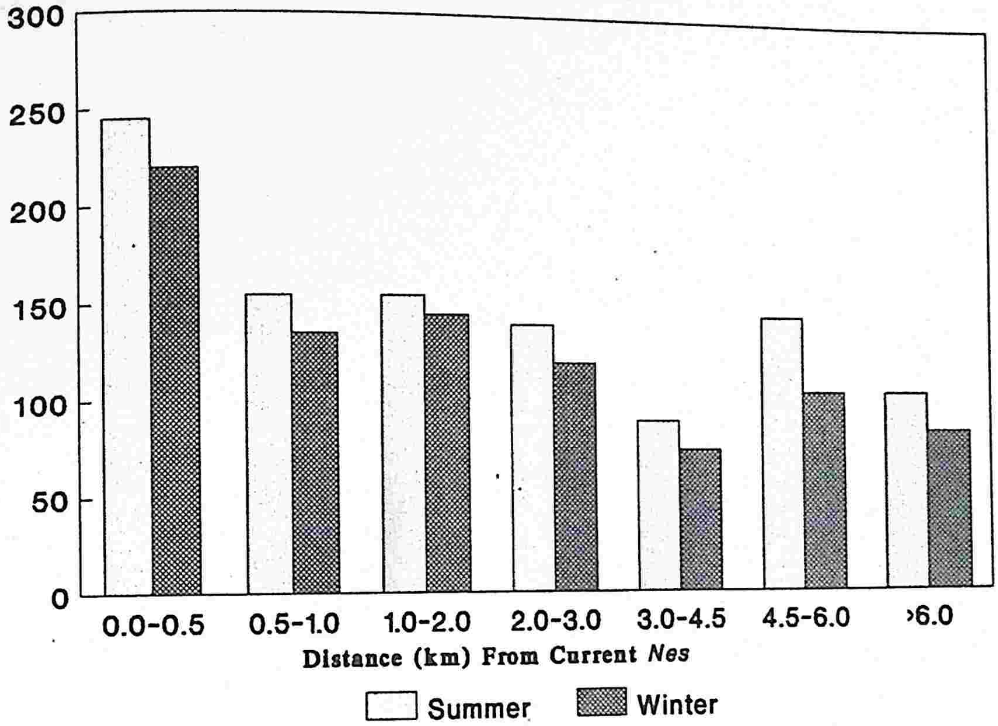


Fig. 6.6a. Average chital pellet group density (number/ha) in relation to distance from current *nes* in summer and winter in Gir.

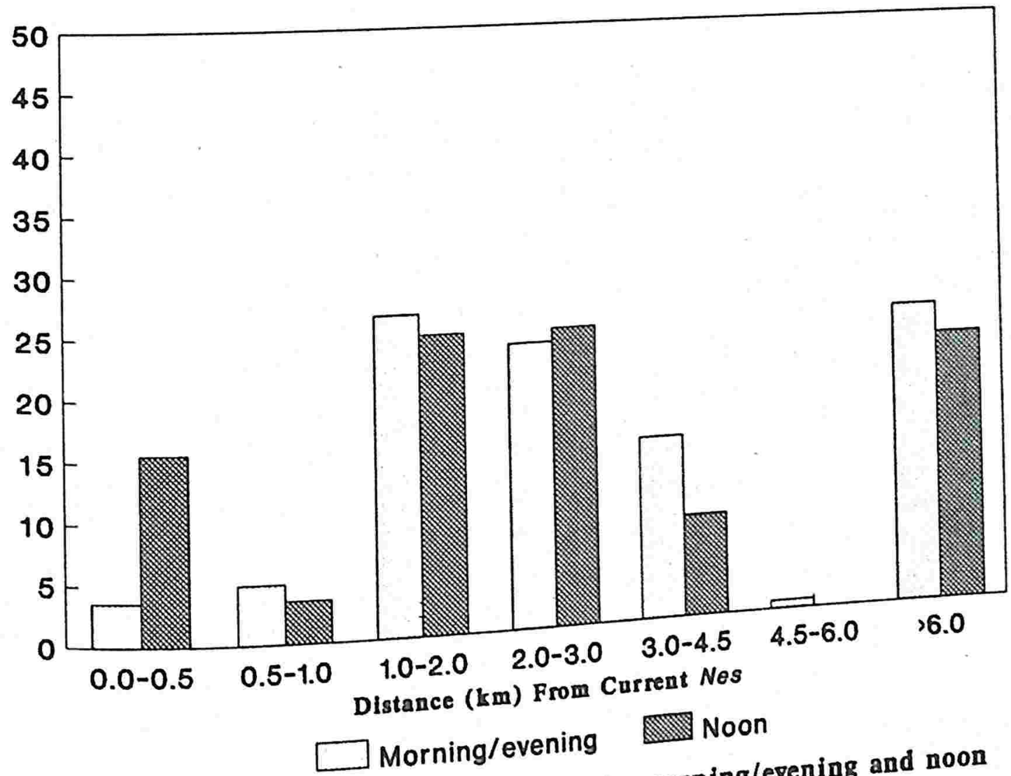


Fig. 6.6b. Percentage of chital sightings in morning/evening and noon hours in relation to distance from current *nes* in Gir.

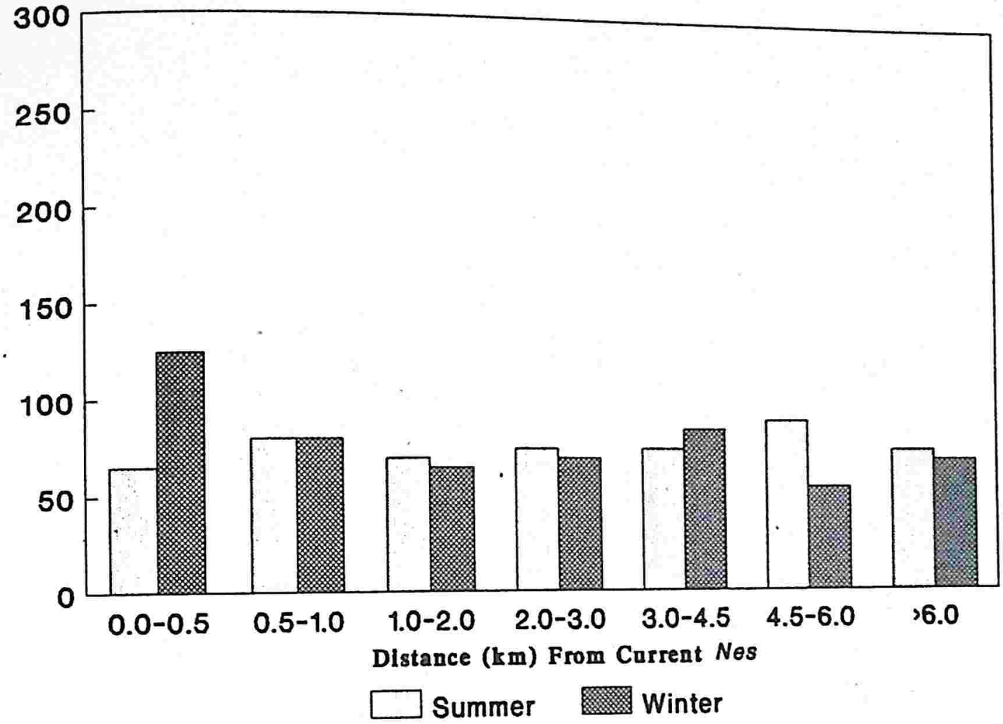


Fig. 6.7a. Average sambar pellet group density (number/ha) in relation to distance from current *nes* in summer and winter in Gir.

