"ECOLOGICAL STATUS AND IMPORTANCE OF GRASSLANDS (VIDIS) IN CONSERVATION OF AVIAN FAUNA IN SAURASHTRA"

Thesis submitted to

Saurashtra University, Rajkot

For the degree of

Doctor of Philosophy in Zoology (Animal sciences)

By

Rajan. D. Jadav

Department of Biosciences

Saurashtra University

Rajkot – 364002

April 2010

SAURASHTRA UNIVERSITY

DEPARTMENT OF BIOSCIENCE

University Campus.

RAJKOT-360005

(INDIA) Gujarat.

Tel: (O) 0091-281-2586419

Fax: 0091-281-2586419

CERTIFICATE

I have great pleasure in forwarding the thesis of Mr. Rajan. D. Jadav entitled "**Ecological status and importance of grasslands (*vidis*) in conservation of avian fauna in Saurashtra**." for accepting the degree of Doctor of Philosophy in Zoology (Animal sciences) from the Saurashtra University Rajkot. This Study was carried out by Mr. Rajan Jadav under my Supervision and has not been submitted in part of full to any other University / Institute for the award of any degree. He has put in seven terms of research work under my supervision.

Forwarding through,

Head

Department of Biosciences,

Saurashtra University,

Rajkot

V. C. Soni

Professor and Guide

DECLARATION

The thesis carries the research work carried out by me at the Department of Biosciences, Saurashtra University, Rajkot, is submitted to the Saurashtra University and the results of this work have not been submitted to any other University for the award of Doctor of Philosophy.

Date:

Place: Rajan. D. Jadav

Dedicated to……

The GIR

My Parents

Shri Govindbhai Vekariya & Shri Revtubha Raijada

Prof. V.C.Soni

Friends

And my wife Janhavi.

Acknowledgements

I sincerely thank the following people and organizations for their unfailing support and help during the course of the thesis:

- Professor V. C. Soni
- Head, Department of Biosciences, Saurashtra University, Rajkot
- Additional PCCF (Wildlife) and Chief Wildlife Warden, Gujarat State Forest Department
- Chief Conservator of Forest, Research division, Gujarat State Forest Department
- DFO, Junagadh (Normal) division, Bhavanagar (Normal) division, Jamnagar (Normal) division, Surendranagar (Normal) division, Dhari (Wildlife) division
- Dr. P. K. Mathur, Sciemtist – G, WII, Dehradun
- Mr. B. J. Pathak, IFS, Field Director, Gir National Park and Wildlife Sanctuary
- Mr. V. S. Solanki, GFS, Assistant Conservator of Forest, Gir East division, Gir National Park and Wildlife Sanctuary
- Mr. Atara, RFO, Dalkhaniya range, Gir East division, Gir NP and Wildlife Sanctuary
- Mr. Siyani, Forester, Forest Research and Demonstration Centre, Rajkot
- Rangers and Field Staff, Junagadh (Normal) division, Bhavanagar (Normal) division, Jamnagar (Normal) division, Surendranagar (Normal) division, Dhari (Wildlife) division
- Librarian and Staff of the WII Library and Documentation Centre, Dehradun
- Librarian and Staff of the Agriculture University, Junagadh

- Staff of Administrative Section, Department of Biosciences, Saurashtra University, Rajkot
- All the faculty members of Bioscience Department: In particular, Dr. A. N. Pandey, Dr. S. P. Singh, Dr. V. S. Thakar and Dr. S. V. Chanda
- Dr. Pankaj Joshi, Junior Scientist, GUIDE, Bhuj
- Dr. Rashik Bhatt, Retd. Professor, Department of Plant physiology and Anatomy, Junagadh Agriculture University, Junagadh
- Dr. Pranav Trivedi, Dr. Bakul Trivedi and Dr. B. M. Parasharya
- Mr. Bhupatgiri and family, Jamwada (Gir)
- Mr. Lalit Chariya and family, Ph. D. Student, Department of Biosciences
- Mr. Kapil Bhatia and Mr. Dhawal Mehta
- Mr. Rajdeep Jhala and Mr. Pratik Joshi
- Mr. Vishal Parmar and family
- Mr. Chandresh Padiya and friends
- Mr. Bhavesh Trivedi, Wildlife Photographer, Rajkot
- Dr. Sumit Vyas and Mr. Rohan Pandya, Ph. D. scholars, Department of Biosciences
- Mr. Dilip Mehta, Rajkot
- Mr. Parth Parmar and Ms. Rajeshri Parmar
- Shri Revtubha Raijada and family
- Shri Govindbhai Vekariya
- My Parents: Mr. Dilip A. Jadav and Mrs. Hemlata Jadav
- My Parents in law: Mr. Naresh R. Parmar and Mrs. Shobhna Parmar
- My family members, Jayalaxmi (Grandmother) and Pranav Jadav (Brother)

- Mr. Lalit K. Misser and Mrs. Renuka Misser
- Dr. Devendrasinh Thakor and Kusumba Thakor and family
- Finally, an acknowledgement to my wife Mrs. Janhavi Jadav

14 April, 2010 Rajan Jadav

CONTENTS

List of Appendices

List of Figures

List of Tables

List of Plates

Chapter 1

INTRODUCTION

1.1 THE GRASSES AND GRASSLAND

The grasses (Poaceae) form a natural and homogenous group of plants with remarkable diversity in morphology. Poaceae (Graminae) forms the fourth largest family among flowering plants with 10,000 species in 700 genera (Bor, 1960). It is an important group of plants playing a vital role in the life of human beings and animals in the form of food, fodder, medicine, oil, etc.

Mankind is sustained more by grasses than by any other group of plants. Man's intimate relationship with grasses dates back to the Paleolithic time when he learnt to burn the forests, domesticate livestocks and cultivate cereals (Leafe, 1988). His existence, in the present numbers and quality of life, would be rather impossible without grasses. A major part of wild fauna, e.g., 477 (20% of the total) species of birds and 245 (6% of the total) species of mammals are solely dependent upon grasslands (Groombridge, 1992). Yet grassland ecosystems have not received the desired attention and have been largely neglected in terms of conservation and proper management, except grazing lands, especially in developing countries including India (Rahmani, 1989).

Grassland is a landscape unit dominated by grasses (Coupland, 1978, Yadava and Singh, 1986). On the other hand, savanna vegetation is characterized by a continuous graminoid stratum, interrupted by trees or shrubs (Johnson and Tothil, 1985). Grasslands extend over about 24% of the world's vegetation (Shantz, 1954). In the tropical and sub tropical plains and mountains of the world; nearly 23% of land is covered by the grassland

vegetation. In Asia they account for about 20% of land cover (Premadasa, 1990). It has been estimated that grasslands covered approximately 40% of the earth's land surface prior to the impact of man and domesticated animals (Clement and Shelford, 1939).

The physiognomy, phenology and diversity of grasses vary with rainfall, topography and type of soil. Temperate savannas are called prairies and steppes and tropical ones are paramos (Sarmiento, 1992). The grazed pampas of South America are richer than tropical savannas in diversity. In Africa the average species richness in the savanna is not far below that of rainforests (Groombridge, 1992).

The richest grassland regions of the world, in descending order of indigenous plants and animals, are African savanna, Eurasian steppe, South American savanna, North American prairie, Indian savanna and Australian grasslands. In Asia, Mongolia supports the most extensive and natural grasslands (Groombridge, 1992). The seral nature of Indian grasslands due to reclamation (clearance), fire, overgrazing, erosion of soil and abandonment has greatly influenced the composition of flora and fauna (Yadawa and Singh, 1986).

The biodiversity of grasslands are usually enhanced by moderate land uses such as grazing and periodic fire (Risser, 1991). But overgrazing, conversion of natural areas into croplands, hunting, monoculture plantations and ill planned developmental activities have caused loss of biodiversity in the grasslands, especially in the Indian subcontinent. For example, birds like Great Indian Bustard (*Ardeotis migriceps*) and Bengal Florican

(*Houbaropsis bengalensis*) have become locally extinct in several grasslands where they were present earlier (Goriup and Karpowiz, 1985).

The study on Canadian prairies by Mondor and Kun (1982), on Lesser Florican (*Eupodotic indica*) in India by Goriup and Karpowiz (1985), and the IUCN review on semi natural grasslands of the world have identified the ever increasing intensive agricultural practices as the major factor responsible for the loss of grasslands. Similarly it is estimated that the Canadian prairies are vanishing at the rate of 500 km^2/yr due to agriculture and plantations (Bakker-Gabb and Lunt, 1990).

The role of protected areas (PAs) in conserving biodiversity is unquestionable. While the majority of the PAs (National Parks and Wildlife Sanctuaries) do contain grasslands, yet these are too small to conserve the whole range of biodiversity. The network of PAs has done relatively little to conserve biodiversity of the grassland, for only 0.3% of the original area throughout the world has come under such network, that too with the little of the original diversity (Groombridge, 1992).

1.2 THE GRASSLAND VEGETATION IN INDIA

The Indian subcontinent supports highly diverse ecological conditions, ranging from warm humid plains of west coast to cold arid regions of Laddakh abutting the Tibetan plateau. The subcontinent is located at the junction of three major biogeographic regions viz. Palearctic, Australian and Ethiopian. It has wide latitudinal zonation, varied topography and climatic zones (Mani, 1974). Owing to its biogeographic affinities and

topographical diversity, the subcontinent is blessed with different types of biota that make India one of the 12 mega biodiversity centers of the world (Khosoo, 1994).

In India, grassland constitutes one of the major biomes. These grassland formations are categorized into five major types (Dabadghao and Sankaranarayan, 1973). Viz. i) *Sehima – Dichanthium* type covering tropical regions such as peninsular India, central Indian plateau, Chota Nagpur plateau and Aravalli ranges. ii) *Dichanthium – Cenchrus – Lasiurus* type distributed over sub tropical and semi-arid regions comprising portions of Gujarat, whole of Rajasthan (excluding Aravalli ranges), Western Uttar Pradesh, Delhi and Punjab. iii) *Phragmites- Saccharum – Imperata* type covering Gangetic and Brahmaputra plains. iv) *Themeda – Arundinella* type found in the north western montane tracks, and v) Temperate -Alpine type covering high altitude regions of Himachal Pradesh, Jammu and Kashmir and Uttar Pradesh.

All the natural and semi natural grassland maintained for livestock/ wildlife are collectively known as rangelands and in India 39.8% (13,813 km^2) of the land falls under this category (Singh, 1988). Of all the states in India, Madhya Pradesh, and Andhra Pradesh have the largest extent of grassland with 46 and 41 percent of total land under them respectively (Singh, 1994).In Gujarat, grasslands extend over an area of 1093.69 km^2 (Anon., 2000). Grasslands are locally called as *Pulmedu* in Kerala, *Bugyal* for Alpine meadows in Uttar Pradesh, *marg* in Kashmir, *Vidis* in SW Gujarat and *Rakhals* in Kutch.

1.3 *VIDIS* OF SAURASHTRA PENINSULA

The open thorny scrub forest with graminoid ground cover, commonly referred to as tropical scrubland savanna, which gradually changes to dry savanna in the process of continuous degradation known locally as "*Vidi*" is a major habitat of Saurashtra peninsula of Western India.

It is not an exaggeration to say that grasslands are the life of the cattle rearing communities of Saurashtra and Kutch, which is an arid to semi-arid region. The grasslands, apart from having their own ecological significance, form one of the most important sources of fodder, especially during fodder scarcity years. Earlier these grasslands were managed by Revenue department with the objective of collecting and distributing grass during scarcity period, which is common in this part of Gujarat. Realizing the ecological and socio-economic importance of the grasslands, government of Gujarat transferred these to Forest department to manage on a scientific basis (which was declared as reserved forest under the Indian Forest Act, 1927).

1.4 MANAGEMENT IN THE PAST

Not much importance was given to management of the grasslands during pre independent period. After independence till 1959, management was done through District Administration. There was a "Ghas Khata" section in the collectorate to look after protection and management of grasslands.

There was no management strategy with the administration during this period. The *modus operendi* was very simple. Cut the grass and store in the godowns for three years to

supply the same during scarcity. The excess grass was stored in the form of 'ganjis' (openly staked grass bales) for one year and auctioned in the month of May-June. There were no serious efforts to minimize the storage losses or to convert inferior grass into durable hay. Hardly any steps were taken for the overall development of the grasslands. As a result, the grasslands suffered and lost their original production capacity.

1.5 MANAGEMENT UNDER FOREST DEPARTMENT

These grasslands were transferred to Forest Department in the year 1959-60 with the hope to improve production status. In 1962, there was a shift in Management of grasslands by Government where *vidis* were categorized into reserve and non reserve *vidis.* Based on their production capacity, *vidis* producing up to 93,000 kg of grass per Annum were classified as non reserve *vidis* and above this as reserve *vidis*.

Reserve *Vidis*: At present Forest department has an area of 59,804.78 ha. (118 *vidis*) under its control. Entire management rests with the Forest Department and collected grass is supplied to Revenue Department for distribution. These *vidis* are grouped into subgroups A and B, where A is not allowed to be grazed after harvesting of grass, whereas B is allowed. In 1972, Government made grassland improvement measures compulsory and stressed on proper storing of grass.

Non reserved *vidis*: They cover a large area of 45,585.37 ha. (510 *vidis*) auctioned annually to local bodies in the month of June-July to fulfill the local needs. In Gujarat there is a system to make these *vidis* available to local bodies on priority basis. At

present, priority is given to (i) Gaushalas or Panjarapole, (ii) Maldhari Co-operative Societies, (iii) Village Panchayats, and (iv) Other Milk Co-Operative Societies.

If none of them are keen to take non reserve *vidis*, then these *vidis* are put to open auction for collection of grass. The leasing organization is supposed to carry out the improvement works under the overall guidance of the Department.

There are private *vidis* too managed by respective authorities. But these are not in a position to supply or support the fodder requirement of villages because they are over exploited.

1.6 CONSERVATION VALUE OF *VIDIS:* Conservation of natural resources is a tradition in Saurashtra. The region has inherited a rich natural heritage. However, in the present context there has been a gradual erosion of cherished values over the years and considerable portion of valuable grasslands has been lost. Considering the importance of the grassland in the region, the conservation values are many. Some of them are mentioned under:

1. **As a source of livelihood**: Apart from being rich source of fuel and fodder for local community, it is an important source of livelihood for "Maldharis" (cattle rearing community) of the region whose economy is entirely dependent on this profession.

2. **Nutritional value:** Some of the grasses available in the Vidis like *Dicanthim annulatum* and *Sehima sulcatum* have high nutritional values.

3. **Biodiversity value**: Providing food and habitat to a great variety of organisms, insects, reptiles and amphibians. Birds like Lesser florican and Great Indian Bustard are found mainly in grasslands. It also harbors last population of Asiatic lion, along with Indian wolf, Indian Gazelle, Black buck etc, listed critically endangered in IUCN red data book.

4. **Medical value:** Grasses like *Cymbopogon martini* yield essential oil which can be used as a remedy for stiff joints and in skin disease.

5. **Construction value:** Many grasses have construction value i.e. making roofs of hut

6. **Socio-economic value:** Grass supply during scarcity, which is common in this part of the state, is a significant role of grasslands, which greatly influence socio economic condition of cattle rearing community.

7. **Ecological and Environmental value:** Grassland protects the land from soil erosion by covering the ground and are carbon sinks, thus have a greater role to play in global greenhouse effect.

1.7 BIOTIC PYRAMID AND FOODCHAIN IN *VIDIS* OF SAURASHTRA

Various wild communities of Grasslands interact with each other, as well as with their surroundings, thus making it a pulsating environment. All these interactions occur continuously at different tropic levels. Usually in a well-balanced ecosystem these tropic levels together will form a “PYRAMID” like structure, which is broad at the base, getting narrower at the tip.

Members of the first tropic level, also known as “producers” or “fixers”. First tropic level is represented by the green vegetation i.e. trees, shrubs, herbs, climbers, leaves, grass, twigs, flowers, fruits and seeds.

At the second tropic level, this grassland ecosystem supports herbivores and some omnivores. These primary consumers of grasslands, include Bluebull (nilgai), Wild Boar, Hare, Rodents, Chinkara, Four-Horned antelope, and Chittal in some places, Langurs, and rarely Sambar. Besides this, in overgrazed areas and non-reserved *vidis*, cattles (Cow, Buffalo, Sheep, Goat and Camel) are present. Avifauna at this level includes Granivorous, and Frugivorous birds like Larks, Quails, Partridges, Parakeets, and Sunbird etc.

Third tropic level of the pyramid is occupied by secondary consumers or small carnivores like Jackal, Fox, Hyaena, Civet Cat, Jungle Cat, Mongoose, Honey Bager, Hedge-hog, etc. They mainly survive on small animals such as hare, rats and gerbils, lizards, small birds and their eggs-young Squirrels, Skink, Frogs, and carrion.

Fourth tropic level is occupied by super-predators like Asiatic Lion and Panther. They occupy the top position of the pyramid, and feed mainly on herbivores, omnivores, controlling their populations and on carrions.

At the top of the pyramid are the scavengers represented mainly by Vultures. These feed on dead animals and carcasses Figure 1.0. Food web for this system was shown in Figure 1.1.

However in recent years, several factors had been affecting this food pyramid. These include overgrazing, poor management, urbanization of some of the grassland *vidis* and gaucher areas, decline in wildlife populations (ex. Vultures), and local migration of wildlife (ex. Lions).

Figure 1.1 Biotic Pyramid in Grassland *Vidis* of Saurashtra

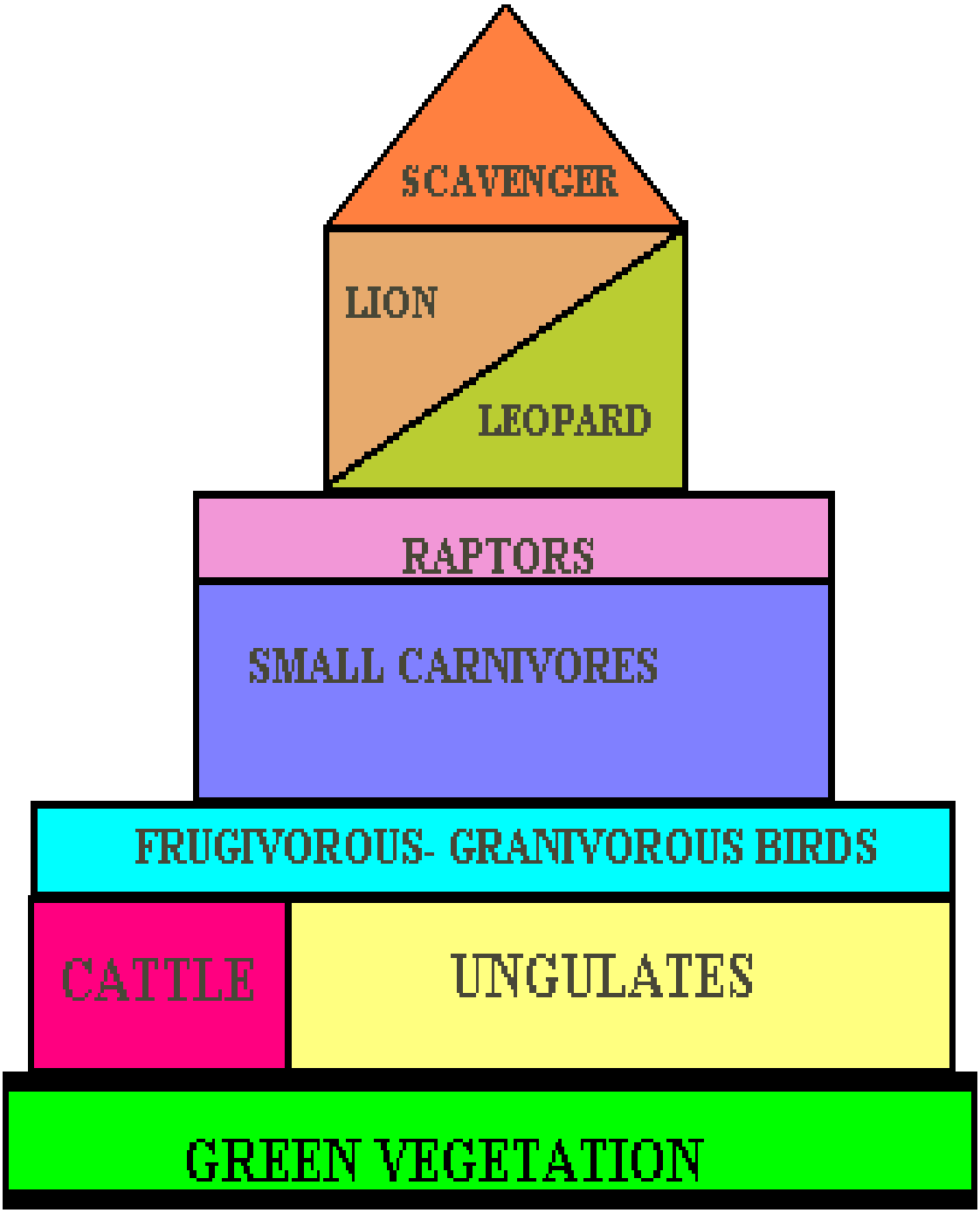
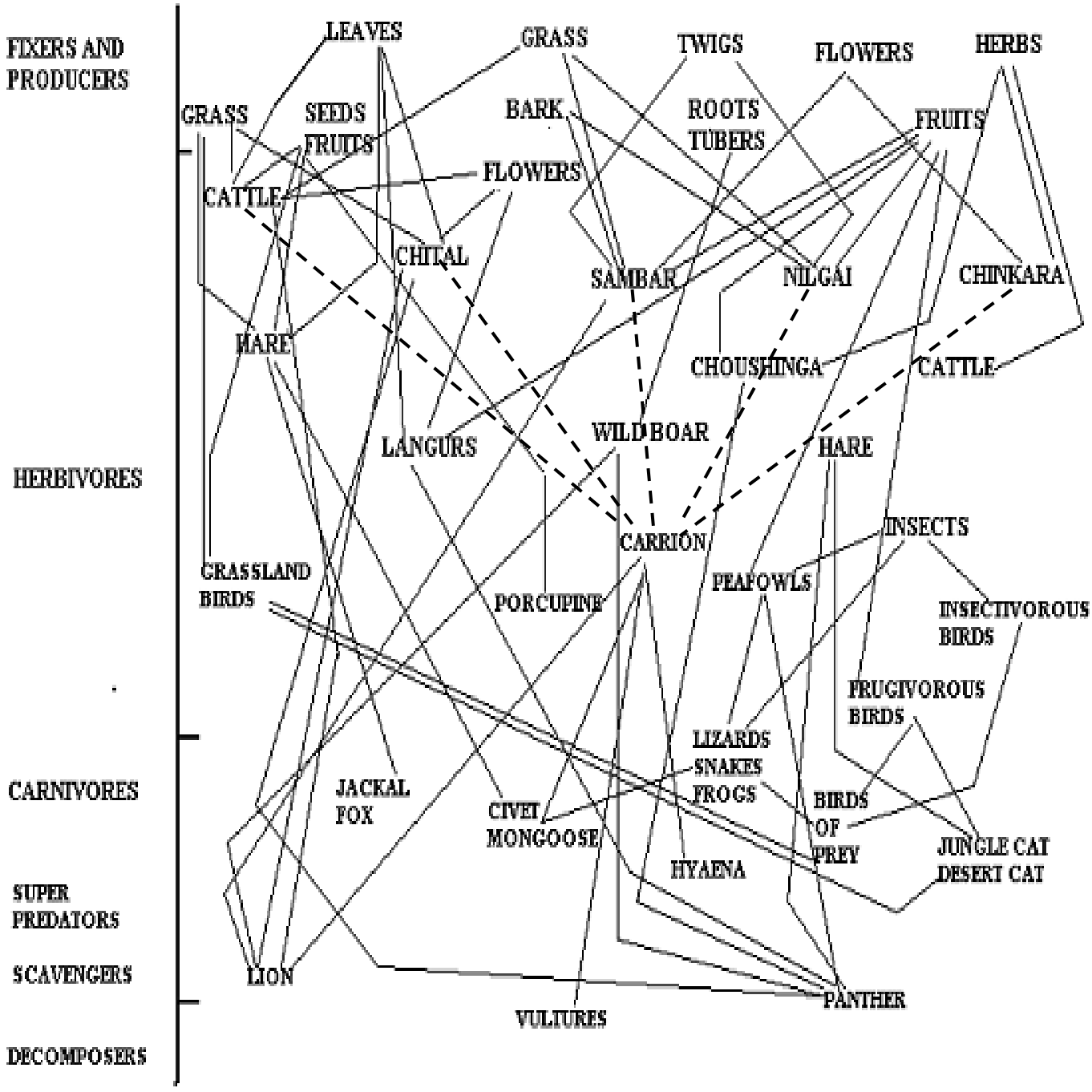
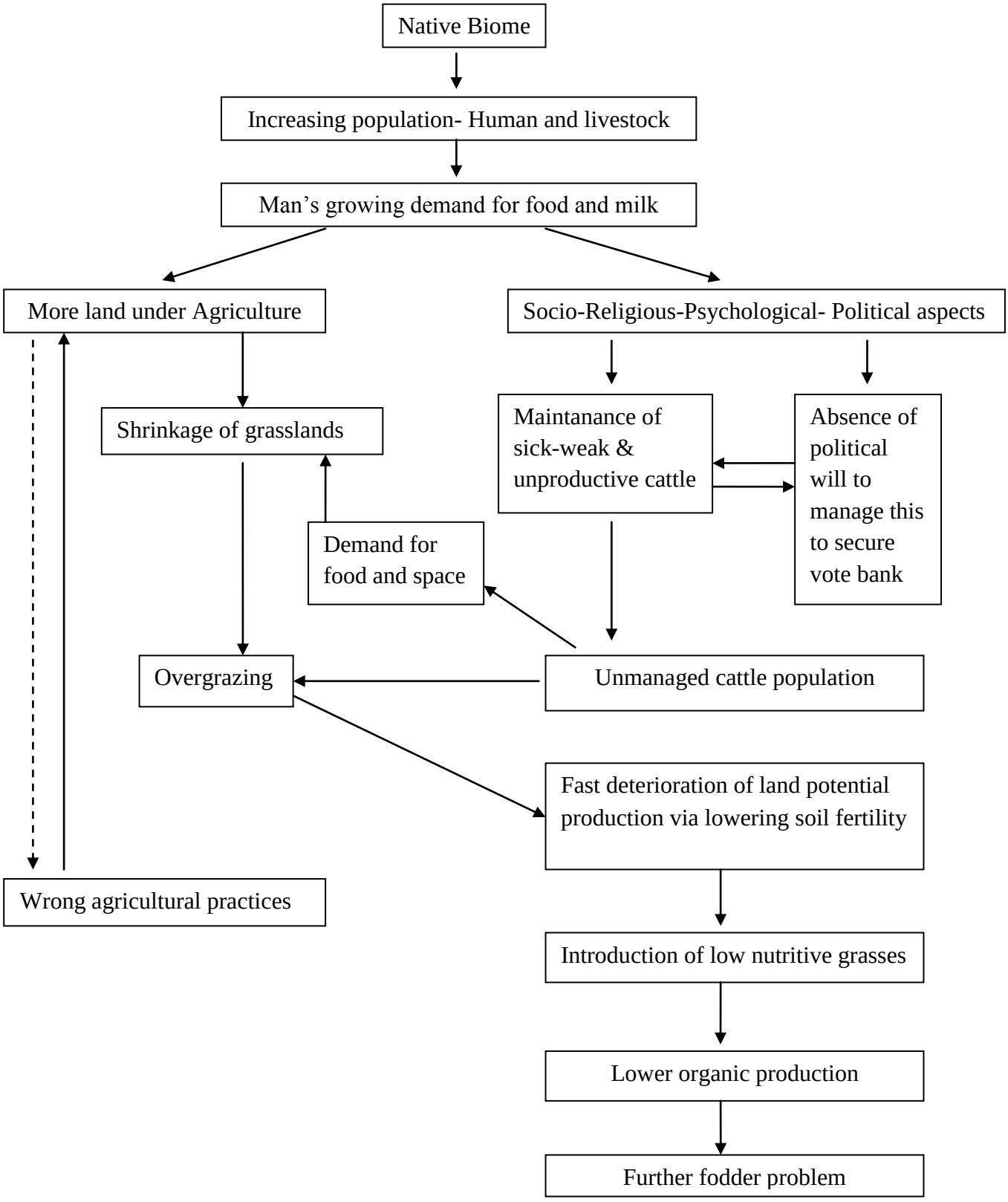


Figure 1.2 Food web in the grassland *Vidis* of Saurashtra



1.8 THE PRESSURE ON GRASSLAND BIOME OF SAURASHTRA:



1.9 ENVIRONMENTAL SETTINGS AND DISTRIBUTION OF *VIDIS* IN SAURASHTRA

An area of 1093.69 sq. km^2 (i.e. 9.84 percent and total forest area) is under grassland cover in ten districts of the state, of which seven districts are in Saurashtra peninsula. It consists of 159 reserve *vidis* and 525 non reserve *vidis* covering 709 sq. km and 635 sq. km of area respectively (Annon., 2006). Total grass cover of Saurashtra is 5.01 % of which Bhavanagar possesses maximum grass cover of 24.02 %, while minimum is in Surendranagar (6.69%) (SAC. 2001).

State Forest Department had categorized all the *vidis* of Saurashtra on the basis of annual grass production.For administrative purpose, these are distributed among seven forest administrative divisions, namely Jamnagar division, Surendranagar division, Bhavnagar division, Dhari Gir East division, Barda Wildlife Sanctuary division, Jungadh division and Gir West wildlife division. In some of the forest divisions grasslands constitute 50 % of the total forest area. District wise distribution of grassland in Saurashtra is given in Table 1.0 (Annon., 2006).

Table: 1.0 Grassland distributions in Saurashtra.

District/Division	Geographical area (km^2)	Total forest area (km^2)	Geographic forested area %	Total grass land area (km^2)	Total forest area as grassland %
Jamnagar	14123	2003.36	18.89	192.20	9.59
Rajkot	11203	365.78	3.27	201.77	55.16
Bhavnagar	11155	315.03	2.82	136.11	43.20
Surendanagar	10489	501.42	4.78	44.51	8.88
Porbandar	2326	118.00	5.07	214.48	6.07
Junagadh	10607	742.49	7.00	106.93	11.58

1.10 VEGETATION IN GRASSLAND *VIDIS* OF SAURASHTRA

Both annual and perennial grasses have composition varying widely in each area. A list of grasses recorded from *vidis* of Saurashtra along with their palatability, common name and habit is shown in (appendix I).

Scattered growth of mostly thorny species, like *Acacia nilotica, A. senegal, Zizyphus sp., A. catechu, A. leucophloea, Commiphora wightii, Maytenus emarginata, Balanites aegyptica,* and *Euphorbia s*p. etc was found in many *vidis*. In some *vidis,* especially of the Junagadh division along with the thorny species, *Boswellia cerata, Butea monosperma, Bauhinia purpurea, Terminalia crenulata*, and *Diospyros melanoxylon* were also present, which hinder production of better quality grasses by creating shade underneath. Along with these *Asparagus racemosus, Dalechampia scandens, Rynchosia minima, Phyllanthus racemosus*, and *Cardiospermum halicacabum* are main climbers in the *vidis* of Saurashtra.

1.11 BIRDLIFE IN GRASSLAND *VIDIS* OF SAURASHTRA

Indian subcontinent has very rich birdlife. India possesses 1230 species of birds belonging to 80 families. This number rises over 2000 with subspecies included. (Ali, 2002).

Saurashtra plateau in western India is unique representative of three biogeographic zones. (i) Zone 4 the semiarid, biotic province 4B Gujarat Rajputana, (ii) Zone 3 The Indian Deserts, biotic province 3B Little Rann of Kutch. (iii) Zone 10 the coasts, biotic province 10A West coasts. Thus characterized by tropical dry deciduous forest, dry teak forest, dry

savanna grasslands, *Euphorbia* scrub, *Boswellia* forest, *Acacia nilotica* forest, *Acacia senegal* forest, *Zizyphus species* forest, dry tropical riverine forest, minor dams and seasonal streams, which provide diverse habitat for avifauna.

The avifauna of the region has been studied and documented in several publications. Ali (1954-55) described 423 species of birds in his book on "The birds of Gujarat". Dharamkumar Singhji (1956) published book "The Birds of Saurashtra" which contains the description of 444 species.

Present checklist includes 526 species of birds belonging to 65 families sighted in Gujarat and 285 species of 60 genera from Saurashtra (Parasharya *et al*., 2004). Among these species like Forest owlet, White backed Vulture, Slender billed Vulture and Long billed Vulture are critically endangered, whereas Great Indian Bustard, Houbara Bustard, and Lesser Florican which are solely dependent on grasslands are endangered. Other birds like Falcons, lesser Whistling Teal, Osprey, Peafowl, and White Spoonbill are vulnerable or near threatened.

1.12 OASIS FOR AVIFAUNA IN SAURASHTRA:

In the second half of the twentieth century, before advancement of agriculture in the region, *vidis;* a major habitat type in Saurashtra were continuous and rich in grass cover. Expansion of agriculture, invasion of *Prosopis*, human habilitation and industries brought major change in land use pattern making present development unsustainable and induced fragmentation which resulted in patchy distribution of grasslands of the region as observed today. The paradox to the phenomenon is, such grassland patches harbor

rich avifaunal diversity. Some example of this are (i) Gir National Park and Wildlife Sanctuary, the largest compact tract of dry deciduous forest in semi-arid western part of the country which harbors 300 species of birds including five subspecies of vultures, Great Indian Bustard, Lesser Florican and high density of raptors (Pathak, 2002) (ii) Velavadar National Park a unique representative of grassland in the region was a private *vidi* of ex- princely state of Bhavnagar. It has 125 species birds with highest numbers of Lesser Florican observed breeding in the country and the largest roosting ground in the world for four species of Harriers, migratory to the area (Singh, 2001) (iii) Hingolgadh nature education Sanctuary managed for nature education was an important bird ringing station in 80's, and harbors 303 species of birds (Naik, *et al.,* 1990).

This protected and scientifically managed "*vidis*" represent once widely spread pristine grassland ecosystem of the region but such examples are few in number. Rest of the vast patches of unprotected grasslands and wastelands which were over exploited and neglected, where there have been no efforts being made to assess their biodiversity, socioeconomic importance and conservation, are of concern in present study. These areas urgently require ecological management strategy to ensure their future, as well as of the different forms of life depending on this crucial and vanishing ecosystem.

1.13 STUDY PERIOD: The present study was carried out from 1st August 2006 to 31st October 2008. The avifauna studies were conducted from 1st August 2006 to 31st May 2007, whereas the grassland studies were conducted in two phases, after the rainy season of 2007, and 2008 respectively (from 1st July 2007 to 30th September 2007, and 1st July

2008 to 31st October 2008). The time from November onwards till date was utilized in data analysis, presentation and compilation of thesis.

1.14 AIM: Present study is to be carried out to highlight the ecological importance of "*vidis*" in conservation of local wildlife considering avifauna as an indicator group.

HYPOTHESIS 1: It is assumed that the grassland *vidis* of Saurashtra are ecologically healthy and important for wildlife conservation especially for avifauna.

1.15 OBJECTIVES: Following specific objectives were set forth.

1. To estimate ecological status of grassland.
2. Estimating loss of biodiversity by general reconnaissance to get idea about status of wild life at present and past in study area.
3. Importance of grassland *vidis* for avian fauna and its diversity.
4. Role of small grassland patches in conservation of local wild life considering avian fauna an indicator group.
5. Assessment of conflict between humans and avifauna for resources in grassland *vidis* and its effects on bird community.
6. Assessing the connectivity of grassland patches and suggesting the possible corridors between fragmented habitats.

Looking at the objectives, the work was divided into two broad categories.

1. Estimating ecological status of fragmented grassland habitat during study period.
2. Estimation of avifaunal diversity, their patterns and processes, identification of threats and solutions, if any and to ensure the future of avifauna in such habitat.

1.16 SPECIFIC OBJECTIVES

Specifically I asked the following questions before the study.

1. What is the exact ecological status of semi arid grasslands in Saurashtra?
2. What are the factors responsible for its ecological degradation and up to what extent?
3. What is the diversity of avifauna in such patches, it's seasonal and temporal dynamics, and how it utilizes resources at different strata at different time.
4. Socio-economical importance of *vidis* and effect of anthropogenic disturbance on avifauna.
5. What is the need to conserve such grassland *vidis* and whether there are any possible corridors, which can form a continuous mosaic.

Chapter 2

STUDY AREA

Saurashtra peninsula and three grassland patches near Rajkot city in central Saurashtra were the study sites for grassland and avifauna studies respectively, where intensive fieldwork was carried out.

2.1 GRASSLAND STUDIES: PENINSULA OF SAURASHTRA (POS).

The Saurashtra peninsula forms a rocky tableland dominantly composed of Deccan lava. It is fringed by coastal plains towards N and S, while towards E its limit is shared with the Northern alluvial plain. It is bounded between N latitudes of 20^0 50' to 23^0 5' and E longitudes of 69^0 20' to 72^0 10' covering about 47,000 sq km sharing 24% area of the state. It spreads over the part of the seven districts of Rajkot, Jamnagar, Junagadh, Amreli, Bhavnagar, Surendranagar and Porbander.

2.2 PHYSIOGRAPHY AND DRAINAGE

The region forms a table land with undulating surface broken by hills and checkered by various dissecting rivers that flow out in various directions. The peninsula provide a criss-crossed outline and over all rugged topography. It can broadly be divided into three distinct upland units, stretching almost parallel to each other in ENE-WSW direction and connected by a NNE-SSW ridge. The eastern fringe of the peninsula that separates it from the mainland Gujarat is the low-lying ground marking a site of the former sea

connection between the Gulfs of Kachchh and Cambay. The peninsula to the north is flanked by the narrow sandy/marshy strip cast of the Gulf of Kachchh.

The maximum relief difference of the peninsula varies from 50m to 1100m.; the average ground elevation however ranges from 100 to 300m. At some places, the relics of the tableland stand out either as erosional conical hills, like that of Chotila at 340 m or as circular hill massifs of intrusive rocks rising to striking heights. These include Girnar hills with a 1117m high peak, Barda-Venu hills at 637 m peak, and Alech- Osham hills with 298 m and 314 m peak heights respectively. Numerous dike ridges extending for long distance and projecting above the basaltic surface attain 10-100 m heights above the general level of the ground. An elevated strip of ground connecting the uplands of Girnar and Rajkot forms the Major watershed divide of Saurashtra.

The peninsula shows a more or less radial drainage pattern, Bhadar, 260 km is the major river with several tributaries; it flows WSW. Shetrunji, 160 km long which is the next major river flows westward. The several other rivers flow due south are Dhatarwadi, Raval, Shingola, Machundari, Hiran, Meghad, Madhuvanti and Saraswati. The east flowing river includes Kalubhar, Sukhbhadar, and Bhogavo. There are several somewhat north flowing smaller rivers; the important among them are Machhu, Aji and Und.

2.3 STRATIGRAPHY AND STRUCTURE

The region contains extensive exposures of basaltic flows of Deccan trap and to a limited extend that of sedimentary rocks of Mesozoic and Cenozoic. The Deccan Lavas cover more than 42000 sq. km and are very prominently exposed forming an elevated tableland with flat topped plateau like hills. The higher peaks are those of intrusive

plutonic masses, whereas ridges are either dykes or narrow fault controlled horsts. The bulk of the trap is made up of the thick succession of lava flows. The Mesozoic sedimentries occupy a small area of about 5000 sq. km towards NE around Surendranagar district.

2.4 SOILS AND LAND-USE

The peninsula shows a variety of soils belonging dominantly to the Entisol and Inceptisol Orders occurring on different land forms of hilly terrain foothills and undulating pediment.

The soils of higher level hilly terrain are very shallow (10-25 cm) somewhat excessively drained show loamy- skeletal texture, severally eroded and generally stoney at surface and subsurface. They are classed as Lythic Ustorthents.

The dominant soils occurring on foothills and inter-hill basins are moderately shallow (50-75 cm), well drained and fine textured. They are slightly alkaline and slight to moderately calcareous. Most of them are severely eroded and have been classed as Typic Ustochrepts and Vertic Ustochrepts.

The rolling and undulating pediments are dominantly occupied by rock outcrop with very shallow to shallow, somewhat excessively drained loamy skeletal to clay skeletal soils. These severely eroded and generally stony soil have been classed as Lithic Ustorthents and Lithic Ustochrepts.

2.5 CLIMATE

The region experiences a semi arid climate in the aridity index range of 20-40 per cent indicating a general deficiency of soil moisture for major part of the year. The mean annual temperature is 26-27^0 C with mean maximum and minimum of 40^0 C and 11^0 C and range of extremes being 47^0 C. the relative humidity is 65-70 per cent. The mean annual rainfall is 450-600 mm received within 20-45 days.

2.6 INTENSIVE STUDY AREA

All the *vidis* in Saurashtra are distributed among seven administrative divisions of State Forest Department which are, Junagadh division comprising the whole of Junagadh district in South Saurashtra, Surendranagar division comprises Surendranagar districts, in North and North East of Saurashtra, Bhavnagar Division, comprising whole Bhavnagar district in South-East of Saurashtra. Dhari-Gir-East division, includes Amreli district in South –Central Saurashtra, whereas Barda division and Gir-West divisions covers Southern and Western part of Junagadh districts respectively in Southern Saurashtra. Jamnagar division is the largest administrative division, comprising Jamnagar and Rajkot districts in Western and Central part of Saurashtra peninsula.

These divisions representing general soil, topography and climatic region of the Saurashtra peninsula were taken as basal units. For the final selection, the sites more than or equal to 100 hectares in area and a continuous patch of vegetation were shortlisted from each division.

These shortlisted sites were then classified into those which were easily accessible and those which were too remote. The former were then further classified on the basis of soil and topographic conditions. The final selection of sites was based upon the history of land use. Preference was given to sites having least disturbance, such as reserve or protected *vidis*. Equal emphasis was also given to sites which were protected for varying durations, for example, soil conservation blocks, felling couples, forestation areas, etc. Based on above criteria, a total of eighty nine sites covering an area of 30,402.017 hectares were selected for intensive study. An area of one acre from each site was selected randomly as sampling plot.

2.6.1 Junagadh Forest Division

Junagadh division comprises grasslands of southern and southwestern Saurashtra which are distributed among nine talukas of Junagadh and Porbandar districts. In present study Porbandar districts was considered as a part of Junagadh division as per early categorization.

A total of eleven reserve *vidis* were selected covering an area of 4333.66 km^2. Among selected sites, eight *vidis* are in Maliya-hatina taluka, two are in Kutiyana taluka, and one belongs to Junagadh taluka (Appendix III-a).

2.6.2 Bhavnagar Forest division

Bhavnagar Forest division administrates nineteen reserve and fourty eight non reserve *vidis*, distributed among nine talukas of the district in southeast of Saurashtra peninsula.

In the present study, fifteen reserve and five non reserve *vidis* covering a total area of 7743.88 hectares were taken under investigation (Appendix III-b).

A practice of protecting and maintaining grasslands as private *vidis,* cultivation and through agencies such as Panjarapores make Bhavanagar district the highest grass covered region in Saurashtra (24.02% - SAC, 2001).

2.6.3 Dhari Gir east division

Grasslands in this division are a part of a single hill chain locally called "Lambidhar". It extends North-West to South-East direction, connecting Chachai Paniya region of Gir PA to Satrunjay hill of Palitana. Thus all the grasslands are identical to each other and share similarity in terms of vegetation, terrain and grass species diversity and composition.

The main significance of this tract is, it acts as a corridor connecting core population of Asiatic lions in Gir to the settelitic meta population, settled in various grasslands of Bhavanagar division.

The region possesses undulating topography. Vegetation includes mainly *Acacia leucophioea, A. nilotica, Zizyphus nummubria, Balanites aegyptica* and patches of *Boswellia* and *Euphorbia* scrub, identical to eastern Gir.

A total of ten grassland *vidis* including Sarasiya *vidi* which is a part of Gir Wildlife Sanctuary, were surveyed in sequence, with respect to their location along "Lambidhar" hill chain from Gir PA. to Satrunjay hill Palitana, covering an area of 2064.45 hectares. (Appendix-III c).

2.6.4 Surendranagar Division

Surendranagar division comprises a vast area of the entire Surendranagar district at North east of Saurashtra peninsula. The district is a gateway to Saurashtra and is unique in terms of geography, fauna and flora. The division represent two biogeographical zones of a country namely biogeographical zone 3B Desert, comprising salt flats, scrublands, little Rann at its northern boundary, and zone 4B Gujarat Rajputana which is a semiarid region at its south and southwest (Rodger *et al,* 2002). The eco-region shares its northern boundary with Rann, the northeastern boundary with Northern alluvial plains of Gujarat, and eastern boundary with coastal zones of Gulf of Cambay (GEC, 2005).

Rainfall varies widely in district. It is considered as the driest part of the peninsula with an exception of its eastern boundary which receives high rainfall, and has flat terrain leading to the formation of wetlands such as Nalsarovar (GEC, 2005).

Northern part of the division is Little Rann of Kutch (LRK), a flat saline desert which turns into wetland during monsoon. Fresh water from river such as Banas, Rupen and sea water from Gulf of Kutch during high tide turns the region into large shallow pool of brackish water.

Thus, due to ecosystem diversity with climatic constraints, and affinities with other regions, it provides scope for variety of grasses to grow in different micro-habitats such a saline, swamp, wetland, plains and dry region.

In the present study, ten *vidis* distributed among 6 talukas of the district covering an area of 4478.14 hectares were selected. Muli taluka possess as the highest number of *vidis* which are degraded due to mining and intense grazing (Appendix-IIId).

2.6.5 Jamnagar Division: A- "Jam".

Jamnagar division is the largest forest administrative division comprising the whole of Jamnagar and Rajkot districts, in western and central region of Saurashtra peninsula.

In the present study, Jamnagar division is categorized and surveyed in two parts namely subdivision A- Jamnagar division "JAM" and B - "RJT". The categorization was based on judicial district boundaries, vegetation, and geographical affinities.

Jamnagar division-A "Jam" comprise entire Jamnagar district, which is the largest district in the peninsula. It is situated at the western most tip of Saurashtra, having the longest coast line. It shares its northern edge with Gulf of Kutch, and Arabian Sea at west making the district ideal site for maritime activities and industrialization. Due to Salaya- Mathura petrochemical pipeline in addition to geographical advantages, area holds industrial giants like Reliance industries and Essar petrochemicals.

All such activities are a direct threat to the land which holds vast patches of native grasslands with high grass diversity. This division represents two biogeographical

provinces namely; 4B semi arid Gujarat rajputana and 10A west coast (Rodger *et al*., 2002).

In this division, nineteen *vidis* covering an area of 4152.25 hectares was surveyed (Appendix-IIIe).

2.6.6 Jamnagar Division: **B- "RJT".**

This part of Jamnagar division includes Rajkot district, in central Saurashtra. Native ecosystem of the region is represented by vast semi arid grasslands which turn in to dry grasslands, in a gradual retrogressive process.

It includes large patches of grasslands, which were protected and maintained earlier by princely states as private game reserves, community grasslands or by local authorities and then transferred and maintained by forest department.

At present, these network of princely grasslands are well intact and in an ecologicaly healthy condition. Some examples are Umath *vidi* and Motisari *vidi* of Jasdan state, Khad Vanathali and Vanasthali *vidis* of Gondal state, Khirasara of Khirasara state and large patches of Rampara- Tithava-Mota jambudiya of Vakaner state. All these grasslands serve community needs for fodder and are an important oasis for wildlife.

In this division, thirteen *vidis* covering an area of 7529.63 hectares were surveyed (Appendix II- f).