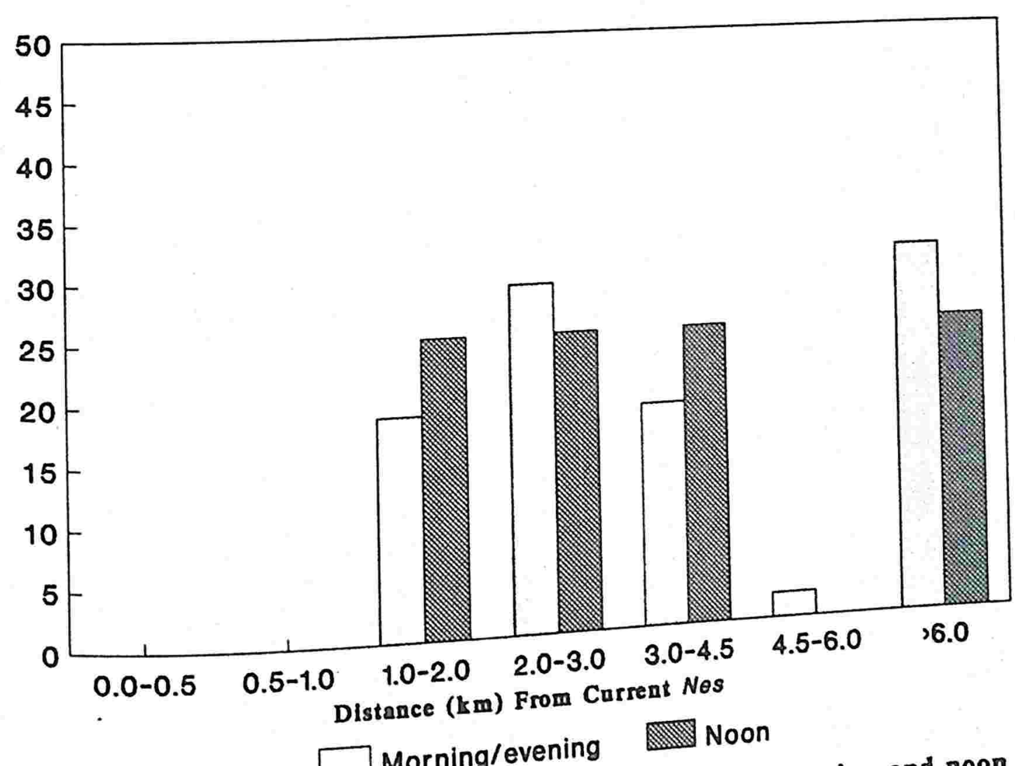
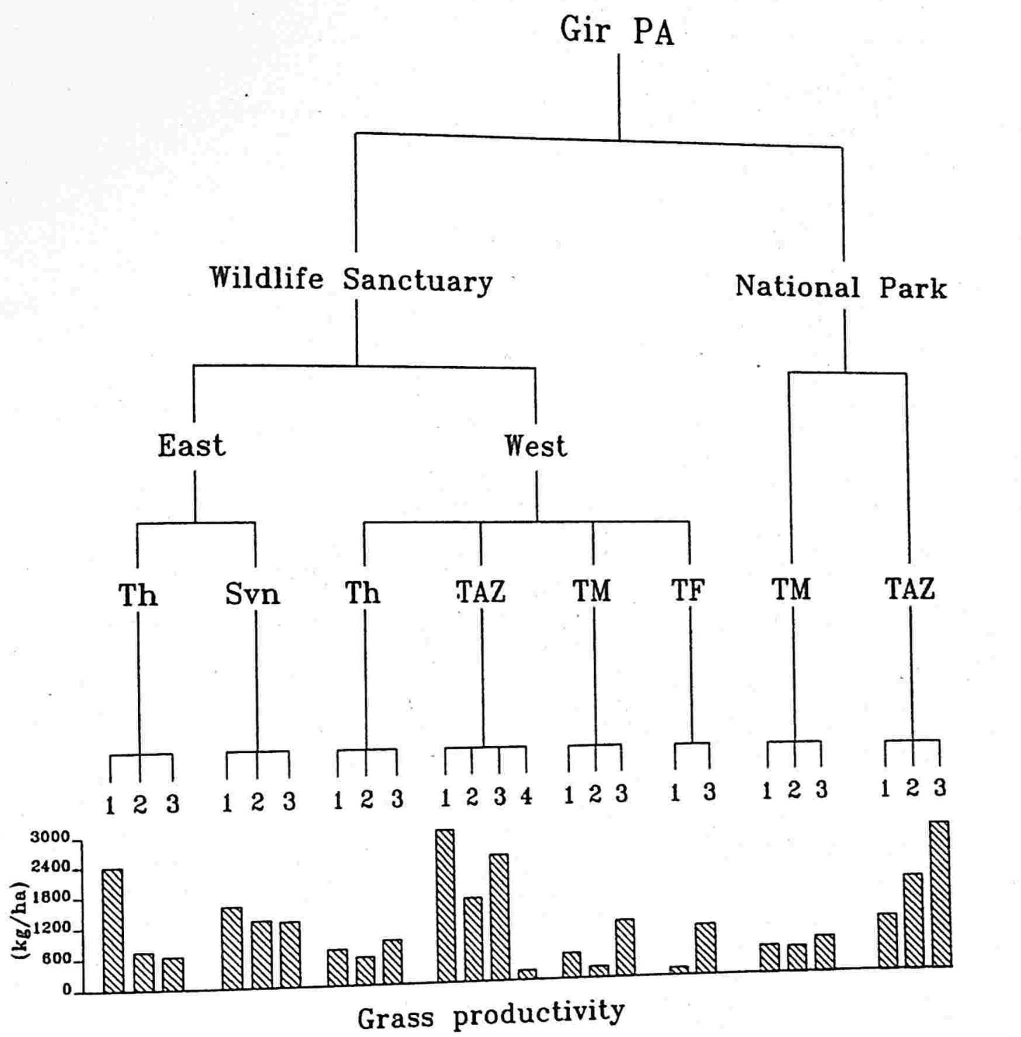


Fig. 6.7b. Percentage of sambar sightings in morning/evening and noon hours in relation to distance from current *nes* in Gir.



Habitat Types

Th = Thorn forest; Svn = Savanna; TAZ = Teak – *Acacia* – *Zizyphus*

TM = Teak mixed; TF = Teak forest

Management Practices

1 = Control; 2 = Under grazing; 3 = Under regular fire;

4 = Under no previous harvesting – outside control area

Fig. 6.8. Average grass productivity under various management practices and habitat types in Gir.

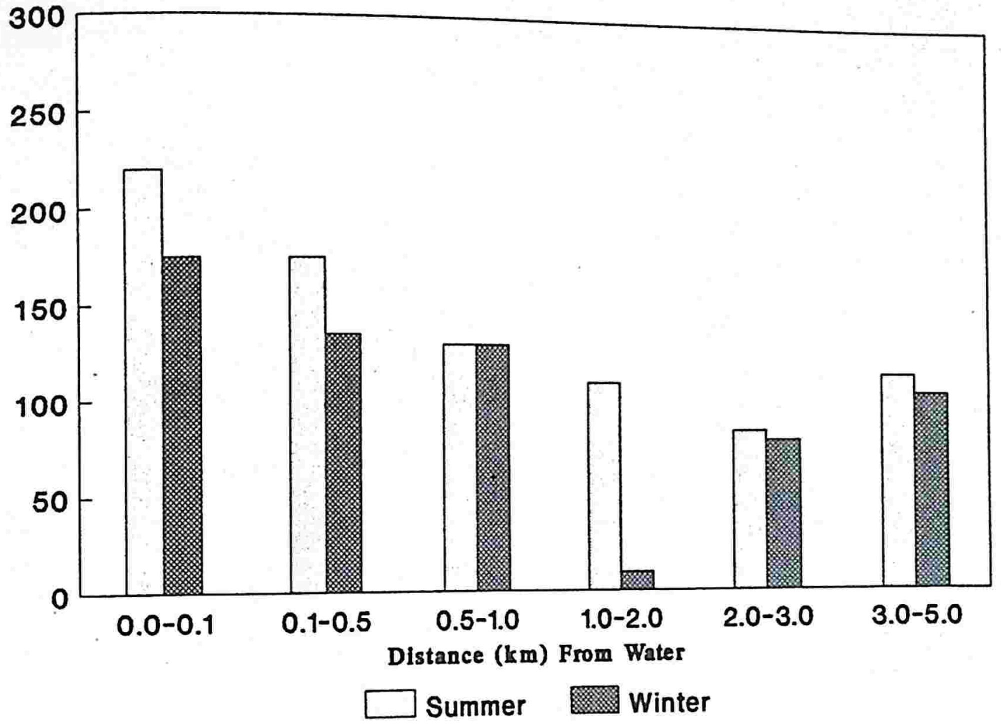


Fig. 6.9a. Average chital pellet group density (number/ha) in relation to distance from water in summer and winter in Gir.

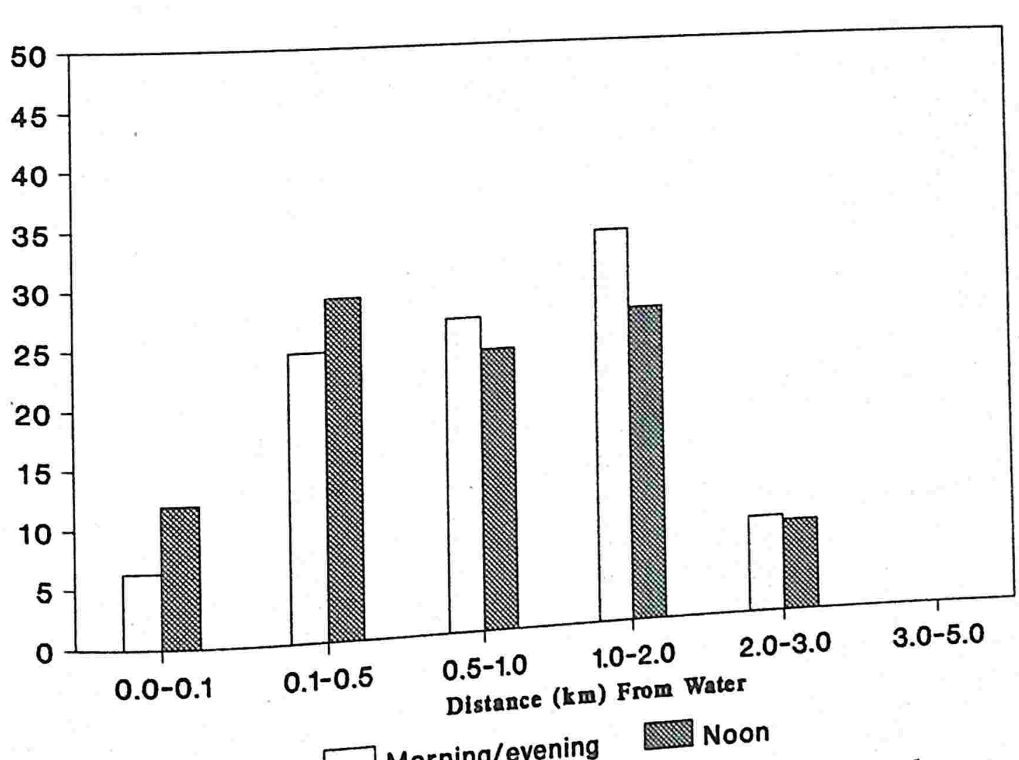


Fig. 6.9b. Percentage of chital sightings in morning/evening and noon hours in relation to distance from water in Gir.

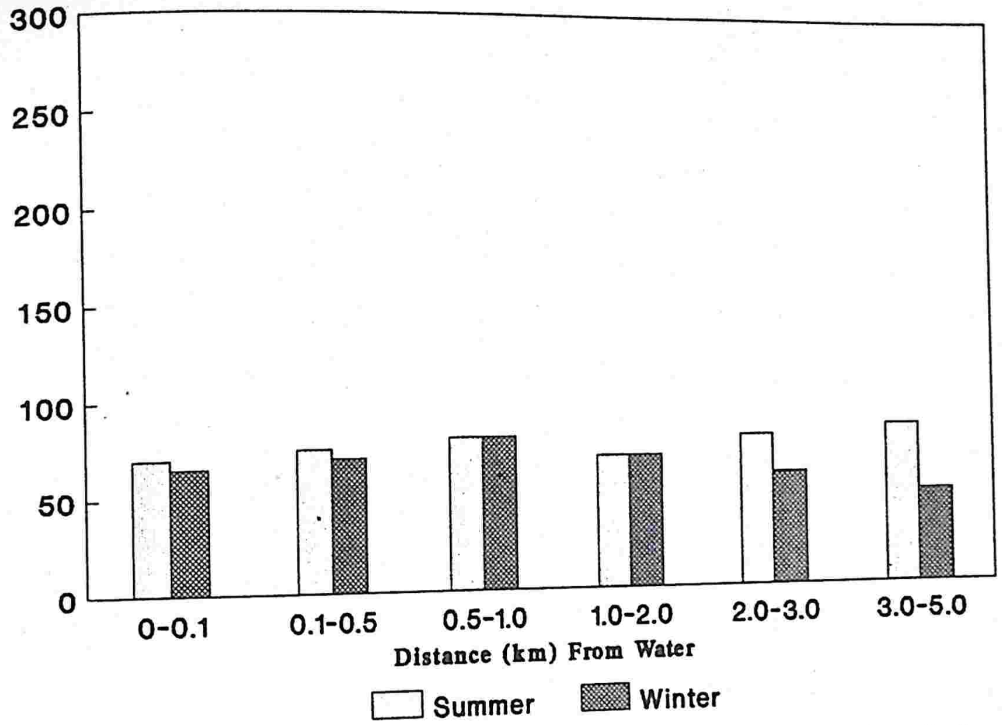


Fig. 6.10a. Average sambar pellet group density (number/ha) in relation to distance from water in summer and winter in Gir.