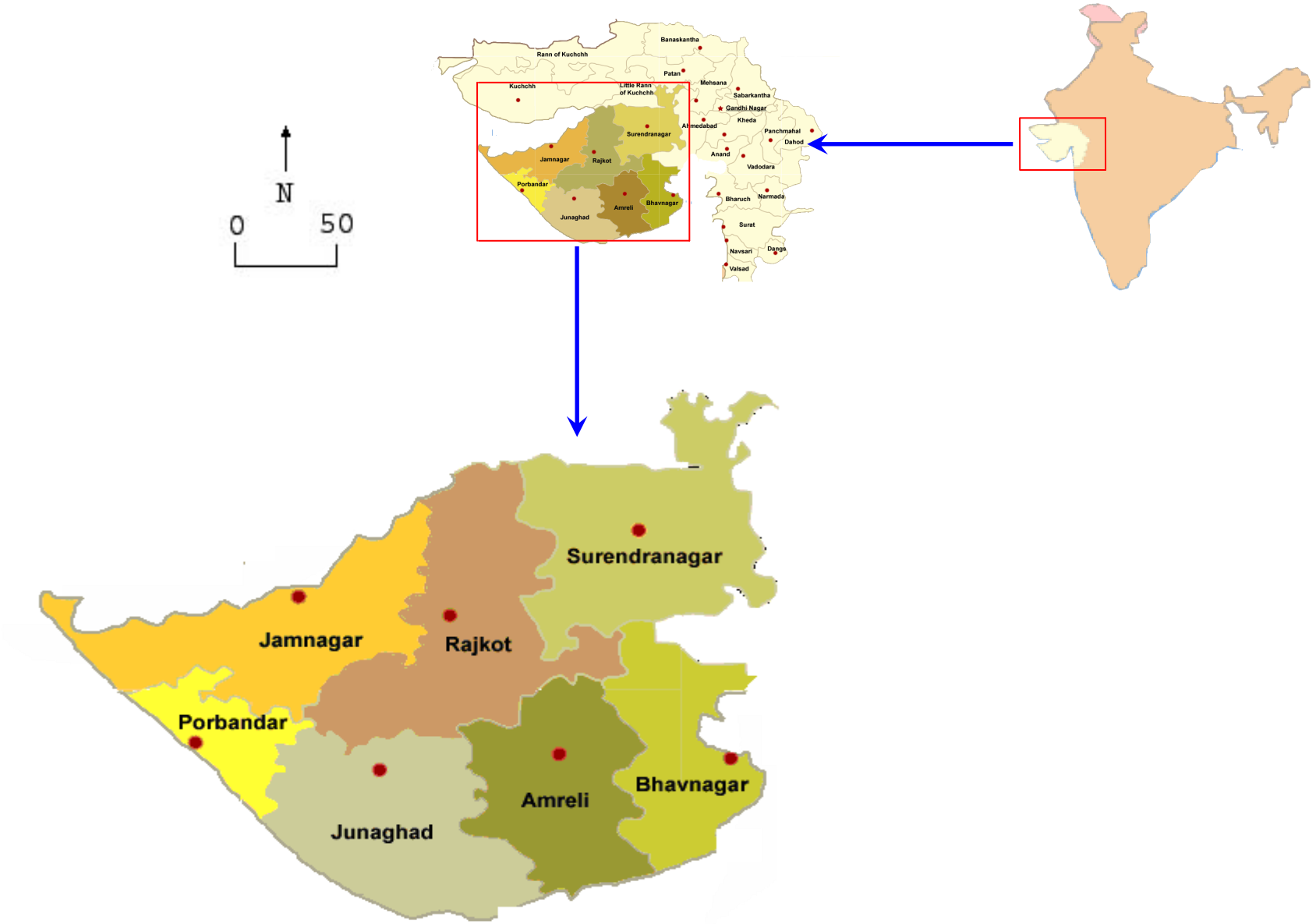


FIGURE: 2.1 PENINSULAR SAURASHATRA.

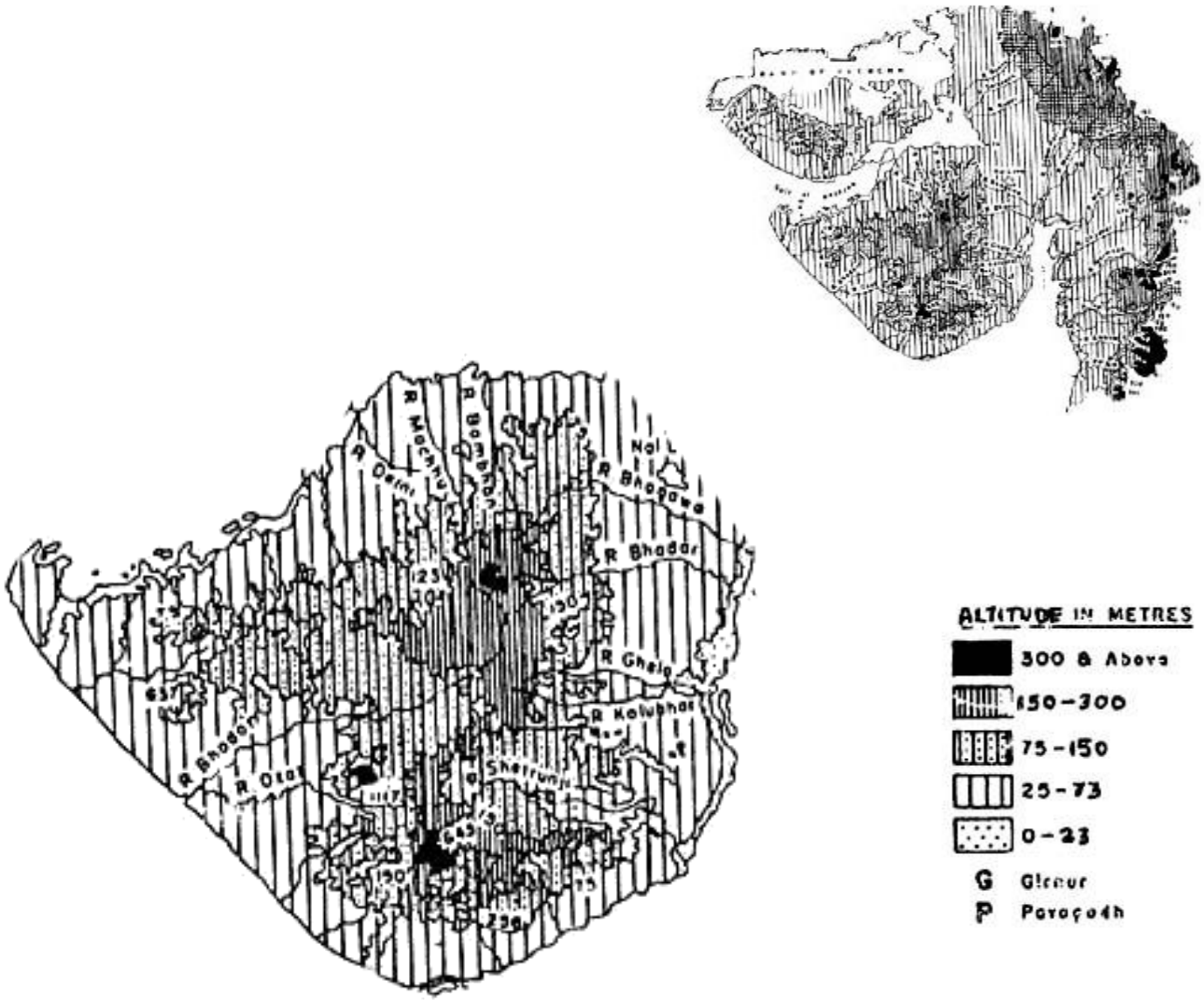


Figure : 2.2 PHYSIOGRAPHIC MAP OF STUDY AREA

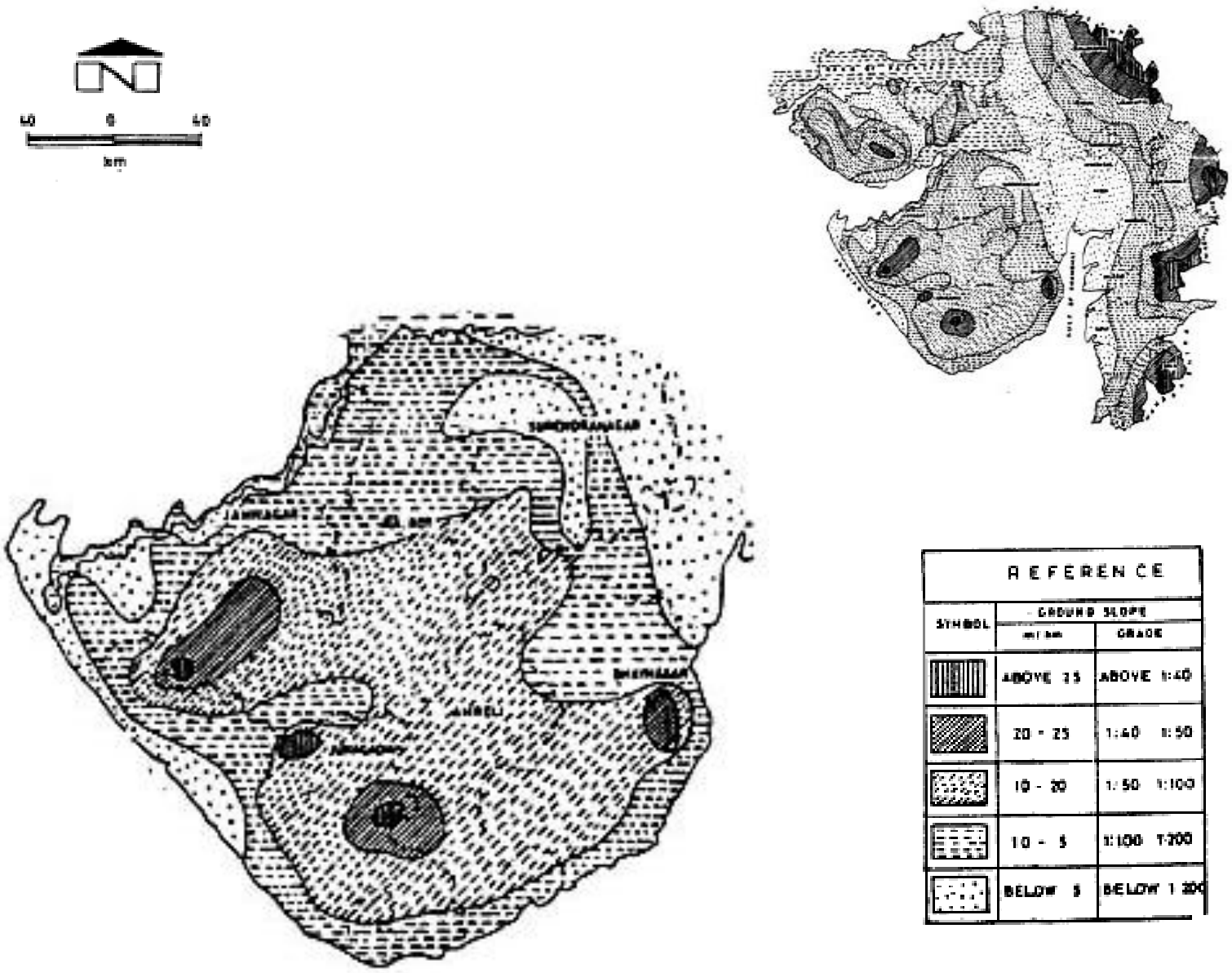


FIGURE : 2.3 GROUND SLOPE MAP OF SAURASHTRA

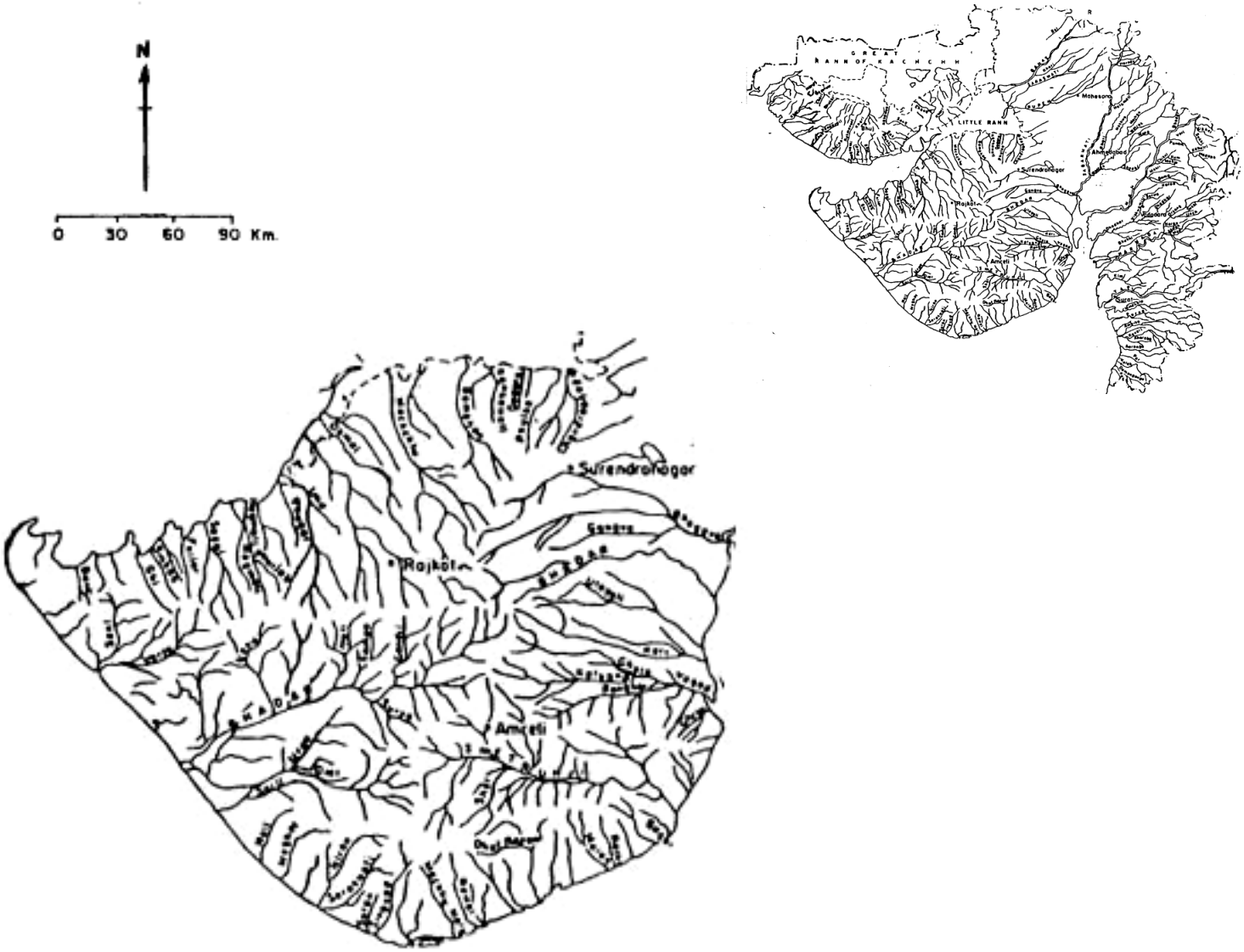


FIGURE: 2.4 DRAINAGE MAP OF SAURASHTRA

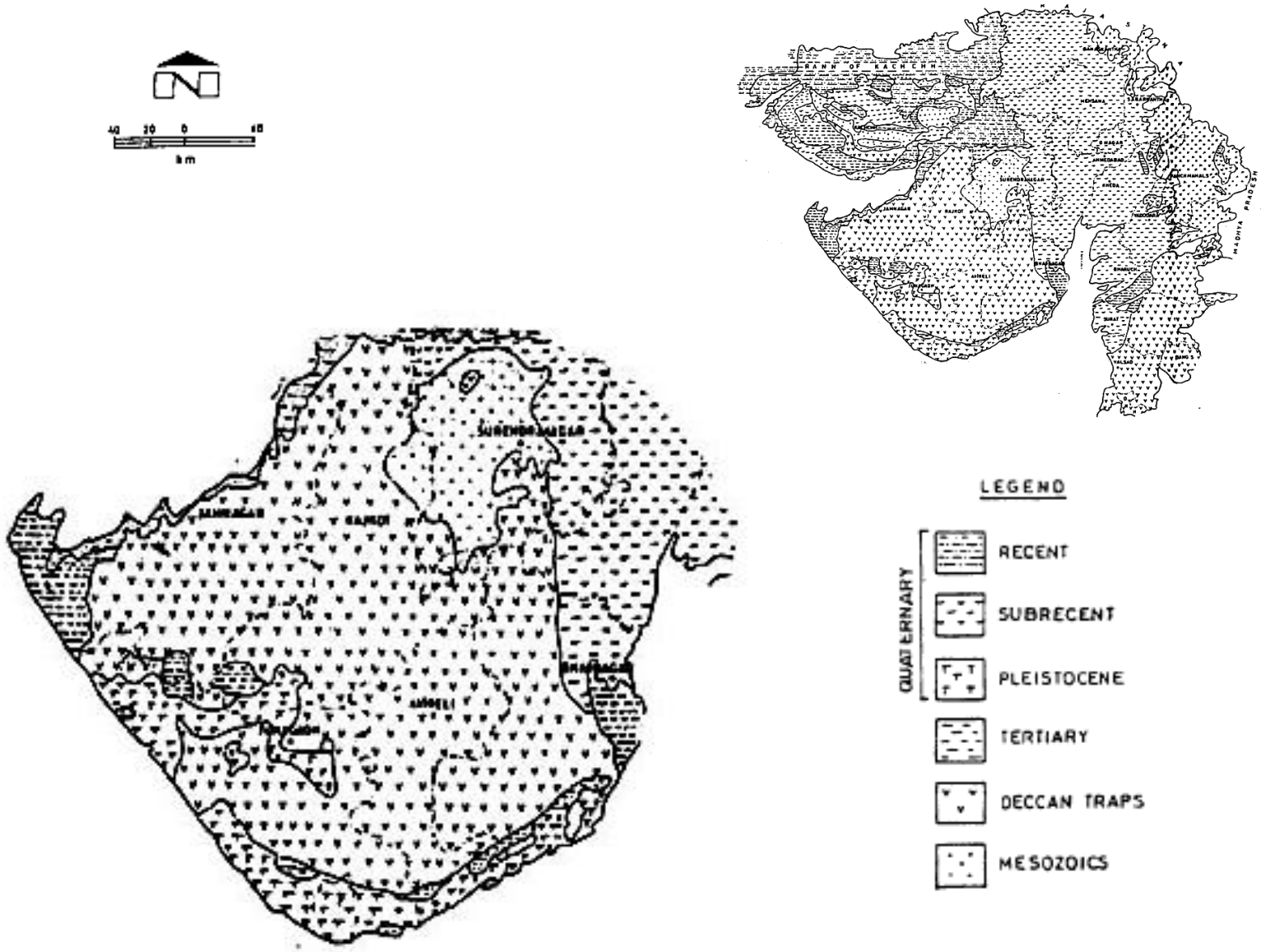


FIGURE: 2.5 GEOLOGICAL MAP OF SAURASHTRA

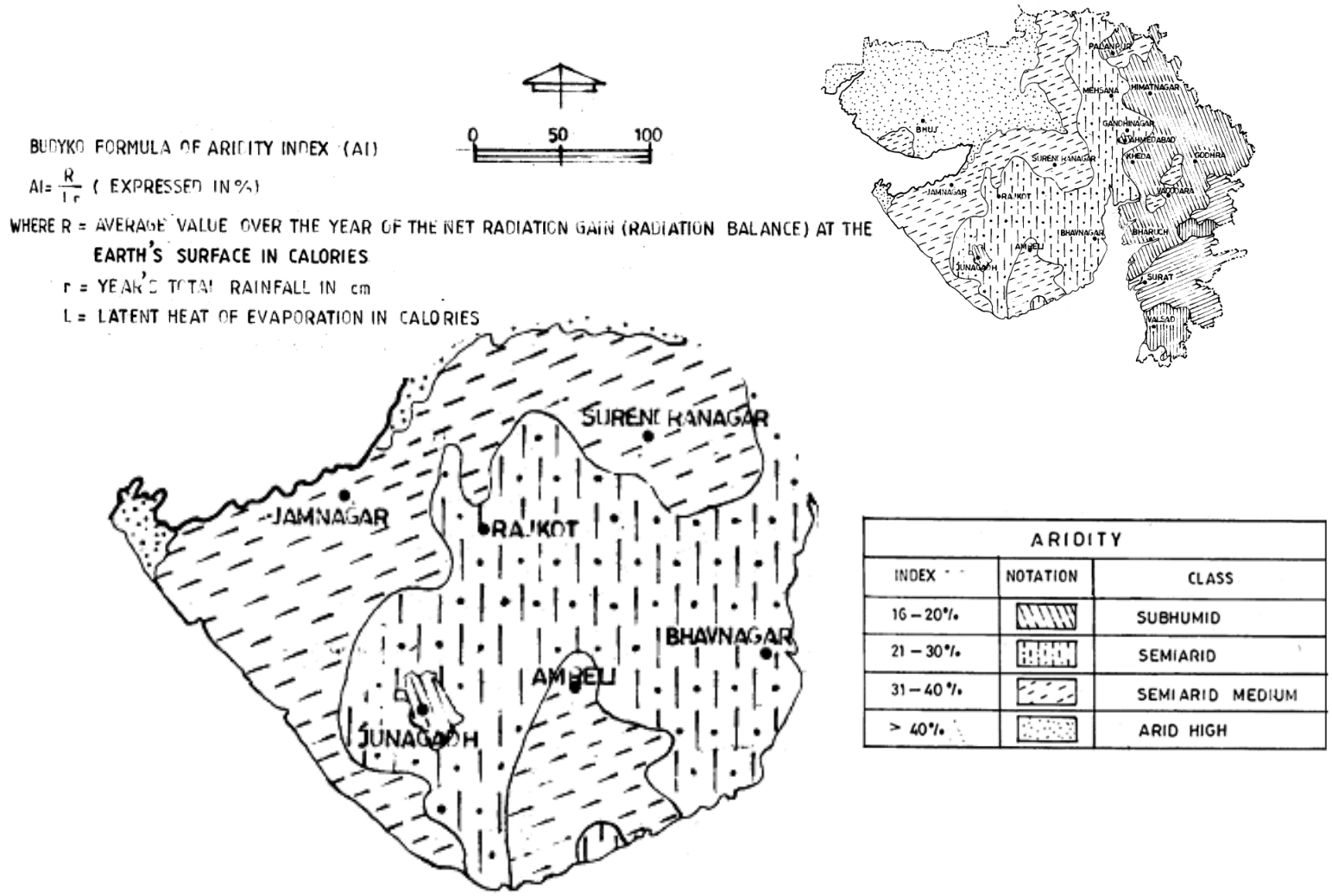


FIGURE: 2.6 ARIDITY PHYSIOGRAPHIC MAP OF SAURASHTRA

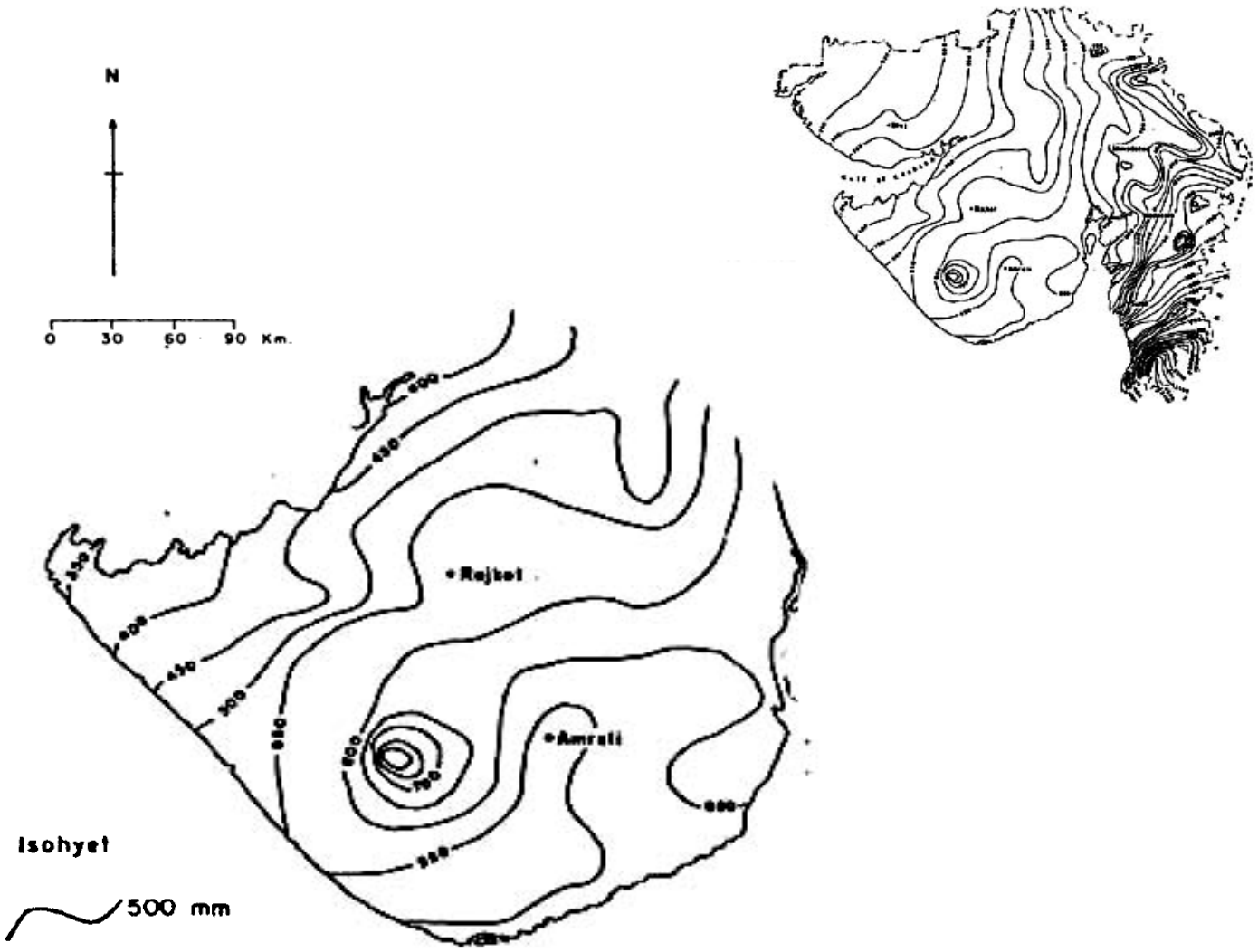


Figure: 2.7 ISOHYETS MAP OF SAURASHTRA

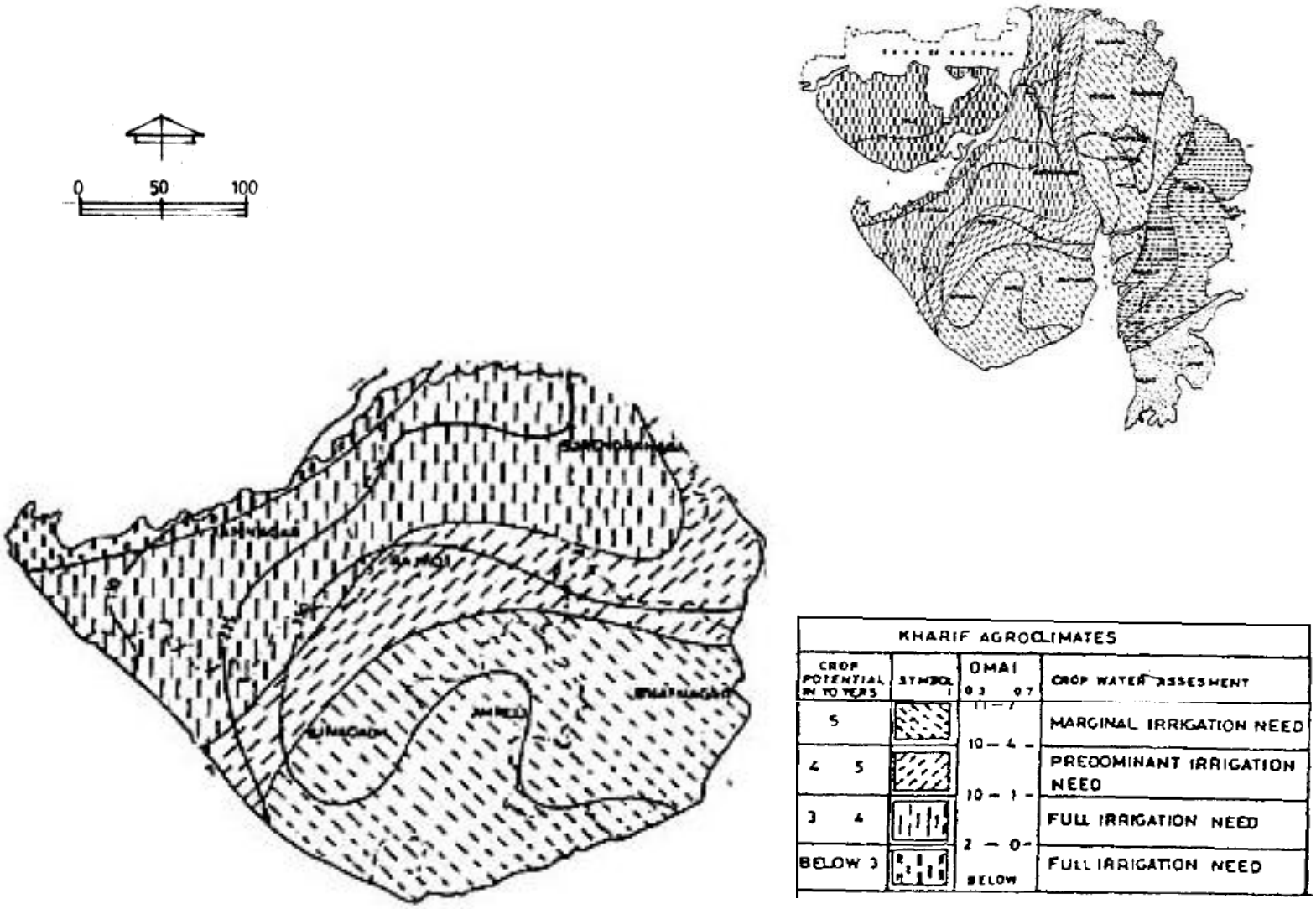


FIGURE: 2.8 AGRO CLIMATIC MAP OF SAURASHTRA

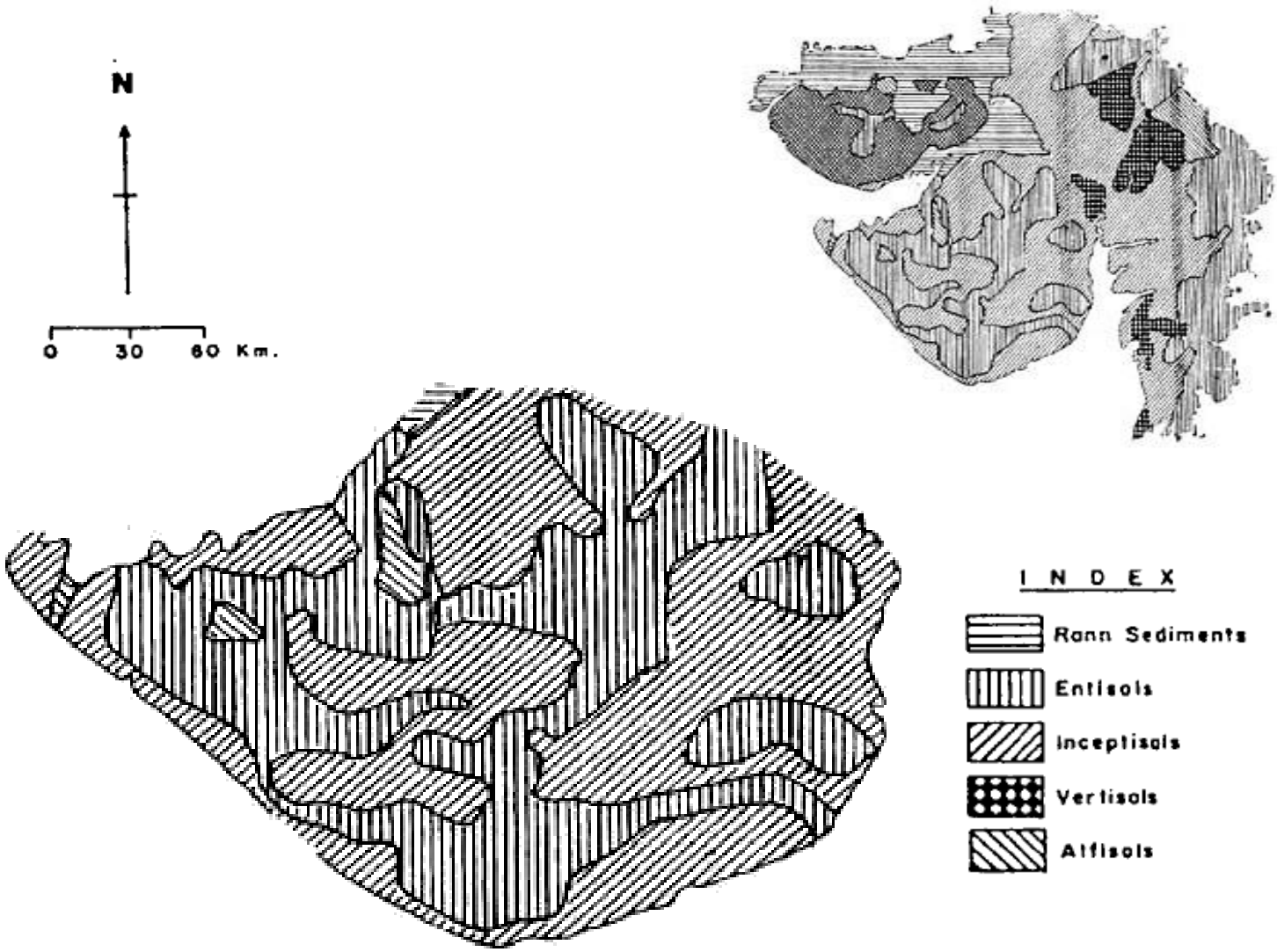
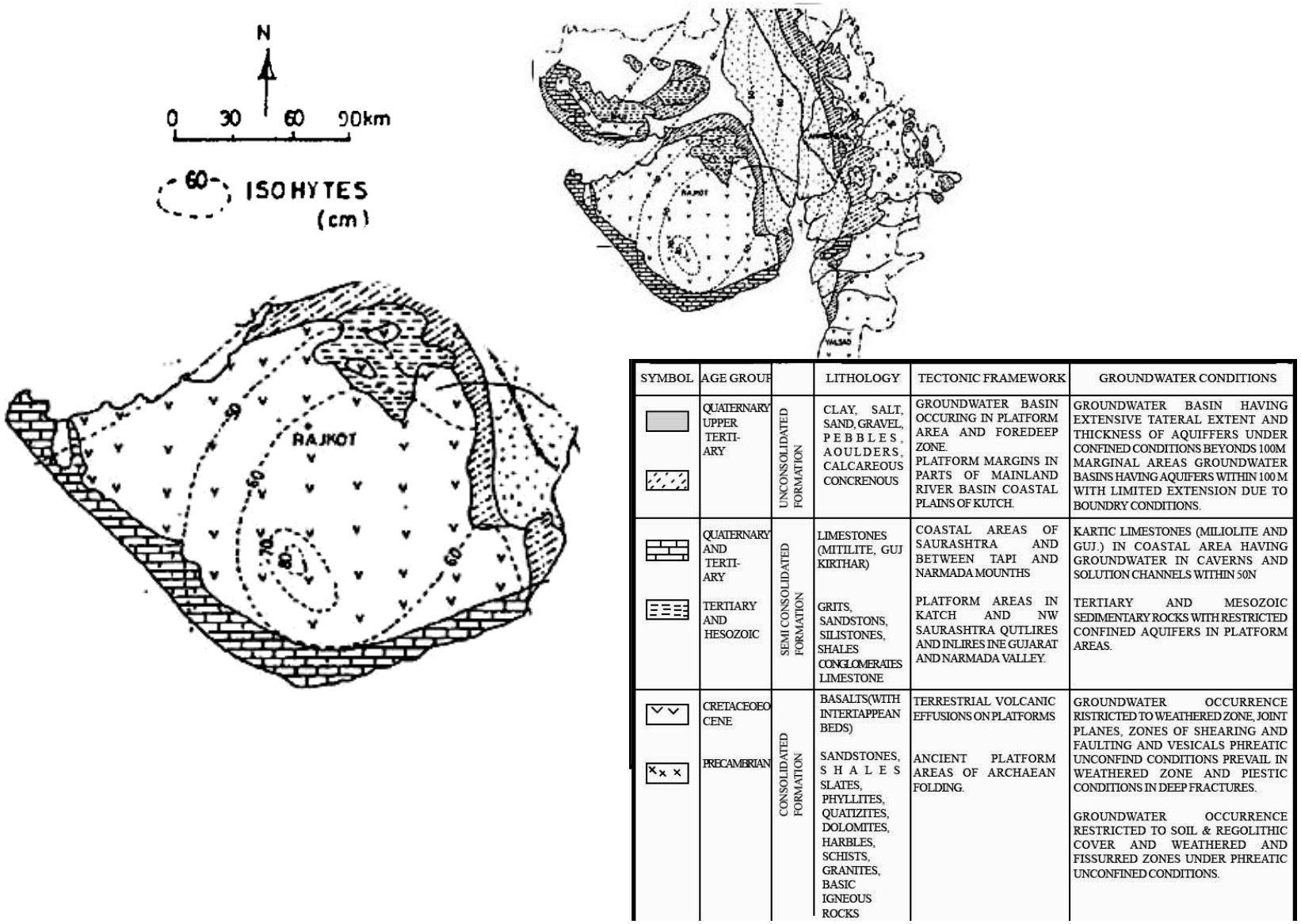


FIGURE: 2.9 SOIL MAP OF SAURASHTRA



SYMBOL	AGE GROUP		LITHOLOGY	TECTONIC FRAMEWORK	GROUNDWATER CONDITIONS
	QUATERNARY UPPER TERTI-ARY	UNCONSOLIDATED FORMATION	CLAY, SALT, SAND, GRAVEL, PEBBLES, AOULDERS, CALCAREOUS CONCRENOUS	GROUNDWATER BASIN OCCURING IN PLATFORM AREA AND FOREDEEP ZONE. PLATFORM MARGINS IN PARTS OF MAINLAND RIVER BASIN COASTAL PLAINS OF KUTCH.	GROUNDWATER BASIN HAVING EXTENSIVE TATERAL EXTENT AND THICKNESS OF AQUIFFERS UNDER CONFINED CONDITIONS BEYONDS 100M MARGINAL AREAS GROUNDWATER BASINS HAVING AQUIFERS WITHIN 100 M WITH LIMITED EXTENSION DUE TO BOUNDRY CONDITIONS.
	QUATERNARY AND TERTI-ARY	SEMI CONSOLIDATED FORMATION	LIMESTONES (MITILITE, GUJ KIRTHAR)	COASTAL AREAS OF SAURASHTRA AND BETWEEN TAPI AND NARMADA MOUNTHS	KARTIC LIMESTONES (MILIOLITE AND GUJ.) IN COASTAL AREA HAVING GROUNDWATER IN CAVERNS AND SOLUTION CHANNELS WITHIN 50N
	TERTIARY AND HESOZOIC		GRITS, SANDSTONS, SILISTONES, SHALES CONGLOMERATES LIMESTONE	PLATFORM AREAS IN KATCH AND NW SAURASHTRA QUTLIRES AND INLIRES INE GUJARAT AND NARMADA VALLEY.	TERTIARY AND MESOZOIC SEDIMENTARY ROCKS WITH RESTRICTED CONFINED AQUIFERS IN PLATFORM AREAS.
	CRETACEOEOCENE	CONSOLIDATED FORMATION	BASALTS(WITH INTERTAPPEAN BEDS)	TERRESTRIAL VOLCANIC EFFUSIONS ON PLATFORMS	GROUNDWATER OCCURRENCE RISTRICTED TO WEATHERED ZONE, JOINT PLANES, ZONES OF SHEARING AND FAULTING AND VESICALS PHREATIC UNCONFIND CONDITIONS PREVAIL IN WEATHERED ZONE AND PIESTIC CONDITIONS IN DEEP FRACTURES.
	PRECAMBRIAN		SANDSTONES, SHALES SLATES, PHYLLITES, QUATIZITES, DOLOMITES, HARBLES, SCHISTS, GRANITES, BASIC IGNEOUS ROCKS	ANCIENT PLATFORM AREAS OF ARCHAEAN FOLDING.	GROUNDWATER OCCURRENCE RESTRICTED TO SOIL & REGOLITHIC COVER AND WEATHERED AND FISSURRED ZONES UNDER PHREATIC UNCONFINED CONDITIONS.

FIGURE: 2.10 HYDRO GEOLOGICAL MAP OF SAURASHTRA

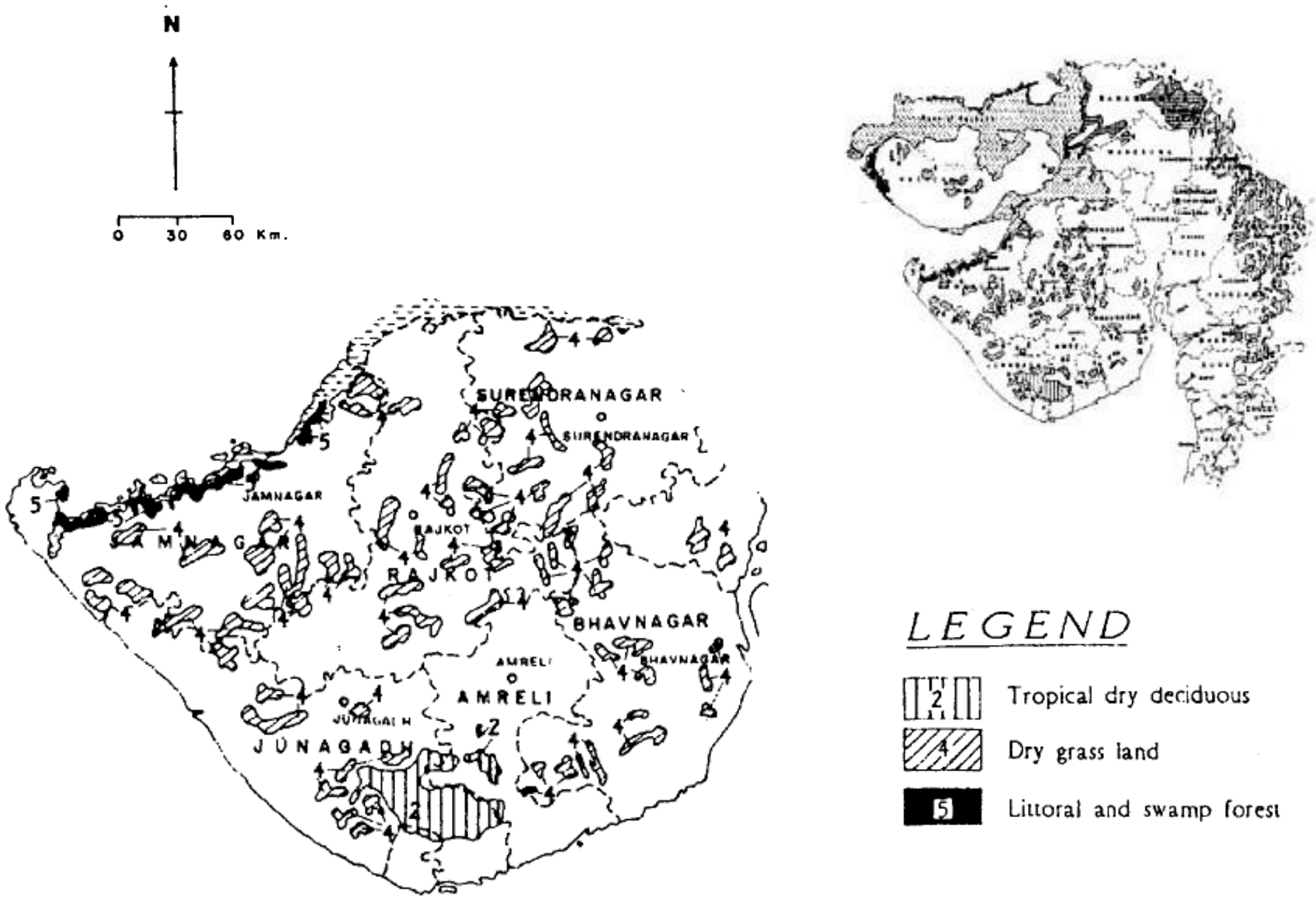


FIGURE: 2.11 FOREST MAP OF SAURASHTRA

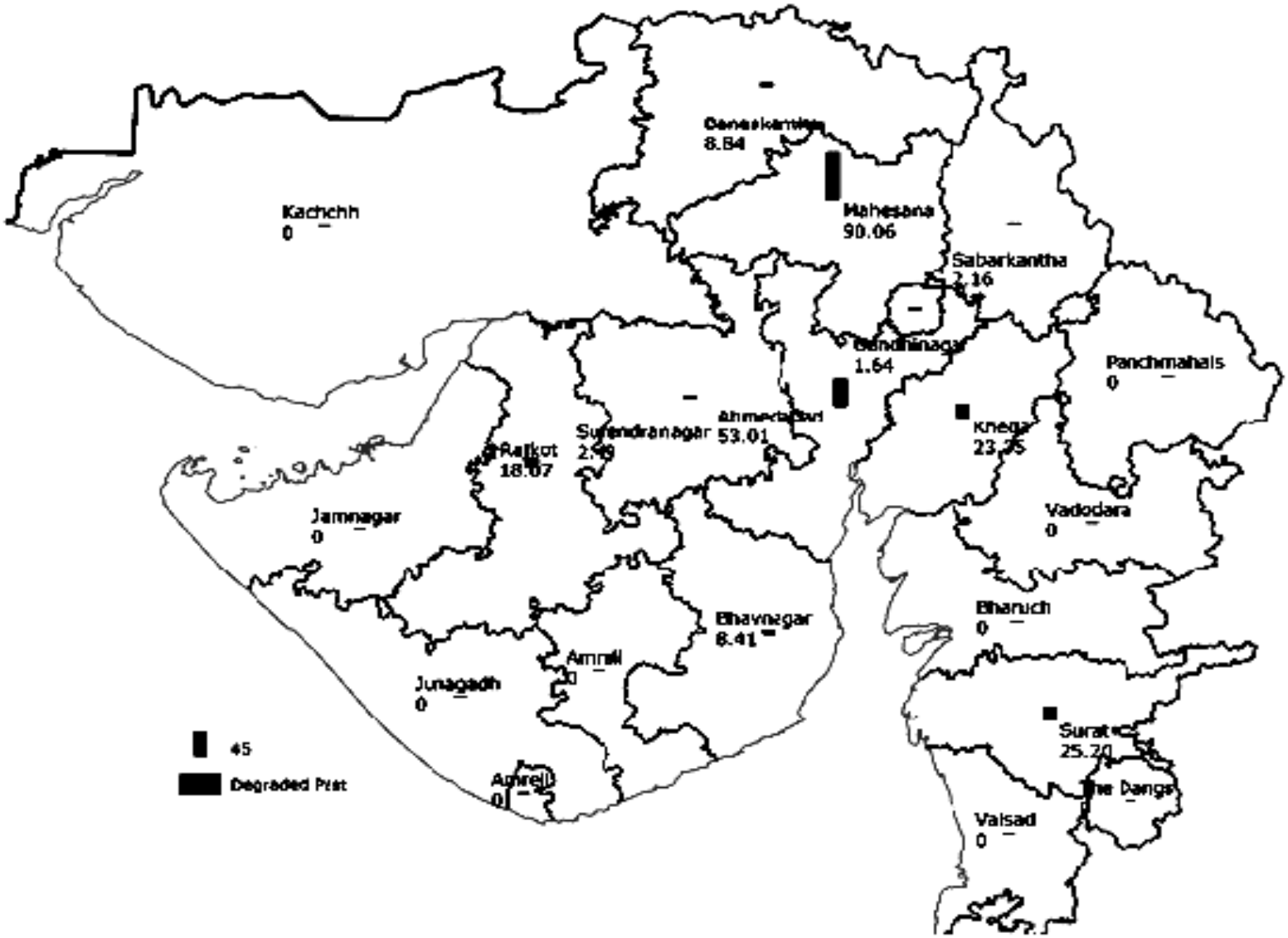


FIGURE: 2.12 DISTRICT WISE PERCENTAGE OF DEGRADED PASTURES IN GUJARAT SAURASHTRA

2.7Avifauna study:

Three grassland areas, around Rajkot city in central Saurashtra were selected to estimate bird population. These grassland areas differ from each other, in terms of patch size, vegetation, management practices, grazing cycle, intensity of anthropogenic activities, degree of disturbance, and land use. Details of each site are given below.

Site: 1 - Raiya – Munjaka grasslands.

Location and Significance

Raiya Munjaka grassland is situated at $20^0$58’ to $23^0$08’N, $70^0$20’ to $70^0$24’E, Altitude - 138m above MSL covering an area of 167 ha. at the Western boundary of Rajkot city (Figure 2.15).

This grassland patch is flanked by two villages namely Raiya and Munjaka. Both the settlements hold high human and livestock population. Thus the area is exposed to grazing and remains affected by anthropogenic pressures throughout the study period. Area holds minimum grass cover especially of dominant palatable grass species of the region.

Authority rights of this grassland lies with H. H. Manoharsinghji, former ruler of the princely state of Rajkot and Gram- Panchayats of Raiya and Munjaka, they auction the land annually to locals, pastoralists, or cattle rearing agencies for grazing purpose. Land use includes agriculture, soil mines, educational premises and residential plots along with gardens. The area is under rapid process of urbanization, which increases the degree of disturbance.

Site- 2: - Khirasara reserve *vidi*.

Historical background

The Khirasara *vidi* was the private hunting ground of Jethwa dynasty of Khirasara state. It is representative of once widely spread savannah grassland in the region. It was said to be the home of migratory Lesser Florican, Striped Hyena, Panther and Wolf. These species became locally extinct from the area in recent past.