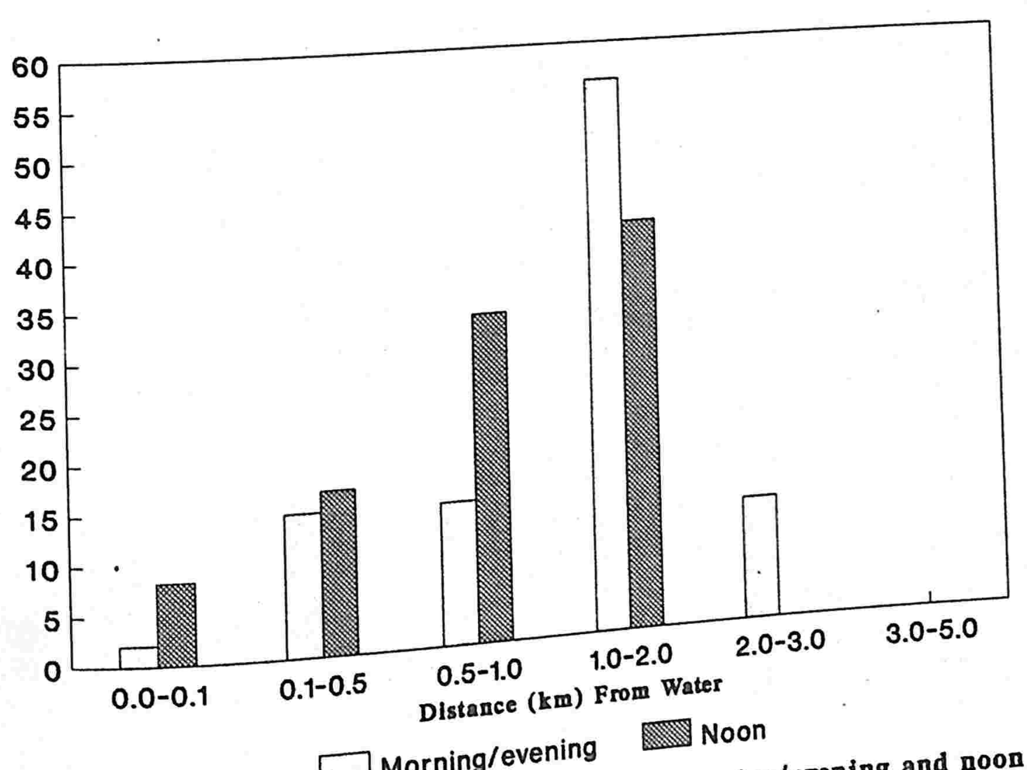


Fig. 6.10b. Percentage of sambar sightings in morning/evening and noon hours in relation to distance from water in Gir.

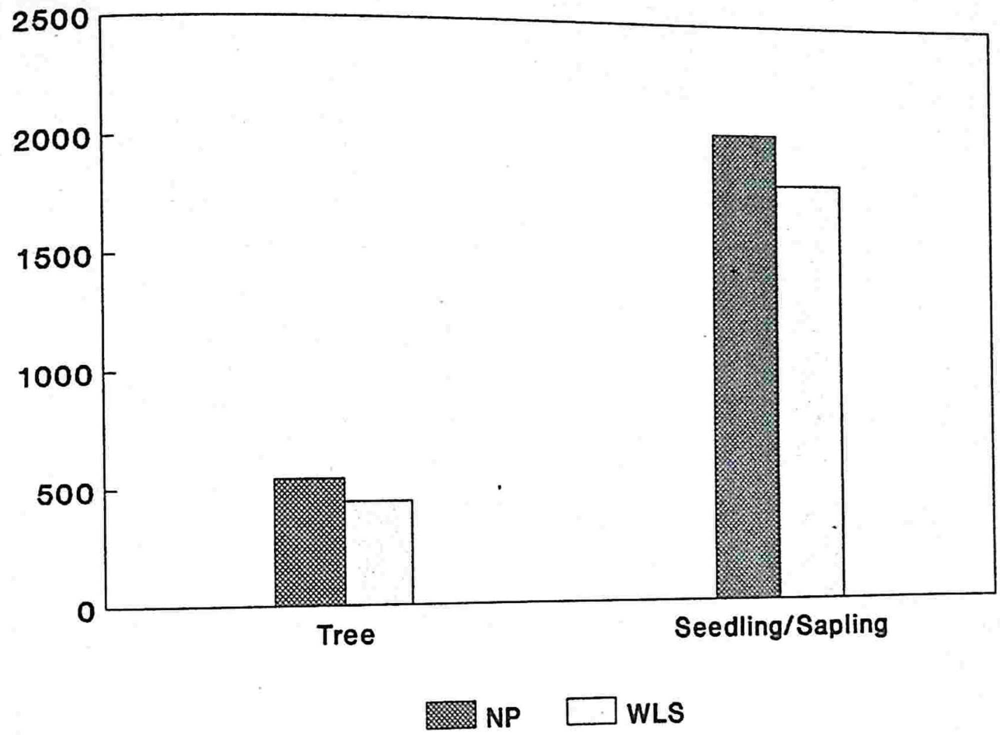


Fig. 6.11. Average tree and seedling/sapling density (number/ha) in Gir national park and wildlife sanctuary.

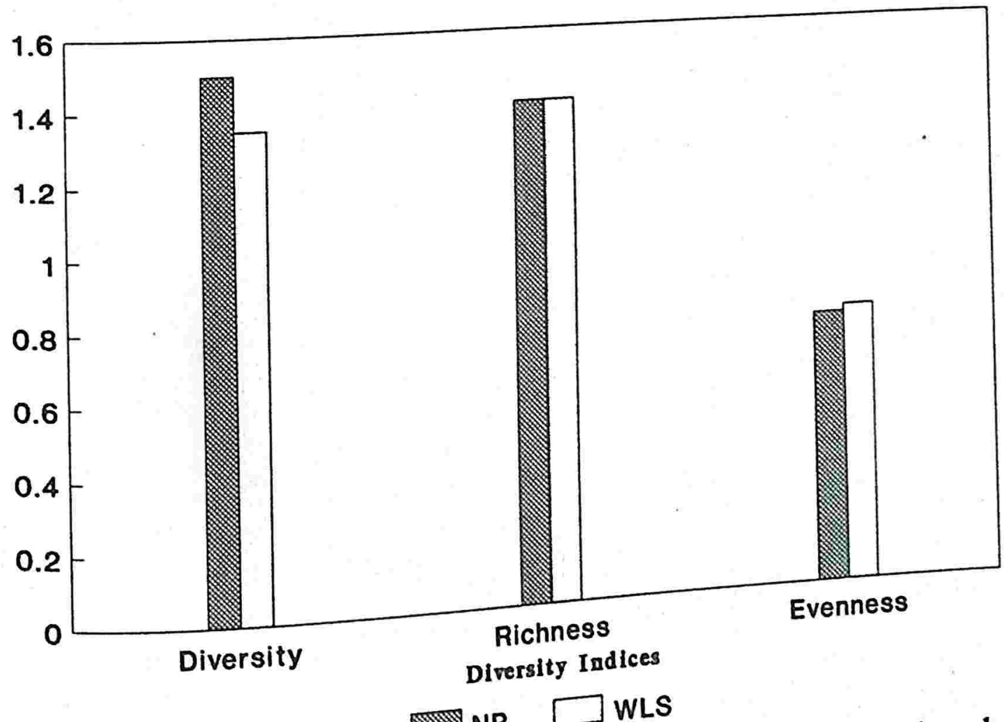


Fig. 6.12. Comparison of average diversity indices in Gir national park and wildlife sanctuary.

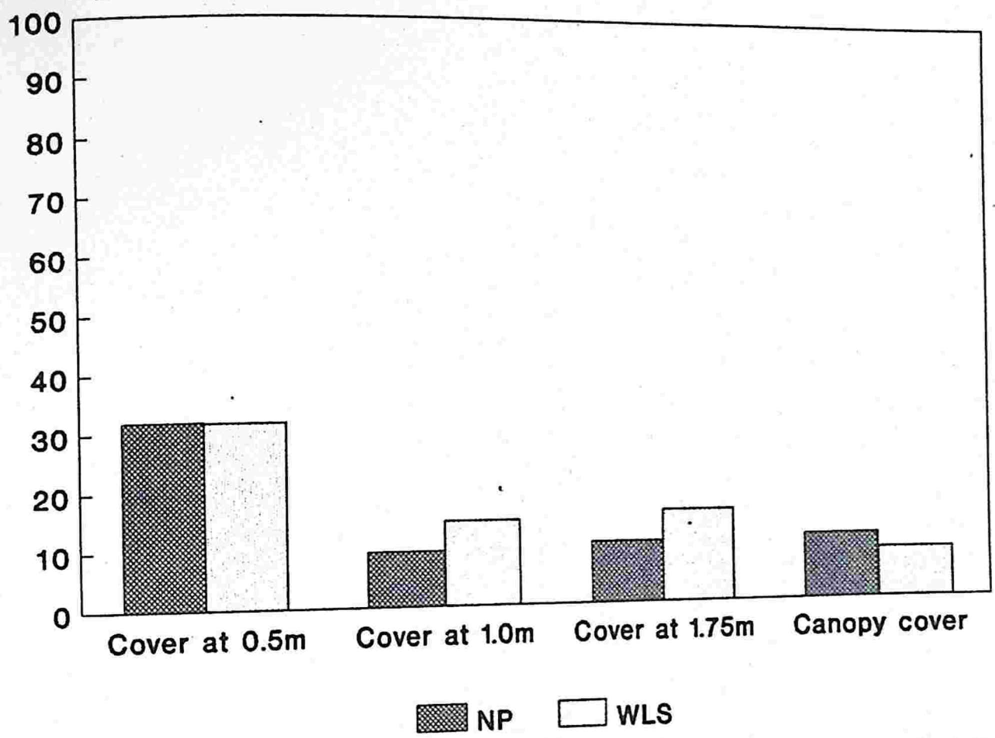


Fig. 6.13a. Comparison of average percentage cover value at three heights in Gir national park and wildlife sanctuary during summer.

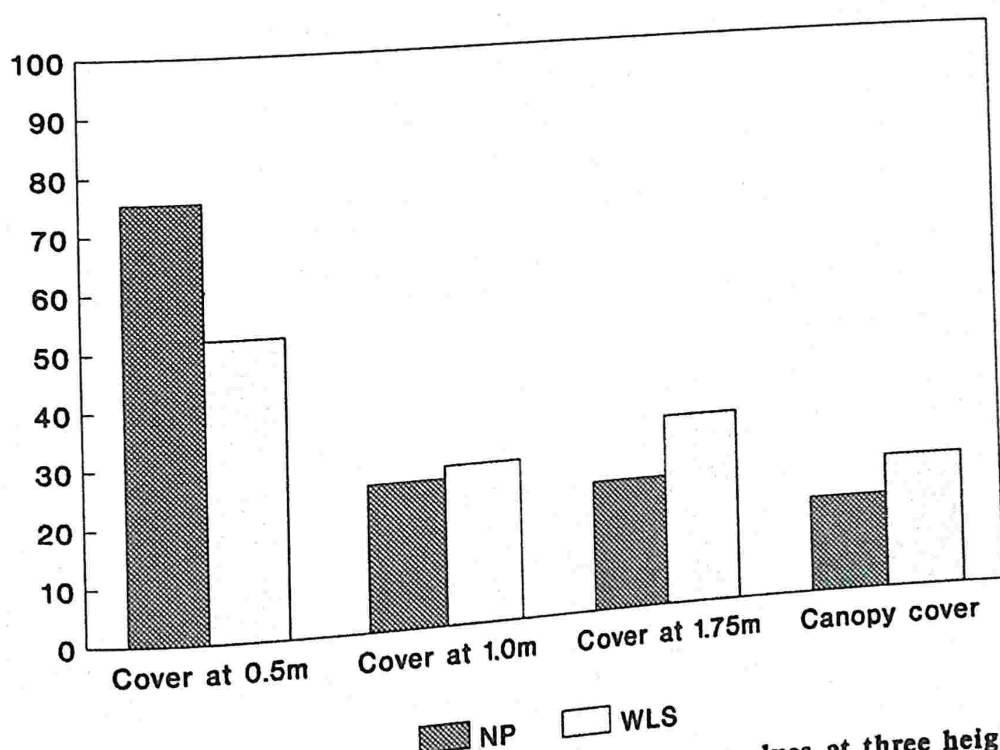


Fig. 6.13b. Comparison of average percentage cover values at three heights in Gir national park and wildlife sanctuary during winter.

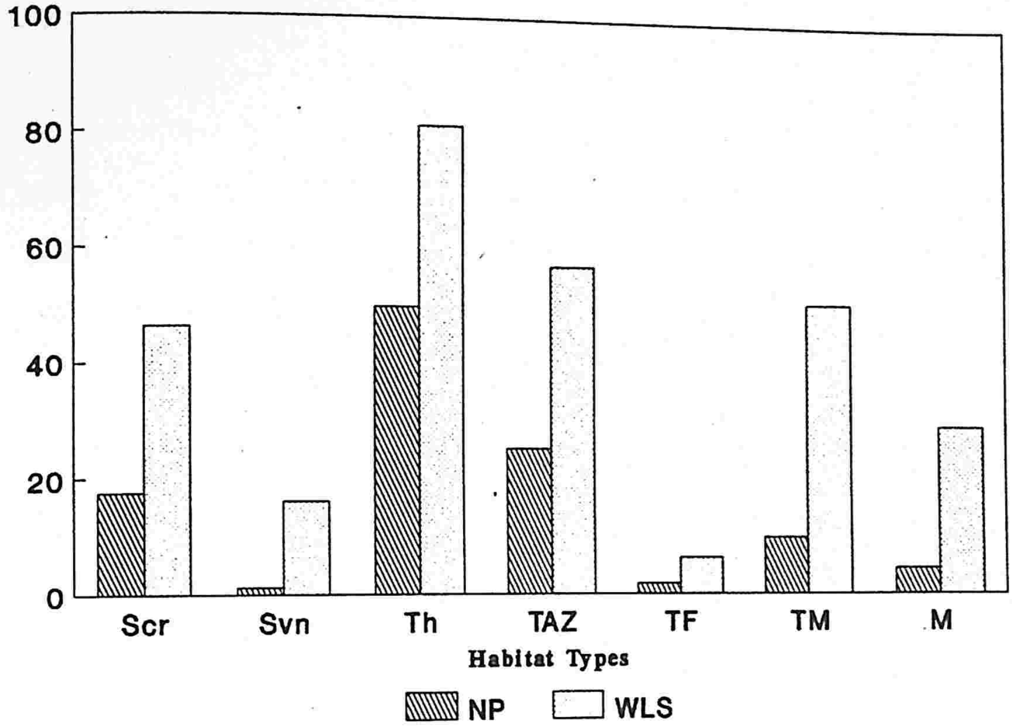


Fig. 6.14. Average percentage of *Zizyphus mauritiana* leaf litter consumed in Gir national park and wildlife sanctuary.

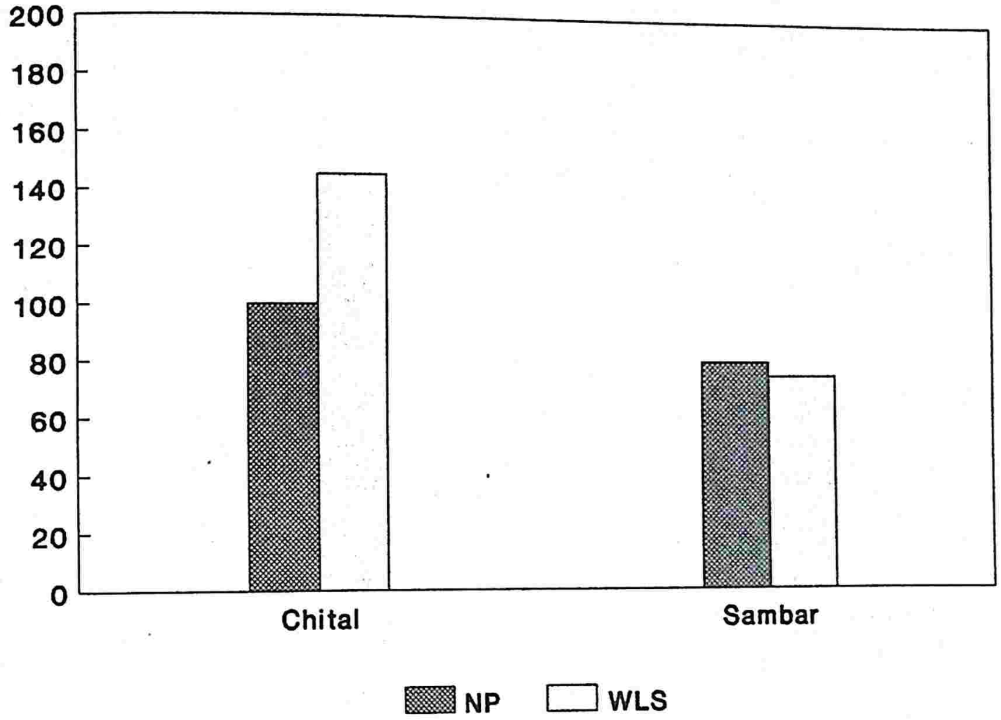


Fig. 6.15a. Average chital and sambar pellet group density (number/ha) in summer in Gir national park and wildlife sanctuary.

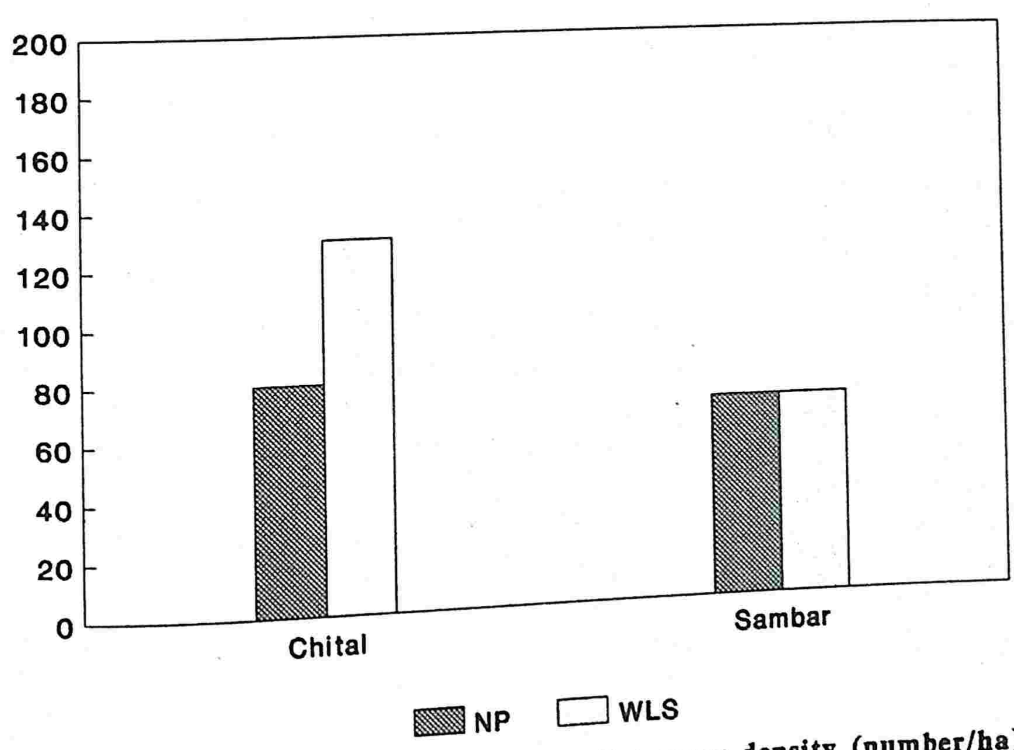


Fig. 6.15b. Average chital and sambar pellet group density (number/ha) in winter in Gir national park and wildlife sanctuary.