The *vidi* was taken over by State Forest Department in 1971 and declared as reserved *vidi,* managed for grass production and collection to fulfill immediate demand of fodder.

Location and Significance

The Khirasara *vidi* is located at $22^0$13’662 to $22^0$11’805 N latitude and $70^0$39’352 E to $70^0$39’835 E longitude near Khirasara village, in Lodhika taluka of Rajkot district (Figure 2.16). It is situated 22 km NW of Rajkot city. The *vidi* encompasses an area of 487.39 hectares, with land survey number 295/296 under legal notification number A.K/176/FLD1671/6655p/Dt. 9.9.1971.

A rubble wall of 1.5 m height is erected on periphery to demarcate the reserve area. The *vidi* is surrounded by four villages, namely Khirasara, Chibhada, Balasar, and Chapra, at Northern, Southern, Eastern and Western boundaries respectively. The Metoda industries area is at NE side. Area face moderate anthropogenic pressure, as the disturbances were regulated up to certain extent by continuous efforts of forest department, which prevent illegal grazing, trespassing and encroachment. Their efforts brought some positive results to the area, but still illegal grazing is a routine practice by locals.

State Forest Department had conducted many habitat improvising programs, such as fencing, construction of check dams, plantation etc. ensuring soil conservation, protection and availability of water for ten months, (all the water sources dries up during April and May). Grasses were harvested annually from mid November to December. Local land use comprises of grassland area and agriculture at the fringes.

Site – 3 Research cum demonstration center, Rajkot.

Location and significance

Located at $21^0$13’362 to 21^0.18’603 N latitude and $70^0$35’253 E to $70^0$35.835’ E longitude, this grassland locally know as Dharmada *vidi* is an intact grassland patch of 96 ha, at the east side of Rajkot city, administrated by of research division of State Forest Department (Figure 2.17).

Earlier the area was under administration of normal forest division, Rajkot range, but in 2004, the land was transferred to research division of State Forest Department for development of research cum demonstration center for farmers. Area was fenced in 2005 by barbed wire, restricting grazing and tres passing. Harvesting was also regulated. Thus site was considered as control plot in present study which was useful to reflect the impact of grazing, harvesting and anthropogenic disturbances on avian assemblages. Protection supported process of grassland succession, independent from human influence.

The area is in close proximity of Randarda talav, an extension of Aji reservoir, on its western side, which is a perennial water source. As the area was geographically small

compared to other study sites, effect of patch size influencing composition of avifauna is an obvious factor.

2.7 Topology

The *vidis* are mostly undulating and have numerous hills, hillocks, narrow ridges and mild slopes.

2.8 Soil

The underlying rock is sandstone belonging to Umia bead series. These sandstones are loose and calcareous and are white in colour, belonging to Jurassic period. The basaltic rocks are called Deccan traps. The Basalt rocks are in half decomposed state all over the region, forming loose pebbles. Soil originated from this rock system in elevated areas of the *vidi* swept away to adjacent low area is mainly black in colour termed as black cotton soil.

2.9 Climate

WINTER: Winter is experienced from November to February with month of October being largely a transition period. Dry and cool NE winds bring waves of cold over the region. January is the coldest month (Avg.> 10^0c).

SUMMER: Dry hot season extends from March to May. May is the hottest Month (Avg. max. temp 40^0c).

MONSOON: Rain fall is confined to monsoon season only usually from first or last week of June and prevails to September or October. Monsoon is marked by high relative humidity ranging from 80% to 92%. Average rainfall in the area is 120mm.

Figure.2.13 Mean monthly climate chart during 2007 at study area.

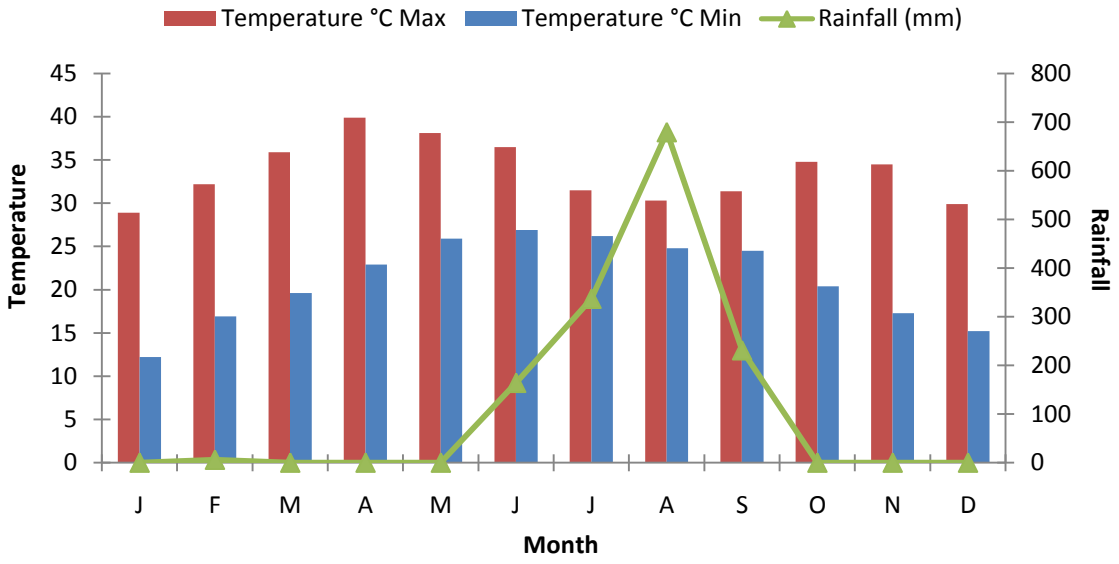


Figure.2.14 Mean monthly climate chart during 2008 at study area.

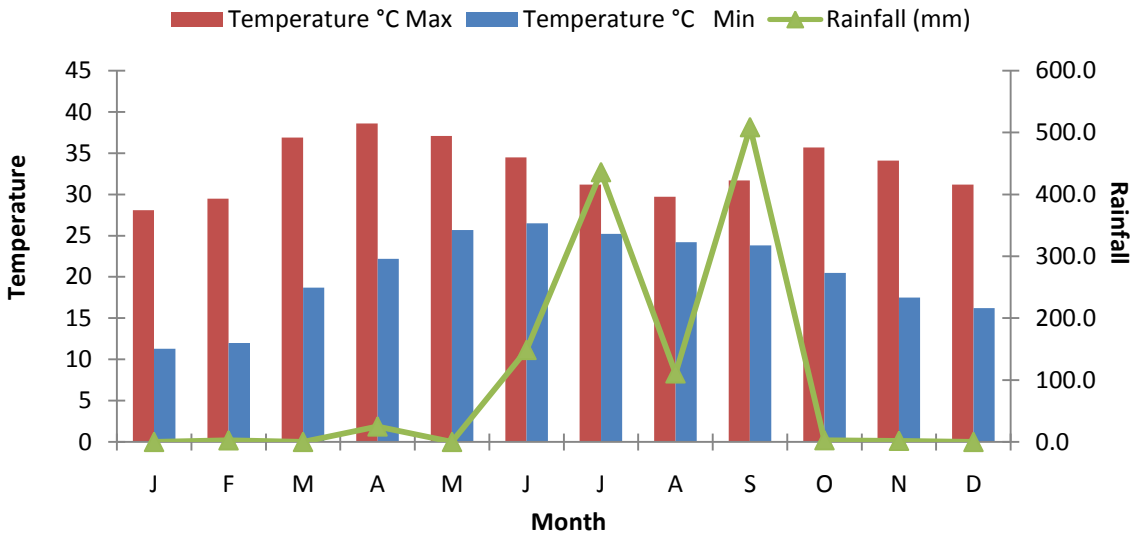


FIGURE 2.15 STUDY AREA SPECIFICATION MAP- Site 1 (T=Transects, ▬ = Transect Path, Raiya and Munjka villages)

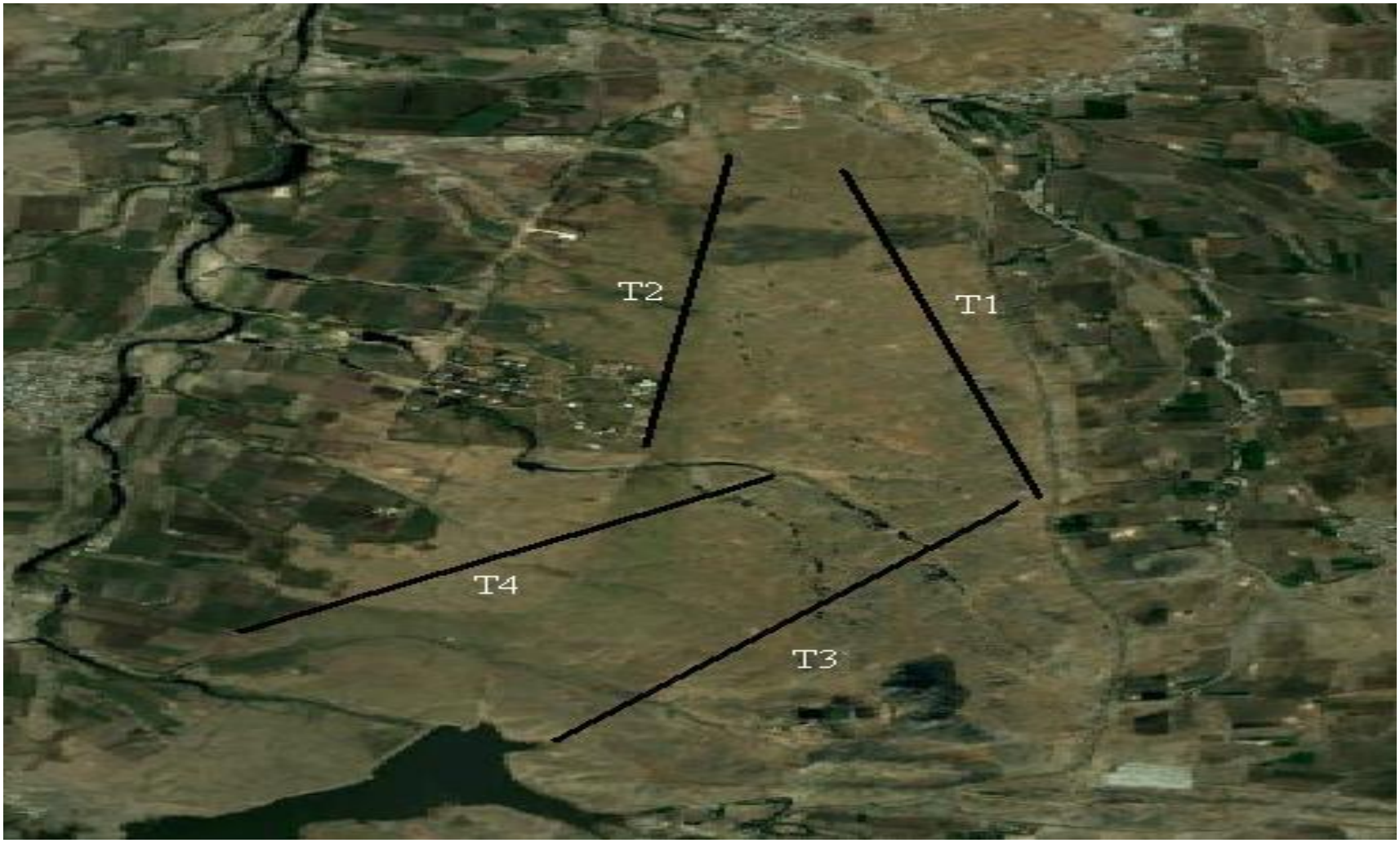


FIGURE 2.16 STUDY AREA SPECIFICATION MAP- Site 2 (T=Transects, ▬ = Transect Path)

FIGURE 2.17 STUDY AREA SPECIFICATION MAP- Site 3 (T=Transects, ▬= Transect Path)

Chapter 3

ECOLOGICAL STATUS OF *VIDIS* IN SAURASHTRA.

3.1 INTRODUCTION

Ecological status of an area is determined by assessing the biodiversity of a region, the environmental conditions prevailing there and their interaction. It represents the overall health and sensitivity of an ecosystem. Ecological status assessment becomes essential for arriving at an appropriate conservation and sustainable management strategies. This assessment is done by evaluating the components along with its functional abilities of an ecosystem. This includes the assessment of species diversity, their abundance, and threats to their habitat by anthropogenic activities (like grazing, mining, dam construction, making of road or railway lines, spread of pipelines, building of an industry) which may alter the physical, chemical and biological integrity of the system (Ali *et al*, 2007, Ramachandra *et al*, 2006).

The deterioration of our ecosystems is a serious threat. In *vidis,* quest for maximization of the biological productivity has intensified exploitation, and has caused immense parturition resulting in less productive and more fragile system of the present day.

At the outset it becomes important to know the status of the entire biological community of the "*vidis*" in an ecological perspective so that an environmentally oriented conservation strategy can be evolved for the region. Besides the biological attributes the cultural and social characteristics of the people are of equal significance for suggesting sustainable ways to use resources.

3.2 AIM: In the present chapter within the limitation of the study, an attempt has been made to assess the ecological status of *vidis* in Saurashtra to understand the grassland ecosystem, affinities among them, types and impact of deteriorating factors, and response of grasslands under the factors of use.

HYPOTHESIS 2: It is assumed that all the grasslands in Saurashtra have same cover and composition with similar pressure.

3.3 OBJECTIVES: Following objectives are set forth to fulfill above mentioned aim.

1. Reconnaissance survey of grasslands of Saurashtra to assess geographical and biological attributes.
2. To recognize grassland covers and composition.
3. To study various constrains both natural and anthropogenic and its effect.
4. To evaluate composition of palatable species that determines the carrying capacity.
5. To work out the progressive and regressive changes under the factor of use.
6. To propose a management strategy for conservation, maintenance and sustainable use of grasslands.

3.4 Methodology

3.4.1 Vegetation study

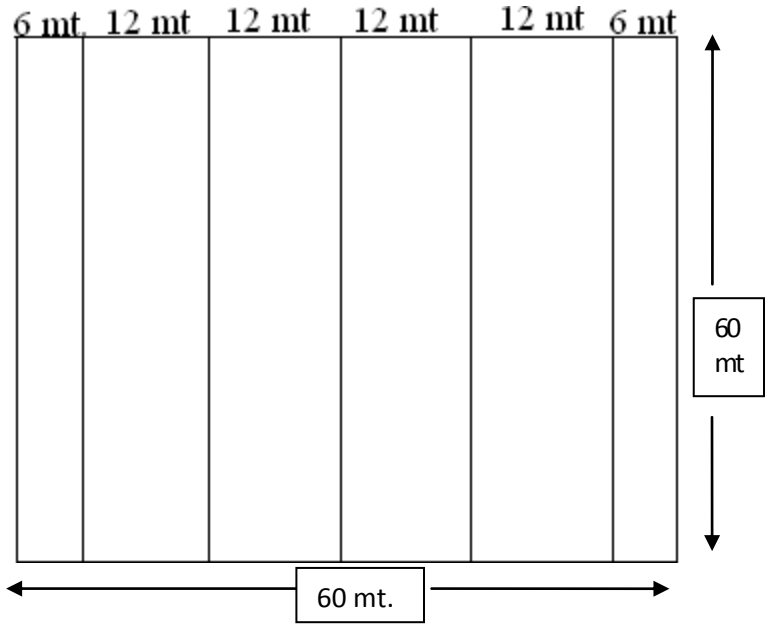
All grass species of the sampling plot were listed under five categories: 1) Common name, 2) Perennial grass, 3) Annual grass, 4) Palatable grass, and 5) Non-palatable grass. The species of uncertain identification were collected and identified as per Bole and Pathak 1988, Bor 1960, Gandhi and Ysufzai 1999, Skerman and Riveros 1990, and Patunkar 1980.

3.4.2 Composition

Composition of vegetation is the proportion and relative abundance of various species present in a plant community. The method followed in the study of composition was "pace transect method" or toe hit method (Canfield 1941).

1. The sampling procedure consisted of determining the base line of sampling plot. Sampling for composition was done on five imaginary lines at right angles to the box line. The first line was taken at a distance of 6 mt. from the starting point of the base line. Subsequent lines were taken each at an interval of 12 mt., so that the fifth line was situated at 6 mt. from the end point of baseline. The total length of the base line was then 60 mt. (Figure 3.1).

Figure: 3.1 Imaginary lines on Sampling plot of survey.



2. For sampling the vegetation. Starting from the base line, data was recorded at every fourth step by putting closely on previously marked line, the toe of right foot. If the toe hit on or a part of a living rooted part of a grass plant, a hit on vegetation was considered to have been secured and the grass species was recorded. Each transect line was of 60 mt. and excluding the two base lines provided a maximum of 20 hits. If effective hits were secured at all the sampling points on the five lines, a total of 100 hits would be secured. In actual practice, hits on some or all the sampling lines were usually missed. To complete the 100 effective hits, additional transect lines were taken between the original lines.
3. The percent cover of each plant species is calculated by totaling the intercept measurements for all individuals of that species along the transect line and converting this total to a percentage by dividing by the total length of the line.

Total cover measured on the transect is calculated by adding the cover percentages of all the species. This total could exceed 100 percent if the intercepts of overlapping canopies are recorded. With this method, relative species composition is based on the percent cover of the various species. Relative composition is calculated by dividing the percent cover for each species by the total cover of all plant species.

3.4.3 Succession studies

The term "Sucession" is applied to changes in community or ecosystem properties following external disturbance (Likens *et al*., 1978). Ideally succession in disturbed ecosystem should be followed from its initiation to the climax stage. However, this is rarely possible. An alternative method is to study separate areas for which different length of time have elapsed since a various disturbance (Drury and Nisbet, 1973; Austin, 1981). In present study different sites were examined with varied intensity of deteriorating factors exposed to varied time duration.

1. Various communities of a locality were examined, compared and arranged in sequence according to the order in which they appear to have given rise to one another.

2. Detailed observation was taken on individual plants, especially on those which were dying and those which appear in their place.

3. These studies carried out in protected areas provide information on the progressive changes, while those carried out on grassland under active use give information on the regressive stages. 4. These observations in the field together with comparison of study spot under similar environmental condition but subjected to different degree use, give

data for constructing the picture of progressive and regressive changes in the major grassland covers (Dabadghao and Sankaranarayan, 1973).

3.5 Results and Discussion

3.5.1 Junagadh Division

Grass vegetation:

Twenty nine species of grass were recorded from Junagadh division (Table 3.1)

Table 3.1 List of grass species recorded from Junagadh division

Andropogon pumilius	*Paspalidium flavidum*	*Vativeria zizanioides*
Apluda mutica	*Sporobolous marginatus*	*Sehima nerosum*
Aristida adscensionis	*Cynodon dactylon*	*Iseilema laxum*
Brachiaria eruciformis	*Dichanthium annulatum*	*Borhriochloa intermedia*
Brachiaria ramosa	*Eragrostis cilianensis*	*Borhriochloa pertusa*
Cenchrus ciliaris	*Eremopogon foveolatus*	*Borhriochloa iischaemum*
Chionachne koenigii	*Eulaliopsis binata*	*Chloris virgata*
Cymbopogon martinii	*Hackelochloa granularis*	*Dactyloctenium aeypticum*
Heteropogon contortus	*Themeda cymbaria*	*Chrysopogon fulvus*
Panicum antidotale	*Themeda quadrivalvis*	

There were eighteen perennial species, nine annual species and two species were annual-perennial in habit.

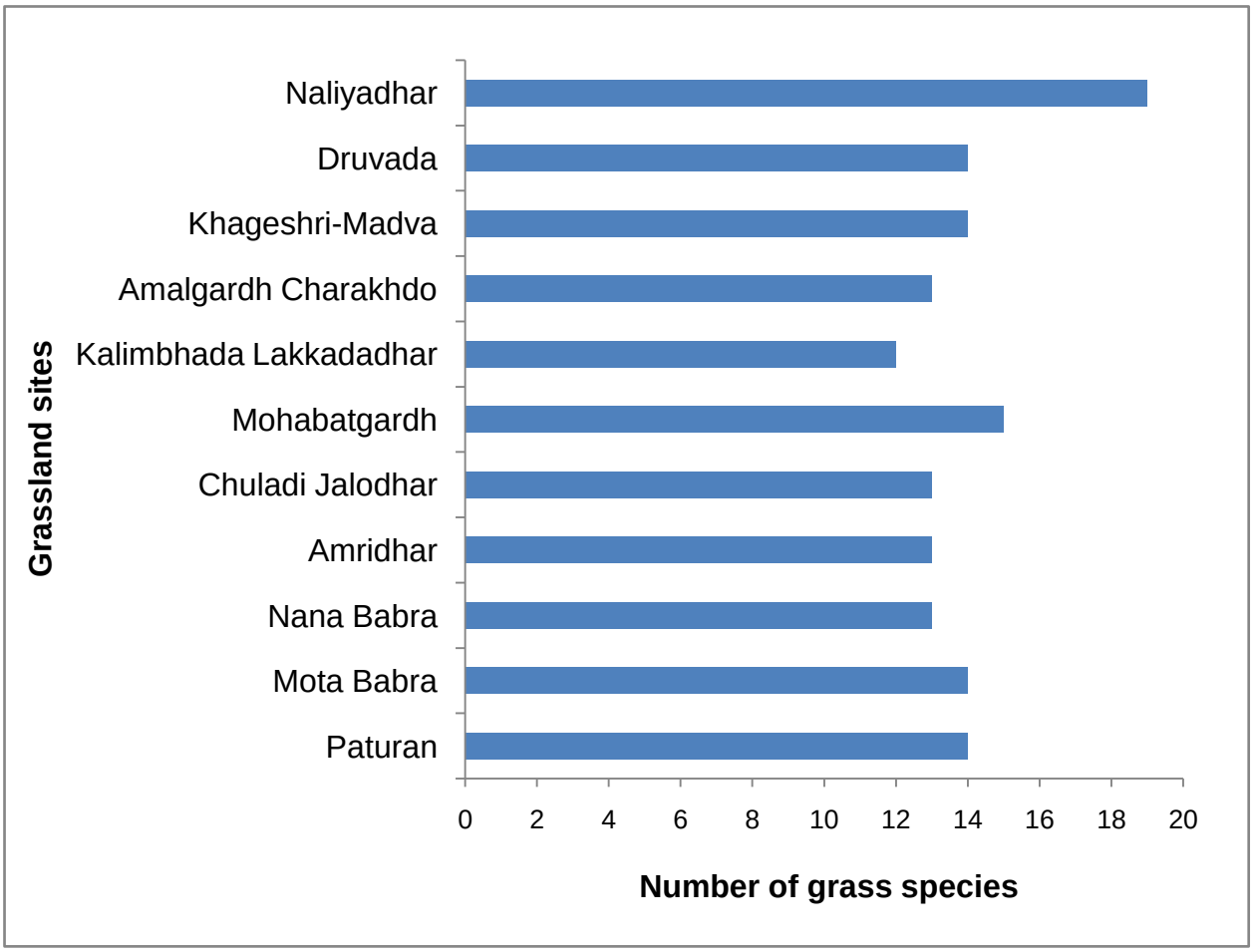
Naliyadhar *vidi* possessed highest number of grass species (19) followed by Mohobattgadh (15). Paturan, Motababra, Khageshri and Druvada possessed 14 species each. *Vidis* such as Chuldi-Jalodhar, Amridhar, Nanababara, Aamalgadh and Charakdo

share similar number of grass species (13) while the lowest number was recorded from Kalimbhada-Lakkadadhar (12) (Figure 3.2).

Grass community and association

Three grass communities in Junagardh division were recognized: *Sehima nerosum-Dicanthium annulatum, Heteropogon - Cymbopogon* and *Bothriochloa – Aristida*. A list of sites representing the community type and associated grass species are given in Appendix-II A.

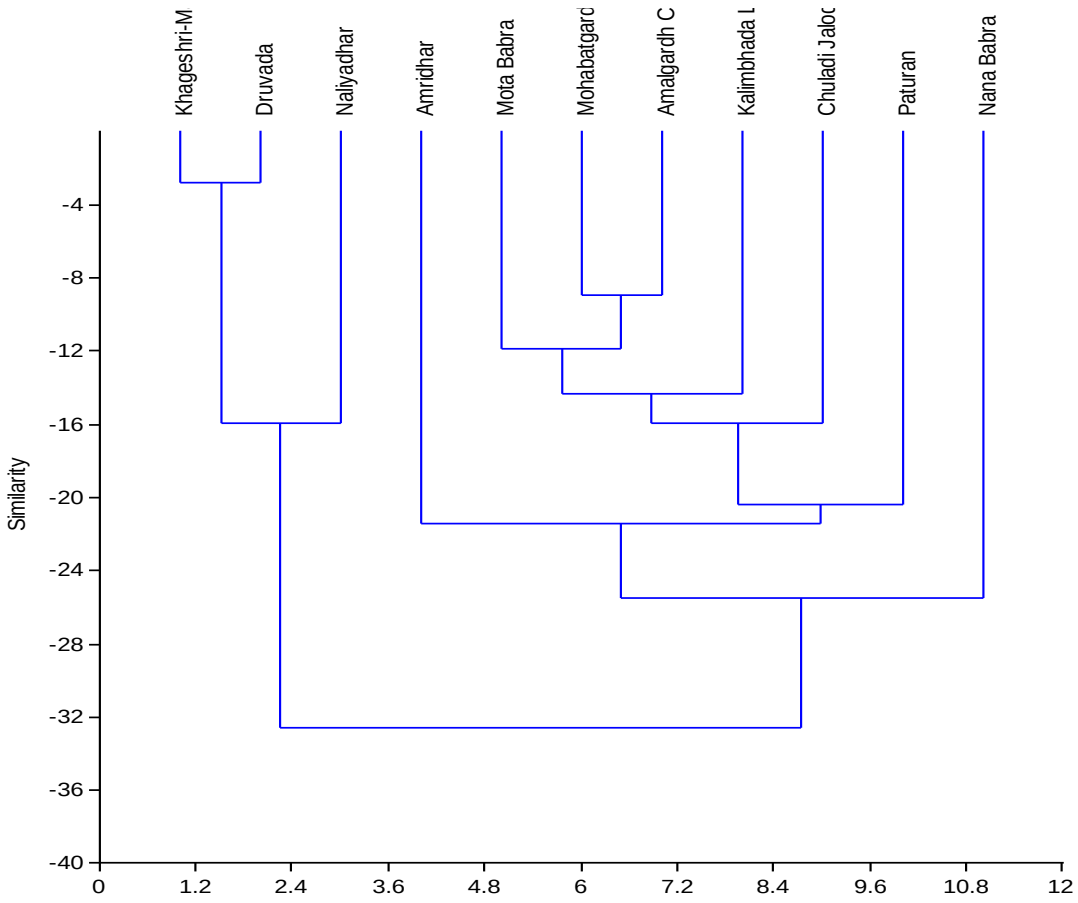
Figure 3.2 Number of Grass species at grassland sites of Junagadh division.



Similarity among *vidis* in terms of grass species and composition

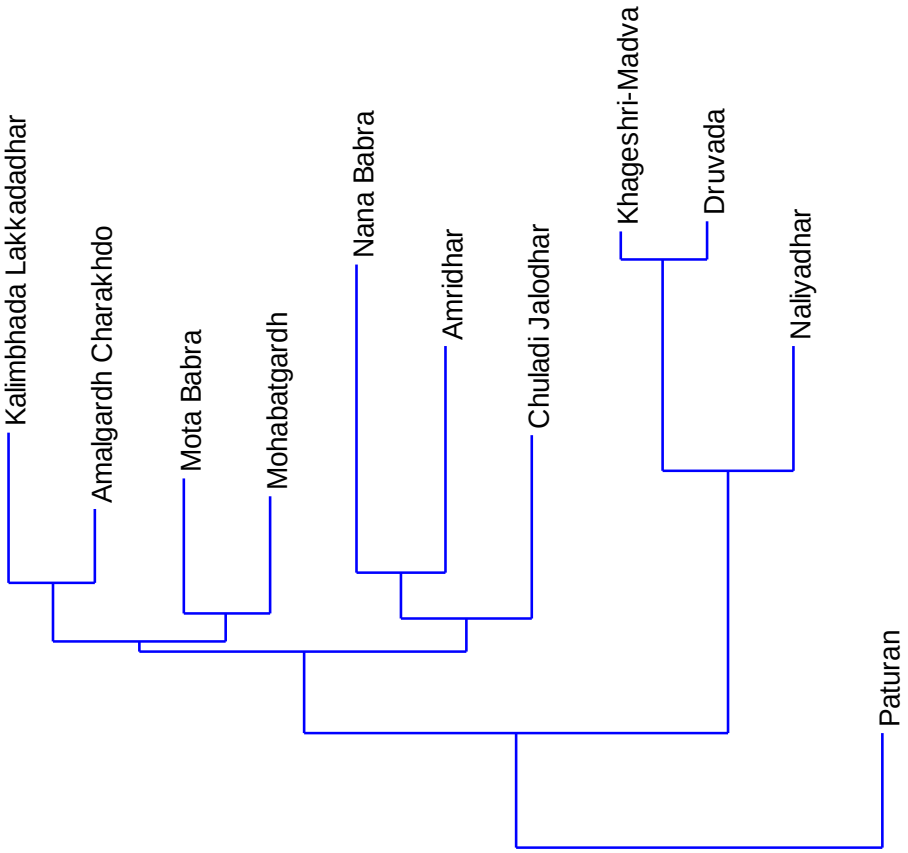
The clusters in figure 3.3 indicate two distinct sets, one comprising Naliyadhar as an outliner with Khageshri, Dhruvada and other with grassland areas adjoining Gir and Girnar PAs. This was further distinguished into one outliner of Nana Babra and a sub set. This sub set comprises an outliner of Amridhar and sub-subsets consisting rest of the *vidis* with their respective similarity patterns. These are Amalgadh-Charakdo – Mohabattgadh with Mota babra, and the whole were found similar to Kalimbhada-Lakkadadhar and Chuladi-Jalodhar, with Paturan *vidi* as an outliner.

Figure 3.3 Dendrogram showing similarity among grassland sites of Junagadh division in grass species occurence.



When similarity in terms of composition was observed (figure 3.4) Paturan *vidi* represented a distinct end. Khageshri and Druvada share affinity with each other and with Naliyadhar. The whole set indicates similarity with a cluster of other *vidis*, where Mota Babra and Mohabbatgadh are similar. Nana babra and Amridhar show affinity with Chuladi Jalodhar, whereas Kalimbhada and Amalgadh share similarity.

Figure 3.4 Dendrogram showing similarity among grassland sites of Junagadh division in grass species composition



The variation and affinity among *vidis* in terms of grass species and composition can be explained on the geographical basis. Naliyadhar *vidi* of Kutiyana taluka is situated near Barda Wildlife Sanctuary on the extreme western side of the division. It shares its

boundaries with grasslands of Jamnagar division resulting in overlapping of species indicating high diversity. The soil of the area is more alkaline as compared to the other parts of the division making it distinct. Khageshri and Dhruvada share geography and topography. These two *vidis* comprise same area, distinguished by different names given after two villages which hold the grazing and lease rights.

Paturan *vidi* is an extended portion of Girnar Wildlife Sanctuary which holds pristine patch of dry deciduous forest, thus this grassland is subjected to a continuous exposure of successive forest regeneration, making it a distinct end in figure 3.4.

Other *vidis* such as Chuldi-Jalodhar, Amridhar, Nanababara, Aamalgadh and Charakdo and Kalimbhada-Lakkadadhar of Maliya-hatina taluka, are adjacent to each other and adjoining western boundary of Gir Wildlife Sanctuary. These grassland *vidis* were fragmented into patches by agriculture and urbanization from an extensive native grassland within due course of time and given different names based on adjutant villages. Aamalgadh and Mohobattgadh are part of Motababara cluster, from which Chuldi, Kalimbhada and Amaridhar were separated. Nanababara and Amaridhar are flanked by road from this cluster and are more exposed to deteriorating factors making them distinct subgroups in figure 3.3.

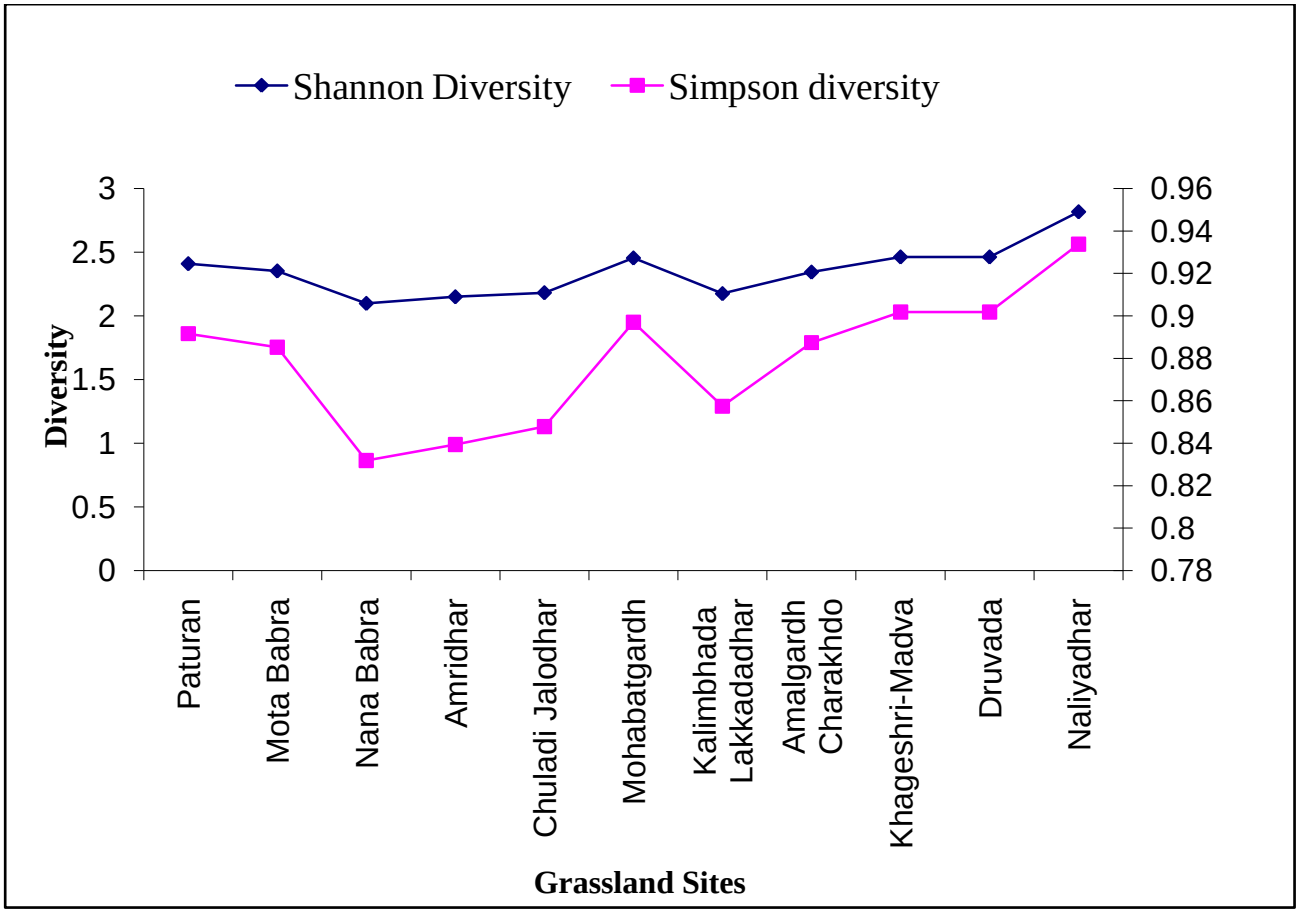
Grass species diversity in grassland sites

Highest Shannon diversity was recorded from Nadliyadhar *vidi* followed by Mohobattgadh and Paturan. All these grassland areas are large intact patches representing native grassland of the division. In Babra-Chuldi-Kalibhada-Aamalgadh- Mohobattgadh cluster diversity increases respectively to attend its maximum at Mohobattgadh.

Mohabattgadh is situated at the center of the cluster, thus it faces lower degree of exploitation. In addition, the area is carnivore infested (Lion, Leopard) region that reduces grazing pressure up to a certain extent, especially in Mohabattgadh (Figure 3.5).

Simpson's diversity shows similar trend due to the same reason. Lowest Simpson diversity was recorded at Nanababara which is situated in the vicinity of three villages. It faces extreme grazing and anthropogenic pressures (Figure 3.5).

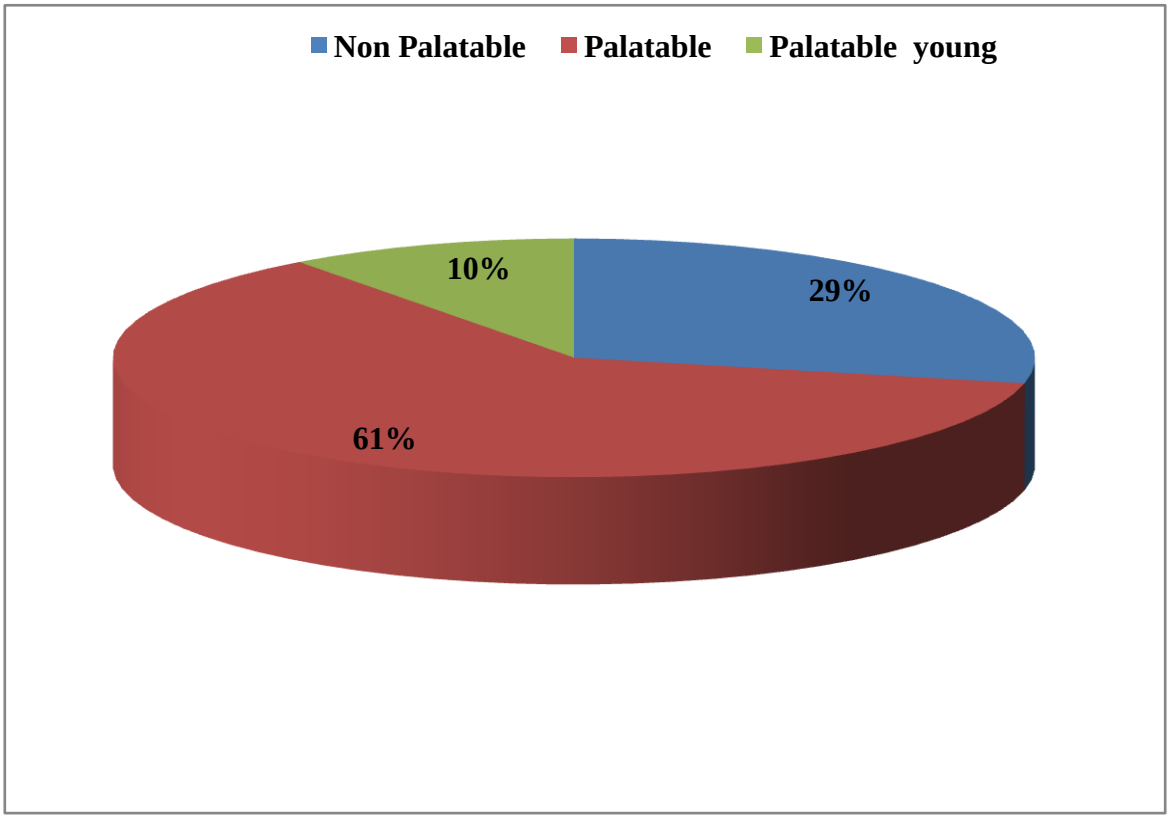
Figure 3.5 Diversity of grasses in grassland sites of Junagadh division



Composition of palatable grass in Junagadh division

The division has 62 percent of palatable grasses and 28 percent of non palatable grass species. The composition of grasses which are palatable when young was found to be 10 percent, thus overall palatability of grasses in Junagadh division was 72 percent during the study period (Figure 3.6).

Figure 3.6 Percentage compositions of palatable and non palatable grasses in grasslands of Junagadh division



Issues and suggestions for grassland *Vidis* of Junagadh division

Vidis of Maliyahatina taluka are being adjacent to the Gir PA and are part of greater Gir. Thus they are used as a habitat provides shelter to a variety of wildlife including Asiatic Lion, Leopards and Wild ungulates. This leads to human-wildlife conflict.

All the grasslands in Junagadh division are in ecologically healthy condition, but deteriorating conditions such as fragmentation, over grazing and encroachment have been observed.

It is high time for suggesting GIS based study, which will provide an idea about the connectivity viz. - a - viz. fragmentation among these grassland patches. This information is useful to design a management policy with a scope for wildlife conservation efforts. Ecological and socioeconomic studies are also in an urgent need to ensure the future of grassland areas in the region.

3.5.2 BHAVNAGAR DIVISION

Grass vegetation:

Thirty two grass species were recorded from this division (Table 3.2).

Table 3.2 List of grass species recorded from Bhavnagar division.

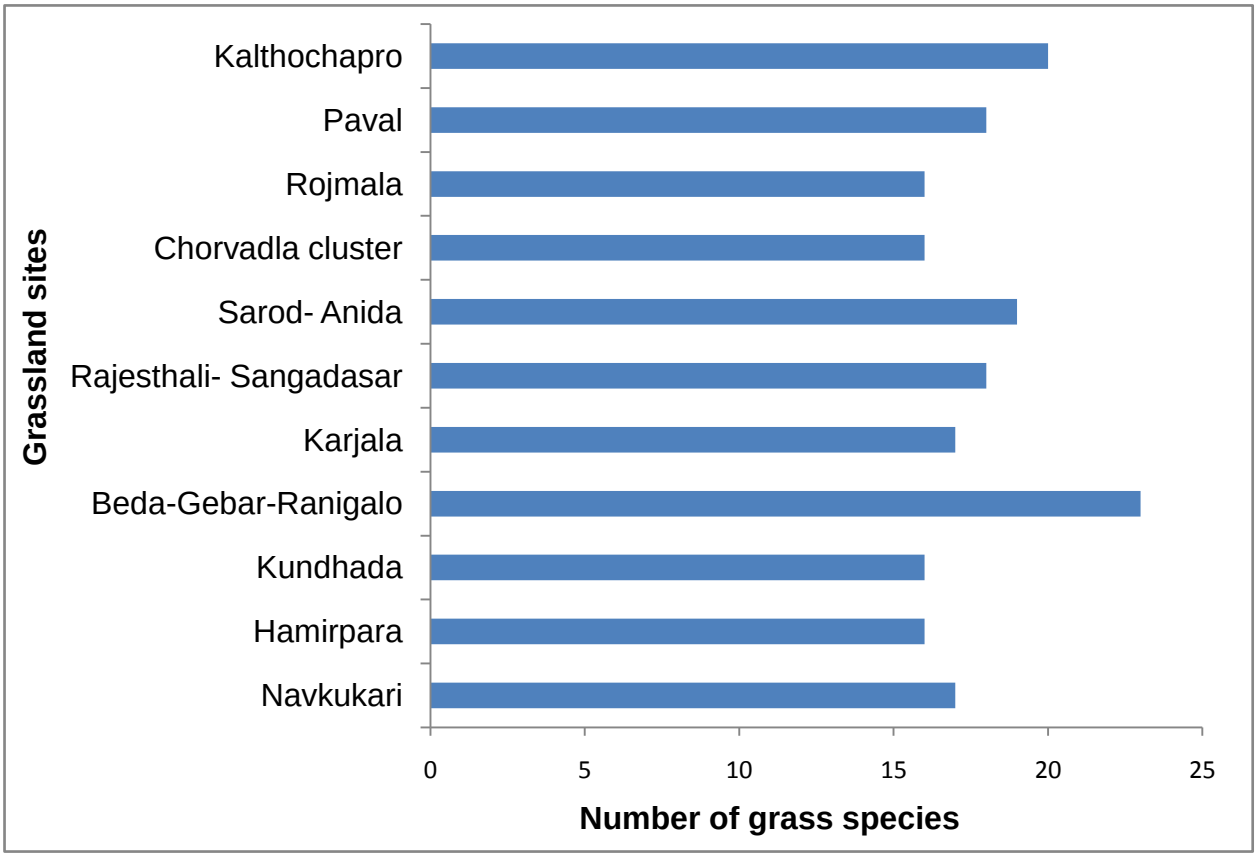
Andropogon pumilius	*Sorghum halepense*	*Ischaemum rugosum*
Apluda mutica	*Sporobolous helovolous*	*Panicum antidotale*
Aristida adscensionis	*Cynodon dactylon*	*Panicum turgidum*
Arundinella setosa	*Dichanthium annulatum*	*Paspalidium flavidum*
Brachiaria eruciformis	*Eragrostis cilianensis*	*Iseilema laxum*
Brachiaria ramosa	*Eremopogon foveolatus*	*Borhriochloa intermedia*
Cenchrus biflorus	*Eulaliopsis binata*	*Borhriochloa pertusa*
Cenchrus ciliaris	*Hackelochloa granularis*	*Chrysopogon fulvus*
Chionachne koenigii	*Themeda cymbaria*	
Coix lacryma-jobi	*Themeda quadrivalvis*	
Cymbopogon martinii	*Urochondra setulosa*	
Heteropogon contortus	*Sehima nerosum/sacculatum*	

There were twenty one perennial species, eight annual species and three species were annual- perennial in habit.

Comparative study of grassland sites within this division shows that, Beda-Gebar-Ranigalo cluster possessed highest number of grass species (23), followed by Kalathochhapro (20), Sarod-Anida cluster (19) , Pavla (18) and Navkukri (17). Chorvadla

cluster of Sihor taluka along with Hamirpara, Kundhada and Rojmala shares the same number of grass species 16 each, which was the lowest (Figure 3.7).

Figure 3.7 Number of Grass species at grassland sites of Bhavnagar division



Grass community and association

Three grass communities in Bhavnagar division were recognized: *Sehima nerosum-Dicanthium annulatum*, *Sehima nerosum* - *Aristida* and *Eragrostris – Aristida*. A list of sites representing the community type and associated grass species are given in Appendix-II B.

Similarity among *vidis* in terms of grass species and composition

Hierarchical cluster in figure 3.8 shows two distinct sets. In first set, Navkukri *vidi* was isolated as an out liner as Hamirpara in subset. Chorvadla cluster and Rojmala which are degraded pastures show affinity.

Second set comprises *vidis* of Sihor, Ghogha, Mahuva and Palitana talukas, where subset shows that Kalthochaparo and Paval are more similar with distinct outliner of Karjala. It suggests affinities between Kundhada and Rajasthali-Sarod cluster. A sub-subset comprising the Sarod-Anida clusters and Beda-Gebar- Ranigalo cluster indicate affinities due to geographical relation.

When similarity in term of composition was observed (Figure 3.9), Karjala forms a distinct outliner, and two sets. One set further divides into subsets of Kundhada – Rajashtli - Sanjanasar and Beda-Gabar-Ranigalo cluster with Sarod Anida suggesting similarities between them.

Second set disintegrates into in two subsets, one suggesting affinities between Kalathochhapro and Pavla and the other which shows Hamirpara as a separate site. Navkukri *vidi* is a distinct outliner possessing similarity with Chorvadla cluster and Rojmala which are similar in terms of use (Figure 3.9).