Table 6.1. Modified output of TWINSPAN showing vegetation succession in terms of species abundance at varying periods after *nes* relocation.

SPECIES	YEARS AFTER RELOCATION			
	1-4	5-8	9-25	>25
Zizyphus nummularia	-	5	-	-
Cassia auriculata	-	0-2	-	-
Capparis sepiaria	0-2	0-2	-	-
Acacia senegal	-	0-2	-	-
Terminalia crenulata	-	-	-	-
Garuga pinnata	-	-	-	0-1
Themeda quadrivalvis	2-4	-	-	0-1
Apluda mutica	2-4	-	-	0-2
Tectona grandis	0-2	-	0-4	0-4
Lannea coromandelica	-	-	-	0-1
Emblica officinalis	-	-	-	0-2
Aristida adscenscinis	-	-	0-2	-
Diospyros melanoxylon	-	-	-	0-1
Acacia leucophloea	-	-	0-2	0-2
Terminalia belerica	-	-	-	0-1
Mitragyna parvifolia	-	-	-	0-2
Acacia ferruginea	-	-	-	0-1
Wrightia tinctoria	0-1	-	-	1-2
Bauhinia racemosa	0-1	-	-	0-2
Acacia nilotica	0-2	-	4	0-2
Zizyphus xylopyrus	-	-	0-1	-
Zizyphus mauritiana	-	-	2-3	1-2
Holarrhena antidysenterica	-	-	0-1	0-2
Grewia tiliaefolia	-	-	-	0-1
Flacourtia indica	-	-	0-1	-
Ehretia laevis	0-2	0-2	-	-
Dichrostachys cinerea	0-2	-	0-1	-
Butea monosperma	-	-	-	0-2
Balanites aegyptiaca	-	-	0-1	-
Anogeissus latifolia	-	-	-	0-4
Adina cordifolia	-	-	-	0-2
Acacia catechu	0-1	0-2	0-2	0-3

- & 0 = NIL; 1 =1-5%; 2 = 6-25%; 3 = 26-35%; 4 = 36-66%; 5 = >66%

Table 6.2. Percentage of trees lopped and cut in relation to distance from current *nes*.

DISTANCE FROM *NES* (km)	% LOPPED	% CUT
	MEAN	MEAN
0.0 - 0.5	26.80	0.00
0.5 - 1.0	25.87	5.54
1.0 - 2.0	14.07	4.22
2.0 - 3.0	17.37	5.03
3.0 - 4.5	05.45	4.59
4.5 - 6.0	15.12	6.72

Table 6.3. Canopy cover variation during summer and winter at varying distances from current *nes* in Gir.

DISTANCE FROM CURRENT *NES*	PERCENTAGE CANOPY COVER	
	SUMMER MEAN±SE	WINTER MEAN±SE
0.0 - 0.5km	4.4±1.1	38.3±8.5
0.5 - 1.0km	9.1±1.8	27.6±3.2
1.0 - 2.0km	11.9±2.3	27.1±2.3
2.0 - 3.0km	18.4±1.4	19.3±1.2
3.0 - 4.5km	15.3±1.6	17.2±1.7
4.5 - 6.0km	7.7±3.3	26.3±3.6
>6.0km	25.1±1.3	19.0±1.0
WITHIN SEASON SIGNIF.	***	***

*** p<.001

Table 6.4. Cover at 0.5m height during summer and winter at varying distances from current *nes* in Gir.

DISTANCE FROM CURRENT *NES* (km)	PERCENTAGE COVER AT 0.5m HEIGHT	
	SUMMER MEAN±SE	WINTER MEAN±SE
0.0 - 0.5	41.1±7.8	50.6±10.1
0.5 - 1.0	22.2±4.1	39.4±5.0
1.0 - 2.0	28.5±3.2	47.4±4.1
2.0 - 3.0	32.2±2.2	46.0±2.3
3.0 - 4.5	35.5±2.6	52.5±3.1
4.5 - 6.0	31.0±4.2	73.7±6.5
>6.0	31.9±2.1	73.9±1.7
WITHIN SEASON SIGNIF.		***

*** $p<.001$

Table 6.5. Cover thickness at 1.0m height during summer and winter at varying distances from current *nes* in Gir.

DISTANCE FROM CURRENT *NES* (km)	PERCENTAGE COVER AT 1.0m HEIGHT	
	SUMMER MEAN±SE	WINTER MEAN±SE
0.0 - 0.5	35.5±7.5	39.4±9.6
0.5 - 1.0	10.2±2.5	24.0±4.4
1.0 - 2.0	14.7±2.4	29.0±3.5
2.0 - 3.0	13.2±1.5	23.5±1.9
3.0 - 4.5	15.5±1.8	31.9±2.8
4.5 - 6.0	11.8±2.2	52.6±7.1
>6.0	11.0±1.3	23.9±1.5
WITHIN SEASON SIGNIF.	**	**

** p<.01

Table 6.6. Cover at 1.75m height during summer and winter at varying distances from current *nes* in Gir.

DISTANCE FROM CURRENT *NES* (km)	PERCENTAGE COVER AT 1.75m HEIGHT	
	SUMMER MEAN±SE	WINTER MEAN±SE
0.0 - 0.5	35.3±7.2	41.5±9.9
0.5 - 1.0	13.7±3.2	38.4±4.7
1.0 - 2.0	16.6±2.3	35.4±3.8
2.0 - 3.0	14.4±1.4	30.9±2.1
3.0 - 4.5	15.9±1.8	31.1±2.7
4.5 - 6.0	10.4±2.3	52.9±7.6
>6.0	13.3±1.4	23.0±1.5
WITHIN SEASON SIGNIF.	*	***

* p<.05 *** p<.001

Table 6.7. Chital pellet group density (number/ha) at varying distances from current *nes* during summer and winter.

DISTANCE FROM *NES* (km)	SUMMER			WINTER			BETWEEN SEASONS SIGNIF.
	MEAN	MIN	MAX	MEAN	MIN	MAX	
0.0 - 0.5	245	50	600	220	50	650	***
0.5 - 1.0	155	50	500	135	50	700	
1.0 - 2.0	155	50	1150	145	50	650	
2.0 - 3.0	140	50	1150	120	50	650	*
3.0 - 4.5	90	50	350	75	50	250	
4.5 - 6.0	145	50	700	105	50	350	
>6.0	105	0	450	85	50	350	**
WITHIN SEASON SIGNIF.	***			***			***

* p<.05   ** p<.01   *** p<.001

Table 6.8. Sambar pellet group density (number/ha) at varying distances from current *nes* during summer and winter.

DISTANCE FROM *NES* (km)	SUMMER			WINTER			BETWEEN SEASONS SIGNIF.
	MEAN	MIN	MAX	MEAN	MIN	MAX	
0.0 - 0.5	65	50	100	125	50	250	
0.5 - 1.0	80	50	300	80	50	200	
1.0 - 2.0	70	50	450	65	50	250	
2.0 - 3.0	75	50	400	70	50	200	
3.0 - 4.5	75	50	250	85	50	200	
4.5 - 6.0	60	50	200	55	50	200	**
>6.0	75	50	500	70	50	300	
WITHIN SEASON SIGNIF.				*			

* p<.05   ** p<.01

Table 6.9. Modified output from TWINSPAN showing vegetation composition in regularly burnt and unburnt localities in Gir.

SPECIES	TREES		SEEDLING/SAPLING	
	BURNT	UNBURNT	BURNT	UNBURNT
Balanites aegyptiaca	--1----	-------	---43-	-------
Sehima nervosum	-222---	--12---	------	-------
Themeda quadrivalvis	244322	--11---	------	-------
Apluda mutica	1	--21---	------	-------
Emblica officinalis	232422	-----1-	------	---2-2-
Zizyphus mauritiana	1	---122-	3---2-	-----22
Acacia catechu	-1-----	12225--	---345	22-----
Butea monosperma	4-1----	-------	4-----	-------
Acacia ferruginea	31-12--	2--2-2-	---2--	-3-2---
Acacia nilotica	-1---2-	-----2-	45----	-----2
Acacia senegal	--1-221	-----1-	------	-------
Dicanthium annulatum	-1----2	-----1-	------	-------
Diopyros melanoxylon	-------	-----1-	------	-------
Zizyphus xylopyrus	-------	-----11	------	-------
Acacia leucophloea	-------	--12---	------	-------
Aegle marmelos	-------	-------	------	-------
Mitragyna parvifolia	-------	1------	------	-------
Morinda tinctoria	------1	---1---	----2-	2------
Tectona grandis	-------	5454232	-2----	3334423
Lannea coromandelica	-------	-----11	------	-------
Wrightia tinctoria	-112445	------1	------	232--22
Grewia tiliaefolia	-1--2--	-1---22	------	2-34-22
Terminalia crenulata	----2--	-2---11	------	-------
Bauhinia racemosa	-------	------3	------	2---44-
Sapindua emarginatus	-------	------2	------	-------
Screbera swietenioides	-------	------2	------	2------
Catunaregam spinosa	-------	------1	------	-------
Acacia leucopholea	-------	-------	------	-----2-
Holorrhena antidysenterica.	-------	-------	------	--2--2-
Dichrostachys cineria	-------	-------	--5---	------2
Soyamida febrifuga	-------	-------	------	-2-----
Azardiracta indica	-------	-------	------	-----2-

- = NIL; 1 = 1-5%; 2 = 6-25%; 3 = 26-35% 4 = 36-66%; 5 = >66%

Table 6.10. Tree density (no./ha) comparison between unburnt and burnt localities in Gir PA.

Sr. No.	LOCALITY	TREES		SEEDLING/SAPLING	
		BURNT	UNBURNT	BURNT	UNBURNT
1.	Dudhala	300	275	400	700
2.	Diaratimbi	175	850	00	600
3.	Vanasali	250	1075	200	1000
4.	Chhodavadi(a)	650	600	1200	500
5.	Chhodavadi(b)	1650	800	1600	1400
6.	Chhodavadi(c)	1575	750	2900	1800
7.	Saatvaya	1625	1025	800	1500

Table 6.11. Chital pellet group density (number/ha) at varying distances from water during summer and winter in Gir.

DISTANCE FROM WATER (km)	SUMMER			WINTER			BETWEEN SEASONS SIGNIF.
	MEAN	MIN	MAX	MEAN	MIN	MAX	
0.0 - 0.1	220	0	1150	175	50	650	
0.1 - 0.5	175	50	1150	135	50	550	**
0.5 - 1.0	130	50	700	130	50	700	
1.0 - 2.0	110	50	1050	100	50	500	*
2.0 - 3.0	85	50	200	80	50	350	
3.0 - 5.0	115	50	350	105	50	350	
WITHIN SEASON SIGNIF.	***			***			***

* $p<.05$ ** $p<.01$ *** $p<.001$

Table 6.12. Sambar pellet group density (number/ha) at varying distances from water during summer and winter in Gir.

DISTANCE FROM WATER (km)	SUMMER			WINTER			BETWEEN SEASONS SIGNIF.
	MEAN	MIN	MAX	MEAN	MIN	MAX	
0.0 - 0.1	70	50	150	65	50	150	
0.1 - 0.5	75	50	450	70	50	300	
0.5 - 1.0	80	50	400	80	50	250	
1.0 - 2.0	70	50	300	70	50	200	
2.0 - 3.0	80	50	500	60	50	150	
3.0 - 5.0	85	50	200	50	50	50	***

** $p<.01$

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

7.1. INTRODUCTION

The overall aim of the management of Gir is the long term conservation of a viable population of Asiatic lion. The steps needed to achieve this have to include the management of habitat for improving the population of ungulates. Various studies in the past since 1972, have brought to light problems in Gir, which were followed by certain management inputs to mitigate them. The results of this study show the impacts of these management practices and provide clues for habitat manipulation required in the future.

This chapter concludes about the hypotheses set for the study (see 1.7) and about the results obtained, and based on these some suggestions are made. All the hypotheses save the 5th were stated as biological (alternate) hypotheses and were accepted in case of significant differences. The suggestions below do not include the quantitative extent and the intervals at which these practices should be carried out. This needs another study with varying degrees of manipulation followed by monitoring.

7.2. VEGETATION MANAGEMENT

The results indicate that most of the area (70%) in Gir is dominated by teak and its associations. There were many localities where the vegetation cover was over 70% teak. Teak had been planted and cut for timber before the 1960s (Joshi 1976) after which teak harvesting has been stopped, save during the cyclones in 1982 and 1984. This lack of cutting has led to extensive coppicing. The value of teak is not much as forage for ungulates. Dense coppicing deters use of the area by species such as chital and nilgai. This was indicated by very little chital evidence in areas under dense teak, suggesting that certain amount of thinning of teak may be desirable to promote the population of chital which is the most abundant and frequently preyed ungulate in Gir. As an experiment, teak dominated areas with different moisture and edaphic conditions should be selected to study the impact of thinning on vegetation and ungulate abundance.

7.3. *MALDHARI* RELOCATION

It is observed that *maldhari* relocation in the past has been beneficial for both vegetation and ungulate communities. Both the species number and density increased after the *nes* relocation, but this change was recorded only at the actual *nes* site. Beyond about 500m from this site the vegetation composition and density was governed by physical features (see 5.3.2 and 6.3.1). Hence, the hypothesis that the past relocation of *neses* with the concomitant decrease in the cattle pressures and increase in fire protection have enhanced vegetation density, is accepted for 500m radius.

The second hypothesis that the rate of succession of vegetation on similar soil and terrain with similar water regime differs with the status of protection afforded from livestock could not be tested since such combination could not be found during this study.

More evidence of chital and less of sambar in grazed areas (see Fig. 5.14 and 5.15) led to the acceptance of biological hypothesis that localities unaffected by heavy livestock grazing are avoided by chital, an edge species but preferred by sambar, an animal of dense cover.

The impact of current *neses* on ungulates is mixed. Evidence of chital were more near a *nes* while sambar maintained a distance of 1-2km. The reason for the proximity of chital to the *neses* was the presence of water, open areas used by chital for yarding and the tolerance of chital for human settlements. Hence, *maldhari* relocation will be favourable for chital if the evacuated sites continue to have the open areas and water. When disturbance caused by the *maldharis* is removed by resettling them more sambar, a preferred prey of lion (Ravi Chellam & Johnsingh 1993) and a disturbance sensitive species, would start using the evacuated sites which are often in prime wildlife areas. As male lions still prey extensively on livestock (Ravi Chellam & Johnsingh 1993), relocation needs to be done in a phased manner giving sufficient time for the prey population to build up and the lions to gradually shift from easily catchable livestock to more agile wild prey. If it is decided to relocate *maldharis* outside Gir, care should be taken that the resettlement scheme does not fail like the one in the 1970s, and should enable *maldharis* to lead a better life than at present. Options to thin vegetation in the relocated *nes* sites as and when required should be kept open.

If *maldharis* are allowed to continue to stay in Gir, the *neses* should be translocated in such a manner that there should be a minimum distance of 8km between any two *neses* so that a vast block of disturbance free forest between any two *neses* will be available for sambar. Such a resettlement of *maldharis* within Gir would require translocation of about thirty *neses* and their livestock outside Gir. No major development around the *neses*, which will be allowed to stay within Gir, involving permanent structures should be allowed. These *neses* can be shifted from one locality to another in a rotation manner as and when needed.

7.4. WATER MANAGEMENT

Results clearly indicate the dependence of chital and sambar on water. Hence, the hypothesis that Sambar and chital which are water dependent are found near water was accepted.

Lion is also dependent on water (Ravi Chellam 1993). The practice of establishing artificial water points in summer is a very sensitive management issue. The maps of artificial and natural water points prepared by Gir officials in 1990-1993 indicate that water points are not evenly distributed and are over-abundant in some places. The number of these water points vary from 250 to 300. In summer lions kill bulk of their prey along and around natural water points and a higher density of artificial water points could lead to greater dispersion of prey affecting the hunting efficiency of lions (Ravi Chellam 1993). Therefore, it is suggested to remove the artificial water points like troughs along the road. Instead, in the periods and localities of water scarcity, artificial water points near some of the 250 used and disused wells in river/stream beds which are all over Gir could be managed. The troughs should be built and the vegetation managed in such a way that the water points look as natural as possible. Other measures such as gully plugging and building check dams should also be taken up to enhance capacity of the habitat to retain more water (Patel 1992). Ungulates have the capability to wander widely to seek water as was found in Sariska with the aid of radio telemetry (Chakrabarty 1993).

7.5. GRASS HARVESTING

Although similar number of evidence found in harvested and unharvested areas indicate that the ungulates were unaffected by grass harvesting, the null hypothesis that grass harvesting does not affect habitat utilization by ungulates could not be tested because of inadequate sampling.

The mature grass stock is unpalatable and hampers fresh grass growth, harvesting from prime and potential wild ungulate habitat is suggested. It can be done as an eco-development measure as the local people can be allowed to cut the grass in a regulated manner. It will not only increase the overall grass productivity but will also generate the much wanted support from local people (Ravi Chellam & Johnsingh 1993).

7.6. FIRE MANAGEMENT

Data collected along the fire lines indicate that controlled fires do not affect the vegetation drastically. These may be beneficial for vegetation by releasing water soluble minerals to the soil (Viro 1974) resulting in vigorous and productive post burn growth, particularly grasses (Vogl 1974). While mature, dry and coarse grass has 2-4% protein, tender grass flushing soon after cool fire can have 10-14% protein and is very much liked by ungulates (Jarman 1974). As a result post burn grasslands attract a large number of ungulates as was observed in Bandipur (Johnsingh 1986). On the other hand, less frequent but intensive accidental fires could cause much damage to vegetation and ungulates. Vegetation could become more sparse, sambar could become less and nilgai more abundant. Such an example could be seen in Banej valley in central Gir.

Hence, fire should be judiciously used in December-January to burn grasslands where grass had not been harvested previously. Rotational burning of patches of grasslands is beneficial to both the grasses and the ungulates.

REFERENCES

Abdi, R.D. (1993). *Maldharis of Saurashtra - a Glimps into their Past and Present.* Suchitra Offset. Bhavnagar. 57p.

Ables, E.D. & C.W. Ramsey (1974). Indian mammal on Texas rangelands. *Journal of Bombay Natural History Society*, 71(1):18-25.

Backeus, I., Z.K. Rulangaranga, & J. Skoglund (1994). Vegetation changes on formerly overgrazed hill slopes in semi-arid central Tanzania. *Journal of Vegetation Science*, 5:327-336.

Bennet, S.S.R. (1987). *Name Changes in Flowering Plants of India and Adjacent Regions. Triseas Publishers.* 772p.

Ben-Shahar, R. (1990). Resource availability and habitat preferences of three African ungulates. *Biological Conservation*, 54:357-365.

Berwick, S.H. (1974). *The Community of Wild Ruminants in the Gir Forest Ecosystem, India.* Ph.D. Thesis, Yale University, USA. 226p.

Berwick, S. (1976). The Gir forest. *American Naturalist*, 64:28-40.

Bhat, S.D. (1993). *Habitat use by Chital (Cervus axis) in Dhaulkhand, Rajaji National Park, India.* M.Sc. Dissertation, Saurashtra University, Rajkot. 82p.

Bhatnagar, Y.V. (1991). *Habitat Preferences of Sambar (Cervus unicolor) in Rajaji National Park.* M.Sc Dissertation, Saurashtra University, Rajkot. 51p.