Figure 3.8 Dendrogram showing similarity in grass species occurence among grassland sites of Bhavnagar division

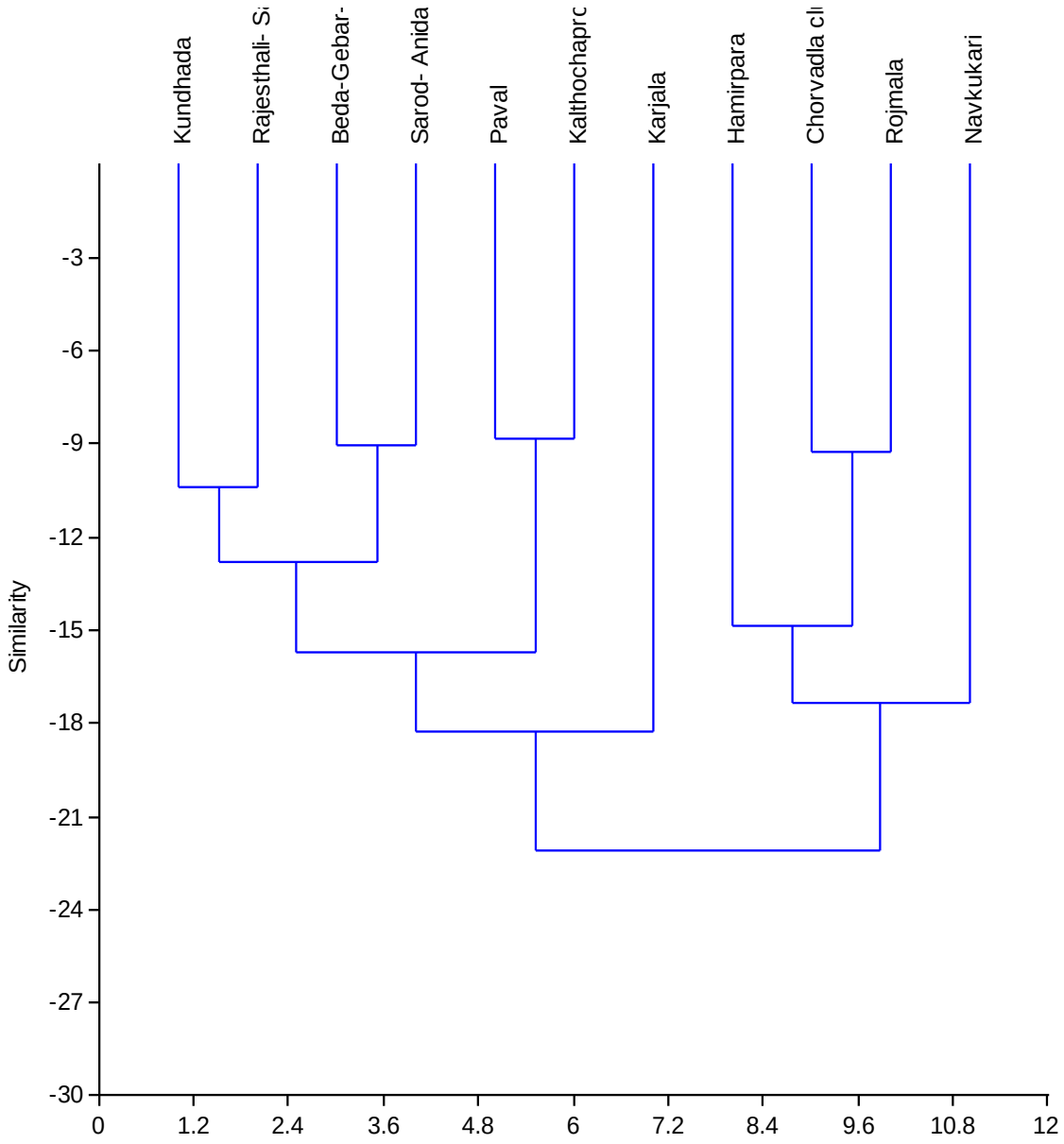
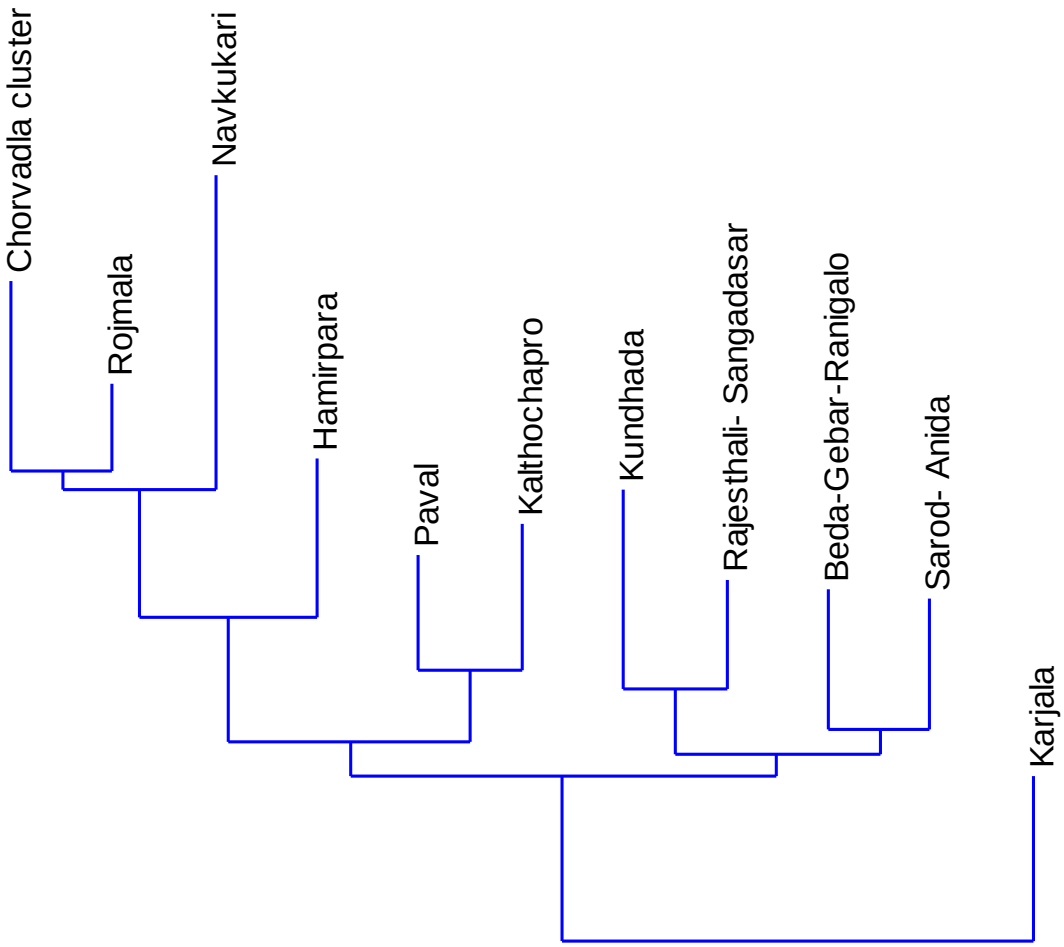


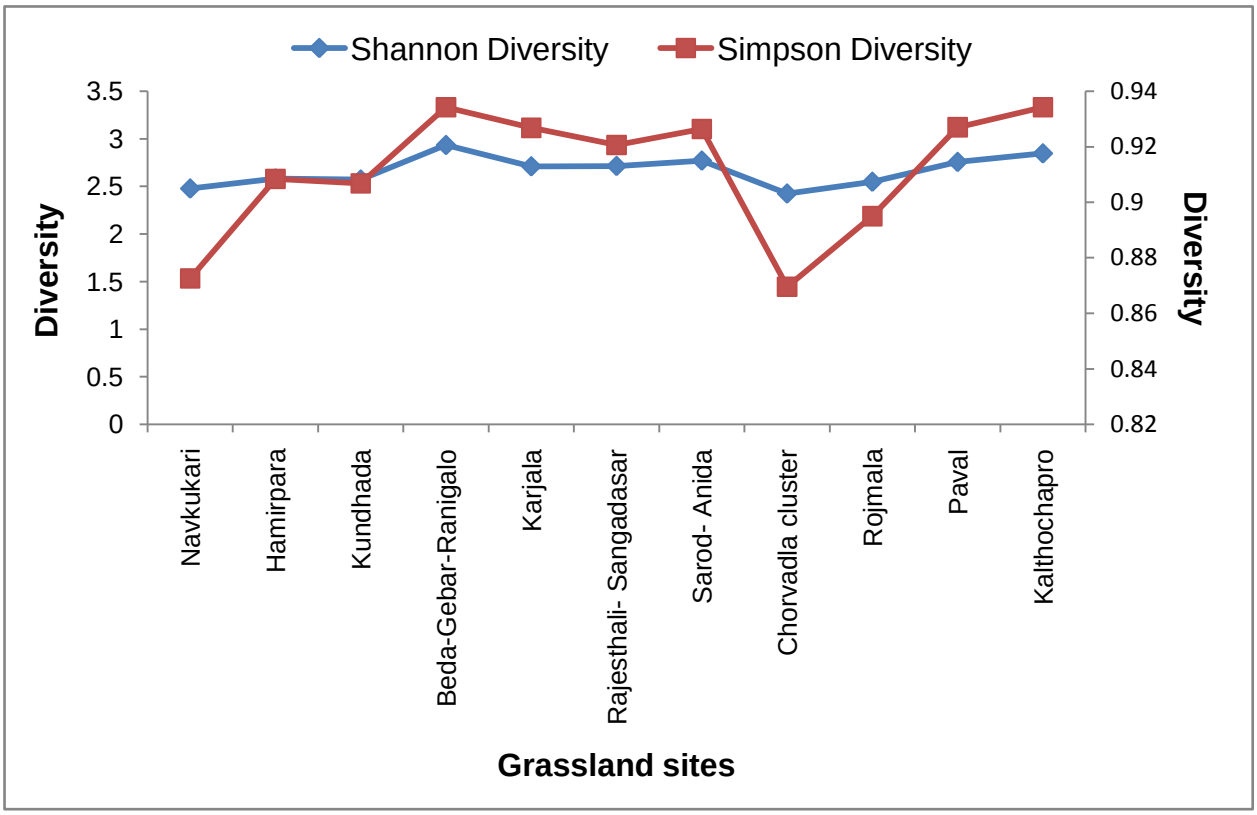
Figure 3.9 Dendrogram showing correlation in grass composition among grassland sites of Bhavnagar division



Grass species diversity in grassland sites of Bhavanagar division

Diversity of grasses was recorded lowest at Navkukari and Chorvadla cluster. Highest diversity was found at Beda-Gebar-Ranigalo cluster followed by Kalthochaparo. Fluctuations in diversity were observed from site to site depending upon patch size, location and intensity of disturbances (Figure 3.10).

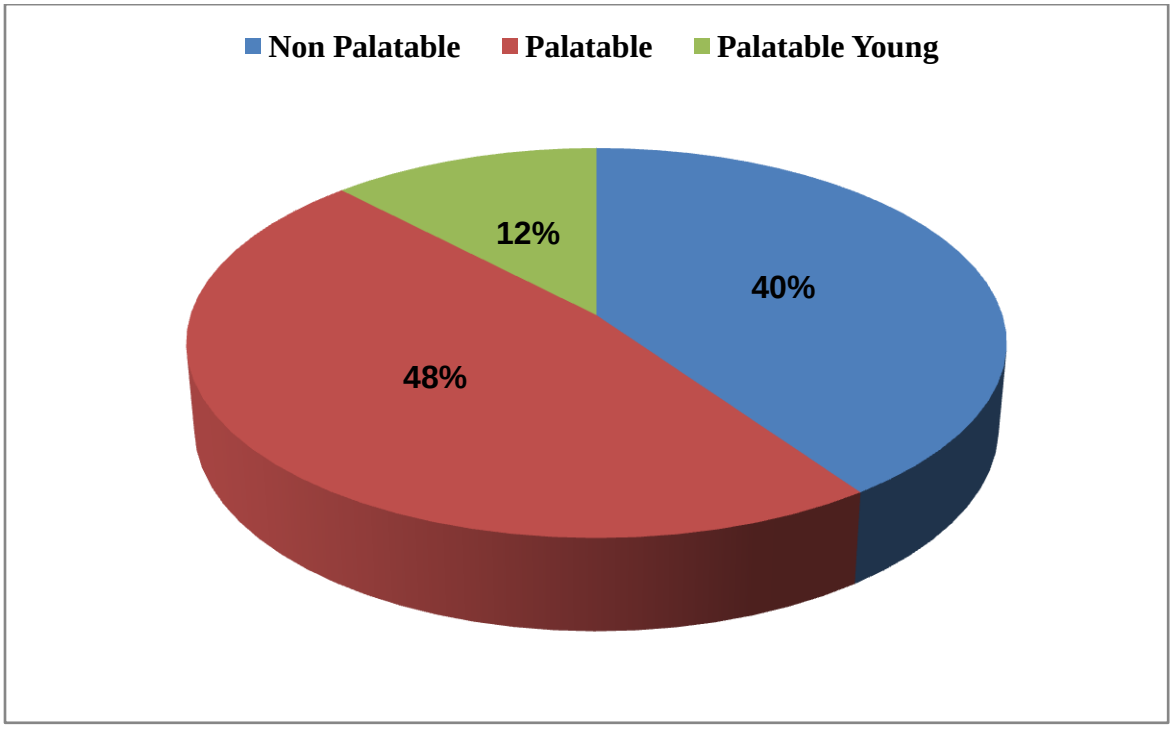
Figure 3.10 Diversity of grasses in grassland sites of Bhavnagar division.



Composition of palatable grasses in Bhavnager division

Overall composition of grasses constituted 48% of palatable grasses and 40% non palatable grasses. Composition of grasses which are palatable in young stage was 12%, making a total of 60% palatable grasses in the entire division (Figure 3.11).

Figure 3.11 Percentage compositions of palatable and non palatable grasses in grasslands of Bhavnagar division



Navkukri *vidi* is located near Alang ship breaking yard, which is one of the largest of its kind in Southeast Asia. This area has dense human and livestock population with high anthropogenic pressure. These factors reduce grass diversity (Figure 3.10) and form outliner (Figures 3.8 and 3.9). Its native grass composition resembles other degraded grasslands, such as Chorvadla cluster (Figure 3.9).

Beda-Gebar-Ranigalo and Sarod- Anida clusters comprise large area of 1867.4 hectares and 1135.62 hectares respectively. These grasslands are protected and monitored by Forest Department due to the presence of Asiatic Lion. Protection provides room for grasses to complete their lifecycle thus these grasslands possess high grass composition and diversity (Figure 3.10). Hamirpara, Kundhada and Rajasthali - Sanjanasar *vidis* of Palitana taluka are separated from Beda-Gaber-Ranigalo cluster as a result of fragmentation.

Kundhala and Sanjansar which are geographically attached to Rajasthali *vidi*, are connected by a degraded pasture to the Beda cluster till date, thus these sites share similarities. Karjala is isolated and has lost connectivity with all *vidis*, but due to its location it is affiliated to the clusters represented as an outliner in (Figures 3.8 and 3.9).

Kalthochaparo *vidi* is situated between two large patches of degraded grasslands which act as buffer zone, and protect it from anthropogenic activities. Thus due to less disturbance it possesses high grass diversity (Figure 3.10). In geographical context it is associated with Paval, (Figure 3.9) as both are representative grasslands of Ghogha taluka, at Southeastern boundary of the division.

Chorvadla cluster of Sihor taluka consisting of grasslands namely Chorvadla, Thala, Malvan, Piparala, and Sikotra Ghodhigalo forms a large patch of 2433.24 hectares. Alike

other large grasslands of the division, this cluster does not possess high grass diversity and composition, because it is surrounded by 18 villages with dense human and livestock population which are completely depended on this area for fodder. Thus degree of disturbance is very high. Continuous use of resources and lack of protection leads to degradation. Trend was reflected on grass species numbers and diversity (Figure 3.7, 3.10).

It can be concluded that in grasslands of the Bhavnagar division, protection, size of area and and degree of exploitation play an important role in the determination of grass species abundance and occurrence.

Issues of Bhavnagar division

The major issues that affect annual grass production and biomass turn over are high grazing pressure, invasion of weed species and encroachment.

Ill planned management practices by forest department, such as platation in grassland like Paval makes harvesting difficult and affects the growth of grass. Forest department does not have proper infrastructural facilities to protect and monitor grasslands (*Per. Comm.* with local staff).

Recent categorization of land as special economical zone (SEZ) is direct threat to the grassland area which can be restored by planned efforts.

Grassland areas of Mahuva and Palitana range are pristine grassland patches, where some areas connected with loose corridors form a large grassland area of semi arid scrub grasslands with high productivity. Thus special emphasis should be given to restore and

protect these tracts. Grasslands within this range namely Ranigalo, Karjala, Gebar, Beda, Kundhada, Rajasthali, and Sangadasar harbour satellitic meta population of Asiatic lions and face issues related to human wildlife conflicts. If properly managed, this grassland can serve as a platform for conservation of local wildlife as well as serve long term socioeconomic benefits.

3.5.3 Dhari Gir east division

Grass species: Twenty four grass species were recorded from the division (Table 3.3).

Table 3.3 List of grass species recorded from Dhari Gir east division.

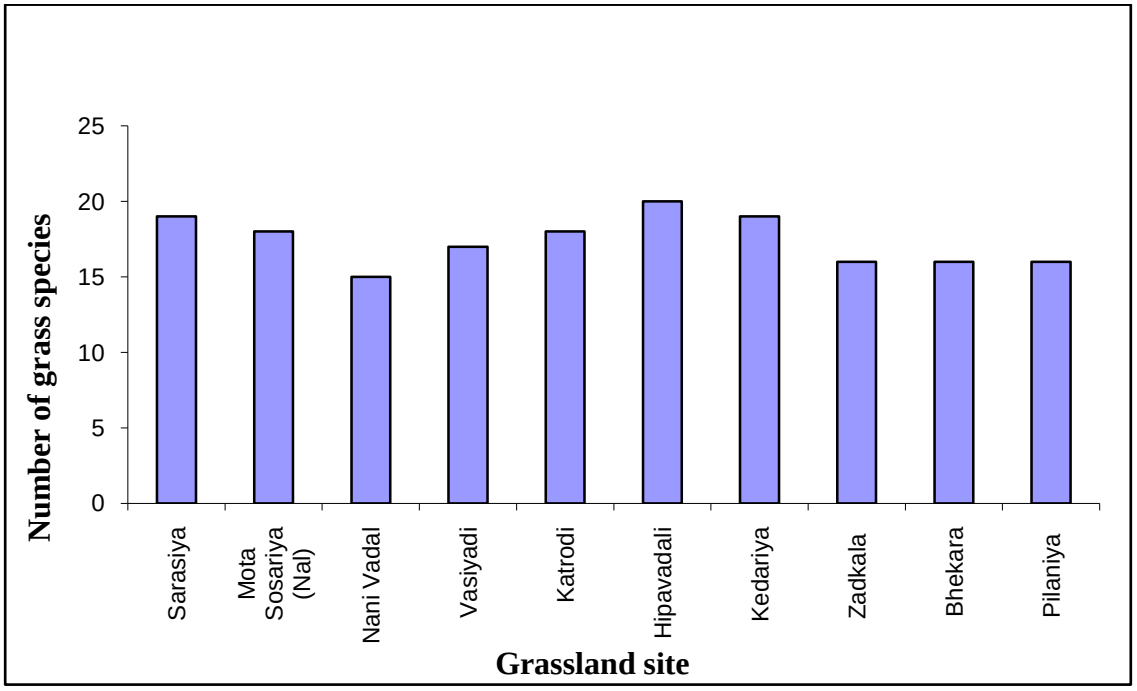
Apluda mutica	*Dichanthium annulatum*
Aristida adscensionis	*Eremopogon foveolatus*
Arundinella setosa	*Eulaliopsis binata*
Brachiaria eruciformis	*Hackelochloa granularis*
Brachiaria ramosa	*Themeda quadrivalvis*
Cenchrus ciliaris	*Sehima nerosum/sacculatum*
Chionachne koenigii	*Iseilema laxum*
Cymbopogon martinii	*Borhriochloa intermedia*
Heteropogon contortus	*Borhriochloa pertusa*
Ischaemum rugosum	*Dactyloctenium aeypticum*
Panicum turgidum	*Chrysopogon fulvus*
Paspalidium flavidum	
Paspalidium germinatum	

There are fifteen perennial, and seven annual species. Two species are annual- perennial in habit.

Highest number of grass species was recorded from Hipavadli (20) followed by Kedaria and Sarasiya with 19 species each, Mota Sosariya and Katrodi with 18 species each, with lowest of 15 species at Nanivadal. Zadkala, Pilaniya and Bhekara possess similar number of grass species 16 each, slightly lower than Vasiyadi (17).

Number of grass species decreases from Sarasiya to Nanivadal and further increases to attend its maximum at Hipavadli. It decreases thereafter to its lowest at Zadkala, Pilaniya and Bhekara (Figure 3.12).

Figure 3.12 Number of Grass species at grassland sites of Dhari Gir (E) division.



Grass community and association

Two different grass communities were recognized in Dhari Gir (E) division: *Sehima nerosum- Dicanthium annulatum,* and *Sehima nerosum - Aristida*. A list of sites representing the community type and associated grass species are given in Appendix-II c.

Similarity among *vidis* in terms of grass species and composition

The cluster in Figure 3.13 shows one distinct outliner of Sarasiya and two different sets. One set consists of an out liner of Vasiyadi and a subset consisting Motasosariya and Nanivadal suggesting affinity among these two *vidis*.

Other set divides into two distinct subsets, one consisting of Katrodi and Hipavadli which are similar to each other and indicate affinity with other subset where Bhekara and Pilania is outliner and Zadkala is similar to Kedariya.

Grass composition similarities suggest that Sarasiya and Hipawadli were similar with Kedariya as an outliner. Nanivadal- Bhekara and Motasosariya-Vasiyali show affinities. They possess high grass composition than Zadakala and Pilania, where Katrodi is the outliner from the cluster (Figure 3.14).

Figure 3.13 Dendrogram showing similarity in grass species occurence among grassland sites of Dhari Gir (E) division.

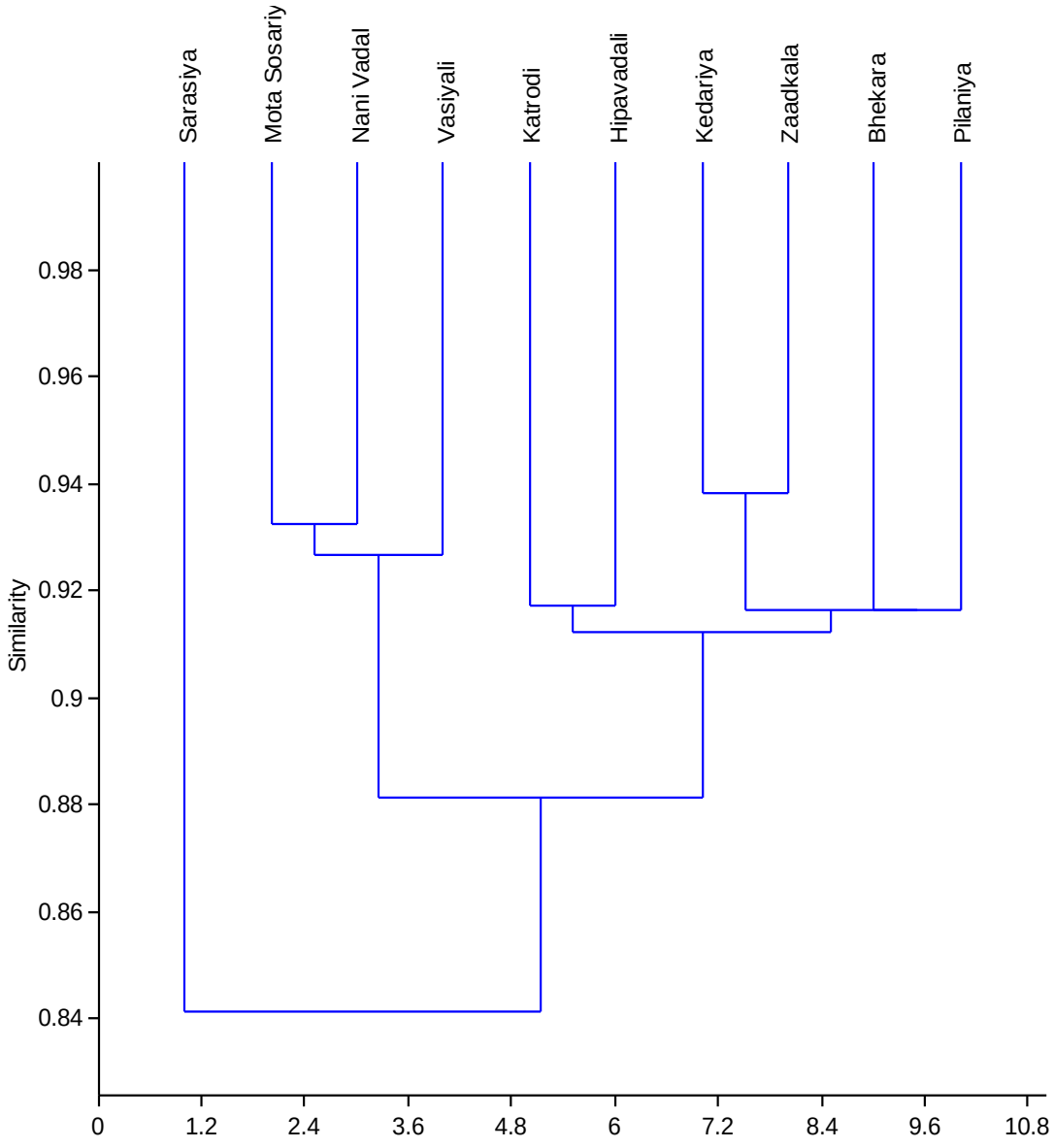
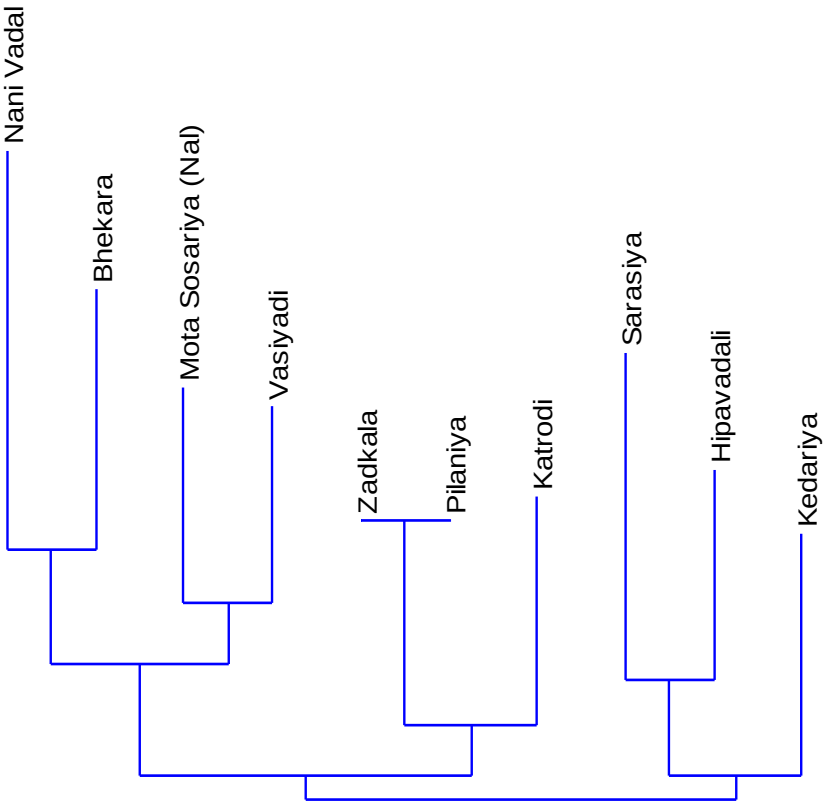


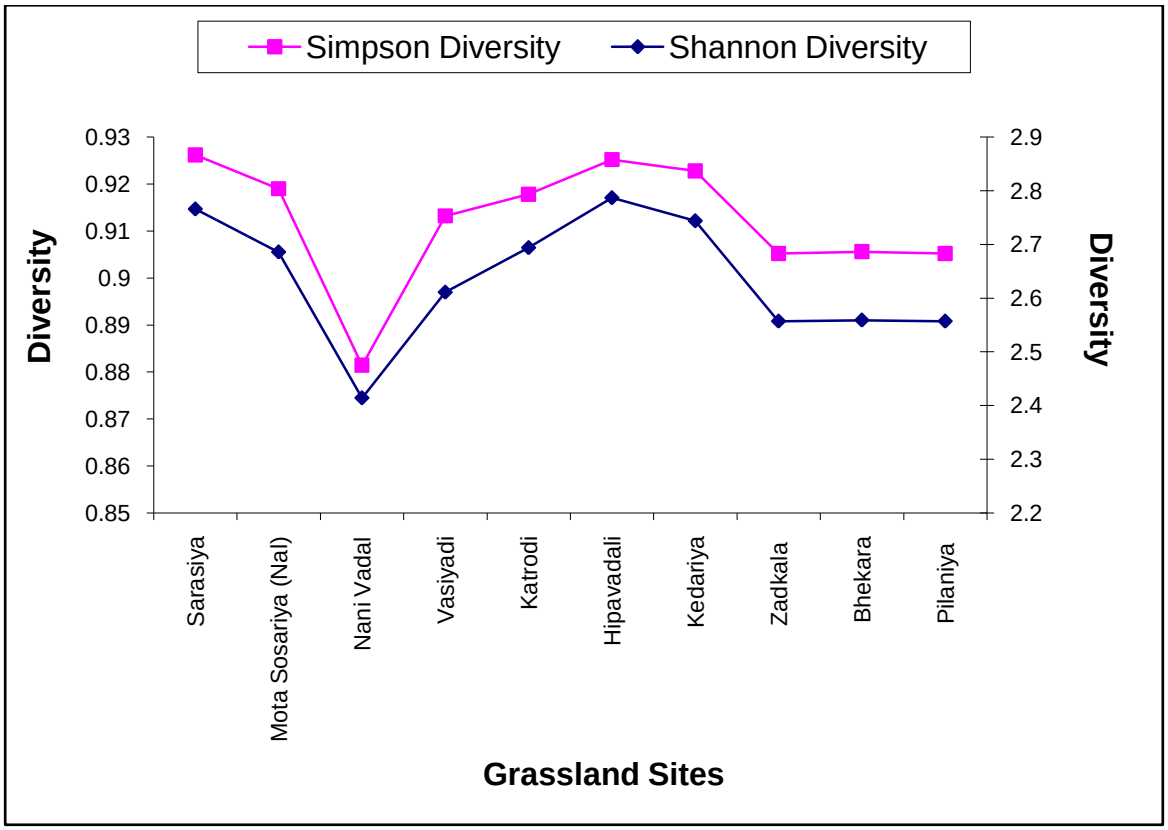
Figure 3.14 Dendrogram showing similariry among grasslands sites of Dhari Gir (E) division in grass composition.



Grass species diversity in Grassland sites of Gir-East division

Highest grass diversity was recorded from Hipavadli, followed by Sarasiya. Grass diversity was similar in Zadkala and Pilania *vidi*s lower than Bhekara. Lowest diversity was recorded from Nanivadal (Figure 3.15).

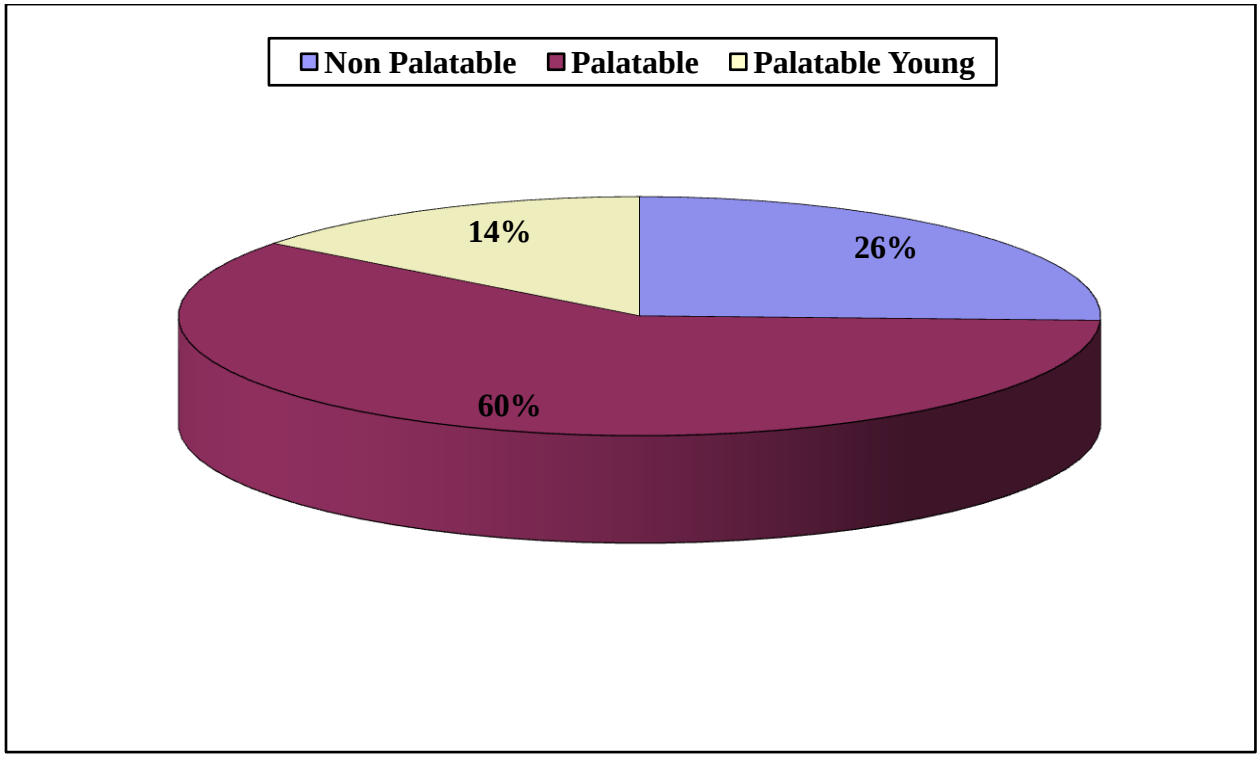
Figure 3.15 Diversity of grasses in grassland sites of Dhari Gir East division



Composition of palatable grasses in Gir East division

Composition of palatable grasses at Gir-east division was 60%. Compositions of Non palatable grasses are 26% along with 14% of grasses which are palatable in early stage of their life history making an overall composition of 74 % of palatable grasses at a certain point of time (Figure 3.16).

Figure 3.16 Percentage compositions of palatable and non palatable grasses in grasslands of Dhari Gir (E) division.



Within division, all *vidis* are similar in terms of grass species diversity and composition due to geographic affinity. The difference among them was their exposure to and intensity of human activities, altering the pattern of land use.

Sarasiya is a part of Gir Wildlife Sanctuary. Thus it receives high protection. It is situated on the interior side of the hill chain like Mota Sosariya nal, Katrodi and Hipavadli, which are the innermost of all, facing less human disturbances. Whereas

Nanivadal and Bhekara are the outer most *vidis* in the hill chain system, more exposed to anthropogenic activities.

Motasosariya and Nanivadal are adjacent to each other forming a cluster with Vasiyadi on its outer part which has close proximity to human settlement.

Zadkala, Pilaniya and Bhekara possess similar grass diversity because they differ only by names given to the single large area.

Zadkala and Kedariya *vidis* are located at the eastern most fringe of the "Lambidhar" which gradually merge in to Beda-Gebar cluster of Bhavanagar division with fragmented regions.

The trend reflected on grass species diversity and composition suggests that location of grassland, its distance from human settlements, and protection plays an important role in the determination of the conditions. These *vidis* varied in disturbance gradient and the effects were clear.

Issues of Grassland of Gir-East division

Grasslands of the region are under immense pressure of human activities as they are surrounded by human settlements from every side. Agricultural expansion and encroachment are the main issues, along wih high grazing, illegal fodder, harvesting and poaching.

These grasslands are important for Wildlife conservation as they act as a corridor between setellitic meta population of Asiatic lion and the core population in Gir P.A.

Thus, their conservation and management should be ensured in the long term conservation planning of a species.

3.5.4 SURENDRANAGAR DIVISION

Grass vegetation

A total of 48 species of grasses were recorded from this division (Table 3.4).

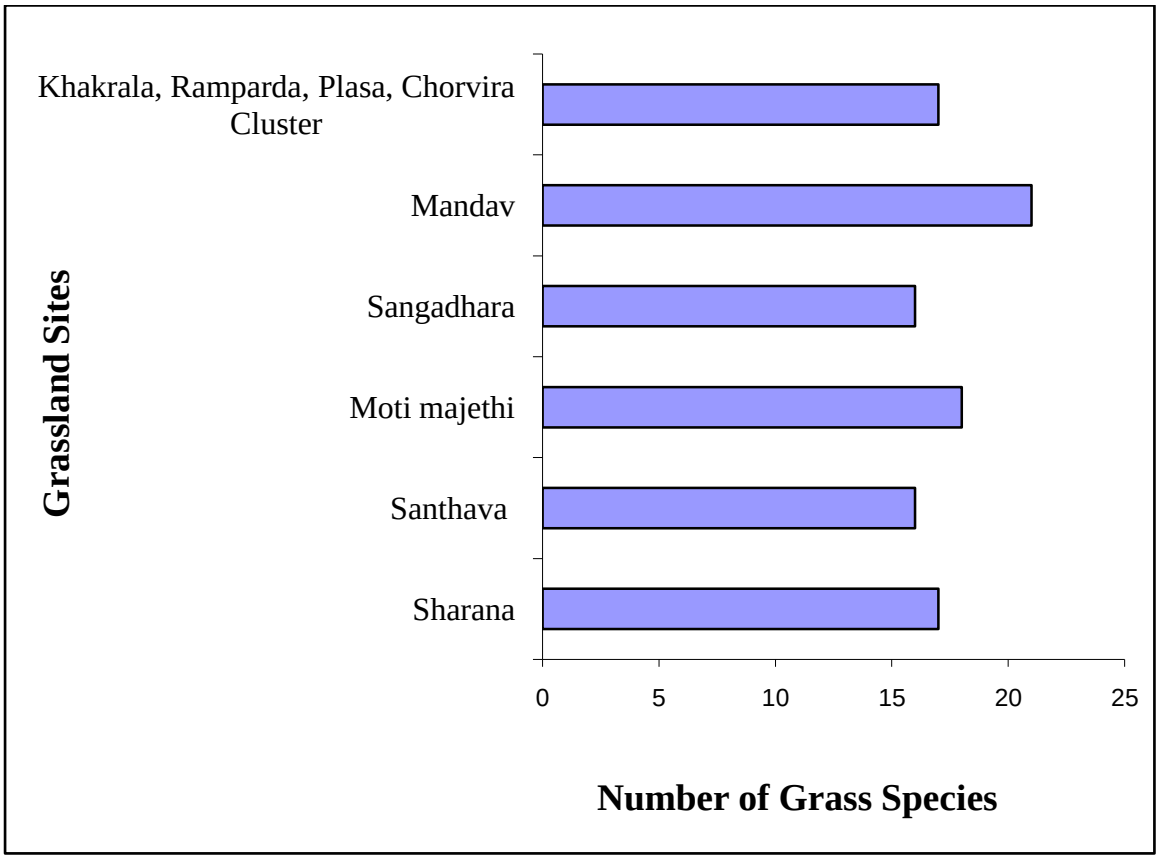
Table 3.4 List of grass species recorded from Surendranagar division

Andropogon pumilius	*Iseilema prostratum*	*Hackelochloa granularis*	*Echonochloa colonum*
Apluda mutica	*Panicum turgidum*	*Halopyrum mcronatum*	*Elyonurus royleanus*
Aristida adscensionis	*Paspalidium germinatum*	*Urochondra setulosa*	*Themeda triandra*
Arundinella setosa	*Saccharum spontaneum*	*Vativeria zizanioides*	*Anthraxon lancifolius*
Brachiaria eruciformis	*Sorghum halepense*	*Paspalum vaginatum*	*Aeluropus lagopoides*
Brachiaria ramosa	*Sporobolous helovolous*	*Sehima nerosum/sacculatum*	*Chrysopogon fulvus*
Cenchrus biflorus	*Sporobolous indicus*	*Iseilema laxum*	
Cenchrus setigerus	*Sporobolous marginatus*	*Borhriochloa pertusa*	
Cenchrus penniseriformis	*Sporobolous verginicus*	*Borhriochloa iischaemum*	
Cenchrus ciliaris	*Cynodon dactylon*	*Chloris barbata*	
Chionachne koenigii	*Dichanthium annulatum*	*Chloris virgata*	
Coix lacryma-jobi	*Eragrostis cilianensis*	*Desmostachya bipinnata*	
Heteropogon contortus	*Eremopogon foveolatus*	*Dactyloctenium aeypticum*	
Ischaemum rugosum	*Eulaliopsis binata*	*Digitaria adscendens*	

There were thirty four perennial, and eleven annual species. Three species are annual-perennial in habit.

When compared site wise, Mandav *vidi* possessed highest number of grass species (21) followed by Motimajethi (18), Sharana and Chorvira cluster with 17 species each. Santhava and Sangadhara had similar number of species 16 each, which was the lowest in the division (Figure 3.17).

Figure 3.17 Number of Grass species at grassland sites of Surendranagar division.



Grass community and association

Four grass communities were recognized in Surendranagar division: *Aeluropus* - *Halopyrum* -*Urochondra, Dicanthium annulatum, Cenchrus – Eragrostis – Aristida* and *Eragrostis – Aristida*. A list of sites representing the community type and associated grass species are given in Appendix-II C.

Similarity among *vidis* in terms of grass species and composition pattern

The cluster in figure 3.18 indicates two distinct sets. One set comprises an outliner of Sharana vidi with a subset suggesting similarity between Santhava *vidi* and Moti Majethi *vidi*.

The other set is divided into two distinct subsets, where Sangadhra *vidi* forms one end, and has affinity with Mandav and Chorvira cluster which are similar. The similarity trend in composition was same. Sarana was the least productive grassland along with Chorvira cluster, and Mandav *vidi* had better grass composition among them (Figure 3.19).

Figure 3.18 Dendrogram showing similarity in grass species occurrence among grassland sites of Surendranagar division.

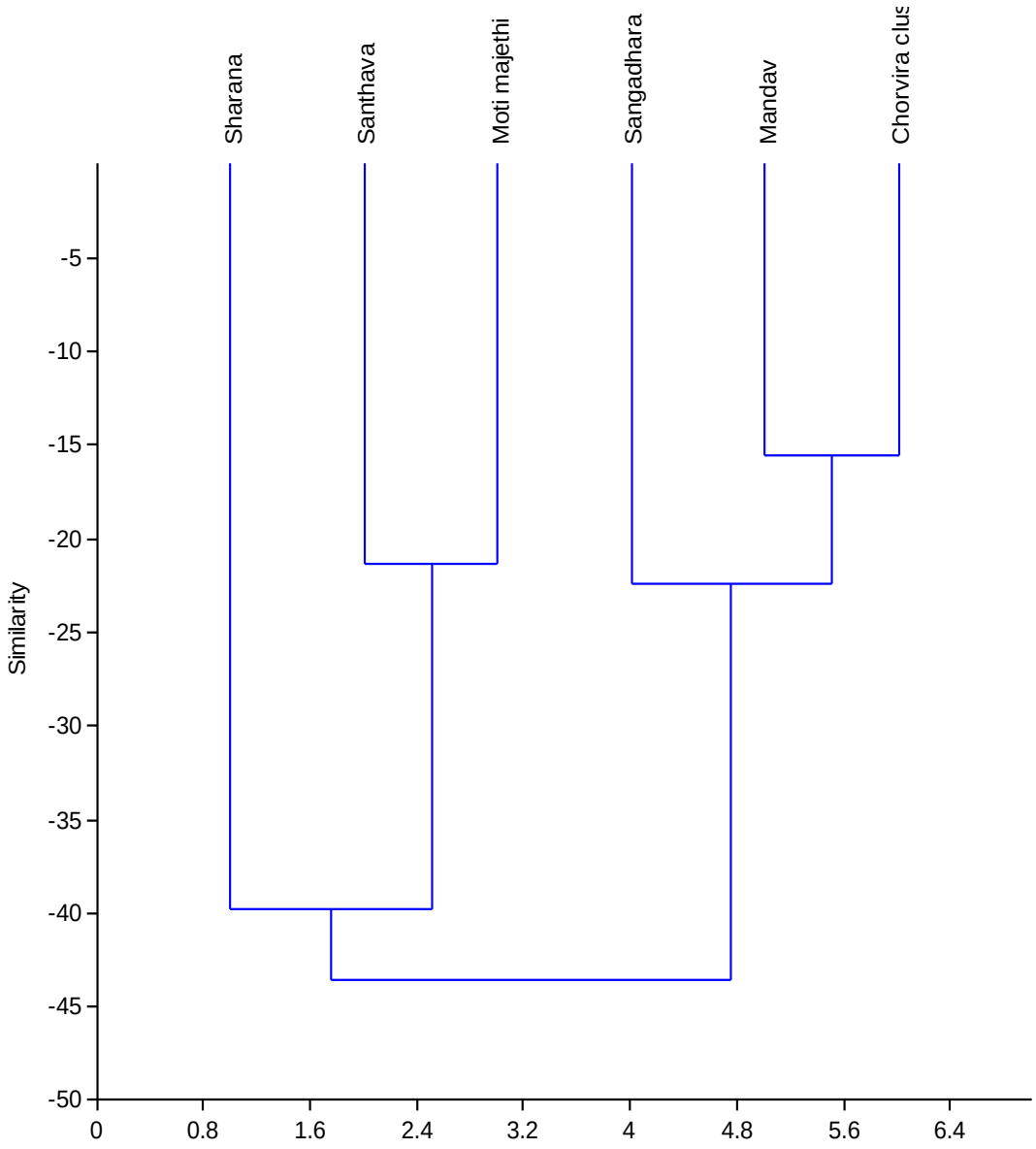
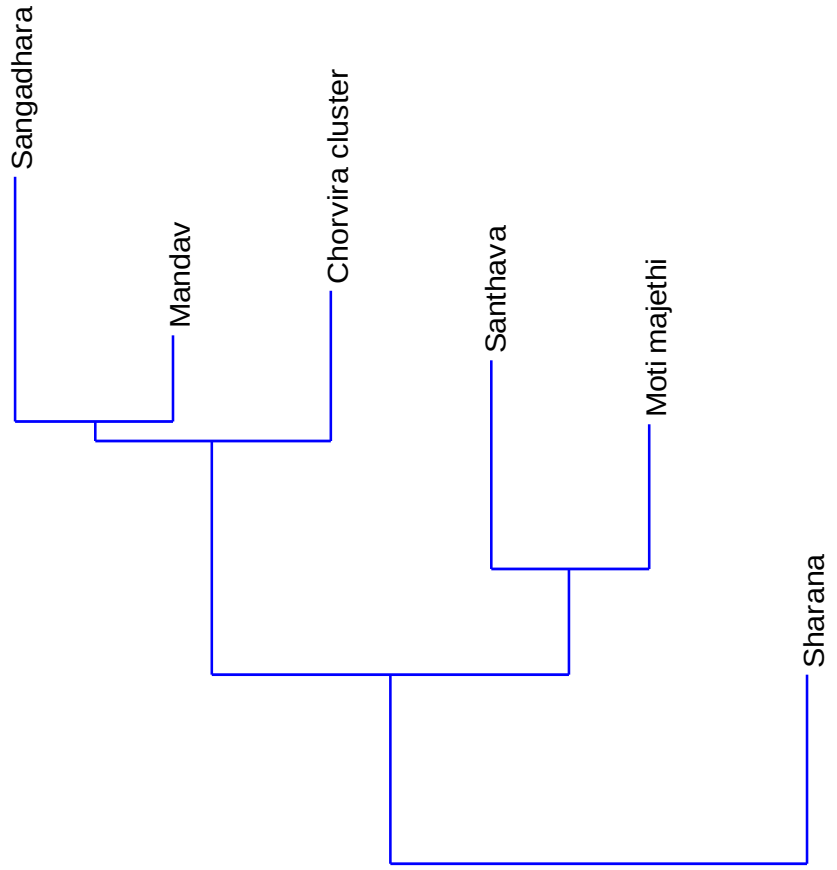


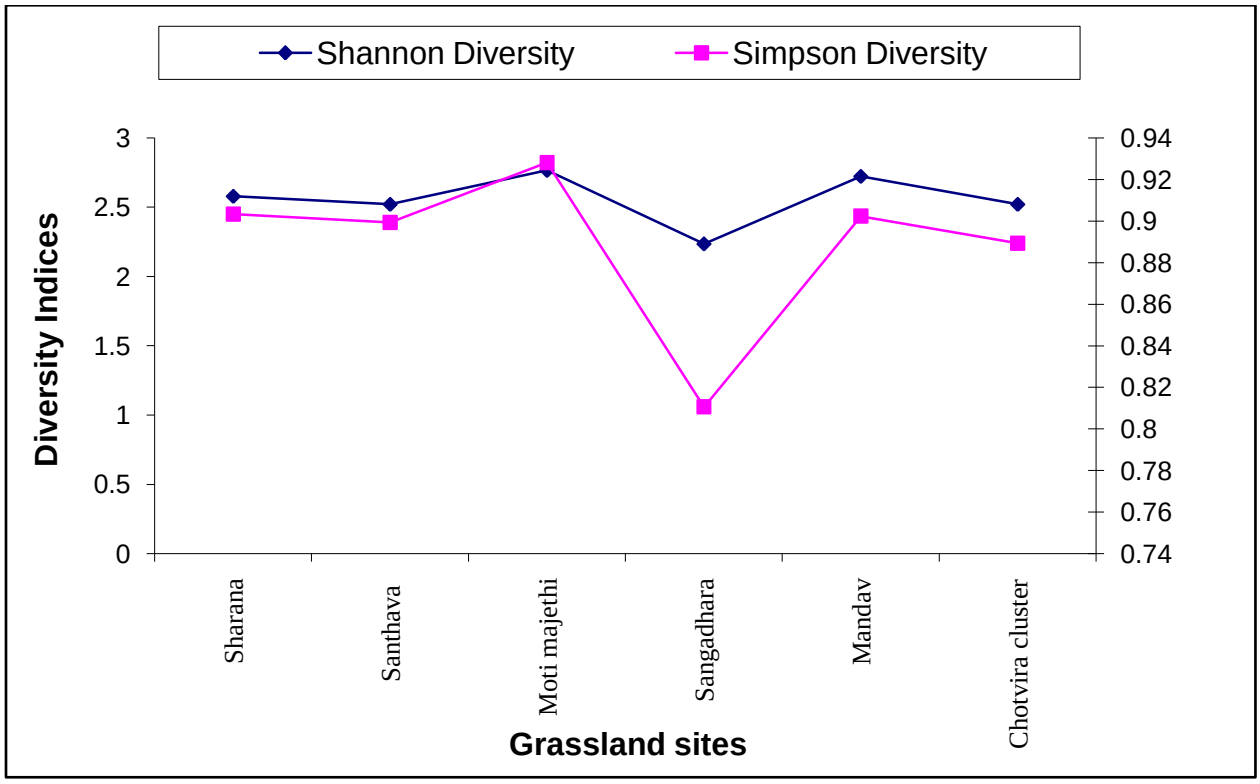
Figure 3.19 Dendrogram showing similarity among grassland sites of Surendranagar division in grass composition.