Bhujanga Rao, D.D (1991). *Habitat Utilization and Distribution Pattern of Indian Wild Pig (Sus scrofa cristatus) in Sariska Tiger Reserve, Rajasthan.* M.Sc. Dissertation, Saurashtra University, Rajkot. 51p.

Bohra, H.C., S.P. Goyal, P.K. Ghosh & I. Prakash (1992). Studies on ethology and eco-physiology of the antelopes of the Indian Desert. *Annals of Arid Zone*, 31(2):83-96.

Bourliere, F. & M. Heady (1983). Present day savannas: an overview. in *Ecosystems of the World, 13: Tropical Savannas.* ed. by F. Bourliere. Elsevier. pp 1-7.

Causton, D.R. (1988). *An Introduction to Vegetation Analysis: principles, practice in interpretation.* Unwin Hyman. 342p.

Chakrabarty, B. (1991). *Habitat Use by Radio Instrumented Chital, Sambar and Nilgai in Sariska Tiger Reserve.* M.Sc Dissertation, Saurashtra University, Rajkot. 44p.

Champion, H.G. & S.K. Seth (1968). *A revised Survey of the Forest Types of India.* Government of India. 404p.

Clements, F.E. (1916). *Plant Succession. An Analysis of the Development of the Vegetation.* Carnegie Institute, Washington Publication. 242p.

Clements, F.E. (1928). *Plant Succession and Indicators.* H.W. Wilson, Newyork.

Crawford, R.M.M. (1989). *Studies in Plant Survival: Ecological Case Histories of Plant Adaptation to Adversity.* in Studies in Ecology, Vol. 11. Blackwell Scientific Publications. 296p.

Daniel, J.C. (1994). Tropical wildlife with special reference to Indian Subcontinent. in *Tropical Ecosystems: A synthesis of Tropical Ecology and Conservation.* ed. by M. Balakrishnan, R. Borgstrom & S.W. Bie. Oxford & IBH publishing Co. Pvt. Ltd. pp 147-165.

De, R.C. & J.J. Spillett (1966). A study of the chital or spotted deer in Corbett national park, Uttar Pradesh. *Journal of Bombay Natural History Society,* 63(3):576-598.

Dewis, J. & F. Frietas (1984). Physical and Chemical Methods of Soil and Water Analysis. *F.A.O. Soils Bulletin 10.* Rome. 275p.

Dharmakumarsinhji, S.K. (1968). The Gir lion. *Cheetal,* 10(2):8-12.

Dharmakumarsinhji, S.K. and M.A. Wynter-Blyth, (1951). The Gir forest and its lions. *Journal of Bombay Natural History Society,* 49:685-694.

Ershov, V.V., A.A. Novikov & G.B. Popova (1988). *Fundamental of Geology.* Mir Publishers. 358p.

Forbes, B.C. (1994). The importance of bryophytes in the classification of human-disturbed high arctic vegetation. *Journal of Vegetation Science,* 5:877-884.

Giles, R.H., Jr. (1978). *Wildlife Management.* W.H. Freeman & Company. 416p.

Gleason, H.A. (1917). The structure and development of plant association. *Bulletin of the Torry Botanical Club,* 43:463-481.

Gleason, H.A. (1926). The individualistic concept of plant association. *Bulletin of the Torry Botanical Club,* 45:1-20.

Gleason, H.A. (1939). The individualistic concept of plant association. *American midland Naturalist*, 21:92-110.

Goyal, S.P., H.C. Bohra & P.K. Ghosh (1986). Food preferences of the Indian antelope (*Antilope cervicapra*) and the gazelle (*Gazella dorcas*) in a desert environment. *Myforest*, 22(3):153-158.

Greig-Smith, P. (1983). *Quantitative Plant Ecology.* in Studies in Ecology, vol. 9. Blackwell Scientific Publications. 359p.

Habibullah, S. (1984). Phytosociological study and net primary production relation of some important tree species in western region. Ph.D. Thesis. The Bhavnagar Univ.

Hill, M.O. (1979). *TWINSPAN: A FORTRAN programme for Arranging Multivairate Data in an Ordered Two-way Table by Classification of the Individuals and Attributes.* Ecology and Systematics, Cornell University, Ithaca, New York. 90pp.

Hodd, K.T.B. (1969). The ecological impact of domestic stock on the Gir forest. *Proceedings of the 11th technical meeting. Vol. 1.* IUCN publications Newseries 17, Morges, Switzerland.

Hubbell, Stephen P. (1979). Tree dispersion, abundance, and diversity in a tropical dry forest. *Science*, 30 March, 203:1299-1309.

Jarman, P.J. (1974). The social organization of antelope in relation to their ecology. *Behaviour*, 48:215-267.

Johnsingh, A.J.T. (1982). Reproductive and social behaviour of the dhole, *Cuon alpinus* (Canidae). *Journal of Zoology*, 198:443-448.

Johnsingh, A.J.T. (1986). Impact of fire on wildlife ecology in two dry desiduous forests in South India. *Indian Forester*, (october):933-938.

Johnsingh, A.J.T & K. Shankar (1991). Food plants of chital, sambar and cattle on Mundanthurai Plateau, Tamil Nadu, south India. *Mammalia*, 55(1):57-66.

Joslin, P. (1973). *The Asiatic Lion: A Study of Ecology and Behaviour*. Ph.D. Thesis. University of Edinburgh. 249p.

Joshi, R.R. (1976). *Working Plan for Gir Forests. Vol I and Vol II*. Government of Gujarat. 152pp.

Joslin, P. (1984). The environmental limitations and the future of the Asiatic Lion. *Journal of Bombay Natural History Society*, 81(3):648-664.

Kent, M. & P. Coker (1992). Vegetation Description and Analysis: A Practical Approach. CRC press & Belhaven press. 363p.

Khan, J.A., W.A. Rodgers, A.J.T. Johnsingh, & P.K. Mathur, (1990). *Gir Lion Project: Ungulate Habitat Ecology in Gir*. Project Report. Wildlife Institute of India, Dehradun. 214p.

Khan, J.A. (1994). Food habits of ungulates in dry tropical forests of Gir lion sanctuary, Gujarat, India. *Acta Theriologica*, 39(2):185-193.

Khan, J.A., W.A. Rodgers, A.J.T. Johnsingh, & P.K. Mathur, (1994). Tree and shrub mortality and debarking by sambar *Cervus unicolor* (Kerr) in Gir after a drought in Gujarat, India. *Biological Conservation*, 68:149-154.

Leuthold, W. (1977). African Ungulates: A Comparative Review of their Ethology and Behavioral Ecology. in *Zoophysiology and Ecology*, Vol. 8, 307p.

Lincoln, R.J., G.A. Boxshall & P.F. Clark (1982). *A Dictionary of Ecology, Evolution and Systematics.* Cambridge University Press. 298p.

Magurran A.E. (1988). *Ecological Diversity and its Measurement.* Croom Helm. 179p.

Marija, J.N. (1990). *SPSS/PC+ Statistics 4.0 for the IBM PC/ST/AT and PS/2.* 444N. Michigan Avenue, Chicago, Illinois 60611.

Mathur, V.B. (1991). *The Ecological Interaction Between Habitat Composition, Habitat Quality and abundance of Some Wild Ungulates in India.* Ph.D. Thesis. University of Oxford, Oxford, U.K. 279p.

Mueller-Dombois. D, & H. Ellenberg (1974). *Aims and Methods in Vegetation Ecology.* John Wiley and Sons. 359p.

Pandit, B.R., S.V.S. Subrahmanyam & K.V. Raghavendra Rao (1992). *Ecology of Gir Forest: Litter Production, Decomposition and Energy Flow in Tropical Dry Deciduous Forest Ecosystem.* Final Report. Department of Life Sciences, Bhavnagar University, India. 34p.

Patel, Chandrakant D. (1992). *Geo-environmental Studies in Gir Forest Area.* Ph.D. Thesis. Department of Geology, M.S. University of Baroda. Vadodara.

Pathak, B.J, D.S. Narve, P.P. Raval, D. Sharma, Shivbhadrasinhji, Bhuva, V. (1994). Report of Lion-human interaction group (first draft report of PHVA for Asiatic Lion (*Panthera leo persica*). *Zoos Print*, Vol IX(1,2):13-14.

Pielou, E.C. (1975). *Ecological Diversity.* John Wiley & Sones. 165p.

Pielou, E.C. (1977). *Mathematical Ecology.* John Wiley & Sones. 384p.

Prater, S.H. (1980). *The Book of Indian Animals*. Bombay Natural History Society. 324p.

Pratt, R.M., R.J. Putman, J.R. Ekins & P.J. Edwards (1986). Use of habitat by free-ranging cattle and ponies in the New Forest, southern England. *Journal of Applied Ecology*, 23:539-557.

Puri, G.S., V.M. Meher-Homji, R.K. Gupta & S. Puri (1983). *Forest Ecology: Phytogeography and Forest Conservation.* Oxford and IBH Publishing Co. Pvt. Ltd. 549p.

Putman, R.J., P.J. Edwards, J.C.E. Mann, R.C. How & D. Hill (1989). Vegetational and faunal changes in an area of heavily grazed woodland following relief of grazing. *Biological Conservation*, 47:13-32.

Rao. B.N. (1983). *Phytosociological study and net primary production relation of some important tree species in eastern region.* Ph.D. Thesis. The Bhavnagar Univ.

Ravi Chellam (1993). *Ecology of the Asiatic Lion (Panthera leo persica).* Ph.D. Thesis submitted to the Saurashtra University Rajkot. 170p.

Ravi Chellam & A.J.T. Johnsingh (1993). Management of Asiatic Lions in the Gir forest, India. *Symposia of the Zoological Society of London*, 65:409-424.

Rodgers, W.A. (1988). The wild grazing ungulates of India: An ecological review. in *Rangelands: Resource and Management. Proceedings of the National Rangeland Symposium, 1987.* ed. by Singh P. and P.S. Pathak. Range Management Society of India, Jhansi. 404p.

Rundel, P.W. (1983). Impact of fire on nutrient cycle in Mediterranean-type ecosystems with reference of chaparral. in *Mediterranean-Type Ecosystems: The Role of Nutrients. Ecological Studies, 48.* ed. by F.J. Kruger, D.T. Mitchell & J.V.M. Jarvis. pp 193-207.