Grass species diversity in Grassland sites of Gir-East division.

Highest diversity of grasses was recorded from Moti Majethi followed by Mandav and Sarana *vidi*. Shannon diversity of grasses at Santhava *vidi* and Chorvira cluster are similar, whereas slight increase in Simpson diversity at Santhava is observed as compared to Chorvira cluster. The lowest diversity was recorded from Sangadhra *vidi* (Figure 3.20).

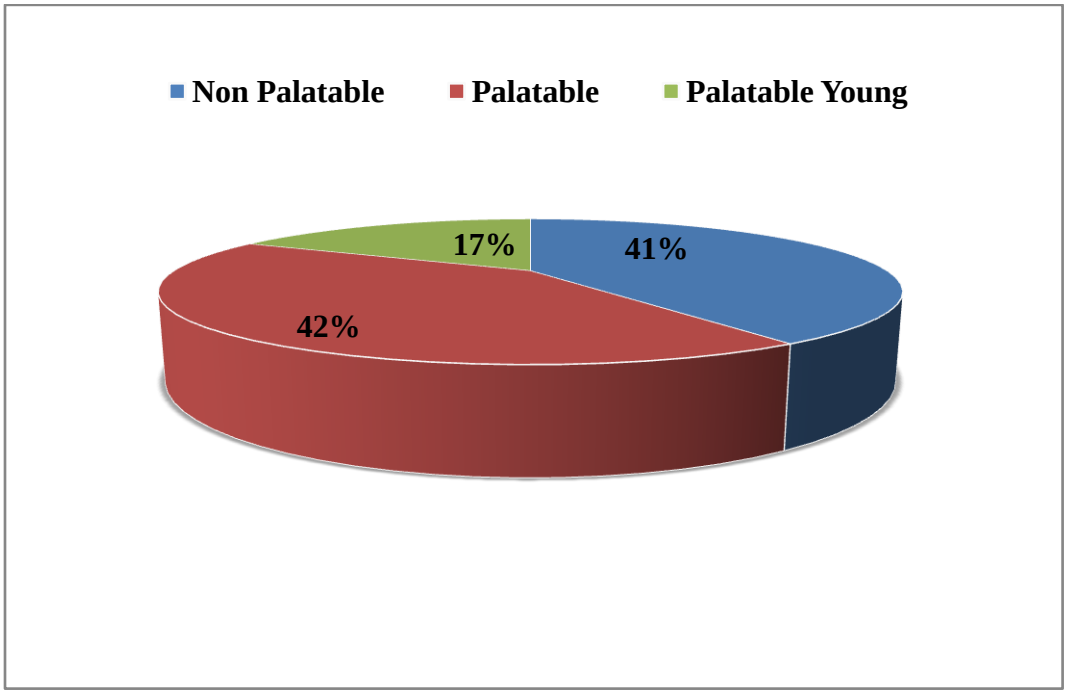
Figure 3.20 Diversity of grasses in grassland sites of Surendranagar division.



Composition of palatable grasses in Surendranagar division

Overall composition of palatable grasses at Surendranagar division was 42% and of non palatable grasses was 41% along with 17% of grasses, which are palatable in the early stage of their life history. The division possesses the least grass cover and productive area as compared to the other parts of the peninsula (Figure 3.21).

Figure 3.21 Percentage compositions of palatable and non palatable grasses in grasslands of Surendranagar division.



Santhava and Moti Majethi *vidis* are situated at the southern boundary of the little Rann, and in the eastern part of the division which receives high rainfall, thus water table is high. Both *vidis* remain flooded during monsoon as they are low laying area, with poor drainage and black cotton soil. It provide ideal conditions for moisture demanding palatable species such as *Dicanthium annulatum, Iselemma laxum* etc. As a result, these areas had high grass species number and diversity.

Sarana *vidi* is a part of unique LRK having diverse form of microhabitats, consisting of swamps, mudflats, saline-uras tracts; *Prosopis* invaded areas and dry grasslands. This

diversity was also reflected in grass species diversity and composition, as it provided scope for grasses of dry, moist and saline environment to flourish.

Sangadhra *vidi* of Halvad taluka is isolated due to fragmentation by agriculture and mining. It lies in a continuous tract of Mandav and Chorvira cluster, suggesting similarity in figures 3.18 and 3.19. The continuous use of the area for anthropogenic activities and its disconnection with other parts resulted in ecological deterioration of the grassland, showing least number of grass species and diversity.

Mandav *vidi* and Chorvadla cluster comprise four different *vidis* namely Khakhrala, Plasa, Ramparda and Chorvira. These are the largest patches of grasslands in the region. These areas share geographical affinities, and are separated by a Chotila- Than highway. Chorvira cluster and Mandav were the most degraded grasslands in the entire division. Reasons for degradation are weathering, soil erosion, and high grazing pressure. Commercial Lignite, Gypsum and Graphite mining are also in practice along with ceramic industry. Top soil was removed from most of the area, due to continuous usage without providing any room for restoration. These areas have cultural, religious and social importance. Fairs and events such as Tarnetar fair attract tourists from worldwide, increasing tourism pressure on the system.

Issues of Grasslands of Surendranagar division.

Grassland *vidis* of Surendranagar division face many issues and threats. Some of the important issues, which require urgent attention, are listed below.

- Invasion of *Prosopis juliflora.*
- High grazing pressure both local and migratory: majority of the local community are pastoralists engaged with cattle rearing profession. The region lies in the annual migratory route of cattle pastoralists, from north Gujarat and Kutch, increasing fodder demand and grazing pressure up to multiple folds.
- Soil erosion
- Uncontrolled mining of Lignite, Graphite and Gypsum.
- Land exploitation by small scale industries, especially of ceramics and development activities.
- Human pressure by religious and cultural tourism.
- Human- wildlife conflict, especially crop raiding by Wild Ass, Blue bull and wild boars.
- Depletion of Biodiversity: due to high ecosystem diversity, region is home to many endangered species such as Wild ass, Indian Wolf, Indian Gazelle, Striped hyena, Spiny tailed lizard (*Uromastrix),* Great Indian Bustard etc. and a variety of avifauna, both waterfowl and terrestrial. It also has a variety of fishes and crustaceans, due to a wide scope of inland fisheries. A species of prawn, *Metapensis cuchhensis* is endemic to the region. All these resources are depleting at a fast rate, due to intense human activities.

3.5.5 JAMNAGAR DIVISION: A- "JAM".

Grass composition

Fourty one species of grass were recorded in present survey from division (Table 3.5).

Table 3.5 List of grass species recorded from Jamnagar division A "JAM".

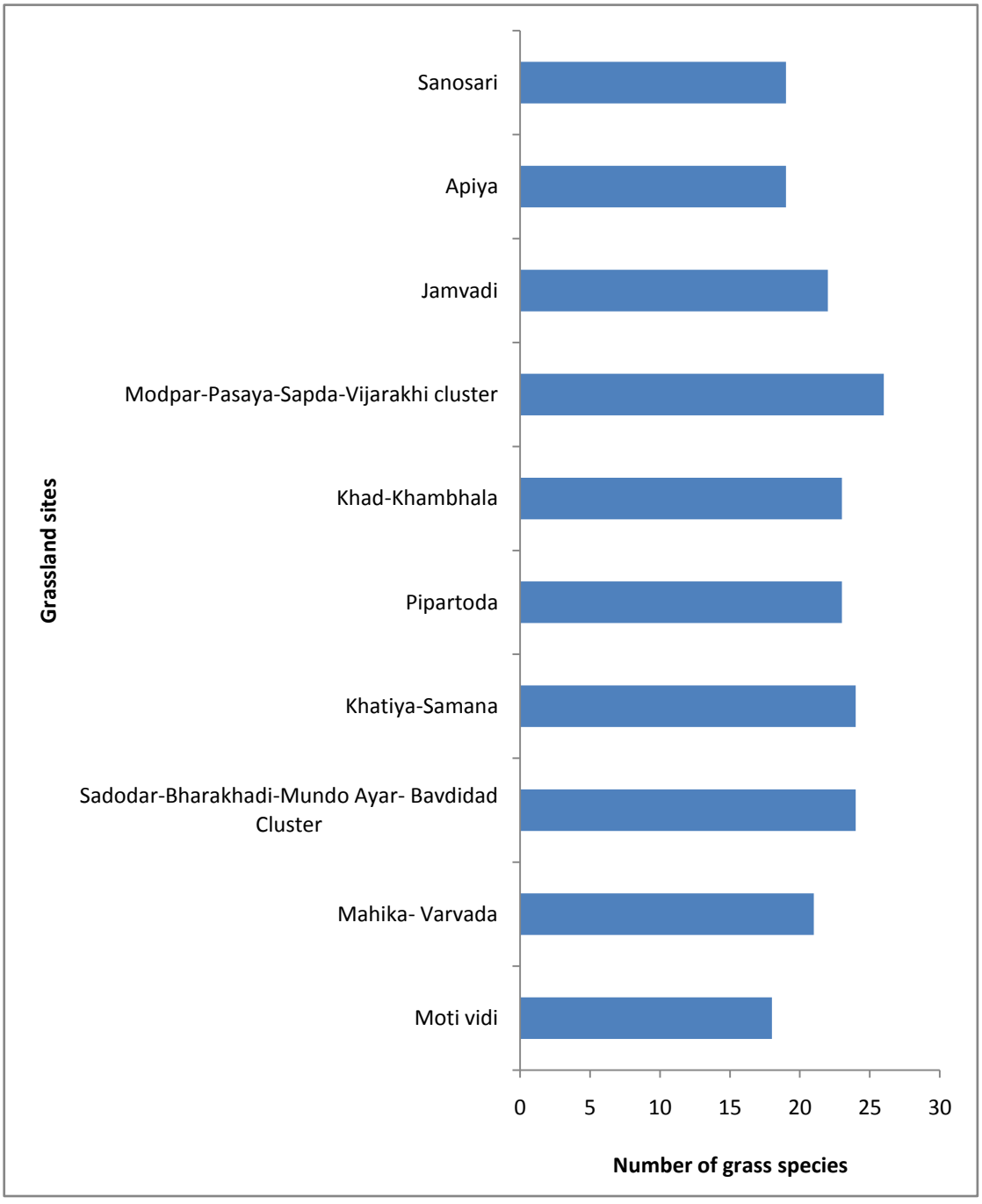
Andropogon pumilius	*Panicum turgidum*	*Borhriochloa intermedia*
Apluda mutica	*Paspalidium flavidum*	*Borhriochloa pertusa*
Aristida adscensionis	*Saccharum spontaneum*	*Borhriochloa iischaemum*
Brachiaria eruciformis	*Sporobolous helovolous*	*Chloris barbata*
Brachiaria ramosa	*Sporobolous marginatus*	*Chloris virgata*
Cenchrus biflorus	*Cynodon dactylon*	*Desmostachya bipinnata*
Cenchrus setigerus	*Dichanthium annulatum*	*Dactyloctenium aeypticum*
Cenchrus penniseriformis	*Eragrostis cilianensis*	*Digitaria adscendens*
Cenchrus ciliaris	*Eremopogon foveolatus*	*Dinebra retroflexa*
Chionachne koenigii	*Eulaliopsis binata*	*Elyonurus royleanus*
Cymbopogon martinii	*Hackelochloa granularis*	*Anthraxon lancifolius*
Heteropogon contortus	*Themeda cymbaria*	*Melenocenchris jacquemontii*
Ischaemum rugosum	*Sehima nerosum/sacculatum*	*Chrysopogon fulvus*
Panicum antidotale	*Iseilema laxum*	

There were thirty six perennial, and twelve annual species. Two species were annual-perennial in habit.

Highest number of grass species was found at Modpar-Pasaya-Sapda-Vijarakhi cluster (26), followed by Sadodar-Bharakhadi cluster and Khad- Khambhala with (24) species each. Pipartoda and Khatiya-Samana had (23) species each. Species number decline

thereafter from Jamvadi (22), to Apaiya- Sanosari with 19 species each to the lowest of 18 species recorded from Moti *vidi* in Jamjodhpur taluka (Figure 3.22).

Figure 3.22 Number of Grass species at grassland sites of Jamnagar division-A "Jam"division.



Grass community and association

Six different grass communities were recognized in Jamnagar division-A “Jam” division: *Sehima- Dicanthium, Heteropogon - Cymbopogon, Sehima – Aristida, Bothriochloa-Aristida, Cenchrus – Dicanthium* and *Eragrostis – Aristida*. A list of sites representing the community type and associated grass species are given in Appendix-II D.

Similarity among *vidis* in terms of grass species composition pattern

Grasslands of the division exhibit patchy distribution.Similarity among *vidis* in this division was influenced by geographical location, interdistance, and topographic affinities. As a result, Apaiya-Sanosari, Sadodar cluster- Khatiya Samana, Pipartoda-Khad Khambhada, and Mahika Varvada - Moti vidi share similarity. Outliner of Jamvadi and Modpar cluster, were observed with their respective subsets Figure 3.23.

The results reflected the same trend when sites were compared on composition basis (Figure 3.24).

Figure 3.23 Dendrogram showing similarity among grassland sites of Jamnagar division-A "Jam" division in grass species occurence.

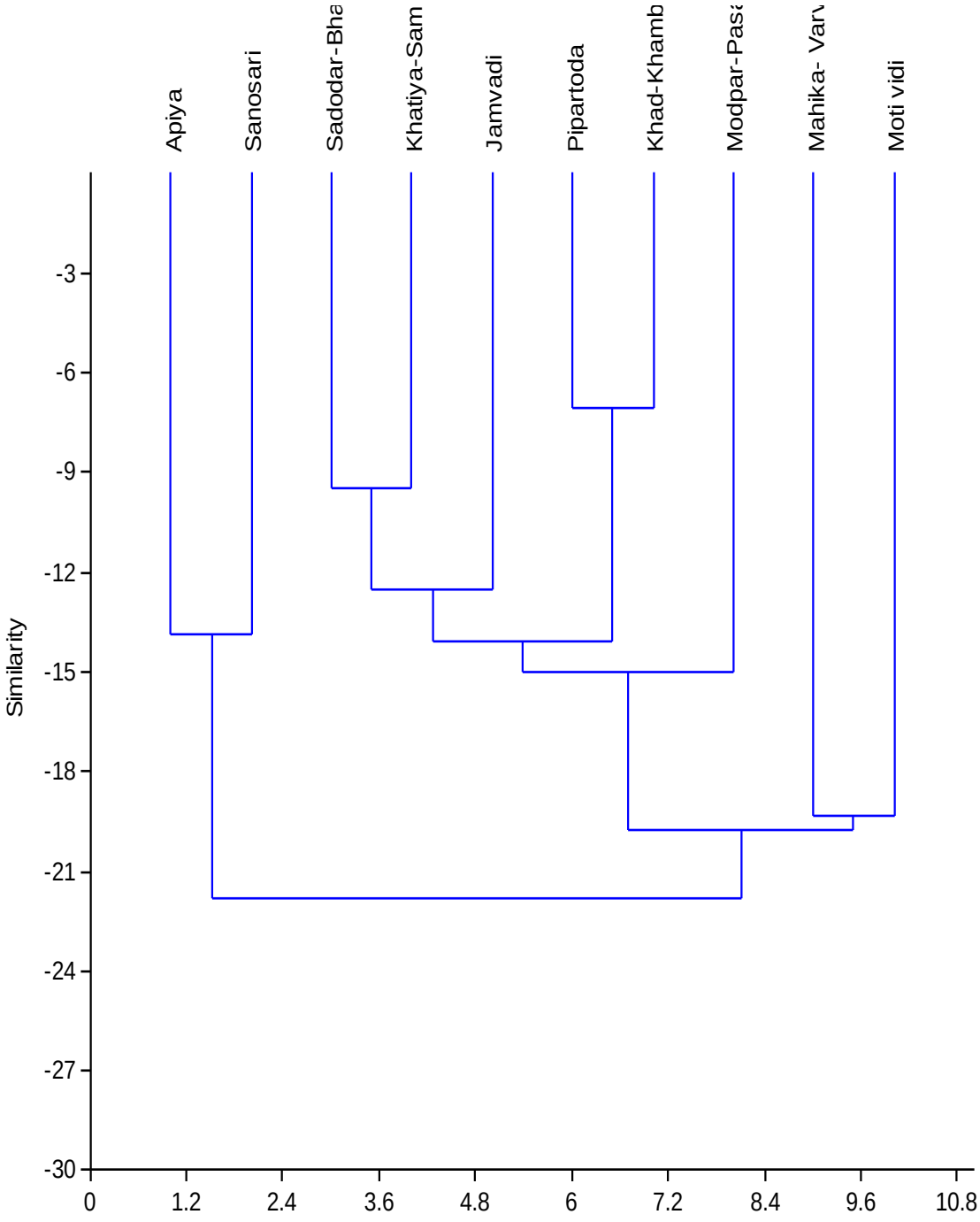
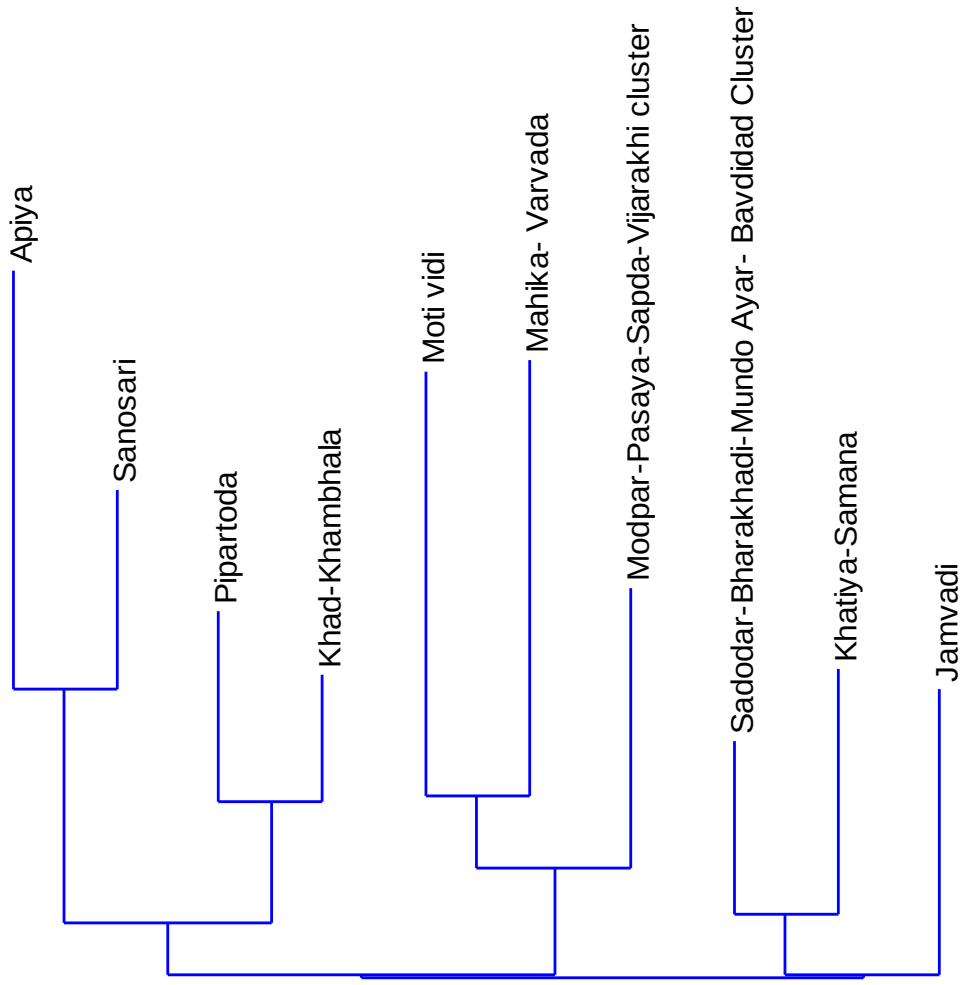
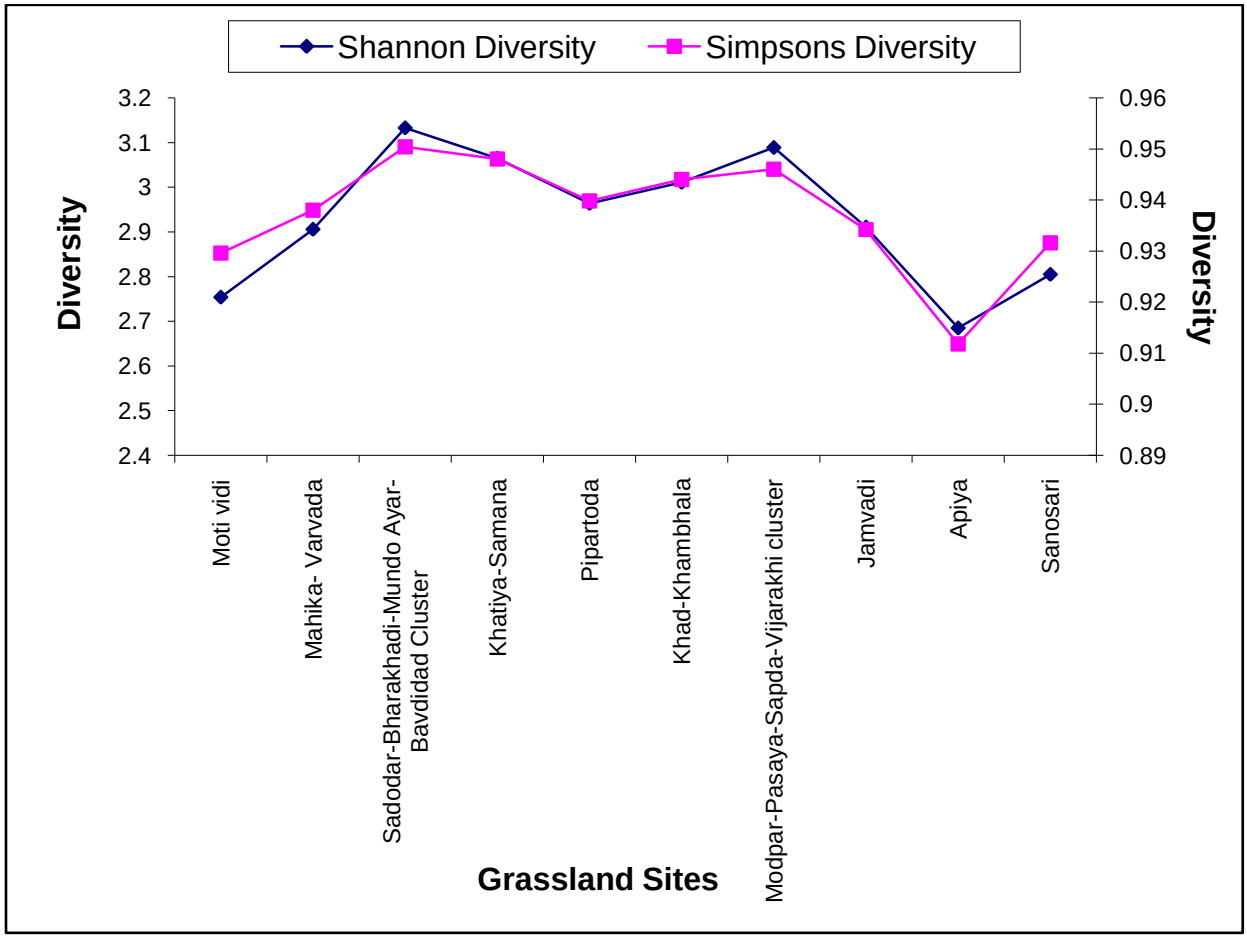


Figure 3.24 Dendrogram suggesting similarity among grassland sites of Jamnagar division-A "Jam" division in grass composition.



Grass species diversity: Highest diversity of grasses was recorded from Sadodar cluster, followed by Modpar cluster and Katiya Samana. Grass diversity increases from Moti vidi to attain maximum at Sadodar cluster, and thereafter decrease slightly at Pipartoda. It increases further to Modpar cluster and decreases thereafter to attain its minimum at Apaiya, which is the most degraded *vidi*. (Figure 3.25).

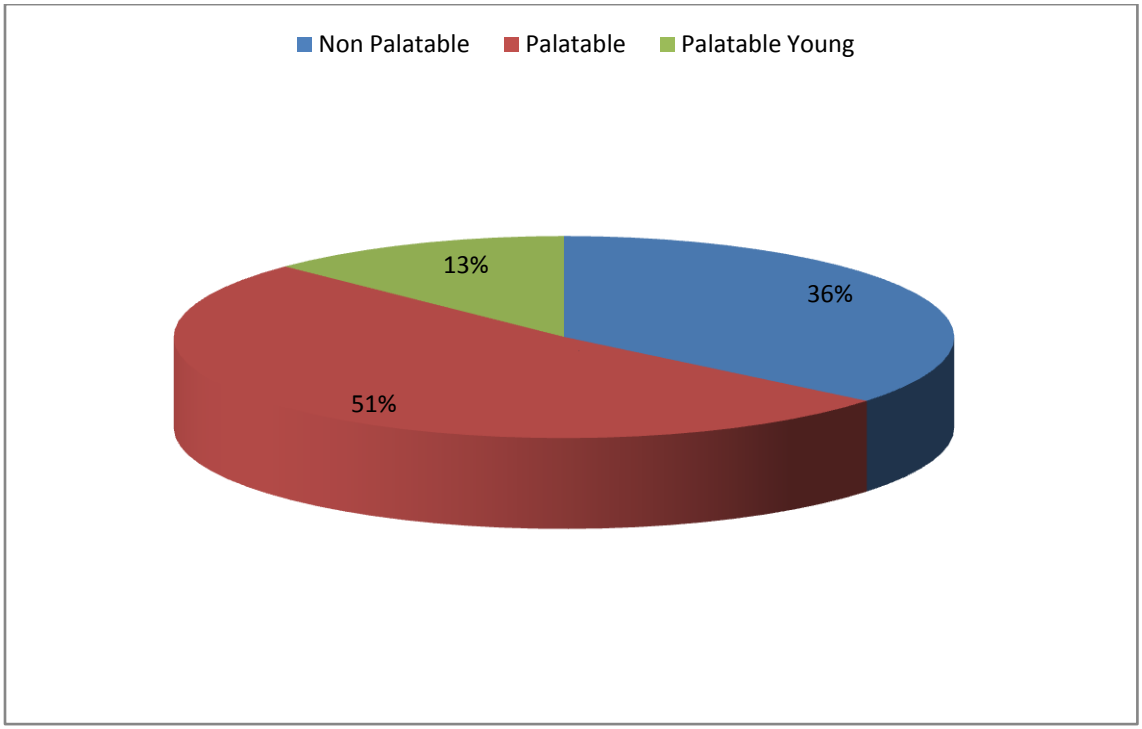
Figure 3.25 Diversity of grasses in grassland sites of Jamnagar division- A "Jam" division.



Composition of palatable grasses in Jamnagar division-A "Jam" division.

Total composition shows 51% of palatable grasses and 36% non palatable grasses, and composition of grasses which are palatable when young was 13%. It suggests that there are 64% of palatable grasses in the entire division Figure 3.26.

Figure 3.26 Percentage compositions of palatable and non palatable grasses in grasslands of Jamnagar division-A "Jam" division.



Issues of Jamnagar division-A "Jam" division.

High grazing pressure, encroachment, pollution and urbanization due to industrialization are some of the issues which require urgent attention. *Vidis* near Sadodar cluster are under the windmill project, which is directly affecting the biodiversity and ecological productivity of grasslands.

3.5.6 JAMNAGAR DIVISION: B - "RJT".

Grass composition: Fifty one grass species were recorded from the division (Table 3.6)

Table 3.6 List of grass species recorded from Jamnagar division B "RJT".

Andropogon pumilius	*Saccharum spontaneum*	*Sehima nerosum/sacculatum*
Apluda mutica	*Sorghum halepense*	*Iseilema laxum*
Aristida adscensionis	*Sporobolous helovolous*	*Borhriochloa pertusa*
Arundinella setosa	*Sporobolous indicus*	*Borhriochloa iischaemum*
Brachiaria eruciformis	*Sporobolous marginatus*	*Chloris barbata*
Brachiaria ramosa	*Sporobolous verginicus*	*Chloris virgata*
Cenchrus biflorus	*Cynodon dactylon*	*Desmostachya bipinnata*
Cenchrus setigerus	*Dichanthium annulatum*	*Dactyloctenium aeypticum*
Cenchrus ciliaris	*Eragrostis cilianensis*	*Digitaria adscendens*
Chionachne koenigii	*Eremopogon foveolatus*	*Dinebra retroflexa*
Coix lacryma-jobi	*Eulaliopsis binata*	*Echonochloa colonum*
Cymbopogon martinii	*Hackelochloa granularis*	*Elyonurus royleanus*
Heteropogon contortus	*Halopyrum mcronatum*	*Themeda triandra*
Ischaemum rugosum	*Tragus biflorus*	*Anthraxon lancifolius*
Panicum turgidum	*Urochondra setulosa*	*Melenocenchris jacquemontii*
Paspalidium flavidum	*Vativeria zizanioides*	*Aeluropus lagopoides*
Paspalidium germinatum	*Paspalum vaginatum*	*Chrysopogon fulvus*

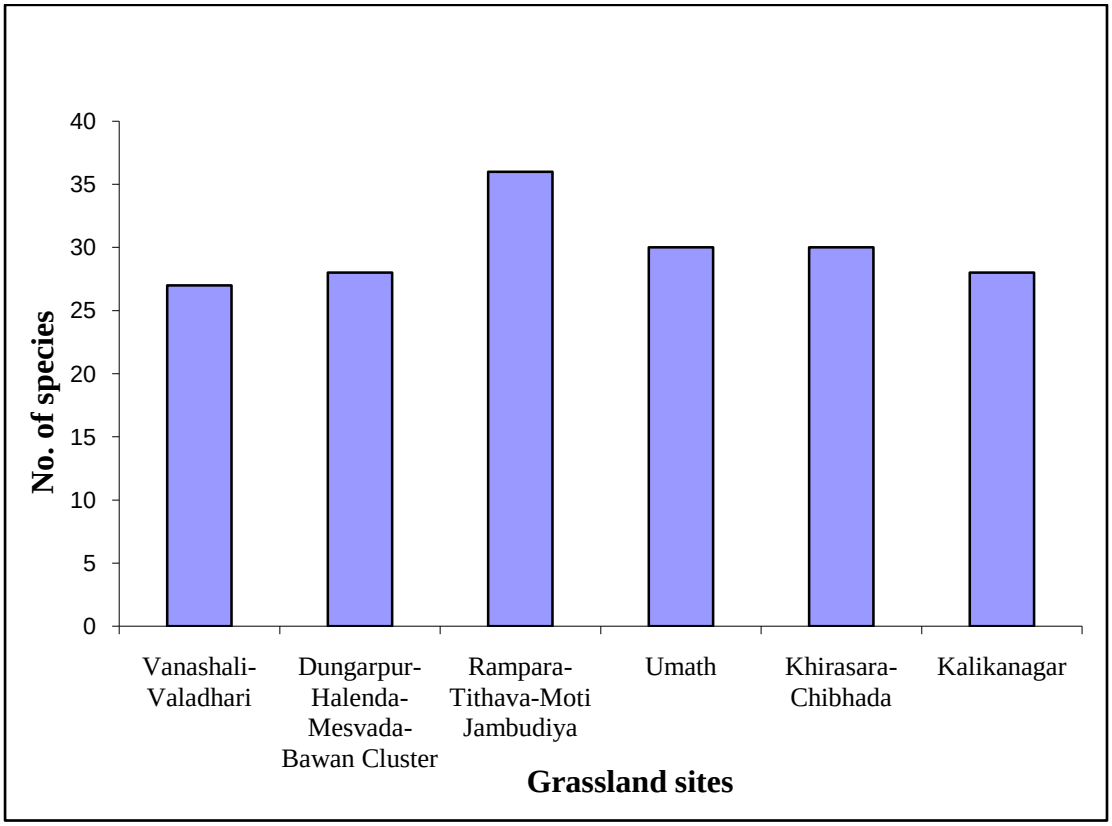
There were thirty three perennial, and fourteen annual species. Three species were annual- perennial in habit.

Highest number of grass species was recorded from Ramparda- Tithava- Mota Jambudiya cluster of Vakaner taluka (36), followed by Umath *vidi* and Khirasara- Chabhada cluster with 30 species each. Dungarpur cluster and Kalikanagar *vidi* shared similar number of grass species (28), which was slightly higher than that of Vanashali- Valadhari cluster with 27 species, which was the lowest (figure 3.27).

There is no significant difference in number of species among sites, as all sites are large patches, with similar climate, topography and land use factors. Slight variation can be explained on the basis of geographical area comprised by the site. Larger patches have high grass diversity and composition compared to smaller areas. Landscape heterogeneity among patches also helps the species to stabilized indicating less difference in species number among *vidis*.

As a result, the highest diversity was recorded from Ramparda-Tithava-Mota Jambudiya cluster which comprises an area of more than 3237.63 hectares. It is followed by Khirasara- Chabhada cluster, Dungarpur-Halenda cluster and Umath *vidi* of Jasdan taluka which share geographic affinity. Lowest diversity was recorded from Vanashali-Valadhari cluster of Gondal Taluka, which was most exploited as compared to the other regions of this division (Figure 3.30).

Figure 3.27 Number of Grass species at grassland sites of Jamnagar division-B "RJT" division.



Grass community and association

Two different grass communities were recognized in Jamnagar division-B "Rjt" division: *Sehima- Dicanthium*, and *Cenchrus – Dicanthium*. A list of sites representing the community type and associated grass species are given in Appendix-II E.

Similarity among *vidis* in terms of grass species and composition pattern

Cluster analysis in figure 3.28 suggests one distinct outliner of Kalikanagar, and two distinct sets. An outliner was a result of geographical isolation of Kalikanagar *vidi* of Morbi taluka, situated at northern boundary of the division. It shares an affinity with *vidis*

of Surendranagar division, especially of Little Rann area. Grass diversity was influenced by Uras and saline track; with marsh habitat in some parts due to close proximity to Surajbari creek, of Gulf of Kutchh.

One set shows similarity among *vidis* of Jasdan and Vakaner taluka, namely Dungarpur-Halenda- Mesvada-Bawal cluster and Rampara-Tithava- Mota Jambudiya cluster respectively. These clusters are geographically apart, but are large patches of grasslands with topographic affinities. Both the clusters are on Deccan trap in central highland along with Umath *vidi* which indicate an outliner due to protection.

The other set suggest similarity among *vidis* of Rajkot and Gondal talukas, namely Vanashali- valadhari cluster of Gondal and Khirasara-Chibhada cluster of Rajkot.These grassland patches are adjutant to each other.

The more magnified grouping was observed when the sites were co-related for similarities in their grass composition. The pattern was influenced by geographical and topographic affinities. The cluster in figure 3.29 suggest that in terms of species composition and diversity, *vidis* of Gondal taluka show similarity with Kalikanagar, and both are similar to Khirasara-Chibhada cluster. All show an affinity to *vidis* of Vakaner clusters, and the entire grassland areas are similar to the Dungarpur cluster in terms of grass composition. This mean that all the grass species present in the division, were represented by Dungarpur cluster.

Figure 3.28 Dendrogram showing similarity among grassland sites of Jamnagar division-B "RJT" division in grass species occurrence and distribution.

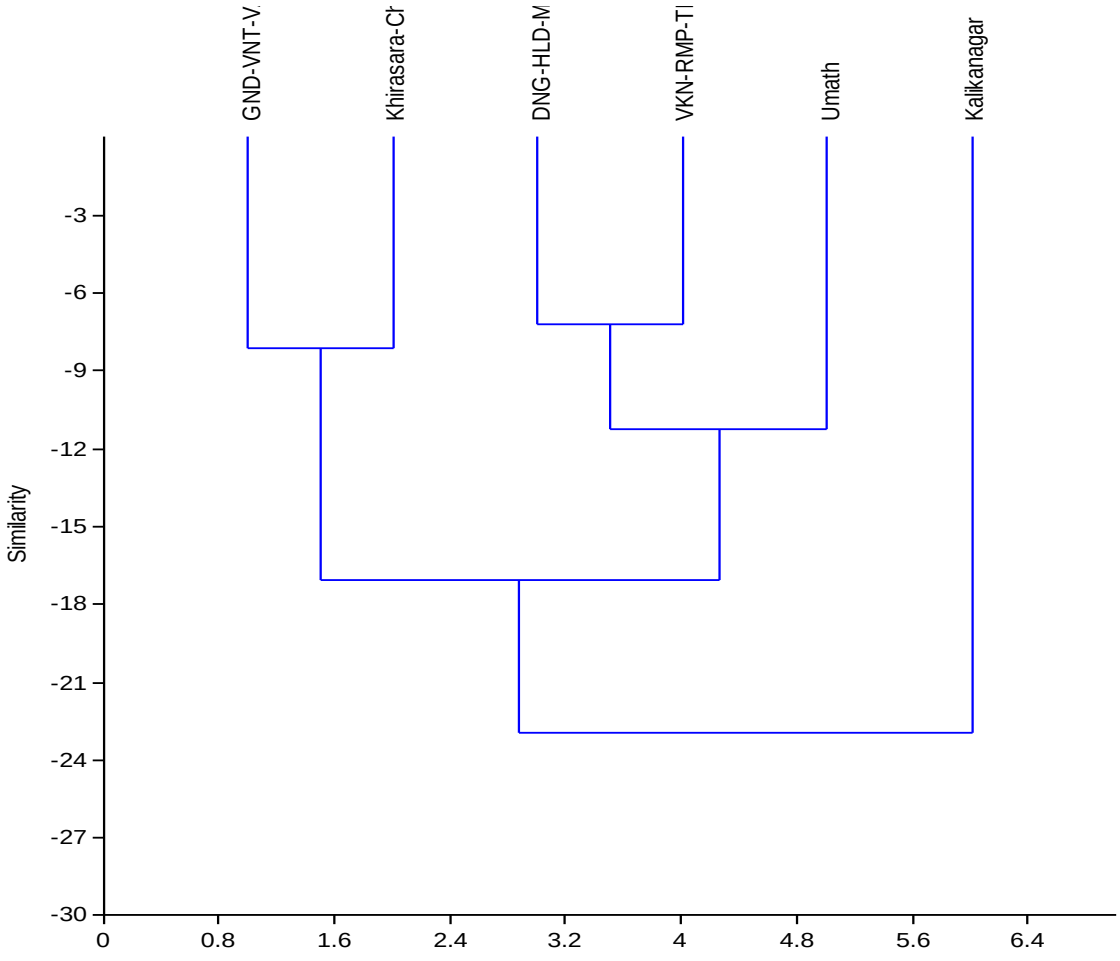


Figure 3.29 Dendrogram showing similarities among grassland sites of Jamnagar division- B "RJT" division in grass composition.

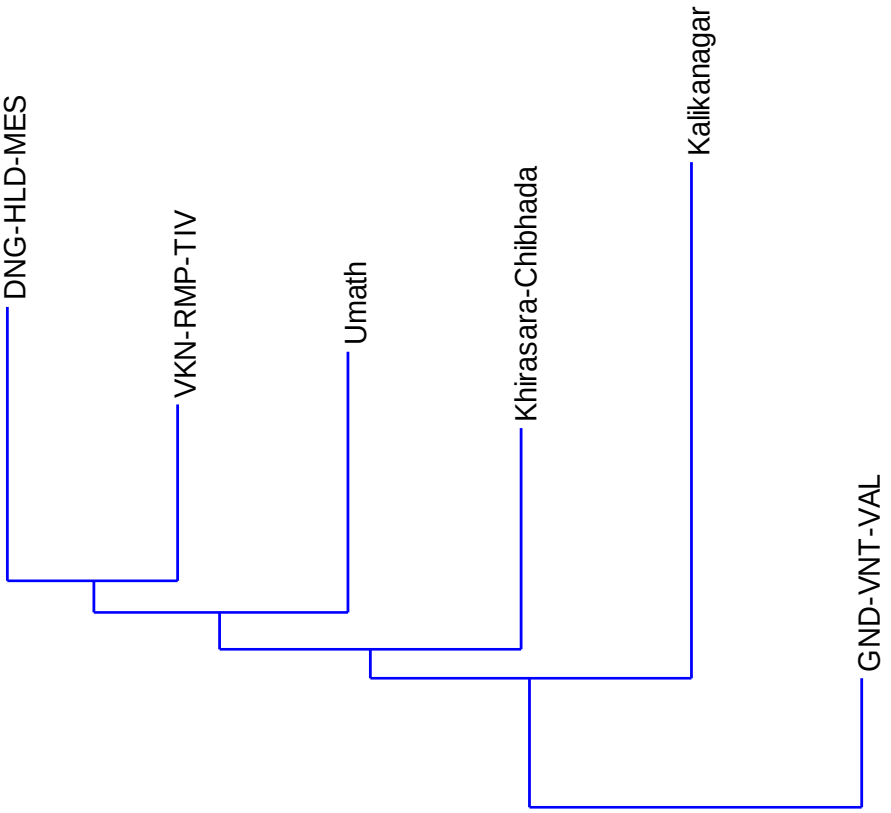
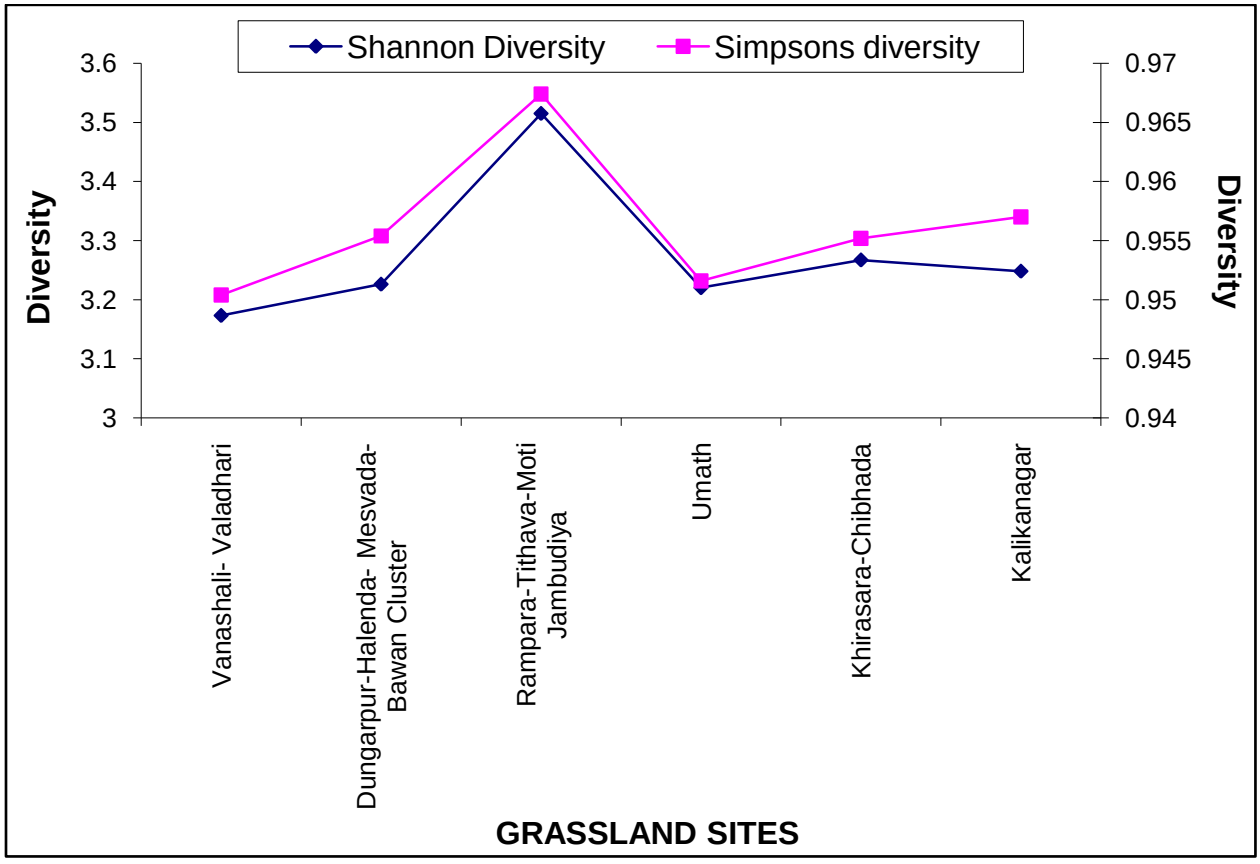


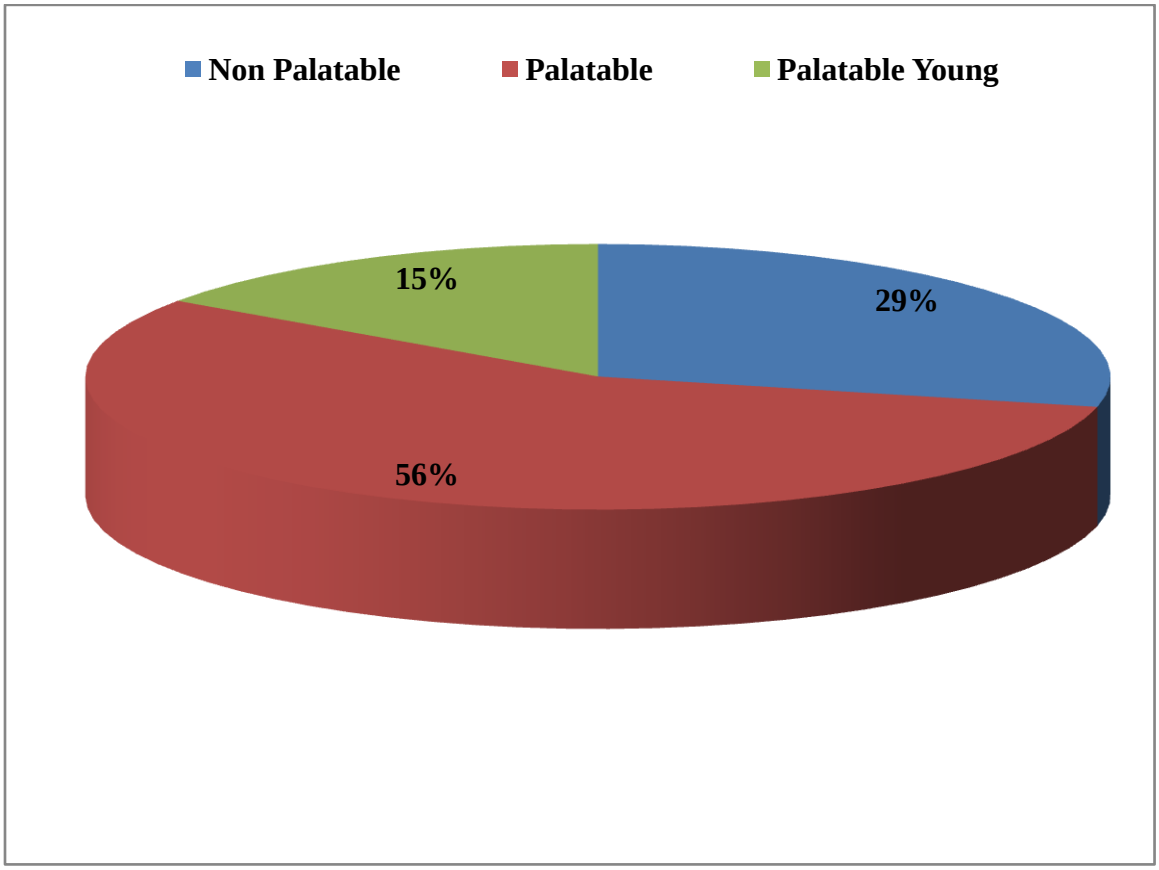
Figure 3.30 Diversity of grasses in grassland sites of Jamnagar division- B "RJT" division.



Composition of palatable grasses in Jamnagar division- B "RJT" division.

Overall composition of palatable grasses at Jamnagar division- B "RJT" was 56% and of non palatable grasses was 29% along with 15% of grasses which were palatable in early stage of their life history. The division was the highest grass productive area as compared to the other parts of the peninsula (Figure 3.37).

Figure 3.31 Percentage compositions of palatable and non palatable grasses in grasslands of Jamnagar division-B "RJT" division.