Ruyle, G.B., J.E. Bwons & Al. F. Schlundt (1983). Estimating snoberry (*Symphoricarpos oreophilus*) utilization by sheep from twing diameter-weight relations. *Journal of Range Management*, 36(4):472-474.

Saberwal, V. K, Jmaes P. Gibbs, Ravi Chellam & A.J.T. Johnsingh (1994). Lion-Human Conflict in the Gir Forest, India. *Conservation Biology*, 8(2):501-507.

Santapau, H. and M.B. Raizada (1956). Contribution to the flora of Gir Forest in Saurashtra. *Indian Forest Records (New Series) Botany*, 4:105-170.

Schaller, G.B. (1967). *The Deer and the Tiger*. The University of Chicago Press. Chicago. 370p.

Sharma, D. & S.N. Prasad (1992). Tree debarking and habitat use by porcupine (*Hystrix indica* Kerr) in Sariska National Park in western India. *Mammalia*, 56(3):351-361.

Sinha, S.P. (1987). *Ecology of wildlife with Special Reference to the Lion (Panthera leo persica) in Gir Wildlife Sanctuary, Saurashtra, Gujarat.* Ph.D. Thesis. Saurashtra University, Rajkot, India. 291p.

Skarpe, C. (1992). Dynamics of savanna ecosystems. *Journal of Vegetation Science*, 3:293-300.

Sokal, R.R. & F.J. Rohlf (1981). *Biometery. The Principles and Practices of Statistics in Biological Research.* Second edition. W.H. Freeman and Co., New York. 859pp.

Strange, L.R.N. (1980). *African Pastureland Ecology with Particular Reference to Pastoral Environment of Eastern Africa.* Food and Agriculture Organizations of the United Nations. 188p.

Sukumar, R. (1990). Ecology of the Asiatic elephent in southern India, II. Feeding Habits and crop raiding patterns. *Journal of Tropical Ecology*, 6:33-53.

Swaine, M.D. (1992). Characteristics of dry forest in west Africa and influence of fire. *Journal of Vegetation Science*, 3:365-374.

ter Braak, C.J.F. (1988). *CANOCO - a FORTRAN program for canonical community ordination by [partial] [deterended] [canonical] correspondence analysis, principal component analysis and redundancy analysis (version 2.1).* Technical Report: LWA-88-02. Agricultural Mathematics Group, Wageningen, The Netherlands.

Trivedi, P. (1993). *Habitat Selection by Indian Peafowl (Pavo cristatus Linn) in Gir Forest, India.* M.Sc. Dissertation. Saurashtra University, Rajkot. 78p.

Vetaas, Ole R. (1992). Micro-site effects of trees and shrubs in dry savannas. *Journal of Vegetation Science*, 3:337-344.

Vickery, Margaret L. (1984). *Ecology of Tropical Plants.* John Willey and Sons. 170p.

Viro, P.J. (1974). Effects of forest fire on soil. in *Fire and Ecosystems.* ed. by T.T. Kozlowski and C.E. Ahlgren. Academic Press. 7-45.

Vogl, R.J. (1974). Effects of fire on grasslands. in *Fire and Ecosystems*. ed. by T.T. Kozlowski and C.E. Ahlgren. Academic Press. 139-194.

Weir, J.S. (1971). The Effect of Creating Additional Water Supplies in Central African National Park. in *11th Symposium of the B.E.S.* ed. by Duffy & Watts. Blackwell Publications.

Weltzin, J.F. & Coughenour, M.B. (1990). Savanna tree influence on understorey vegetation and soil nutrients in northwestern Kenya. *Journal of Vegetation Science*, 1:325-334.

White, H.M. (1938). *Field and Laboratory Technics in Wildlife Management*. Univ. Of Mich. Press. Ann. Arbr. 105p.

Whittaker, R.H. (1953). A consideration of climax theory: the climax as a population and pattern. *Ecological Monograph*, 23:41-78.

Whittaker, R.H. & S.A. Levin (1977). The role of masaic phenomenon in natural communities. *Theoretical Population Biology*, 12:117-139.

Yeaton, R.I. (1988). Porcupines, fires and the dynamics of the tree layer of the *Burkea africana* savanna. *Journal of Ecology*, 76:1017-1029.

Young, A. (1969). *Slopes*. Oliver & Boyd, Edinbergh, 288p.

Zonn, S.V. (1986). *Tropical and Subtropical Soil Science*. Mir Publishers. Moscow. 422p.

Appendix I. List of plants found in vegetation plots.

Scientific Name	**Local Name**
Acacia catechu	Khair
Acacia ferruginea	Babar khair
Acacia leucophloea	Harmo
Acacia nilotica	Bawal
Acacia senegal	Gorad
Adina cordifolia	Haldarvo
Aegle marmelos	Billi
Ailanthus excelsa	Arduso
Alangium latifolium	Ankol
Albizzia odoratissima	Sarasado
Albizzia procera	Krangsa, Karangi
Anogeissus latifolia	Dhavdo
Artocarpus heterophyllus	Fanas
Azardiracta indica	Limdo
Balanites aegyptiaca	Hingor
Bauhinia purpurea	Asundro
Bombax ceiba	Semal
Boswellia serrata	Saledi
Bridelia retusa	Ekal kanto
Butea monosperma	Khakhra
Capparis sepiaria	Kanthara
Carissa carandas	Karamdi
Casearia elliptica	Mojal
Cassia auriculata	Awal
Cassia fistula	Garmalo
Clerodendrum phlomoides	Erni
Cordia dichotoma	Gundo
Dalbergia latifolia	Shisham
Dalbergia sissoo	Sissoo
Dichrostachys cinerea	Madhith
Diospyros melanoxylon	Timbervo
Ehretia laevis	Vad vadia
Emblica officinalis	Amri, Amla
Erythropsis colorata	kodaro
Erythrina variegata	Jangali khakhro
Ficus bengalensis	Vadlo
Ficus racemosa	Umra
Ficus religiosa	Piplo
Ficus amplissima	Pipli
Flacourtia indica	Lodri

Contd......

Appendix I contd.

Scientific Name	**Local Name**
Garuga pinnata	Karapti
Gmelina arborea	Sivan
Grewia tiliaefolia	Dhraman
Helicteres isora	Aterdi
Holorrhena antidysenterica	Kalükado (Kadhukado)
Holoptelea integrifolia	Charel (Sarel)
Hymenodictyon excelsum	Bhamar Chhal
Ixora arborea	Nevri
Lannea coromandelica	Moledi
Lantana camara	Dario
Manilkara hexandra	Rayan
Miliusa tomentosa	Umdi
Mitragyna parvifolia	Kalam (Kadam)
Morinda tinctoria	Rangari, Al
Moringa oleiflora	Sargavo
Pongamia pinnata	Karanj
Pterocarpus marsupium	Biyo
Sapindus emarginata Schleichera	Arithi
oleosa	Ujal, Kusum
Screbera swietenioides	Markho, Nakti
Soyamida fabrifuga	Ron
Sterculia urens	Kadayo
Syzygium cumini	Jambudi
Syzygium rubicundum	Ravano
Tamarindus indica	Ambli
Tamarix troupii	Paransavi
Tectona grandis	Sag
Terminalia belerica	Baheda
Terminalia crenulata	Sajad
Wrightia tinctoria	Dudhlo
Catunaregam spinosa	Mindhol
Catunaregam uliginosa	Gangedi
Zizyphus mauritiana	Bordi
Zizyphus nummularia	Chani bor
Zizyphus oenoplia	Kanthar
Zizyphus xylopyrus	ghutbordi

Appendix II. List of Plants and their parts eaten by ungulates.

Scientific Name	**Parts Consumed**
Acacia catechu	L, Fl,
Acacia ferruginea	L, Fl,
Acacia leucophloea	L, Fl, P
Acacia nilotica	L, Fl, P
Acacia senegal	L, Fl
Adina cordifolia	-
Aegle marmelos	TL, F
Ailanthus excelsa	L, P
Alangium salvifolium	-
Albizzia odoratissima	-
Albizzia procera	-
Anogeissus latifolia	L
Artocarpus heterophyllus	L, F
Azardiracta indica	-
Balanites aegyptiaca	L, F
Bauhinia purpurea	L, F
Bombax ceiba	TL
Bridelia retusa	TL
Butea monosperma	-
Capparis sepiaria	L
Carissa carandas	L, F
Casearia elliptica	L, F
Cassia auriculata	-
Cassia fistula	TL
Clerodendrum phlomoides	-
Cordia dichotoma	TL, F
Dalbergia latifolia	TL,
Dalbergia sissoo	-
Dichrostachys cinerea	L, P
Diospyros melanoxylon	TL, F
Ehretia laevis	-
Emblica officinalis	L, F
Erythropsis colorata	-
Erytherina variegata	-
Ficus bengalensis	-
Ficus racemosa	TL, F
Ficus religiosa	TL
Ficus amplissima	TL, F
Flacourtia indica	L, F

Contd.....

Appendix II contd.

Scientific Name	Parts Consumed
Garuga pinnata	F
Gmelina arborea	-
Grewia tiliaefolia	TL, F
Helicteres isora	L
Holorrhena antidysenterica	TL
Holoptelea integrifolia	-
Hymenodictyon excelsum	-
Ixora arborea	-
Lannea coromandelica	L, F
Lantana camara	-
Manilkara hexandra	TL, F
Miliusa tomentosa	F
Mitragyna parvifloia	-
Morinda tinctoria	F
Moringa oleiflora	-
Pongamia pinnata	-
Pterocarpus marsupium	TL
Sapindus emarginata Schleichera	TL, F
oleosa	-
Screbera Swietenioides	TL
Soyamida fabrifuga	TL
Sterculia urens	TL
Syzygium cumini	L
Syzygium rubicundum	F
Tamarindus indica	L
Tamarix troupii	TL
Tectona grandis	-
Terminalia belerica	TL, FL, F
Terminalia crenulata	TL, F
Wrightia tinctoria	TL, F
Catunaregam spinosa	TL
Catunaregam uliginosa	TL, F, FL
Zizyphus mauritiana	F
Zizyphus nummularia	L, F
Zizyphus oenoplia	L, F
Zizyphus xylopyrus	L, F