Issues of grasslands of Jamnagar division- B "RJT".

As mentioned, grasslands in this division are in large patches, with heterogeneity among them. This heterogeneity was greatly disturbed in the recent past due to grazing pressure and urbanization. It requires immediate attention in this sector, to conserve and utilize native grasslands of the region.

3.5.7 Study among grassland divisions of Saurashtra.

Grass flora: A total of 58 species were recorded from Saurashtra penninsula, of which thirty eight species were perennial, seventeen species were annual and three species were annual-perennial in habit. A list of grass species recorded from Saurashtra in the study, along with its habit and palatibility is given in Appendix I.

Table 3.7 shows the tribe wise distribution of genera found in the region and their percentage of occurrence.

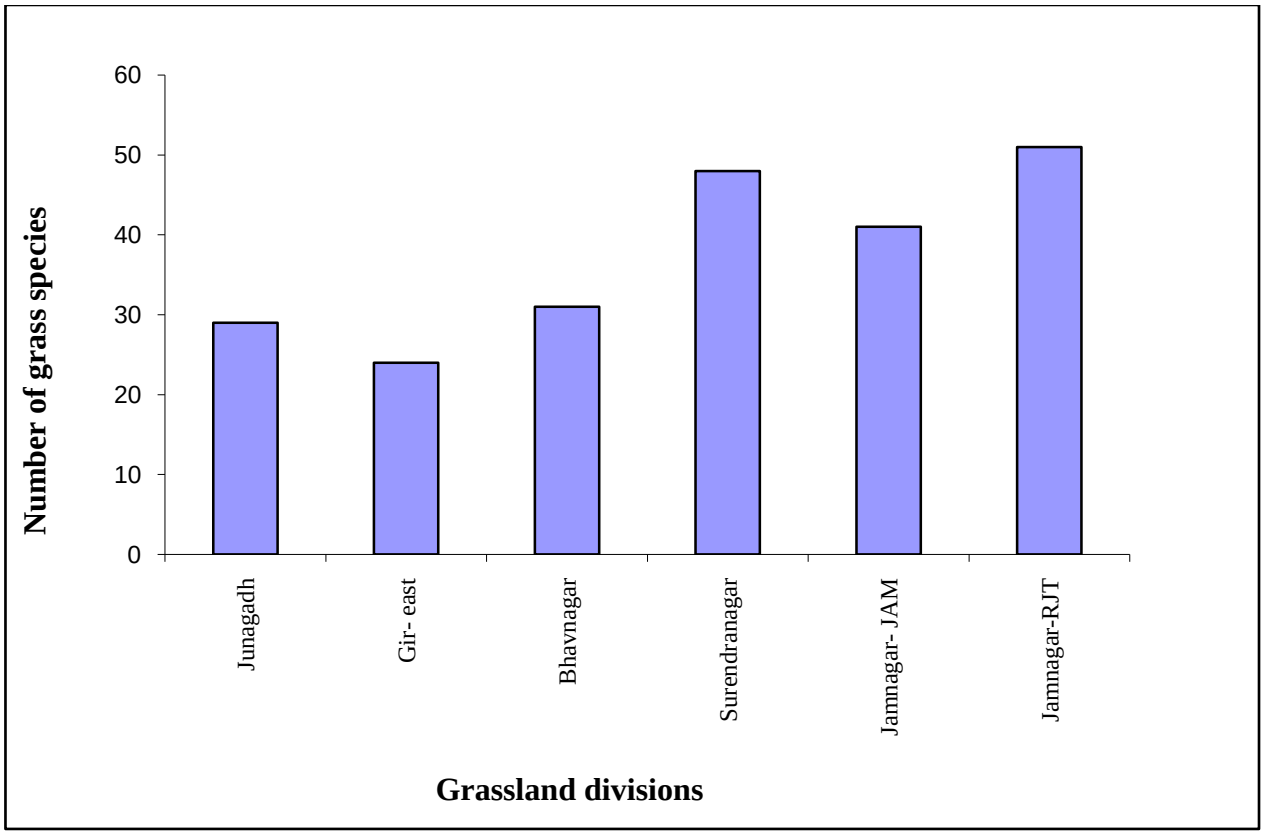
I Panicoideae			
S.No	**Tribe**	**Species**	**%**
1	Andropogoneae	24	54.62525
2	Maydeae	2	2.569697
3	Paniceae	13	15.98182
Total of Panicoideae		39	73.176
II Pooideae			
1	Aristideae	2	13.95101
2	Sporoboleae	5	1.45303
3	Chlorideae	4	3.440404
4	Eragrosteae	5	6.673232
5	Aeluropodeae	1	0.25
6	Arundineae	1	0.9444
7	Zoyseae	1	0.11111
	Total of Pooidae	19	26.832
	Grand Total	58	100

It is evident from the table that sub-family Panicoideae is well represented in the area with all its tribes while the sub-family Pooideae has poor distribution. The tribes Andropogoneae and Paniceae are dominant tribes of the region. The peninsular India is one of the two main centers of high concentration of the Andropogoneae and Paniceae

(Stroke, 1942). It was found to be also true for the Saurashtra Penninsula. Andropogoneae, Paniceae, Aristideae, Chlorideae, and Eragrosteae are chiefly tropical and sub tropical with their extension in temperate regions (Patunkar, 1980) and are well represented here.

Grass species distribution among divisions: Grassland *vidis* of Jamnagar division- B- "RJT" posses the highest number of grass species (51), followed by Surendranagar division (48), Jamnagar division- A-"Jam"(41), Bhavnagar division(31), Junagadh division(29) and Dhari- Gir east division with 24 species which was least among all (Figure 3.32).

Figure 3.32 Number of Grass species recorded at Forest divisions of Saurashtra.



Grassland Communities

Nine grassland communities were recognized in Saurashtra, in relation to different habitats, micro-geomorphic conditions and factors of use. *Sehima- Dichanthium* type was recorded in hilly to mild undulating terrain area on gravel soil and basalt underlying rocks. *Sehima- Aristida* type was recorded from hills, piedmont slopes, and foothills. Whereas in similar conditions with oceanic ecoclimate on level soils, as in the intervening valley portions *Dichanthium* type was found to be dominant. *Heteropogon – Cymbopogon* and *Bothriochloa – Aristida* communities are related to the habitat conditions. For example, *Bothriochloa – Aristida* community dominates on dry hills and hillocks with mild grazing. Low lying heavy soils and alluvial plains consisted *Cenchrus – Dichanthium* community. *Eragrostris- Aristida* community dominated highly degraded grasslands with sandy soil, along with *Cenchrus- Eragrostris- Aristida* community which dominate grasslands with similar conditions but with moderate use. *Aleuropsis- Halopyrum- Urochondra* community was recorded from only one site of Surendranagar division which consists sandy, saline marsh condition and salt water creek. Division wise distribution of grassland sites representing grassland communities is given in Appendix II.

Similarity among divisions in terms of grass species composition pattern

To investigate these trends, exploratory analysis was conducted. Cluster analysis and multi dimensional scaling MDS, which represented similarity among divisions through dendrograms and two dimensional plot (Figures 3.33, 3.34, 3.35). These figures show the arrangement of grassland divisions with respect to species similarity matrix and composition.

Cluster in figure 3.33 suggests that Surendranagar division was isolated and represented as outliner. The set indicates that Jamnagar division –A- "Jam" was unique and share similarity with other divisions in order as represented in subset, where Bhavnagar division was an outliner and the sub-subset containing Jamnagar division-B-"RJT", Junagadh division and Dhari-Gir east division shared close similarity. Clear results were obtained when divisions were classified on the bases of co-relation in grass cover and composition, suggesting neighbouring groups. Junagadh division and Dhari Gir east division shared similarity among them, and Bhavnagar division was similar from Dhari-Gir east side to the cluster. Likewise Surendranager division and Jamnagar division-B-"RJT" were similar and Jamnagar division-A-"Jam" shared similarity from "RJT" side figure 3.34.

A two dimensional MDS plot revealed that Junagadh – Gir east were similar with Bhavanagar division at its side. And both parts of Jamnagar division were similar with Surendranagar as outliner (figure 3.35).

Figure 3.33 Dendrogram showing similarity among grassland divisions in grass species occurrence and distribution.

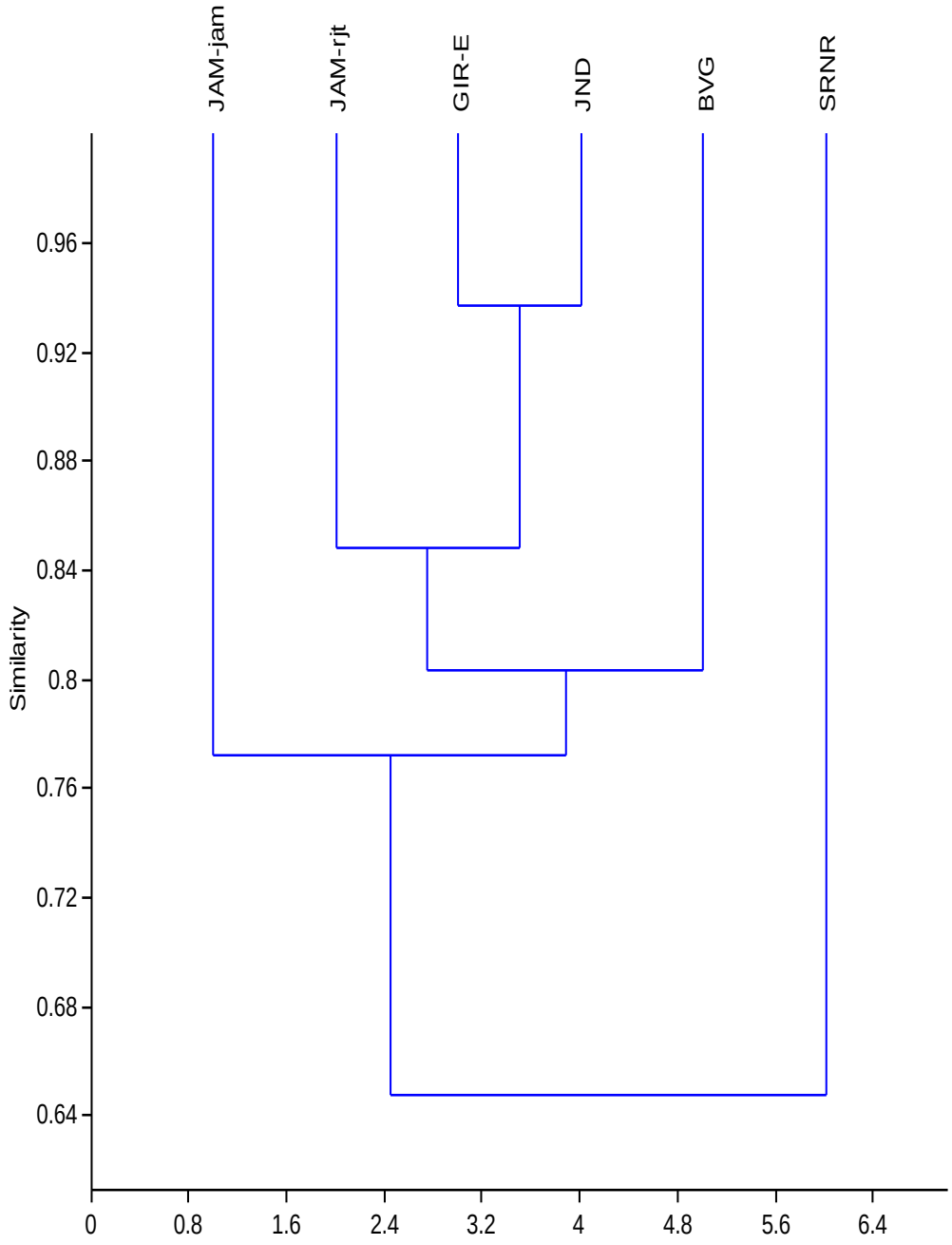


Figure 3.34 Dendrogram showing similarity among grassland divisions in grass composition.

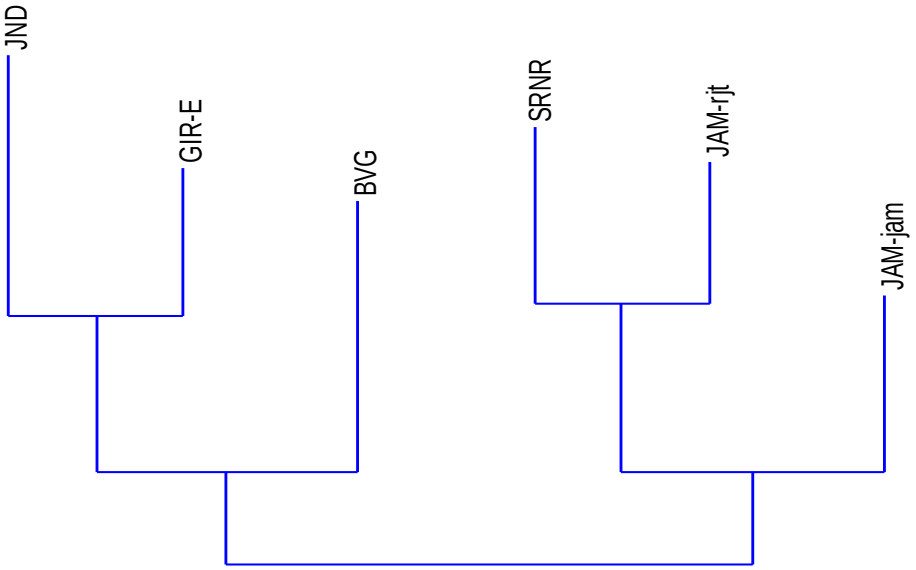
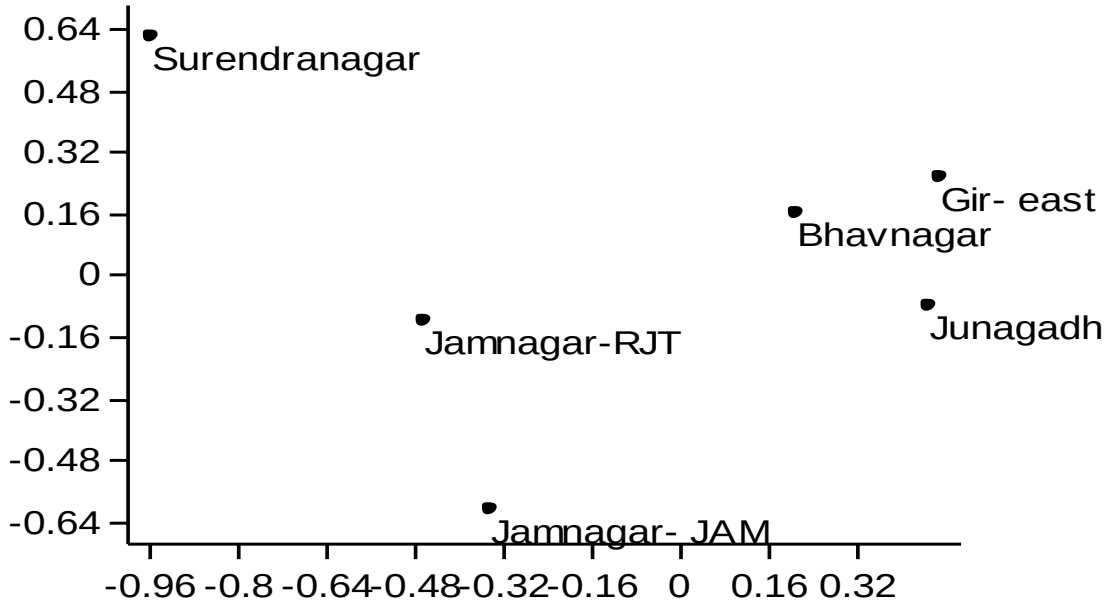


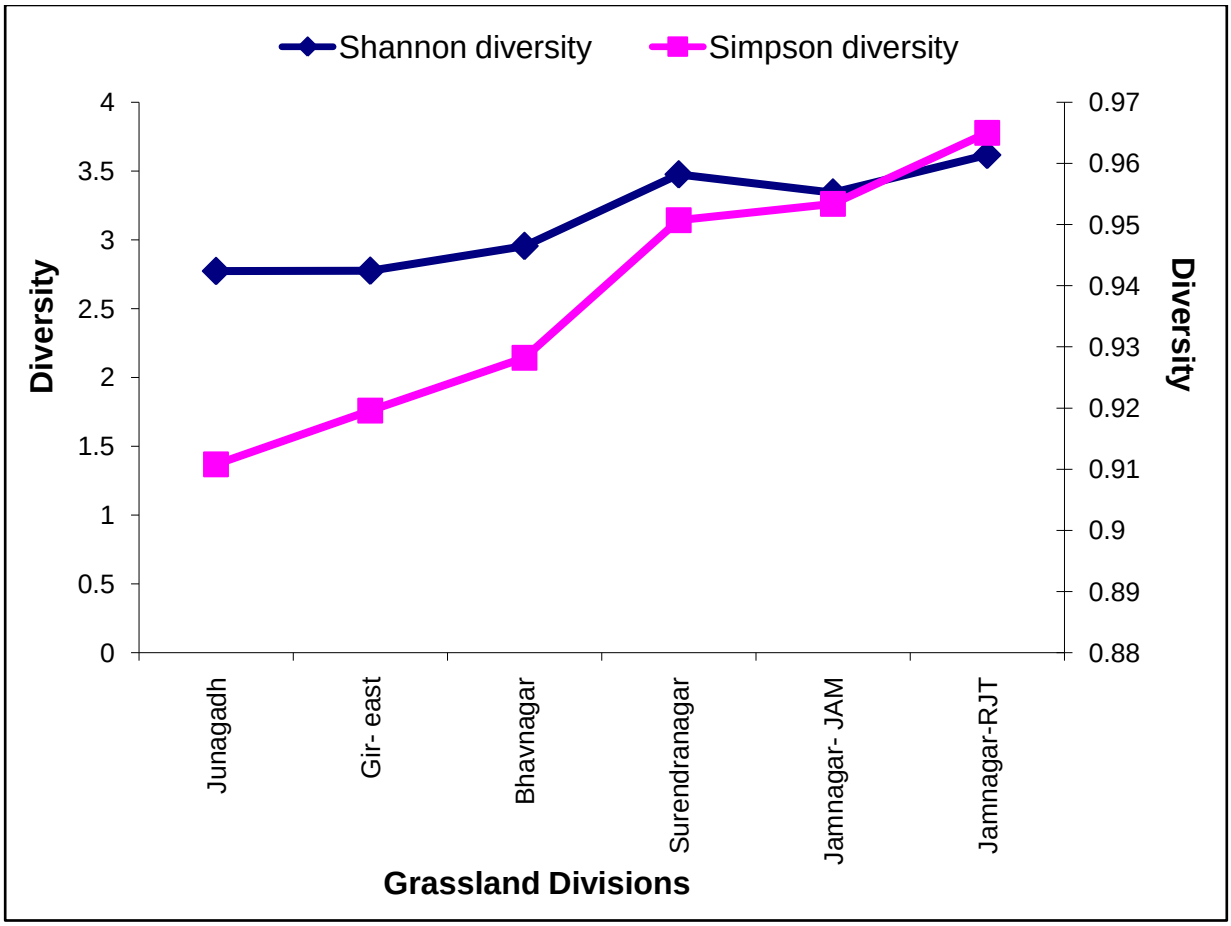
Figure 3.35 Similarities among grassland divisions based on MDS.



Grass species diversity in grassland divisions of Saurashtra.

Highest grass diversity was recorded from Jamnagar division-B "RJT", followed by Surendranagar division, and Jamnagar division-B "Jam". Diversity of grass increased from Junagadh division to Rajkot (Figure 3.36).

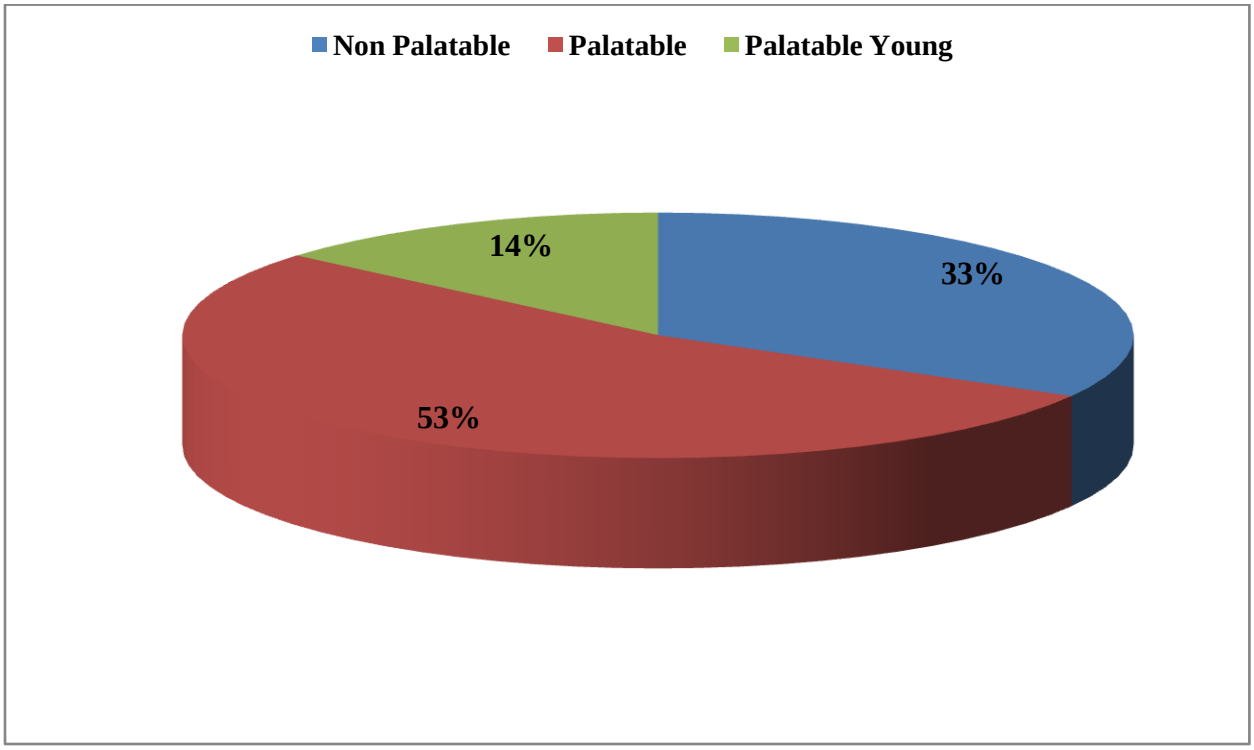
Figure 3.36 Diversity of grasses in grassland divisions of Saurashtra.



Composition of palatable grasses in Saurashtra.

Overall composition of palatable grasses in Saurashtra was 53% and of non palatable grasses was 33% along with 14% of grasses, which were palatable in early stage of their life history (Figure 3.37).

Figure 3.37 Percentage compositions of palatable and non palatable grasses in grasslands divisions of Saurashtra.



3.6 Succession Trends.

Examination of protected or lightly grazed sites in Saurashtra under various divisions shows that the highest expression of grass cover on gravelly soils consists in the establishment of a *Sehima* community, with *S. nervosum* as the dominant species. Sites such as Sarasiya and Hipavadli in Gir-East division, Chuldi, Babra cluster and Paturan in Junagadh division, Beda-Gebar cluster and Sarod-Anida cluster in Bhavnagar division, Mahika-Varvada *vidi* in Jamnagar Division, and Umath and Khirasara *vidi* in Rajkot district, of Jamnagar division represent the *Sehima* community.

On level soils, as in the intervening valley portions, a *Dichanthium* community, with *Dichanthium annulatum* as the principal species, represents the highest development of the grassland. Sites such as Paturan, Nana Babra, Khageshri and Dhruvada *vidi* in Junagadh division, Sarasiya *vidi* in Gir-East division and Moti-Majethi *vidi* of Surendranagar division etc. represent the *Dichanthium* community. On the basis of the dominance of *Sehima nervosum* and *Dicanthium annulatum*, the cover type has been designated as *Sehima-Dicanthium* (Appendix II). The findings match with that suggested by Dabadghao and Sankaranarayan (1973) and Whyte (1964).

The grasslands on hills which are subjected to annual harvesting and soil erosion, favor the appearance of a *Cymbopogon, Heteropogon, Andropogon* community, either pure stand or in combination as may be seen from the comparison of the sites such as Mota Babra and Chuladi *vidi* of Junagadh division, Katrodi, Hipavadli, and Zadkala *vidi* of Gir-East division, and Moti vidi of Jamnagar division and Khirasara *vidi* in Rajkot district, of Jamnagar division. These sites posses hilly terrain and are subjected to harvesting and

erosion. The erosion and continuous leaching of soil nutrients occurring in the hills along with grazing, appears to restrict grassland development to the stage of dominance of *Cenchrus ciliaris* along with inferior species such as *Aristida* and *Eragrostris* species with *Cenchrus ciliaris* as the principal species. Sites like Amridhar *vidi* of Junagadh division, Khirasara *vidi* of Rajkot district and Pipartoda *vidi* in Jamnagar division, Hipavadli *vidi* in Gir-East division and Paval and Kalthochapro *vidi* of Bhavnagar division, Sangadhara and Mandav *vidi* of Surendranadar division etc. are among those representing this community.

Dabadghao and Sankaranarayan (1973) reported that erosion and continuous leaching of soil nutrients in the hills give emergence to *Themeda/ Pseudanthistiria* community, but in present study it was observed that *Cymbopogon, Heteropogon* followed by *Cenchrus* community dominate in these conditions. The difference in the findings are due to geographical scale of study area, as the work conducted by Dabadghao and Sankaranarayan evaluated succession trend in entire *Sehima-Dicanthium* cover type which spreads over the whole of Peninsular India, whereas this study was focused only on Saurashtra region. Thus, the local trend emerges, which may not be significant or applicable at large scale. Other hypothetical reason may be that it was an anti deteriorating tactic exhibited by grassland to reduce pressure from the patch to regulate further deterioration, but it has to be justified with proper scientific tools.

On level soils with increasing moisture availability, the *Dichanthium* community is replaced partially or wholly by an *Iseilema* community, with *I. laxum* as the chief species. Sites such as Moti-Majethi *vidi*, which remain flooded during rainy season and Santhava

vidi, which possesses high moisture in Surendranagar represent this stage. Further increase in moisture conditions appears to favour the establishment of an *Ischaemum* and *Eremopogon* community with *Ischaemum rugosum* and *Eremopogon foveolatus* as the main species. This, when subjected to grazing, is replaced by *Echinociloa*, *Dactyloctenium aegyptium* and *Cynodon communities* which give rise to *Chloris virgata* under sever grazing. If the factors continue, inferior species such as *Aristida* and *Eragrostris* appear and dominate.

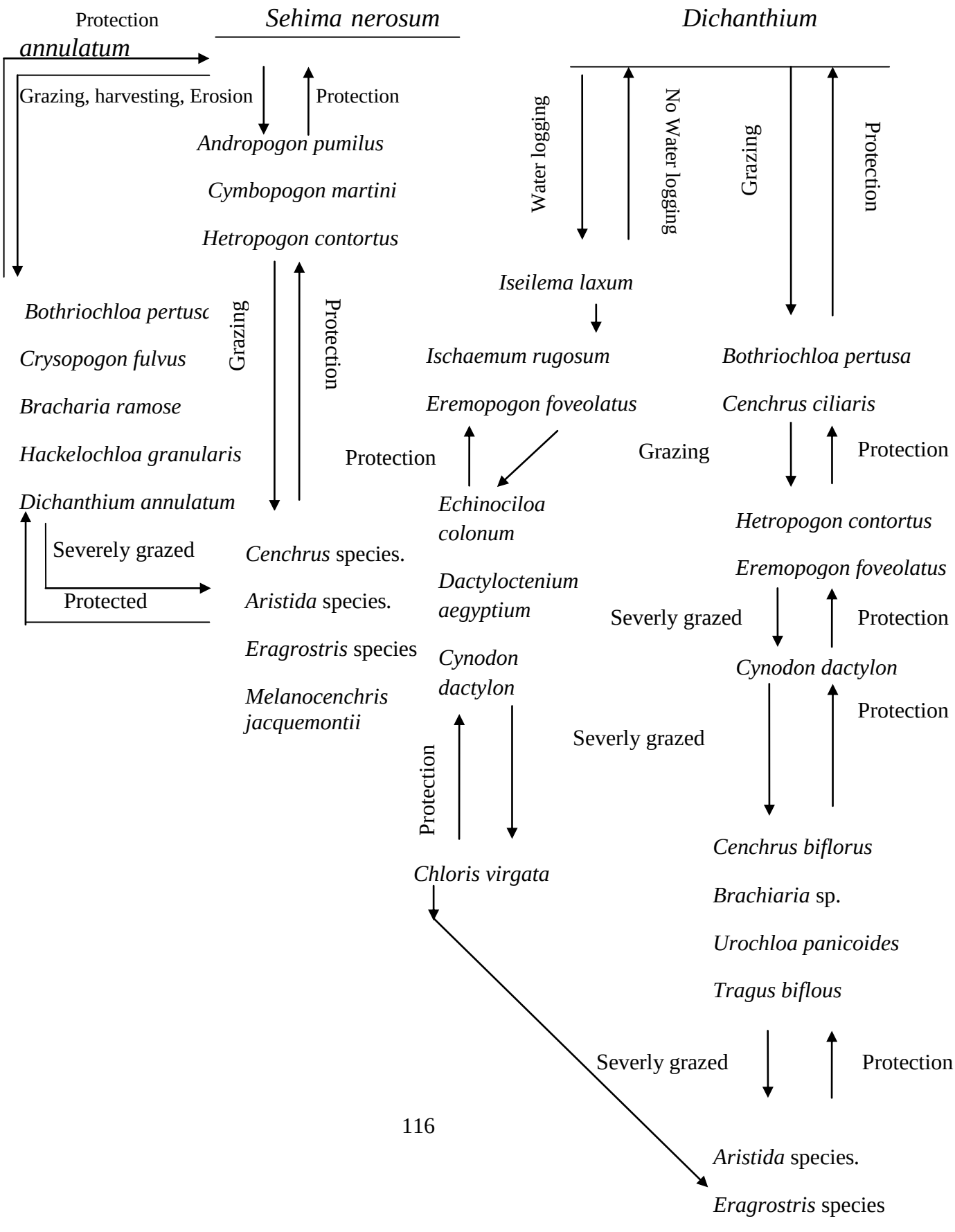
When the *Sehima-Dichanthium* cover is subjected to grazing, these communities are replaced by *Chrysopogon*, *Bothriochloa*, *Bracharia*, *Heckelochloa* and *Bothriochloa*, *Cenchrus* communities, respectively. The main species of the former was *C. fulvus*, *B. ramose* and that of the latter was *B. pertusa* and *C. celiaris*. The *Chrysopogon* community is a degradation stage and may show an average cover of 21 percent; while in its best development over 50 percent whereas *Bothriochloa* community has a cover of 12 percent. The sites representing these communities are Naliyadhar, Khageshri and Amridhar vidi in Junagadh division, Sarasiya and Mota- Sosariya in Gir-East division, Paval *vidi* of Bhavnagar division and Umath *vidi* of Rajkot district in Jamnagar division.

With further grazing at this stage, these communities are replaced by *Heteropogon* and *Eremopogon communities*, with *H. contortus* and *E. foveolatus*, respectively as the chief species. The *Heteropogon* community has an average plant cover of 37 percent, as on sites Mota Babra, Amalgardh, Mohabatgardh and Kalimbhada of Junagadh division. On hilly sites with shallow soils, *Heteropogon contortus* seems to be of the annual form,

while in the plains or on level sites with fairly deep soils, the perennial form of this species predominates.

Further grazing at this stage brings about the appearance of *Cynodon dactylon*, which under the influence of sever grazing gives rise to *Cenchrus*, *Brachiaria* community and depending upon the soil condition, *Urochloa* and *Tragus biflous* appear alongwith as in Santhava *vidi* of Surendranagar and Apaiya vidi of Jamnagar division. These, when subjected to further deterioration give rise to essentially annual communities represented mainly by *Aristida*, *Eragrostis* and *Melanocenchris*. Appearance of *Cynodon dactylon* is also influenced by proximity to agriculture land and encroachment in the grassland (Figure 3.44).

Figure: 3.38. Flow chart of successional trends in *Sehima- Dicanthium* covers.



3.7. Succession base management

It is obvious that in the management of this type, *Sehima nervosum* and *Dichanthium annulatum* should be considered as key species on gravelly and on level, well-developed soils, respectively. Since *Sehima nervosum* occurs on hilly sites, any poor management of a well developed *Sehima* stand would tend to result in accelerated erosion which in turn would fasten the rate of deterioration. Adequate soil conservation measures would, therefore, be necessary in any plan for the optimum utilization of this cover type. Under the influence of erosion, where the succession seems to have been arrested at the *Cenchrus* stage, probably because of excessive leaching of soil nutrients, contour furrowing with fertilizer is likely to give good results. Similarly, these measures would be essential when deteriorated grasslands are taken up for improvement. Since *Sehima nervosum* has been found to be difficult to establish either through seeds or rooted slips, an improvement programme based on reseeding will have to give considerable emphasis to *Chrysopogon*, which can be easily established. In view of the dominance of inferior *Cymbopogon*, species brought about by harvesting on otherwise comparable sites, this practice is required to be used more judiciously, where an optimum stand of *Sehima* could be maintained. In regions where tree species are likely to invade the grassland, like in Paturan occasional burning and seasonal harvesting may be of importance.

In present scenario, *Dichanthium*, *Iseilema* and *Ischaemum rugosum* grasslands should be used for hay production, which appears to be the best utilization of this kind of land. For grazing on these wet soils, the post-monsoon period would prove to be the safest.

Saurashtra region is especially known for its cattle breeds. Since *Sorghum* and cotton are the main crops of this tract, animal nutrition is fairly satisfactory. Grass reserves of both *Sehima-Chrysopogon* and *Dichanthium-Iseilema* are kept for hay purposes and constitute a business proposition around cities. Manurial trials conducted at a few places have indicated that the production can be increased by the application of a mixture of nitrogenous and phosphatic fertilizers (Bal and Athavale, 1935; Zende and Kundalkar, 1954; Dabadghao, 1954). Response of legumes to applications of sulphur was also reported from Dharwar (Whyte, 1964).

Attempts at improving *Sehima-Dichanthium* grasslands through reseeding were generally not successful (Burns, 1929; Dabadghao, 1954), probably due to lack of good quality seed. Simple closure with contour furrowing, however, has proved useful for regenerating hilly grasslands (Burns, 1929, 1932; Albertson, 1958). On the management side, rotational grazing was shown to increase the carrying capacity of the grassland considerably (Burns *et al*., 1932; Kumar and Godbole, 1939).

3.8. Measures to Check Further deterioration

There are three points which should be applied in practical approach, 1) Controlled grazing and harvesting 2) Occasional fires and 3) summer irrigation wherever possible.

Controlled grazing and harvesting is challanging in practice, but can be practiced by exposing a part of the *vidi* to grazing stock and protecting the other portion turn by turn. Similarly, removal of the net productivity should be calculated on the basis of carrying capacity of the *vidi*. Excess removal must be checked. Further, in order to maintain enough number of grazing lands, expansion of industrial areas should be preplanned.

For harvesting the fodder, if the overall turnover of grass is properly managed, and if the required needs are satisfied with the quantity, few of the grasslands, if left unharnessed in rotation may improve its quality ecologically (for details see in Chapter 5).

The second step is not difficult and can be practiced wherever necessary, in order to control the spread of unpalatable forbs and undesirable species.

Summer irrigation may involve considerable financial support but in the areas where dams or reservoirs are available, this may be feasible.

3.9. Future Management Strategy

These grasslands should be managed as an ecosystem. In the past, over enthusiasm, strict protection and plantation activities in the grassland resulted in the thick growth of trees, thus reducing the productive capacity of the grasses. Any strategy to be adopted in future for managing these grasslands should therefore involve the above statement as a guiding principle. In the strategy, I have tried to focus on grassland management issues, which were not given importance.

Effective management must be based on accurate information. Developing and using information therefore, is an essential part of the conservation strategy at all level from site specific to region-level. The conservation strategy for grassland of this region can be primarily segmented into three elements.

(a) Saving the grasslands: This means taking steps to protect species (genetic biodiversity), habitat and ecosystems. Protection from grazing animals is the foremost hurdle challenging the saving of grasslands. Unless this is done at appropriate social, political and legal levels, the strategy will tend to be less meaningful. It is a hard fact that in India, protection is accorded only when the area is declared as a Protected Area for its flora and fauna. Therefore, possibility should be explored to declare some representative grassland as Sanctuaries and National Parks to protect them for future. This is the best way to maintain their habitat and protect the diversity in-situ.

(b) Studying and monitoring grasslands: It means documentation and collection of biological wealth of grasslands especially its genetic resource for future use. Detailed ecological research should be a part of this strategy, to assess the changes in ecosystem diversity of grasslands in the light of increased human influence and cattle population and deforestation in and around grasslands so that effective management steps can be takien to fulfill the local needs. It should not be forgotten to study the social and ethnic issues involved in the management at a sustainable level.

(c) Sustainable use of grasslands : This means utilizing the available resources sustainably so that they last indefinitely making sure that the resource is used to improve the human living condition in and around and that these resources are shared equitably. Strategy should involve the mass mobilization of rural population, through proper awareness programmes about resource use not only from grasslands but also from other community grazing lands. Their

participation is invariably to be focused in the conservation program since these land resources are used commonly by the villagers for resources, sustenance and use.

The basic inventory and fundamental research should form the basis for Treatment Action Plan coupled with effective monitoring system for individual *vidis*. Restoration of degraded patches should be planned for the grazing land biome in Saurashtra.

Chapter 4

COMPOSITION AND ORGANISATION OF BIRD COMMUNITIES

4.1 BIOTIC COMMUNITIES: AN INTRODUCTION

The term community has been variously defined and interpreted in the past. Ecologists have perceived communities as either 'organized' units or chance assemblages

Clements (1916), Gleason (1917,1926) with the former view regarding communities as discrete, repeatable assemblages of species that are closely integrated and possess properties similar to those of individual organisms and the latter view considering communities as no more than fortuitous coincidences or random assemblages (Wiens 1989). Elton (1927) defined animal community as a characteristic and interacting set of animals found in a habitat. Whittaker regarded a natural community as 'a distinctive living system with its own composition, structure, environmental relations, development and function' (Southwood, 1987). Landres and Mac Mohan (1980) described community as 'groups of interacting populations, among which no gene exchange takes place, but whose demography or gene pools are affected by the interaction'. Southwood (1987) defined community as "a group of organisms (generally of wide taxonomic affinities) occurring together in a location; many of them will directly interact with each other within a framework of both horizontal and vertical linkages." Communities have also been defined on the basis of habitat or microhabitat units (e.g. rocky inertial communities, a tree), life forms (e.g. tree or herbaceous communities), and taxonomic groups viz. bird or lizard communities (Wiens, 1989).

Biotic communities are characterized by two properties, structure or organization (called *patterns*) and function or dynamic (called *processes*). The former includes distribution of species in communities, their variety and abundance and the trophic structure, which connects different components of a community. The latter entails causal processes such as colonization, competition, predation, parasitism, climate, history, and chance events (Southwoods, 1987).

4.2 AVIAN COMMUNITY ECOLOGY: CONTEXT OF THE PRESENT STUDY

4.2.1 Introduction: The focus of bird community ecology has been on identifying patterns that characterize natural assemblages of species and processes that cause these patterns (Wiens, 1989). A pattern is 'a particular configuration of properties of the system under examination' and the process is the 'underlying causes' or 'factors that produce a particular relationship among observations' (Wiens, 1989). The major focus of development in bird community ecology has been finding the 'true nature, stability and predictability of community structure (Raman, 2001). Based on this pursuit, there are three prevalent views of community structure. These are referred to as equilibrium, non-equilibrium and dynamic equilibrium states (Raman, 2001). The processes that shape or influence the communities have been categorized as deterministic (predictable) and stochastic (chance) processes (Raman, 2001). The important aspects addressed in the study of bird communities include patterns of bird species richness, distribution and abundance in an area and factors affecting these parameters. These include bird species-habitat relationships, mechanisms of species co-existence (e.g. resource partitioning, and foraging guilds) and impacts of anthropogenic/natural disturbances on bird communities.

Wiens (1989) has provided a detailed chronological account of development of bird community ecology.

4.2.2 Determinism and local influences: In the phase of community ecology, local ecological processes (intrinsic factor) were mainly regarded of significance in determining the richness and composition of communities. Competition and habitat (mainly vegetation structure) were regarded as the driving forces of community organization. In extrinsic factors, influence of human activities influence trends of community composition.

4.2.3 Regional influences - the role of history, geography and land use: As more studies were conducted at different scales (from a habitat type to landscape and regional) and on different continents, it became apparent that species composition of communities was also influenced by regional (geographical, evolution and historical) factors (Ricklefs and Schluter 1993). For instance, very high bird diversity in certain parts of the Neotropics was explained on the basis of refugia hypothesis in which historical (geological) processes were largely responsible for shaping the unusually rich species pools of some sites in the region (Haffer, 1969). A balance between immigration and local extinctions contributes to species richness on the island connected by land bridges with mainland in geological past. For such island, Terborgh (1974) regarded the size of islands as an important determinant of bird species richness with bigger islands possessing higher richness due to lower extinction rates. Wilcox (1978) showed that time since isolation was an important criterion in determining local species richness in lizard communities although larger islands experienced less extinction than smaller. Diamond

(1972) showed the effect of disruption of faunal inflows through submergence of land bridges in reducing the species pools of islands of the southwest Pacific.

The foregoing suggests that the communities need to be viewed at hierarchical scales beginning from local habitat patch to a landscape containing several habitats to a region and finally the continents (Ricklefs and Schluter, 1993). Hence, the scale at which a community is being viewed would provide perspective on composition and organization. This would change as one goes lower or higher in the hierarchy. Wiens *et al.* (1987) showed how the relative importance of patterns and processes changed with change in scale at which these were viewed. Translating these observations to my studies, semi arid grasslands of the region could be viewed as patches in a larger regional context. These patches contain several smaller habitat patches with varied intensity of anthropogenic influence. Vegetation types are similar between the sites, (V.C.Soni, *per comm.*) as grassland patches fragment from a large native biome experiencing similar factor of use in the recent past. One would expect that if only local factors were important, similar vegetation type at the sites would have more similar bird communities. However, if regional factors were also involved, the pattern would vary as per the influence of geographical barriers, history and land use, etc.

4.3 Scope of the present study

At the outset, it becomes important to know the status of the biological community of the "*vidis*" in an ecological perspective, to evolve a conservation strategy for the region. In *vidis* of Saurashtra, besides the biological attributes of the region, the cultural and social

characteristics of the people are of equal significance. All the grasslands are surrounded by dense human and livestock population exceeding the carrying capacity of the area.

The avifauna profile and effects of human activities on avifaunal assemblages remain largely unknown for the region. A few past studies were conducted which either provided avifaunal checklists (Ali, 1954-55, Dharamkumar Singhji, 1956) or were specific to the region (Naik, *et al*,1990., Singh and Tatu, 1992).

Thus, the present study evaluates the structure of the avian fauna assemblages in the grasslands having varied anthropogenic pressures and management practices. It was intended to fulfill gaps in knowledge about biodiversity of semi arid grasslands and impact of use.

Within the limited scope of the study, a habitat hypothesis was not tested. The study areas are relatively small in size and geographically similar so no significant change in the habitat structure was observed. A lack of vegetation records for a specific region in the past and limited time, man power and monetary funds restricted the scope of the study.

An outcome of the study provides useful baseline information to understand the grassland avifauna, its structural and functional aspects. It also highlights effects of human activities on birdlife. This information proves useful to design a management strategy for the native grasslands and its avifauna, and provide platform for the further research in the area.

4.4 Methodology

4.4.1 Reconnaissance

Reconnaissance has been regarded as a powerful tool to get baseline information (Rodgers, 1991) about any area. This method was used to get familiar with the grasslands (*vidis*), its environs, bird life and regional factors. In this phase, some paths in the area were selected for transects. Attention was paid to specific areas within *vidis*, to highlight its characteristics, and were categorized as fringes, center part etc. It also helped in synthesizing a broad picture of the avian habitats in selected grasslands. Since the reconnaissance also generated a preliminary checklist of birds, this information was compiled and used as baseline data on the basis of which the intensive study of the birds was planned.

4.4.2 Intensive study:

After gathering baseline information, the next step was to choose a relevant method for intensive study. Line transects of variable width and open width without distance estimates (Verner, 1985) were considered appropriate for the intensive study.

The assumptions of variable width line transects are as follows (Emlen, 1971).

1. All birds on the line are detected.
2. The probability of observing a bird decreases with distances from the transect, or remains constant to a given distance and then declines rapidly.
3. Birds do not move in response to the observer before detection.
4. No birds are counted more than once.
5. The observer identifies the species correctly.

4.4.3 Transects:

After the initial surveys, transect localities were chosen based on their habitat features and extent of human influences. Besides this, feasibility for repeated samplings was also considered for selecting these locations. Three line transects in site 1, four in site 2 and two in site 3, each of 1 km length were walked during the study period. Salient features and locations of these transects have been outlined in Table 4.5, 4.6 and 4.7. Transect width of all transects at three sites are outlined in table 4.1. Table 4.2, 4.3 and 4.4 gives the details of sampling efforts at site 1, site 2 and site 3 respectively. The nine regular transects of three sites were sampled seven times each covering a distance of 63 kms.

The line transects were walked twice a day i.e. once each between 06:30 to 10:00 hrs and 16:00 to 18:45 hrs. The exact timing varied based on seasonal changes in light conditions and intensity of bird activity. Transects were walked in all three seasons, but bird data of summer was not included in this study, because grasslands do not exist from April to May. Thus the data collected during that period was not significant to draw any conclusion.

The parameters recorded on transects were-

- Name of the bird species
- Time of sighting
- Number of birds
- Bird occurrence
- Habitat
- Activity

- Bird calls
- Remarks (under which other relevant observations were recorded, if necessary)

Each call was treated as a separate sighting and was considered for data analysis at par with actual sighting. It was considered as one bird in term of number and occurrence unless it was possible to make out the number of calling birds. Binoculars of 8 X 40 were used during the reconnaissance period. For intensive study, 12 X 50 binoculars were used. A pedometer and a GPS receiver were used to measure and record the distance walked and locations on trails. The nomenclature (both common and binomial names) and systemic order of bird species and families follow Buceros (Manakadan and Pittie, 2001).

Table 4.1 Detail of transects width at study sites.

Sites	**T1**	**T2**	**T3**	**T4**
Site1	45	28	45	-
Site 2	35	45	42	35
Site 3	35	25	-	-

Table 4.2 Sampling efforts at Site 1

Transect No	Transect Name	No of Visit	Distance in km.
T1	UNI 1S – UNI 1E	7	7
T2	UNI 2S – UNI 2E	7	7
T3	UNI 3S – UNI 3E	7	7
	Total	21	21

Table 4.3 Sampling efforts at Site 2

Transect No	Transect Name	No of Visit	Distance in km.
T1	KHI 1S – KHI 1E	7	7
T2	KHI 2S – KHI2E	7	7
T3	KHI 3S – SEC.14	7	7
T4	SEC14 - DARGAH	7	7
	Total	28	28

Table 4.4 Sampling efforts at Site 3

Transect No	Transect Name	No of Visit	Distance in km.
T1	RND1S –RND 1E	7	7
T2	RND2S –RND 2E	7	7
	Total	14	14

Table 4.5 Salient features and location of transects at site 1

TRANSECTS	LOCATION	VEGETATION AND FLORA	TERRAIN	UNIQUE FEATURES
T1	UNI-1S $22^0$17.733'N to $70^0$44.421'E	Highly grazed patch, dominated by *Aristida adscenionis*, with scattered patches of *Prosopis juliflora*, cultivation on edges	Undulating and flattened on top	Surrounded by human settlements, perennial stream present, mining of soil.
	UNI-1E $22^0$17.972'N to $70^0$43.900'E			
T2	UNI-2S $22^0$17.290'N to $70^0$43.246'E	Patches of palatable grass spices *(Sehima nervosum*) with scattered *Acacia-Zyzyphus* scrub.	Flat to undulating	Perennial water stream present, less influence by human activities, cultivation on edges.
	UNI-2E $22^0$17.792'N to $70^0$43.472'E			
T3	UNI-3S $22^0$17.392' N to $70^0$43.410'E	Patches of palatable and non grass species, *Acacia nilotica*, and *Zyzyphus sp.* Scrub. Invasion of *Prosopis juliflora.*	Undulating to flat	Perennial water stream present, urbanization on southern edge, cultivation present, Public road passing.
	UNI-3E $22^0$16.936'N to $70^0$43.743'E			

Table 4.6 Salient features and location of transects at site 2

TRANSECTS	LOCATION	VEGETATION AND FLORA	TERRAIN	UNIQUE FEATURES
T1	KHI-1S $22^0$12.545' N $070^0$39.601' E KHI-1E $22^0$12.918' N $70^0$39.475' E	Palatable grasses, open savannah, scrub vegetation with *Aristida adscenionis* dominated patch at edge.	Flat to Undulating,	Covers middle to fringe. No water source. Highly effected by grazing on edge.
T2	KHI- 2S$22^0$12.918' N $70^0$39.475' E KHI-2E $22^0$12.694' N $070^0$3' E	Palatable grass species (*sehima nervosum*) with thick pocket of *Acacia sp*.	Flat to Undulating	Perennial water stream at end less influenced by human activities, and grazing. Middle of the area.
T3	KHI-3S $22^0$12.694' N $70^0$39.097' E KHI-3E $22^0$12.005' N $70^0$38.902' E0	Patches of palatable and palatable grass species, *Zyzyphus sp*. Scrub.	Undulating to Flat	Passing from boundary, moderately affected by grazing and human activities
T4	KHI-4S $22^0$12.005' N $70^0$38.902' E KHI-4E $22^0$12.005' N $70^0$340.904' E0	Thick patches of *Acacia sp.* With reverine belt, palatable grass species	Flat to Undulating	Passing through middle of an area, ungrazed by livestock reverine belt.

Table 4.7 Salient features and location of transects at site 3

TRANSECTS	LOCATION	VEGETATION AND FLORA	TERRAIN	UNIQUE FEATURES
T1	RND-1S N21^{0}13’362E 070^{0}35’253	Palatable grasses, open savannah, scrub vegetation with *Aristida adscenionis* dominated patch on edge.	Flat to Undulating,	Covers middle to fringe. No water source.
	RND-1E 21^{0}13’518 N 70^{0}34.475’ E			
T2	RND-2S 21^{0}14’503 N 070^{0}35’835 E	Palatable grass species *(Sehima nervosum*) with thick pocket of *Acacia sp*.	Flat to Undulating	No water source. Middle of the area.
	RND-2E 21^{0}14’603 N 070^{0}35’30 E			

4.5 Data analysis

Line transects data were used to estimate month wise species richness, species distribution and feeding guild composition on the basis of food preference. Indices like abundance, density, diversity, and encounter rates were worked out to understand the community structure and to observe the effect of various changes in the habitat.

Statistical analysis was done using EXCEL (Microsoft) program along with Past statistical software.

4.5.1 Species Encounter Rate

Since measurement of bird densities involves many biases (Verner, 1985), species encounter rate was determined as an index of rarity/abundance of different species. The formula used for deriving the encounter rates was:

Encounter Rate= n/L

Here, n = No. of Occurrences of a Species, whereas L=Total length of all transects on which the bird was sighted at least once.

MER is the Mean of the Encounter Rate of species during study period.

4.5.2 Density

Density means the number of individuals of a species per unit area. Density estimate in this study follows King Method (Overton and Devis, 1969).

Density = n / L X 2W

Here, n = number of birds sighted, L = total transect length, and W = transect width

4.5.3 Diversity Indices

The concept of local species diversity is being related to vegetation structure was propounded by Mac Arthur (1961) in North America. Unlike species richness, diversity measures take both, abundance and species richness into account. The most widely used measure of diversity is Shannon and Simpson diversity indices.

4.5.4 Shannon's diversity index: $H' = -\Sigma^{S*}_{i=1} [(n_i / n) \ln (n_i / n)]$

Here**,** n_i is the number of individual of *i*th species in a sample, and n is the total number of individuals of all the species in a sample.

4.5.5 Simpson's Index: $\lambda = \Sigma^{S}_{i=1} [n_i (n_i-1)/n (n-1)]$

Here**,** n_i is the number of individual of *i*th species in a sample, and n is the total number of individuals of all the species in a sample.

4.5.6 Richness:

Index of species richness would be S, the total number of species in a community. However, since S depends on the sample size, it is limited as a comparative index. Hence, Menhinick (1964) index is used to measure species richness which is independent of sample size (Ludwig and Reynolds, 1998).

Richness**:** $R=S/\sqrt{n}$

Here, S stands for the total no. of species in a community, and n is the number of individuals.

4.5.7 Species area relation: Species area relations continue to be a major tool in both basic and applied ecology (Lomolino, 2001). It has been successfully used in community studies and biogeography to compute minimal area for sampling (Barkman, 1989), to standardize sampling effort (Moreno and Halffter, 2001), to estimate species richness (Palmer, 1990, Soberon and Llorente, 1993, He and Legendre, 1996; Koellner *et al* 2004; Krishnamani *et al* 2004), and to characterize community structure (Martin, 1981; Rafe, *et al* 1985; Storch, *et al* 2003). Some of the potential applications of species area relationship in conservation biology include impact assessment of disturbance on ecological communities (McGuinness, 1984; Lawrey, 1991; Flather, 1996), design of nature reserves (Wilson and Wills, 1975; Humphreys and Kitchener, 1982), evaluation of vulnerability of communities to extinction (Matter *et al*., 2002), calculation of extinction debit or deficit and rate of faunal relaxation after habitat fragmentation (Brooks *et al.*, 1999).

Analysis: A species accumulation curve was plotted by regressing bird species richness against area for all the three study sites and by fitting a power function model to the data in log-log space (Pomeroy, 1993). The relative positions of the region indicate their conservation value. Regions that lay above the regression curve were deemed to harbor high diversity.

4.5.8 Taxonomic distinctness:

Taxonomic distinctness of a community can be mathematically defined as the mean taxonomic path length between any two species chosen randomly from the community, and it is less affected by sampling intensity or species richness unlike its predecessors. It

is sometimes expanded, with the inclusion of relative abundance as a measure of 'taxonomic diversity' of assemblages. A frequently-held criticism over incorporating phylogenetic information into diversity measurement relates to the general lack of consensus among taxonomists regarding generic and species limits (e.g., Crozier, 1992; Krajewski, 1994). But this has now been found to be largely unfounded (Isaac and Purvis, 2004; Dillon and Fjeldsa, 2005), although the question of optimum number of taxonomic categories for computing phylogenetic diversity remains debated (Polasky *et al*, 2001; Rodrigues and Gaston, 2002a; Ellingsen, *et al*., 2005). The taxonomic distinctness algorithms have been increasingly used in assessing structure and composition of faunal assemblages (e.g., von Euler, 1999), to measure biodiversity (e.g., Ricotta, 2004,) and to prioritize reserves for conservation network (e.g., Polasky *et al*., 2000; Rodrigues and Gaston, 2002b).

Analysis:

I quantified taxonomic distinctness of avifauna was quantified for each site using algorithm developed by Clarke and Warwick (1998). Taxonomic distinctness is a non-metric derivative of taxonomic diversity, and refers to the average phylogenetic path length between any two species randomly chosen from the assemblage. The index is given for a quadrate as

$$TD = [\sum\sum_{i<j} W_{ij}]/ [S/(S-1)/2]$$

Where Wij = Taxonomic distance between species *i* and *j* measured in a phylogenetic space using a hierarchy of taxonomic categories, and

S = Total number of species present in the site.

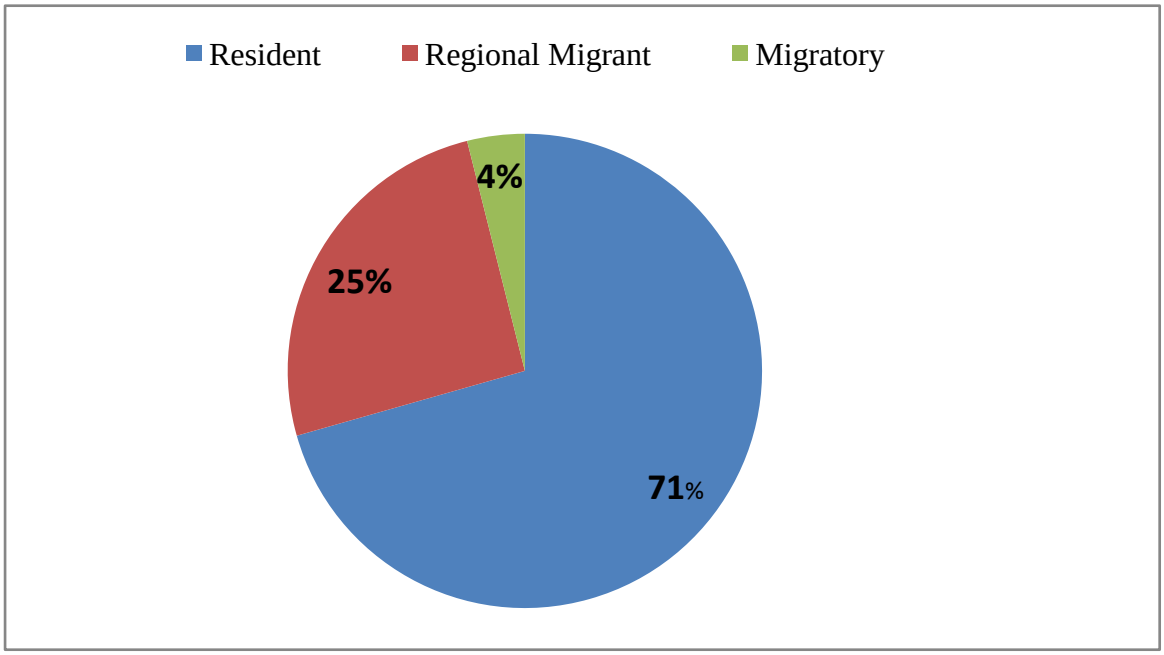
Eight taxonomic categories above species were recognized (viz., genus, tribe, subfamily, family, super family, infra order, suborder and order) within the framework of Sibley and Monroe's (1990) classification of birds to derive distances between all pairs of a species in a site (following Von Euler and Svensson, 2001; La Sorte and Boecklen, 2005). The statistical software PAST v1.32 (Hammer *et al*., 2004) was used to compute taxonomic distinctness.

4.6 RESULT: *THE PATTERNS*

4.6.1 Bird community dynamics at Raiya- Munjka Grasslands. (SITE -1).

In all, 51 species belonging to 23 families were recorded from site 1 (Annexure – 4.1). In this site, *Alaudidae* family was found dominant with 7 species (13.72 %) followed by *Cisticolidae*, *Passeridae* and *Phasianidae* with 4 species (7.84%) each. Out of these, a total of 36 species (70.59%) were resident to the area, whereas 13 species (25.49%) were regional migrants and 2 species (3.92%) were seasonal migratory Figure 4.1.

Figure 4.1 Composition of Residential/Migratory birds at site 1.

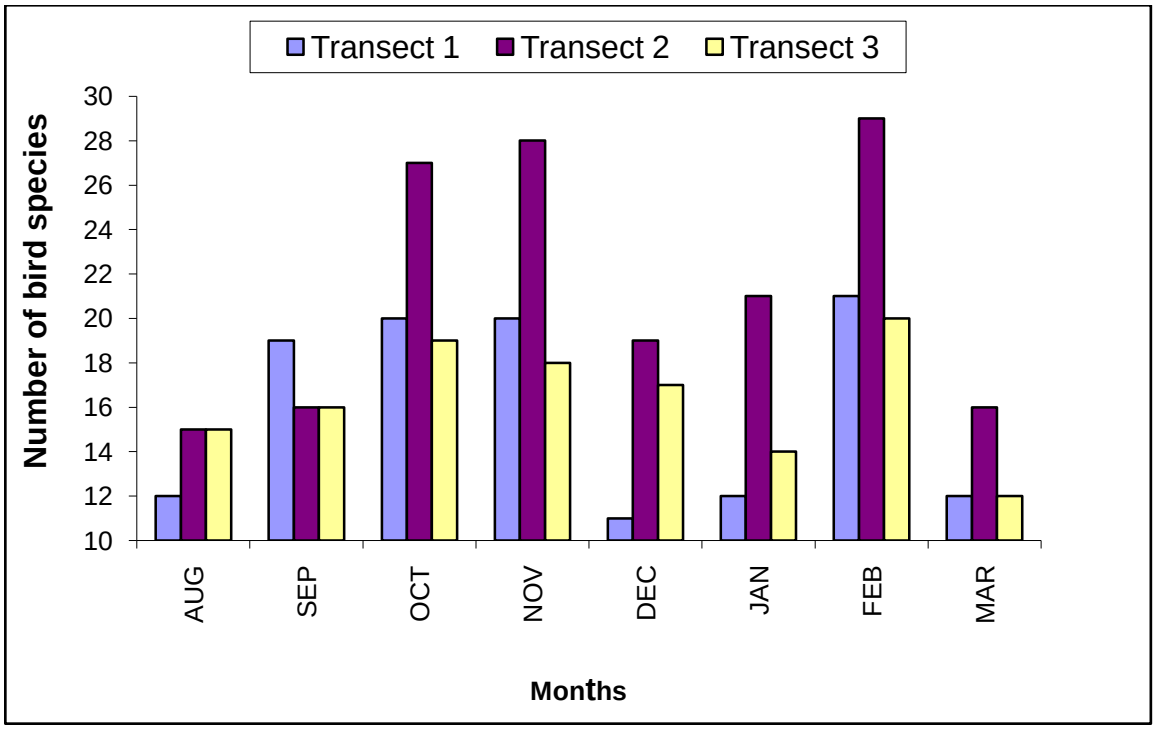


4.6.2 Transect Study:

Quantitative data of bird community was obtained from three transects at site-1. A total of 1938 individuals were observed in 968 sighting during the study period. Appendix IVb.

T-1 was found supporting maximum number of species in February, November and October. Incline in species number was observed from August to November and from January to February. Gradual decrease in species number was recorded after November to January and February to March, to attain its minimum. Trends were similar in T-3 and T-2. At T-2, the minimum number of species was recorded in August (Figure 4.2).

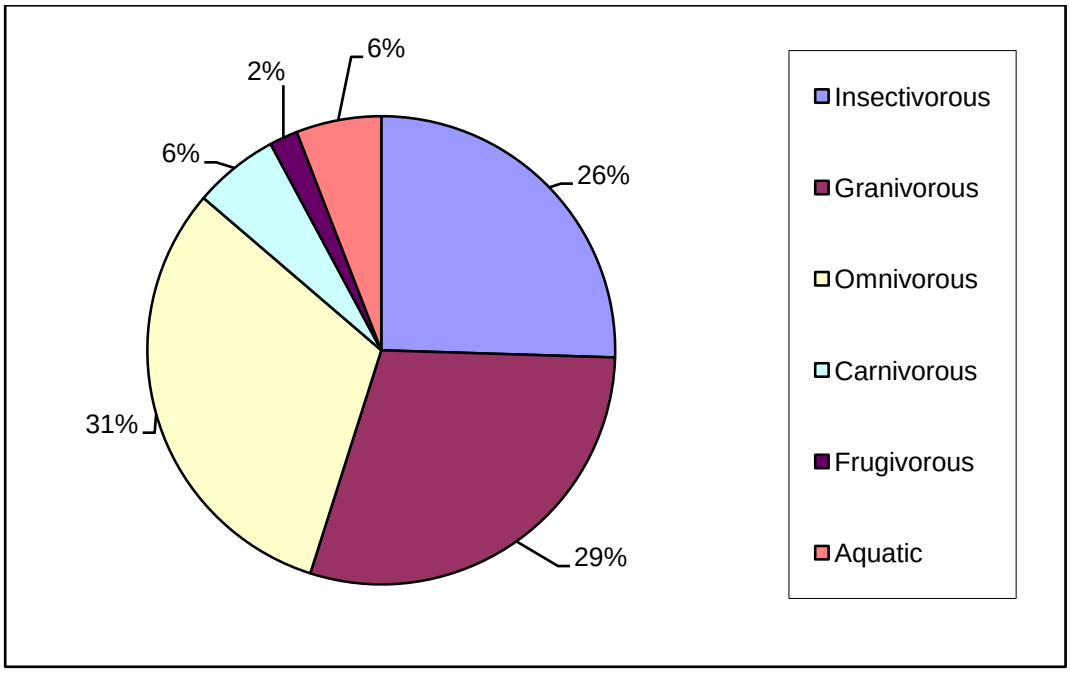
Figure 4.2: Monthly Distribution of Bird species on Transects at site 1



4.6.3Feeding Guild Composition

There were 6 foraging guilds. Omnivorous was found dominant with higher number of species, in proportion of 32% followed by granivorous and insectivorous with 29% and 25% respectively (Figure 4.3).

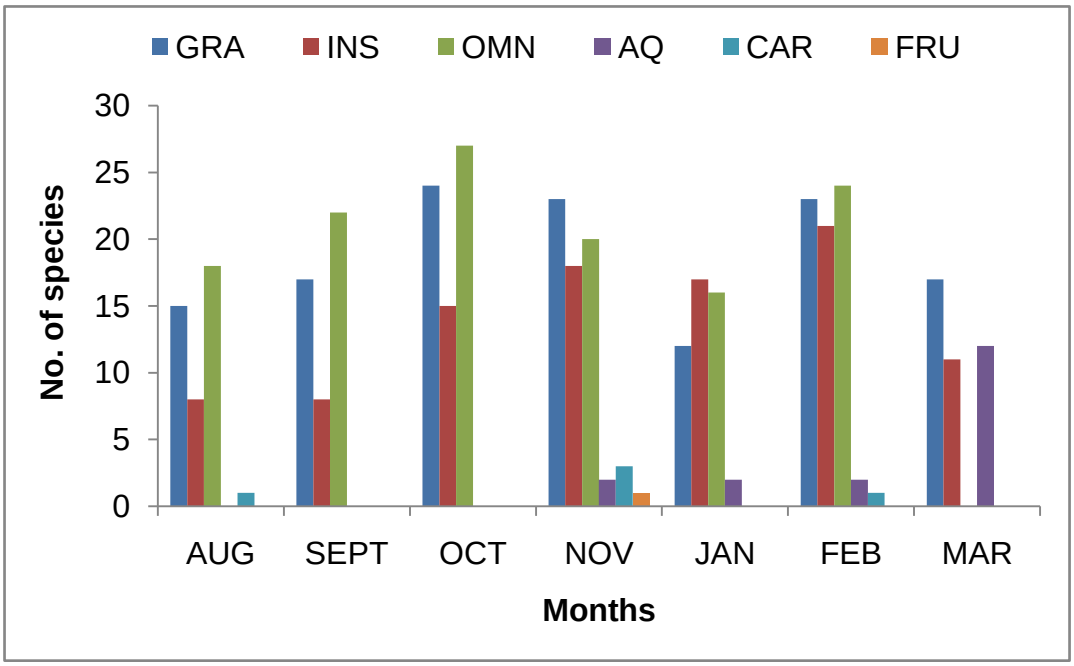
Figure 4.3 Feeding guild proportion at Site 1.



4.6.4 Monthly Variation in Feeding Guild Composition

The month of October favored high guild diversity. Granivore contribution was higher in October, February and September respectively. It decreased from October to January. Insectivorous was high in February, November and October respectively and very low in March. Omnivorous showed its highest proportion in October which gradually decreased in January, and again rised in February. Carnivorous species were found only in August, November, and February in low proportion. Other guilds such as Frugivorous and Aquatic were in non significant proportion and a result of chance sighting (Figure 4.4).

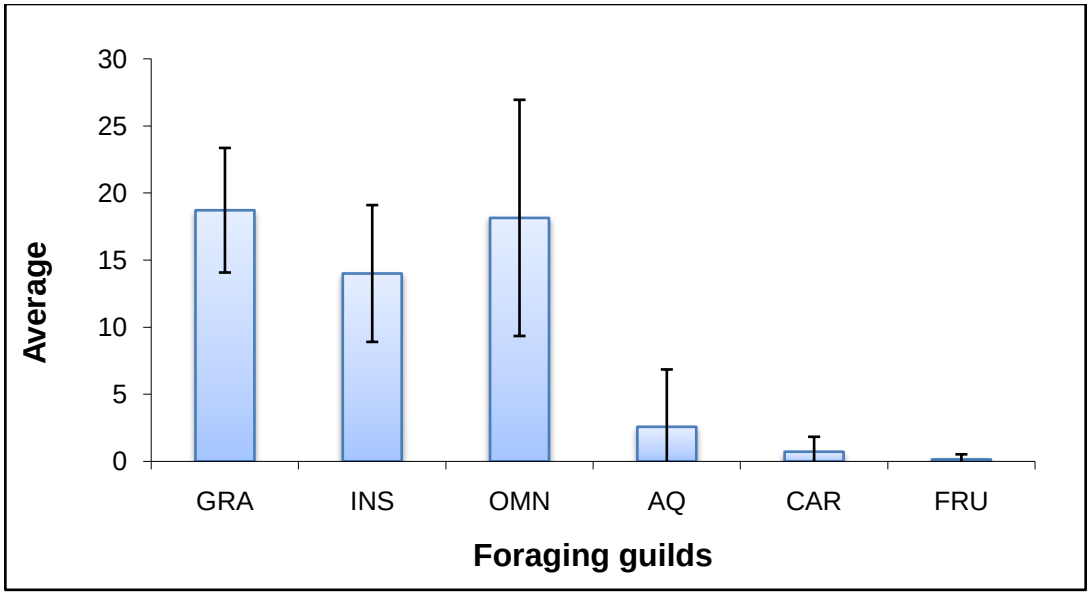
Figure 4.4 Monthly variations in feeding guild composition at site 1



4.6.5 Monthly Fluctuation in Feeding Guild Composition

Omnivorous guild was found highly affected and showed maximum fluctuation (8.8± 3.3), followed by insectivorous (5.0± 1.92) and granivorous (4.6± 1.75) (Figure 4.5).

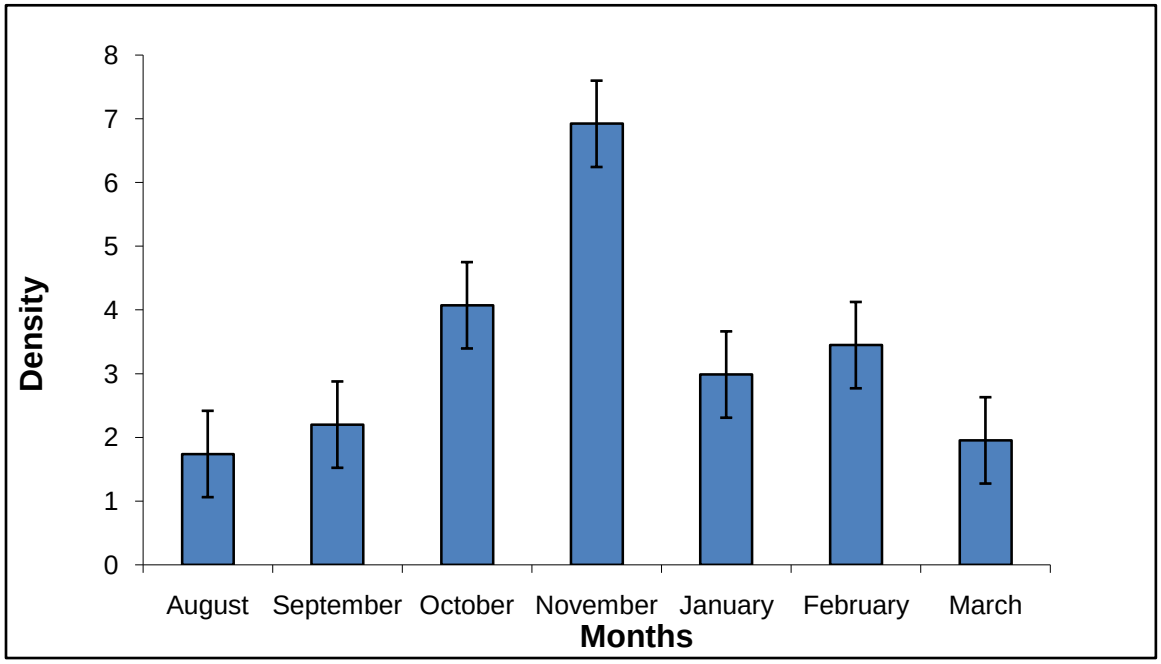
Figure 4.5 Fluctuations in feeding guild composition at site 1



4.6.6 Density

Density was found maximum in November followed by October and minimum in August. It increased twice from September to November and from January to February. It was least in March (Figure 4.6).

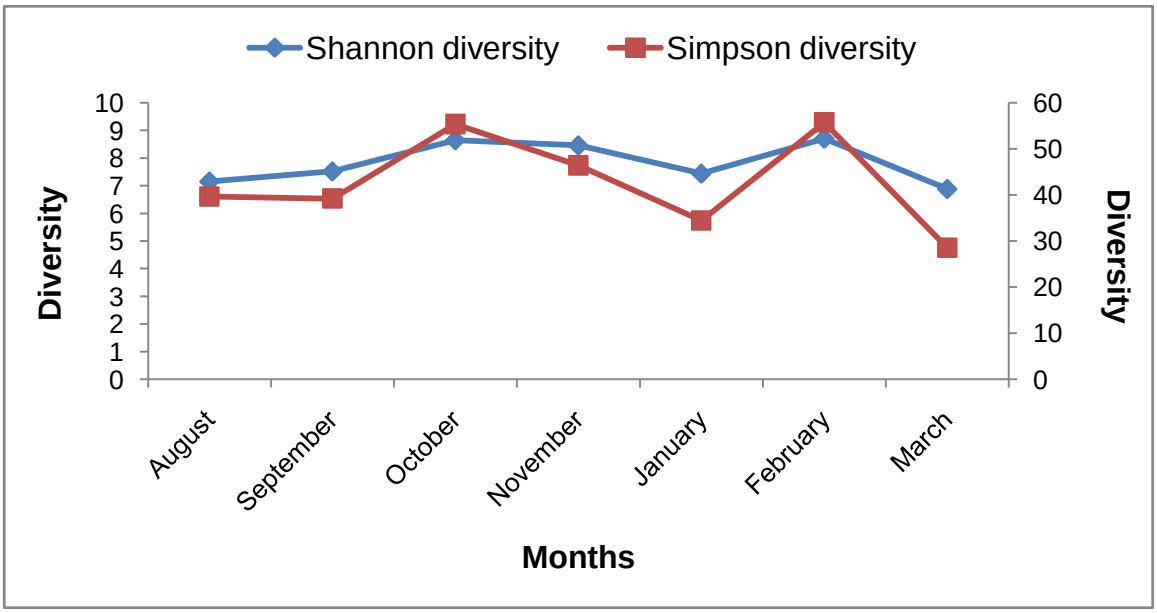
Figure 4.6 Monthly bird species density at study site 1



4.6.7 Diversity Indices

Highest Shannon diversity was recorded highest in February, followed by October and November. It increased from September to November and from January to February (8.70). Decline was observed from October to January and February to March. Simpson diversity was the highest in February. It decreased from October to January and recorded least in March (Figure 4.7).

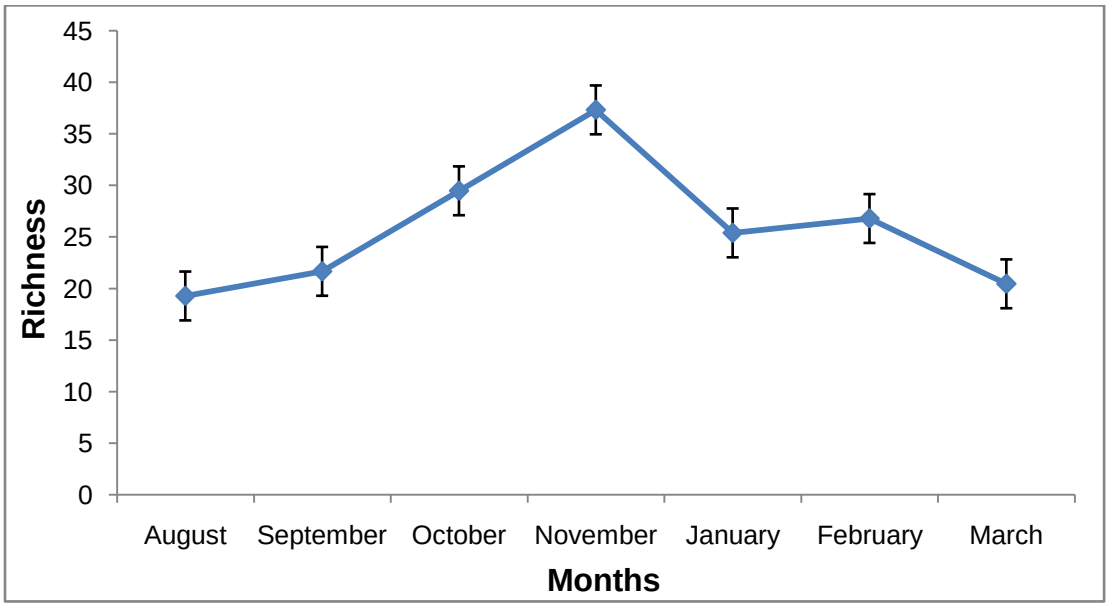
Figure 4.7 Monthly profile and variation in species diversity indices at site 1



4.6.8 Species Richness

Species richness was the highest in November followed by February and October. It was at its lowest in the months of August and March respectively (Figure 4.8).

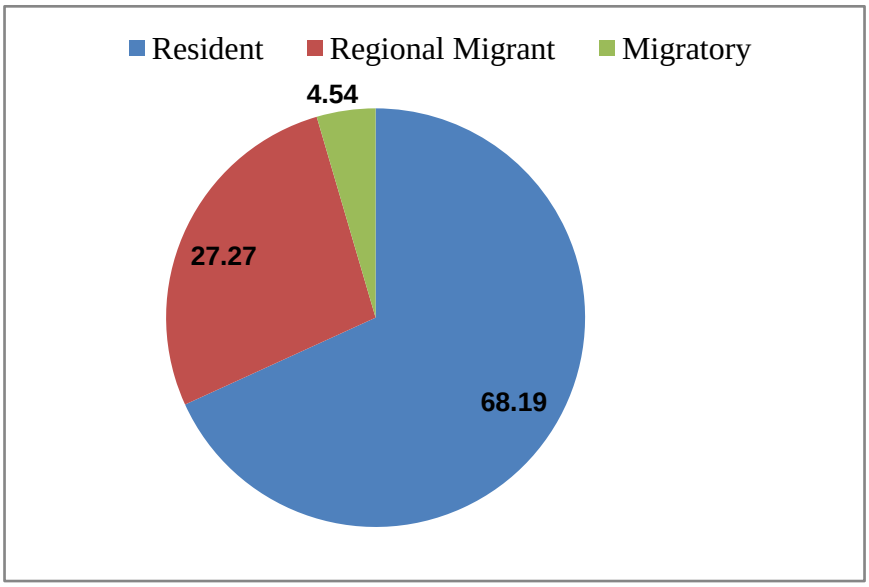
Figure 4.8 Monthly profile of bird species richness



4.6.9 Bird community dynamics at Khirasara Vidi (SITE -2)

A total of 66 species of 30 families were recorded (Appendix IVa) during the study period. In this, *Muscicapidae* and *Phasianidae* were dominant with 6 (9.09 %) species followed by *Acciptridae* and *Motacillidae*, with 5 (7.57%) species. Out of 66 species 45 (68.19%) species were residential, 18 (27.27%) species were regional migratory and 3 (4.54%) were seasonal migrants (Figure 4.9).

Figure 4.9 Composition of Residential/Migratory birds at site 2



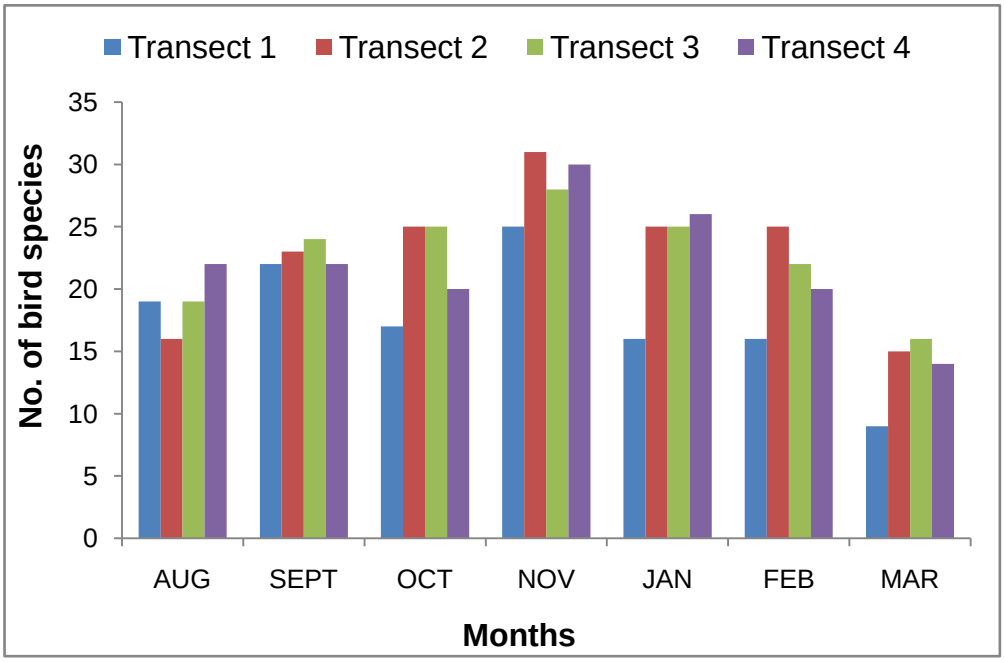
4.6.10 Transect Study

Quantitative data in bird community was obtained from four transects on site-2. A total of 3083 individuals was observed in 1677 sightings during the study period. (Appendix IVb)

T-1 supported the maximum number of species in October followed by September. On T1, the number of species increased from September to November and it gradually decreased from January to March.

On T-2, maximum species were encountered in November followed by October, January, and February respectively. Minimum number of species was observed in August and March. T-3 and T-4 had a similar trend. Bird number increased from August to November, and decreased thereafter to March to attain minimum values (Figure 4.10).

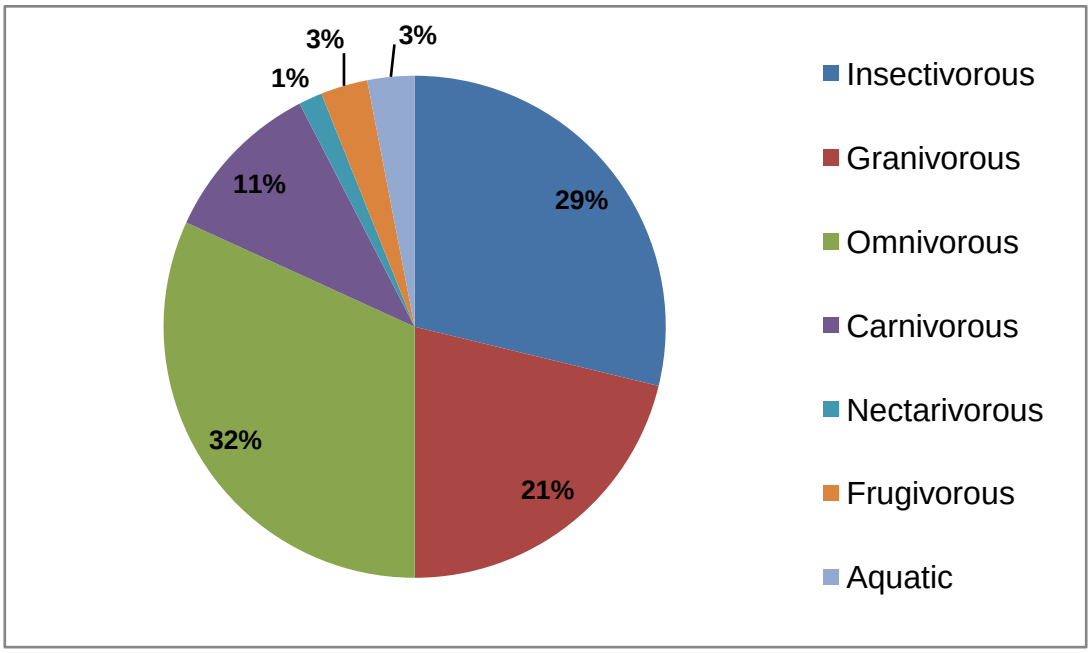
Figure 4.10 Monthly distributions of bird species on transects at site 2.



4.6.11 Feeding Guild profile

A total of seven feeding guilds were recorded. Omnivorous (31%) was found dominant followed by insectivorous (29%), granivorous (21%), carnivorous (11) and other with insignificant numbers (Figure 4.11).

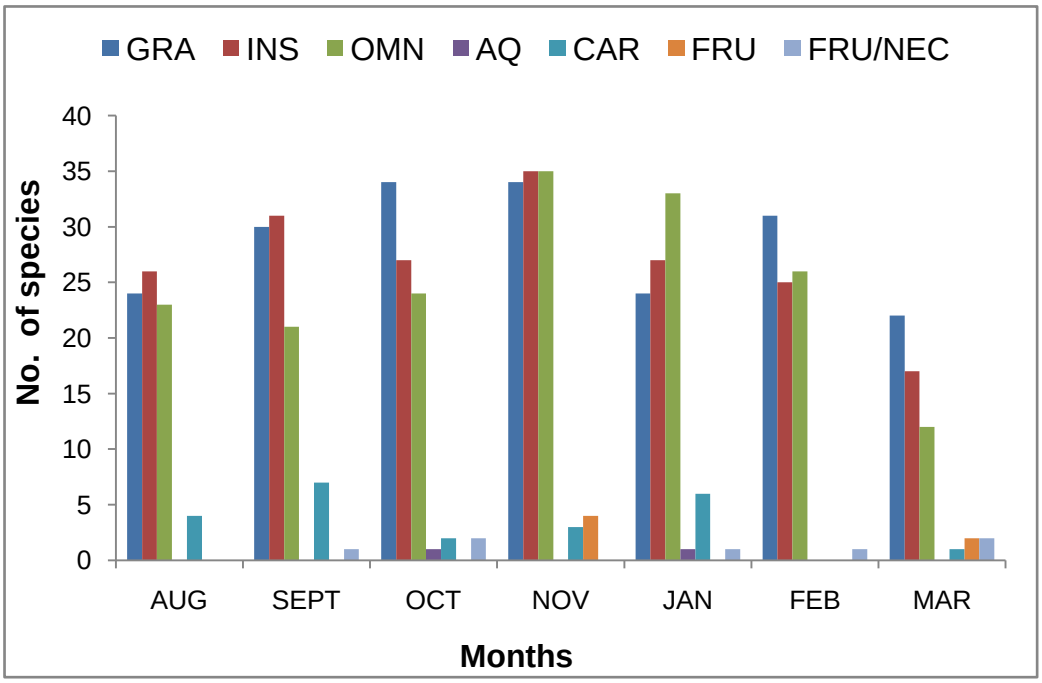
Figure 4.11 Feeding guilds proportion at site 2.



4.6.12 Monthly Variation In Feeding Guild Composition

Species of granivorous guild dominated the proportion in October and November with 34 species each. Its proportion increased from August to November and decreased thereafter from January to March. Insectivores showed similar variation with high proportion in November with 35 species. Omnivorous species number was high in September and least in March. Carnivores were encountered from August to January (Figure 4.12).

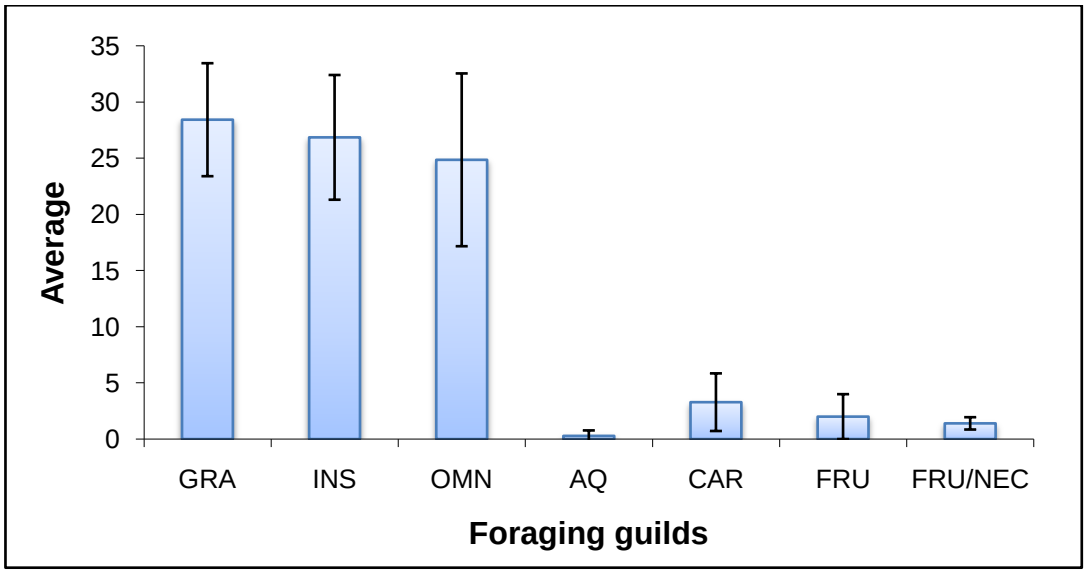
Figure 4.12 Monthly variations in feeding guild composition at site 2



4.6.13 Monthly fluctuation in feeding guild composition.

The highest fluctuation was found in omnivorous guild (7.69± 1.4), followed by insectivores (5.5± 2.0) and granivores (5.0 ± 1.9) (Figure 4.13).

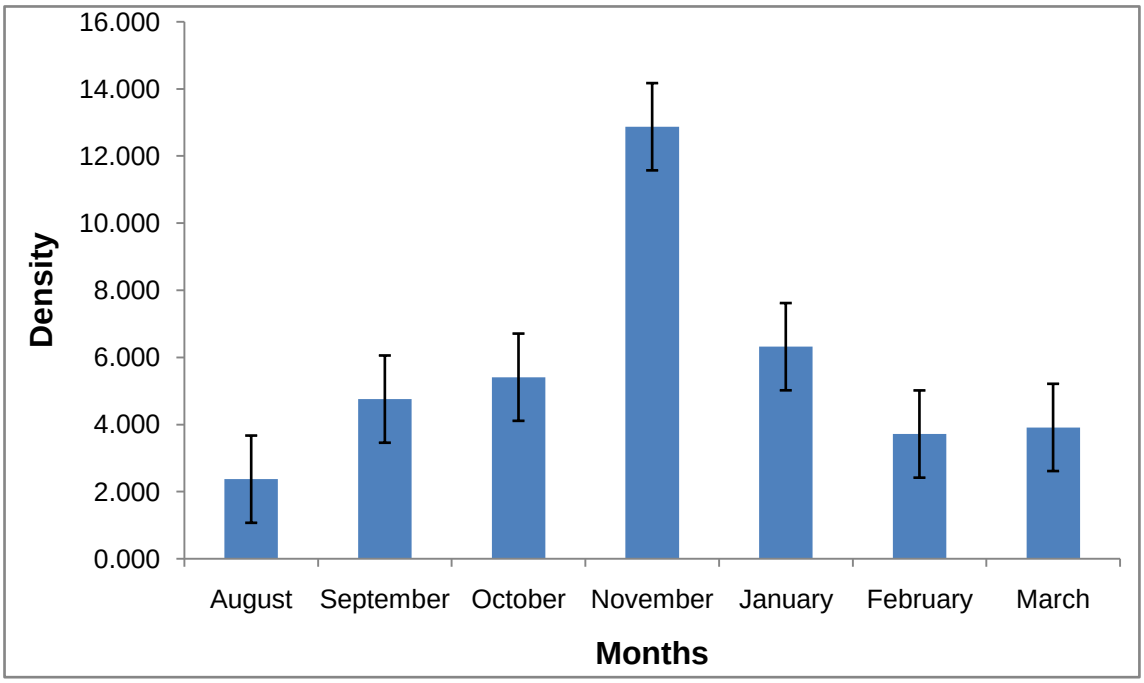
Figure 4.13 Fluctuations in feeding guild composition at site 2



4.6.14 Density

The density was highest in November followed by January and October respectively. Minimum density was found in the month of August. Density of birds increased from August to November and decreased thereafter in February. It again increased from February to March, to attain its minimum (Figure 4.14).

Figure 4.14 Monthly bird species density at study site 2

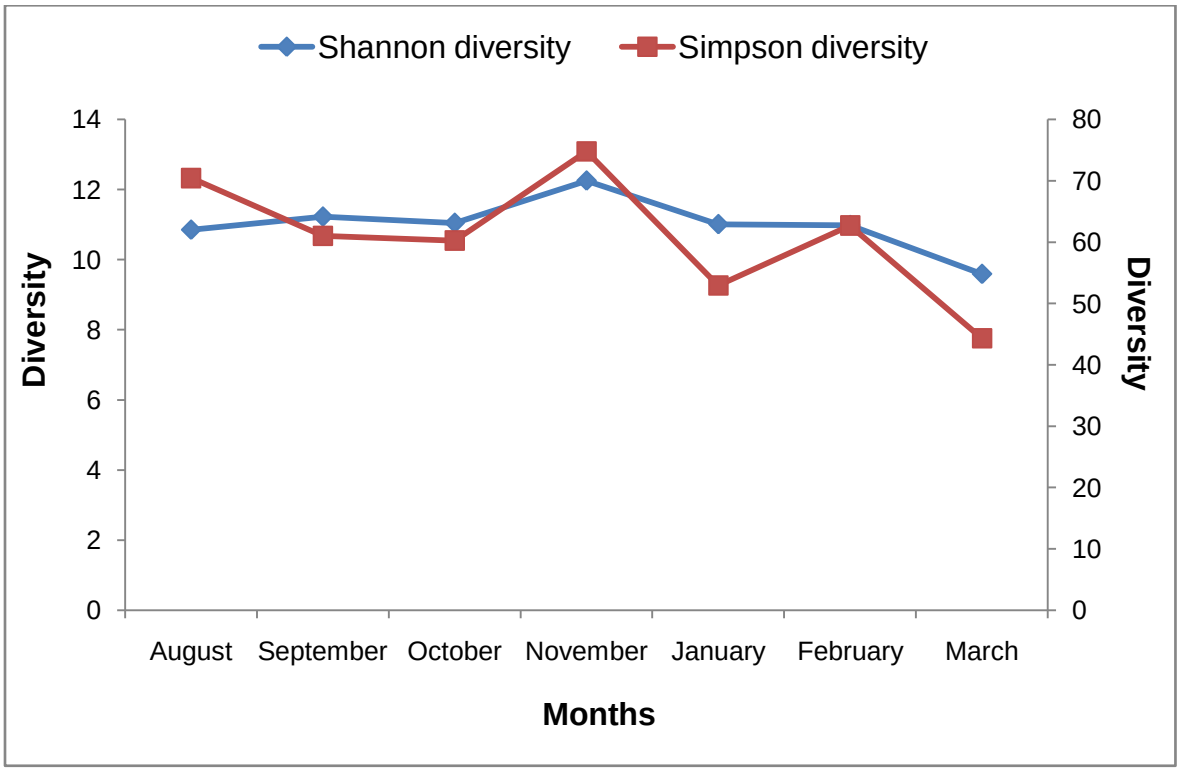


4.6.15 Diversity Indices

Shannon diversity increased from August to November and was recorded to be minimum in March.

Simpson diversity was the highest in November followed by August. It decreased thereafter from October to January, and recorded least in March (Figure 4.15).

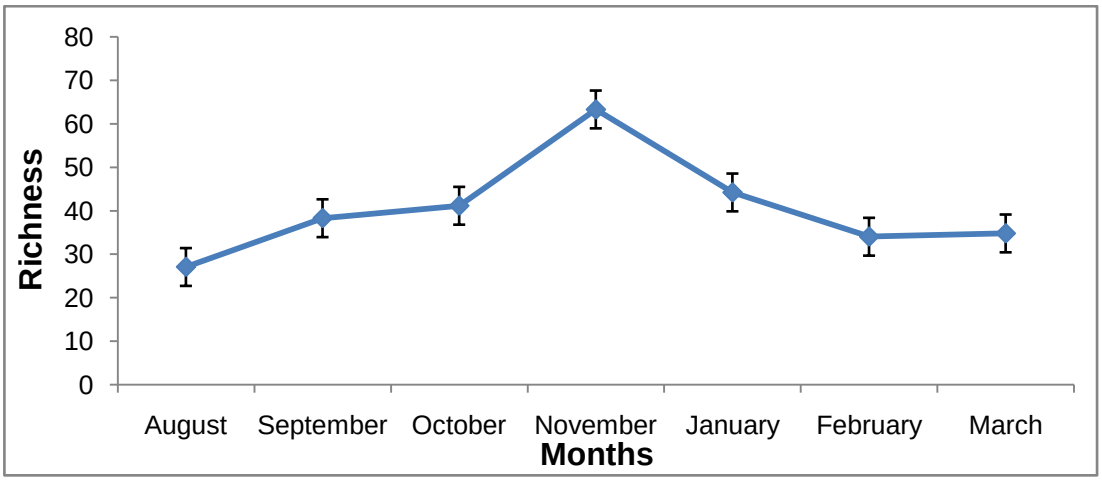
Figure 4.15 Monthly profile and variation in species diversity indices at site 2



4.6.16 Species Richness

Bird species richness was the highest in November followed by February and October respectively. Minimum richness was in August. Species richness increased from August to November and decreased thereafter. Low incline was recorded in March (Figure 4.16).

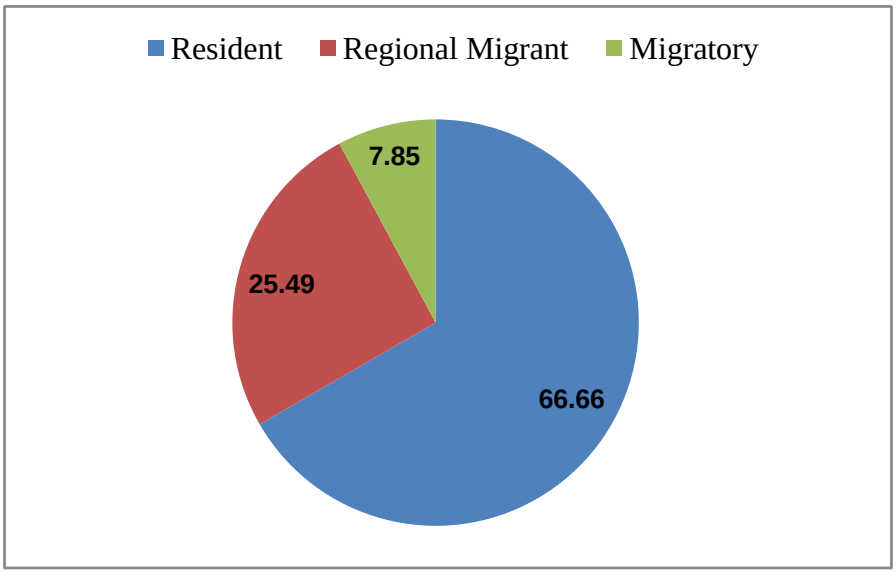
Figure 4.16 Monthly profile of bird species richness at site 2



4.6.17 Research cum Demonstration Center Site 3

51 species of birds belonging to 27 families were recorded (Appendix IVa). *Accipitridae*, *Motocillidae*, *Muscicapidae* and *Phasianidae* family were dominant with 4(7.84%) species each followed by *Alaudidae*, *Cisticolidae*, *Colmbibia*, *Hirundinidae* and *Timaliinae* with 3(5.88%) species each. Of these 34 (66.66%) species were residential, 13 (25.49%) were residential migratory and 4 (7.85%) species were migratory (Figure 4.17).

Figure 4.17 Composition of Residential/Migratory birds at site 3

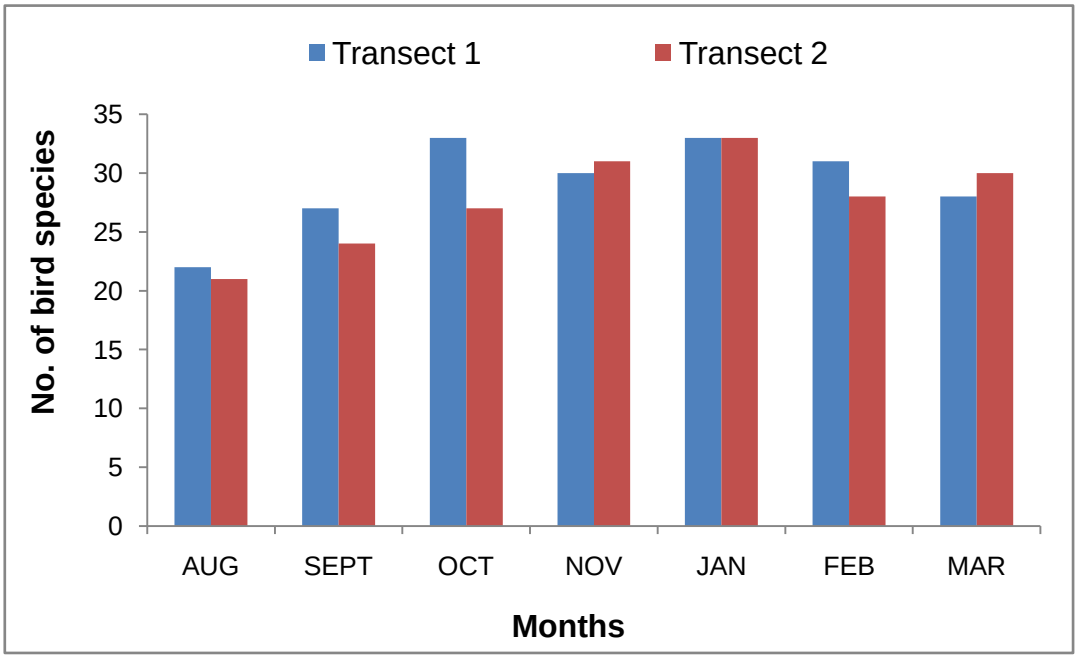


4.6.18 Transect Study:

Quantitative data in bird community was obtained from three transects on site-3. A total of 2764 individuals were observed in 1477 sighting during the study period. (Appendix IVb)

On T-1, maximum number of species recorded was in October and January respectively followed by February and November. On T-2, species number was highest in January followed by November and March. Minimum number of species on both transects was in August (Figure 4.18).

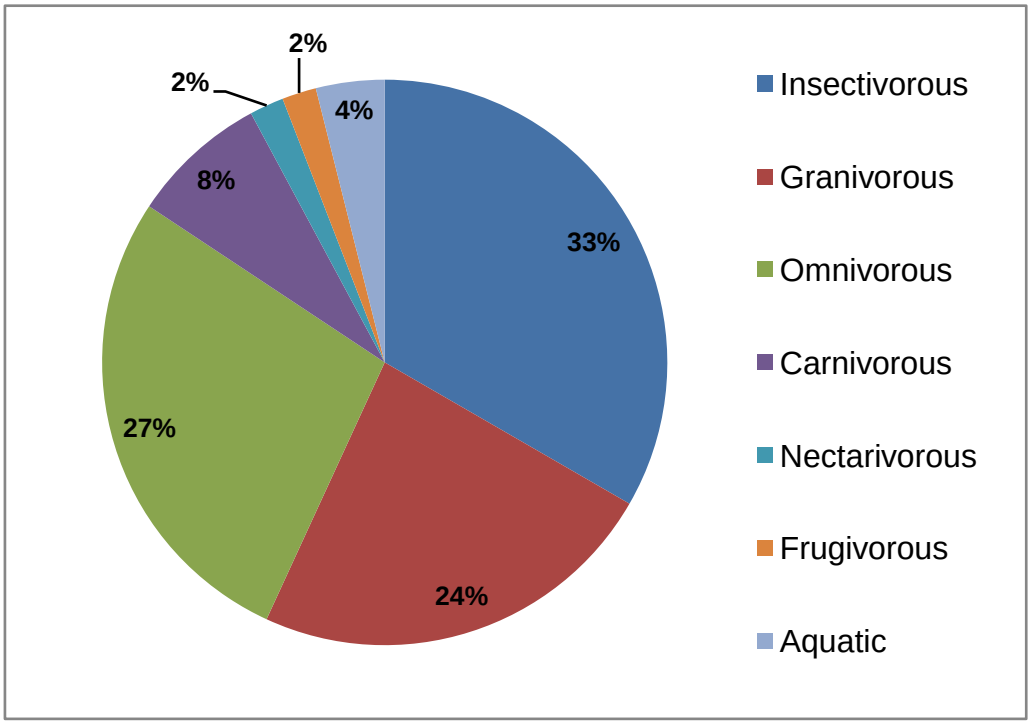
Figure 4.18 Monthly distributions of bird species on transects at site 3



4.6.19 Feeding Guild Composition

Seven foraging guilds were recorded. Insectivorous (33%) was found to be dominant followed by omnivorous and granivorous with 27% and 24% respectively. Other guilds present were insignificant in number for analysis (Figure 4.19).

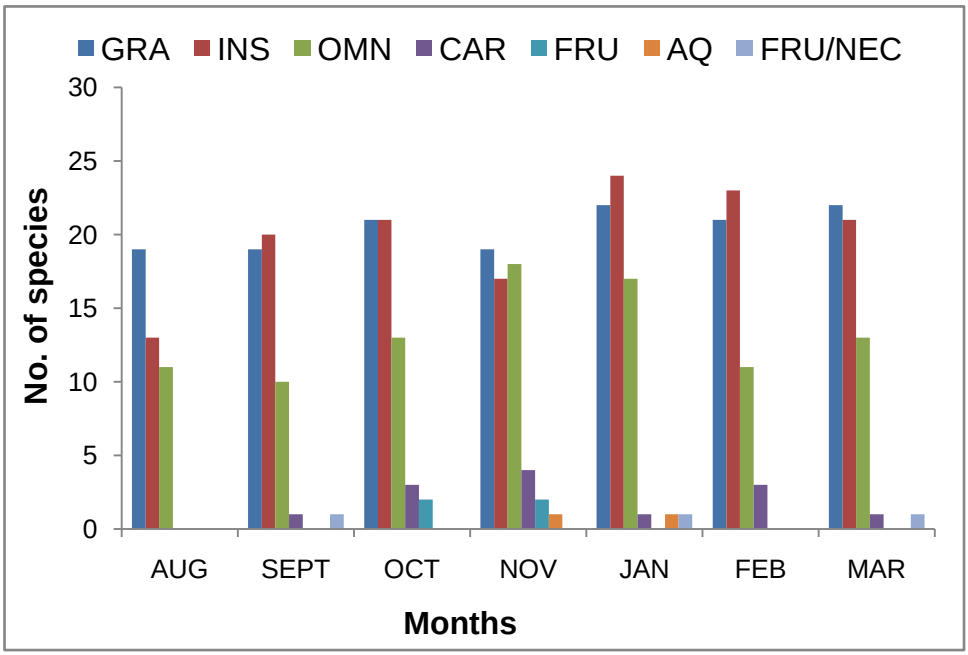
Figure 4.19 Feeding Guilds Proportion At Site 3



4.6.20 Monthly Variation in Feeding Guild Composition

High feeding guild diversity was observed in October. Insectivore composition was high in January followed by February and March respectively. Its composition was least in August. Omnivores were high in November and low in September. Granivorous species were high in composition in January and March, followed by February. Their number increased from October to January. Carnivores were recorded from September to March (Figure 4.20).

Figure 4.20 Monthly variations in feeding guild composition at site 3

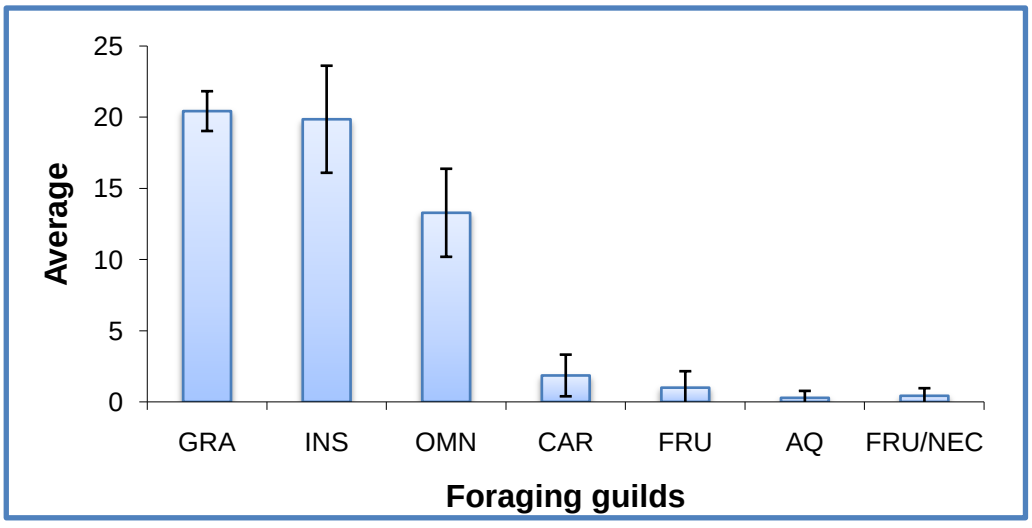


.

4.6.21 Monthly Fluctuation in Feeding Guild Composition.

Insectivore (3.76± 1.4) and omnivore (3.09± 1.1) species were most affected and showed similar fluctuations. Granivores showed less fluctuations (1.39± 0.52) (Figure 4.21).

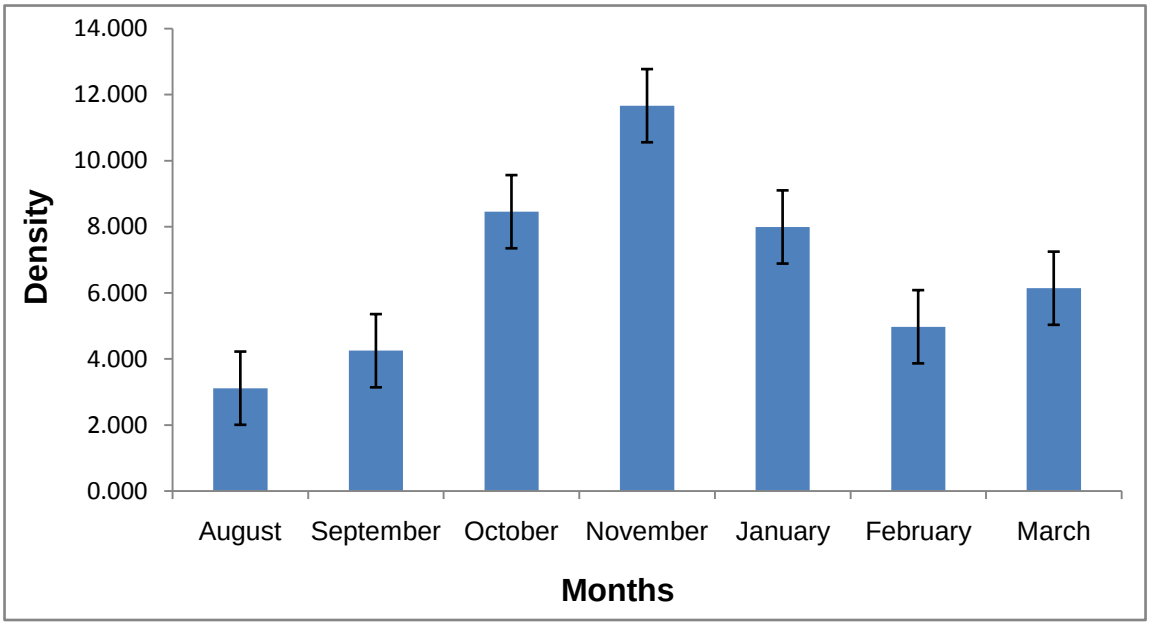
Figure 4.21 Fluctuations in feeding guild composition at site 3.



4.6.22 Density

Density was the highest in November followed by October. Minimum density was in August. It increased from August to November and gradually declined thereafter. It showed slight increase from February to March (Figure 4.22).

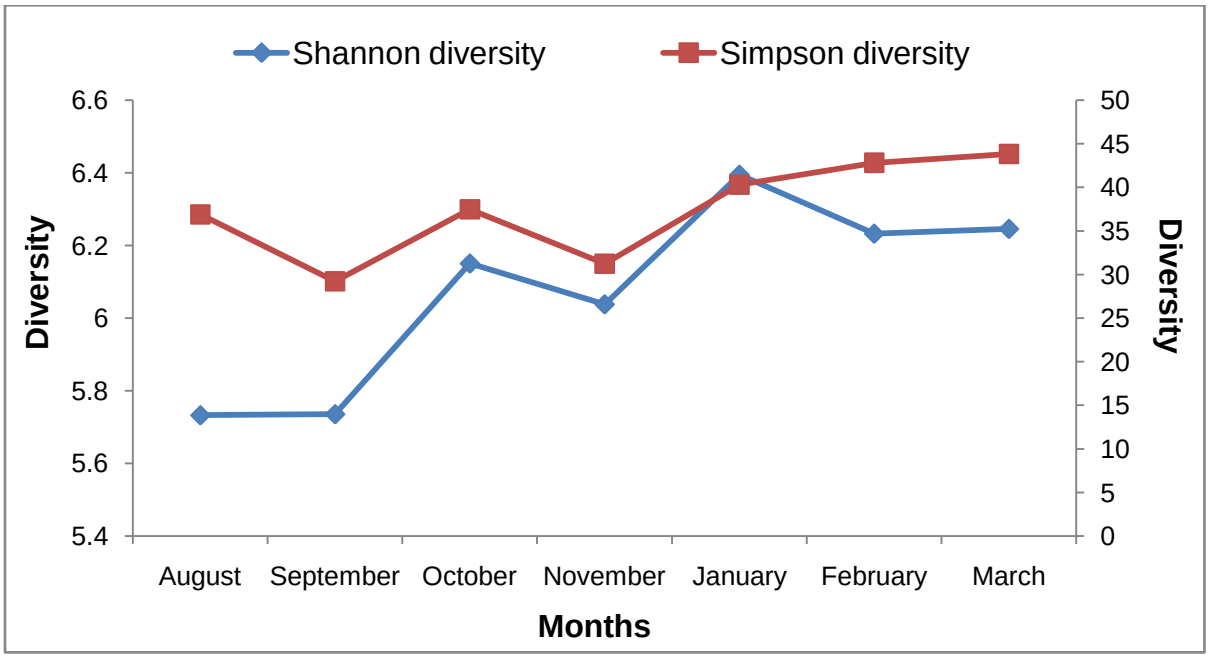
Figure 4.22 Monthly bird species density at study site 3.



4.6.23 Diversity Indices

Shannon diversity exhibited two peaks, first from September to October, and November to January to attain its maximum. It declined from October to November and January to February and slightly increased up to March. Least diversity was observed in August. Simpson diversity was maximum in March and minimum in November. It showed steady incline from November to March (Figure 4.23).

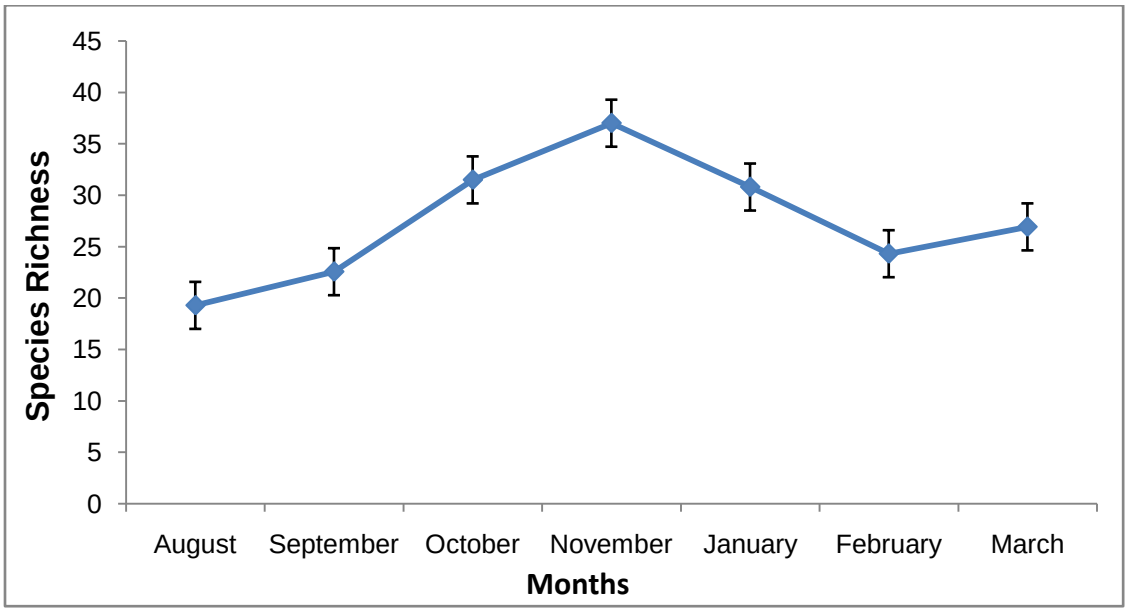
Figure 4.23 Monthly profile and variation in species diversity indices at site 3



4.6.24Species Richness

Highest species richness was observed in November followed by October and January respectively, whereas the least was recorded in August. It increased constantly from August till November, and declined thereafter (Figure 4.24).

Figure 4.24 Monthly profile of bird species richness at site 3



4.7 Comparative Study among sites

4.7.1 Overall species richness: In all, 79 species belonging to 34 families were recorded at the three study sites (Appendix IVa). Of these, 32 species (40.6%) and 22 families (64.7) were common between all the sites. Seven (8.9%), eleven (13.9%), and six (7.6%) species were exclusive of fifty species of birds at site 1, sixty-six at site 2 and fifty-one at site 3 respectively. One family at site 1, five at site 2 and three at site 3 were exclusive, whereas 3 families were common between sites 2 and 3. Eleven species each were common in sites 1 and 2 and between 2 and 3 respectively. Only one species was common between sites 1 and 3. More migratory species were recorded at site 2 than sites 3 and 1 respectively. All sites had a higher proportion of resident species. Proportions of terrestrial, arboreal and mixed niche species were different at the three sites (Table 4.8).

Table 4.8 Overall bird species richness of study sites

Parameter	Site 1	Site 2	Site 3
No. of families	23	30	28
No. of species	50	66	51
Resident species	36 (70.59)	45 (68.2)	34 (66.6)
Migrant species*	15 (29.3)	21 (31.8)	17 (33.3)
Aquatic species	3 (5.8)	5 (7.6)	5 (9.8)
Terrestrial species	27 (54)	30 (45.4)	24 (47.09)
Arboreal species**	16 (32)	26 (39.4)	18 (37.21)
Species with mixed niche	4 (8)	5 (7.6)	4 (7.8)

Figures in parentheses show percentage * includes extralimital as well as local migrants ** % f terrestrial spp.

Overall there are 19 families (25%) with only one species. Four families each had two, three and four species respectively, while five families (36.70%) had five or more than five species. These five most dominant families include 37% of the total species encountered at three sites (Table 4.9). Site 2 was richer in all dominant families of terrestrial birds except Alaudidae which was higher at site 1.Thus it suggest that site 1 was richer in terms of open area birds. Site 2 had much higher number of species than site 1 in families Accipritridae (raptors), and Motacilliadae (wagtails). Site 2 and site 3 were more similar (Table 4.9).

Table 4.9 Species richness of dominant bird families at study sites

Family	Total species found in area	Site 1	Site 2	Site 3
Alaudidae	18	7	3	3
Accipritridae	10	2	5	4
Motacilliadae	13	1	5	4
Muscicapidae	14	3	6	4
Phasianidae	8	4	6	4
Total	53	17	27	22

4.7.2 Species richness and composition patterns on transects a comparative study.

Rarefied species richness: A total of 7,775 individuals of 79 species were encountered with a frequency of 4,126 on nine transects at the three study sites. (Appendix IVb)

Table: 4.10 Rarefied species richness of sampling units at study sites.

	T1 Site 1	T2 Site 1	T3 Site 1	T1 site 2	T2 Site 2	T3 Site 2	T4 Site 2	T1 Site 3	T2 Site 3
10	8.95318	8.89643	8.23581	8.48296	8.94344	8.96408	9.06783	8.75448	8.85907
20	14.2845	14.1917	12.6448	13.2285	14.3261	14.383	14.6126	13.8587	14.0952
30	18.0022	17.9608	15.6438	16.5854	18.1929	18.2824	18.5806	17.4654	17.7973
40	20.6834	20.7813	17.8221	19.1333	21.1114	21.2227	21.5325	20.1482	20.5418
50	22.6736	22.9802	19.4837	21.153	23.4048	23.5264	23.808	22.2226	22.6559
60	24.1884	24.7522	20.8024	22.7989	25.266	25.3895	25.6179	23.8768	24.3367
70	25.3671	26.2194	21.8832	24.1665	26.8155	26.9364	27.0969	25.2296	25.7091
80	26.3023	27.4617	22.7924	25.3198	28.1321	28.2495	28.333	26.3597	26.8556
90	27.0571	28.5335	23.573	26.3048	29.2691	29.3852	29.3858	27.3211	27.8323
100	27.6757	29.4726	24.2544	27.1552	30.2642	30.3833	30.2965	28.1517	28.6784
150	29.5742	32.9221	26.7176	30.1176	33.8674	34.0851	33.5218	31.0864	31.7131
200	30.507	35.2154	28.2689	31.9315	36.1845	36.6077	35.5361	32.9197	33.683
250	31.0389	36.8864	29.2997	33.2175	37.8505	38.5111	36.9363	34.193	35.1092
300	31.3764	38.1564	29.9862	34.2193	39.1398	40.0187	37.9707	35.1288	36.1965

350	31.6102	39.1451	30.4329	35.0448	40.1896	41.2414	38.7672	35.8432	37.0498
400	31.7835	39.9283	30.711	35.7482	41.0756	42.2434	39.4014	36.405	37.7325
410	31.8131	40.0652	30.7512	35.8772	41.2375	42.4213	39.5134	36.5032	37.8524
420	31.8412	40.1963	30.7872	36.0028	41.3949	42.5924	39.6211	36.5974	37.9675
430	31.8681	40.322	30.8192	36.1252	41.5482	42.7569	39.7249	36.6878	38.078
440	31.8937	40.4426	30.8476	36.2445	41.6975	42.9151	39.825	36.7747	38.1842
450	31.9181	40.5583	30.8726	36.3608	41.843	43.0672	39.9216	36.8582	38.2861

Rarefied species richness for 9 transects at the three sites (Table-4.10) showed that T2 at site 1, T3 at site 2 and T2 at site 3 were richest transects. T3 at site 1, T1 at site 2 and site 3 were poorest in terms of species richness. When all transects were compared for their species richness (250 individuals), the results remained true. Thus, with increasing number of individuals the gradient of bird species richness of sampling units changed only marginally.

Transects with the lowest species richness had cover of non palatable grasses and were on edges. They were exposed to pressures. Intensive human activity (roads, tres passing, cultivation) and invasion of *Prosopis* **(**Table-4.5, 4.6**)** like T3 in site 1, T1 in site 2. When compared among sites, site 3 possessed highest richness as the area was regulated for grazing, traes passing and invasion of *Prosopis.*

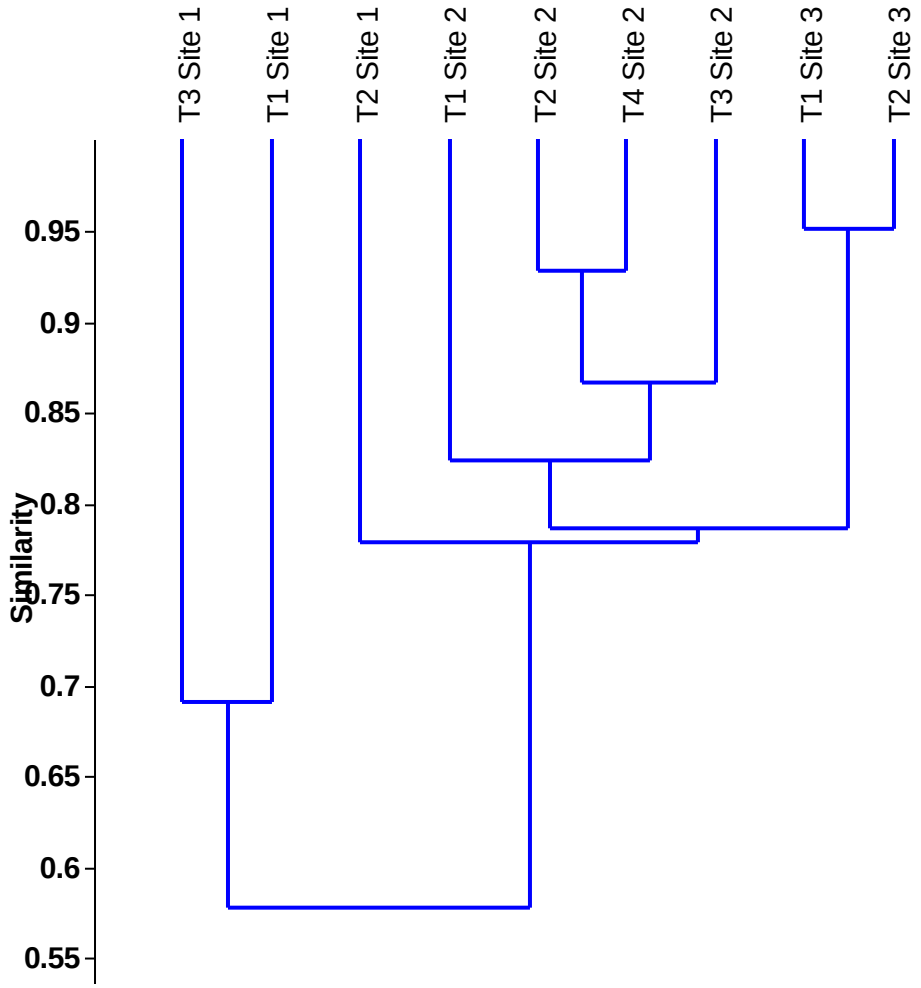
The species rich transects had more palatable grasses present with lower influences of human activities like T2 in site 1, T3 in site 2 (Table- 4.5, 4.6).

As the habitat on all transects was more or less same, the impact of human influences on species richness was clear.

4.7.3 Species Composition patterns:

To investigate these trends further, exploratory analysis was conducted – cluster analysis and multidimensional scaling (MDS) which represented similarity in species composition of transects through a dendrogram and two dimensional plots (Figure 4.16, 4.17). Figure 4.16 and 4.17 show the arrangement of sampling units with respect to species similarity matrix.

Figure 4.25 Dendrogram showing similarity in species composition of transects



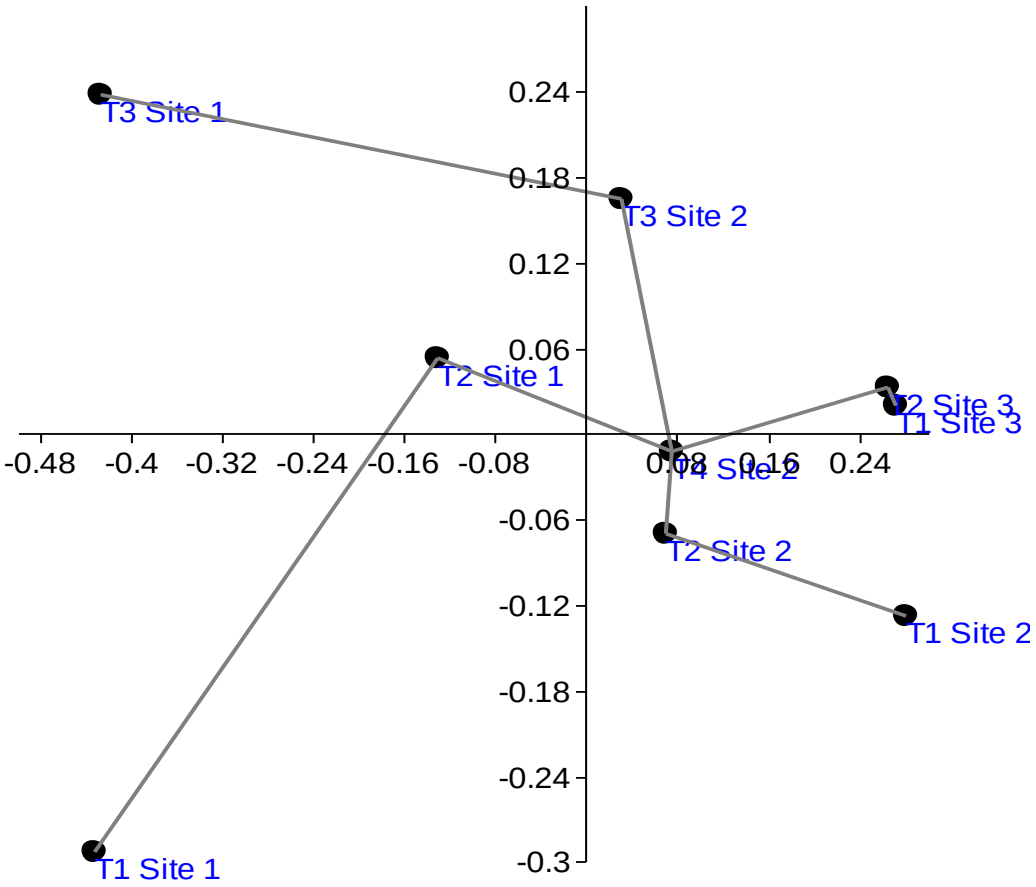
The cluster in figure 4.16 indicates two distinct sets. One set suggests similarity between T1 and T3 of site 1, as both are exposed to similar constraints with varied intensity. Other set comprises of one distinct outliner of T2 site 1 and two sub sets. The subsets contain transects of site 2 and site 3 respectively where both the transects of site 3 are similar in terms of species similarity matrix.

In site 2, T2 and T4 are more similar followed by T3. T1 is represented as outliner. T2 and T4 are interior most transects followed by T3 and T1 which are outermost among all.

Transects do not overlap in each cluster. Respective transects of respective sites show similarity.MDS analysis in figure 4.16 reveals same results as figure 4.15.

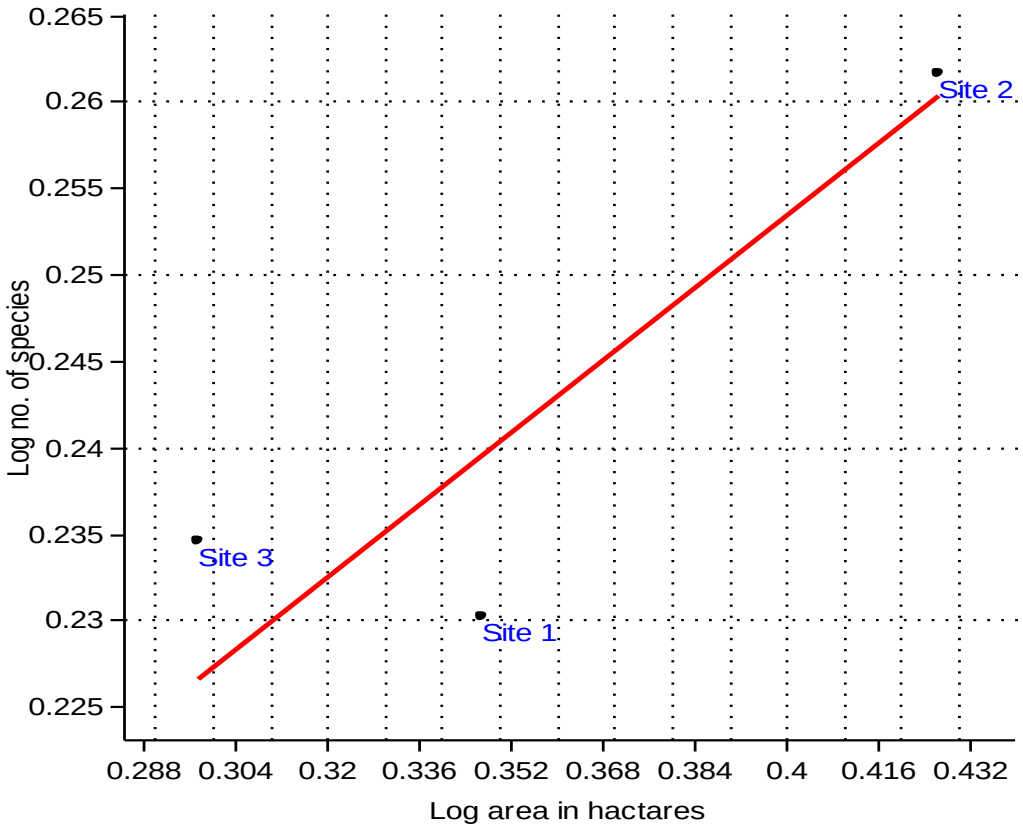
Thus, location (distance) between transects and geographical factors have a significant effect in influencing the similarity in bird species composition.

Figure 4.26 Similarity in species composition of transects based on MDS



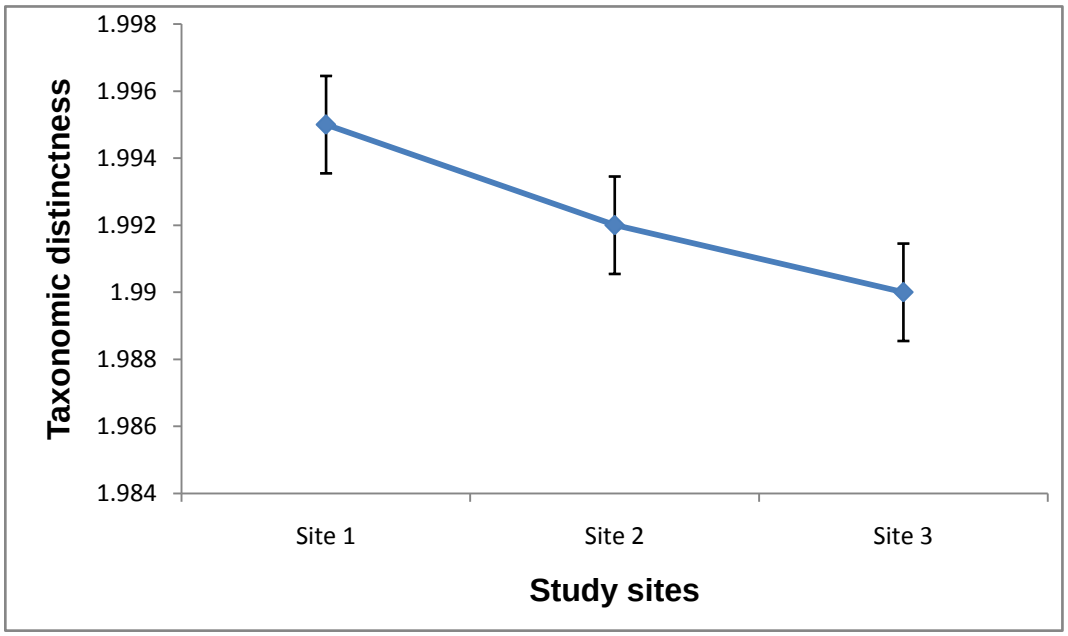
4.7.4 Species area relation: On examining the species accumulation curve for three regions of varing patch size (Figure 4.27), site 2 emerged as a region of high avian diversity as reflected by its position in the figure. It was followed by site 3 and site 1 respectively.

Figure 4.27 Species area relationship curve



4.7.5 Taxonomic distinctness: The variation among the sites in taxonomic distinctness were nonetheless observed to be only marginal with site 1 representing highest limits of gradient followed by site 2 and site 3 respectively (Figure 4.28).

Figure 4.28 Taxonomic distictness among study sites



4.7.6 Species abundance patterns: In terms of relative abundance, only a few species had very high abundance, but several species had low and intermediate abundance values (see appendix IVb, IVc). The species abundance curves (figure 4.29, 4.30 and 4.31) appeared to show a lognormal pattern of distribution for all sites with the broken stick model of species abundance distribution.

In terms of relative abundance (R.A.), eight species at site 1 and 10 species each, at site 2 and site 3 respectively accounted for 50% of the individuals. Encountered on transects, four species among these were common between all the sites. These were white throated munia (*Lonchura malabarica*), red winged bush lark (*Mirafra erythroptera*), laughing dove (*Streptopelia senegalensis*) and common babbler (*Turdoides caudatus*). All the four were widespread species. White throated munia was the most abundant species at all the sites followed by laughing dove and common babbler. In site specific profile, cattle egret

(*Bulbulus ibis*) was the most abundant at site 1 and grey headed bunting (*Emberiza fucata*) was abundant at site 2 and site 3 respectively. Grey headed bunting is migratory to the area and was found most abundant at site 3. Cattle egret is human dependent species and its high abundance indicate higher level of grazing and human presence. Thirteen species at site 1, twelve at site 2 and ten species at site 3 were rare (R.A. between 0.5 to 0.25%), of which two species (Common Hoopoe and Pipit spp.) were common between the three sites. Among the 12, 25 and 10 very rare species (R.A. < 0.25) at site 1, site 2 and site 3 respectively, three species were common between the three areas. The common species belonging to above categories were non grassland specialist species with wide distribution or migrants. Thirteen species at site 1 and eleven species each at site 2 and 3 respectively had intermediate abundances (0.5 – 2.0%), with three species being common. Eighteen species at site 1, nineteen species at site 2 and seventeen species at site 3 had high abundances (> 2.0%) with sixteen species being common among sites. None of the species at all the sites had similar abundance rating.

Figure 4.29 Species-abundance curve for site 1

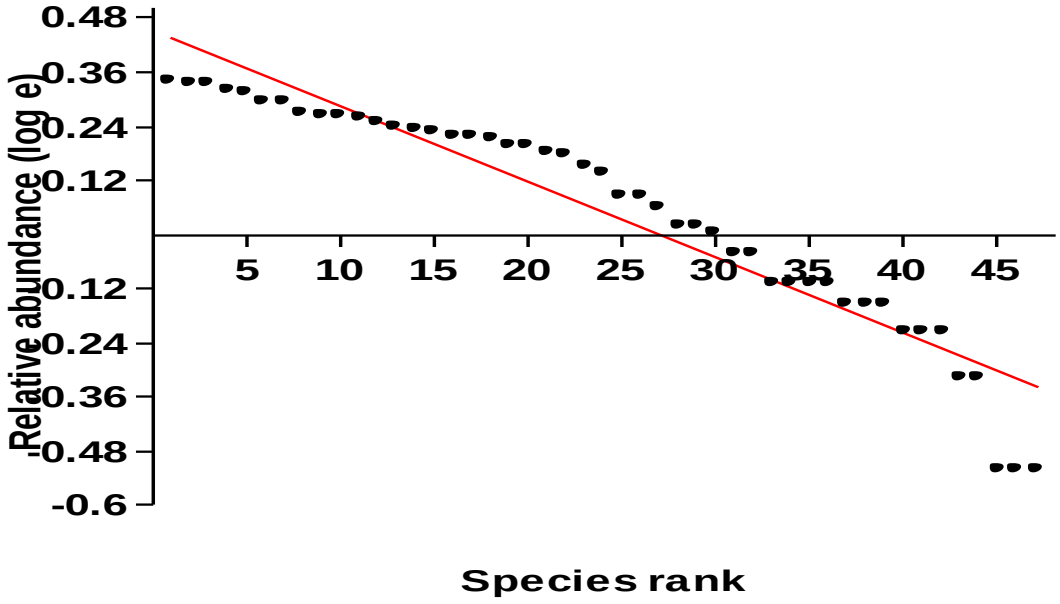


Figure 4.30 Species-abundance curve for site 2

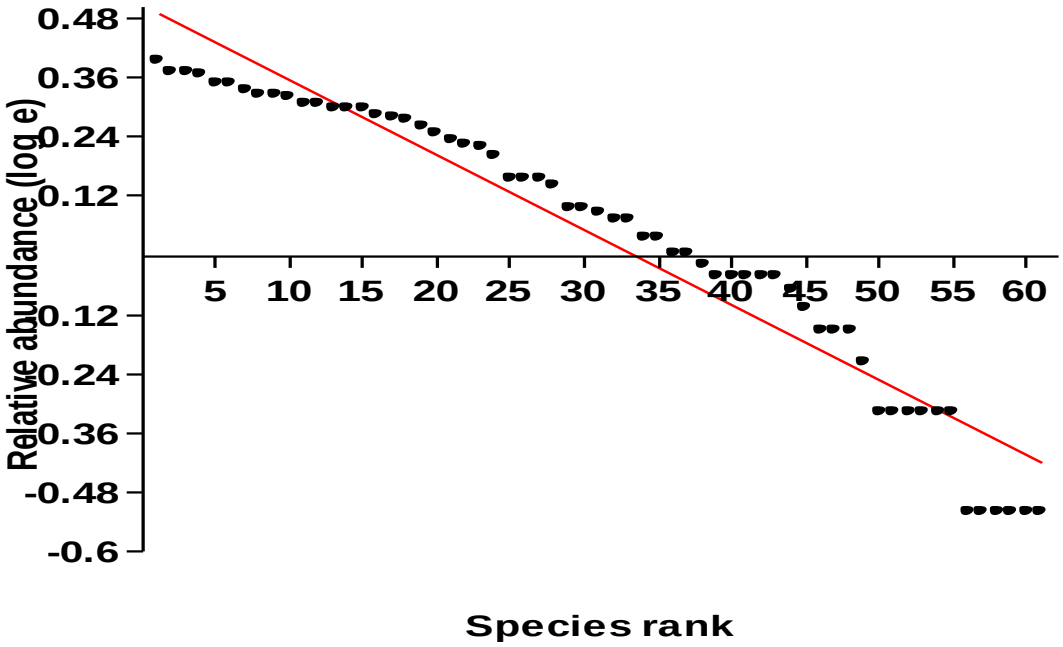
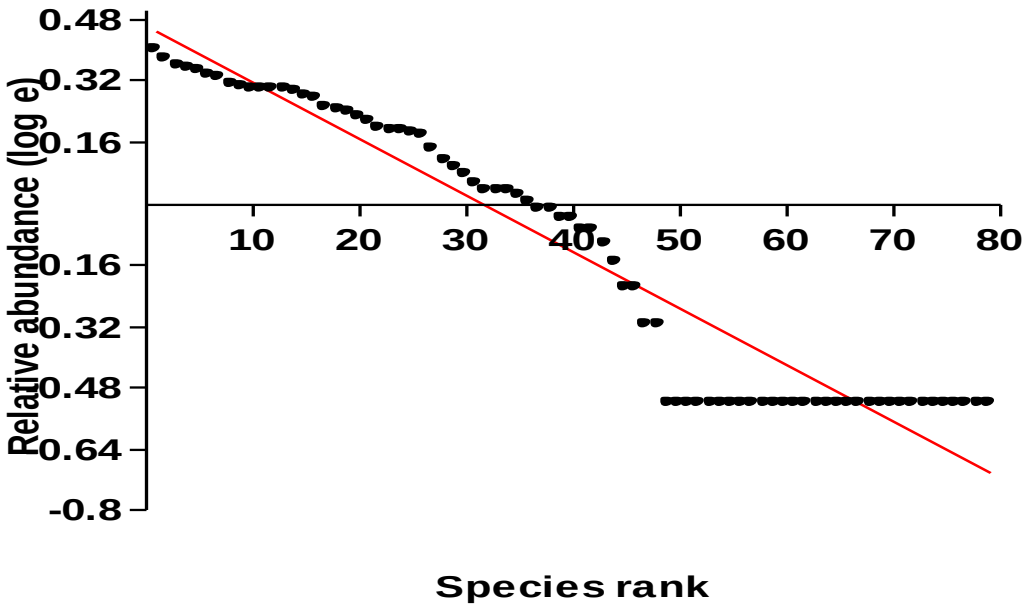


Figure 4.31 Species-abundance curve for site 3



4.8 Discussion:

4.8.1 Overall species richness: There were no past records available for the study sites. In grassland landscape of Saurashtra, species richness of study sites was lower than Rampara sanctuary (131 species, Singh and Tatu, 1992), Hingolgadh Sanctuary (303 species, Naik *et al*., 1990) and Velavadar National Park (125 species, Singh, H.S., 2001). When only grassland specialist species were considered, the areas had about 23 species. Considering the overall documented species richness of study sites, the number of species recorded was close to 79. Thus none of the area could be considered as very rich area in terms of bird species richness in the grassland biome of the peninsula.

The result indicates the impact of management practices as the protected areas were maintained especially for biodiversity conservation and the small grassland patches are

maintained for hay collection. Exploitation of resources and long exposure to ill planned management strategies resulted into impoverishment of avifauna.

The avifauna of the three areas showed many similarities, though there were important differences in species composition. Presence of Alaudidae (Larks) in higher proportion at site 1 indicates that species of this family can tolerate high pressure. Human activities and habitat degradation decreases population of natural predators such as reptiles and small carnivores eg. jackals (Soni *et al*., 1995) which increase chances of predation. Such birds are using this area only for reproduction, and thus their high occurrence was limited to the breeding season. For affinity among sites 2 and 3, land use pattern and factors of use are responsible.

Higher species composition at site 2 was a result of patch size (Figure 4.27) on distribution of grassland avifauna. Increased space and other factors are responsible for sustaining larger composition of resident and migratory avifauna. The paradox of the patch size hypothesis observed in the present study was higher avian diversity at site 3 (96 hectare) as compared to site 1(167 hectare).This suggests that in addition to patch size, protection has a key role in determining avifaunal diversity in these grassland patches. The statement is only true under the condition that habitat among the sites has no significant difference.

4.8.2 Correlations of species richness and composition: There appeared to be an ascending bird species richness gradient from site with higher disturbance to the site with minimum disturbance. It suggests the impact of anthropogenic pressure. The statement

was found to be true for transect profile of species richness. Transects with high species richness T2 at site 1, T3 at site 2 and T2 at site 3 had more palatable grasses with lower influence of human activity which supported birds for roosting, breeding and foraging. The reverse was true for species deficient transects such as T3 at site 1 and T1 at site 2, which were exposed to greater intensity of human activities (roads, trespassing, grazing), with non palatable grasses and were on edges. Here, composition of grasses was considered on a qualitative basis, under the light that less exploitation leads to regeneration of palatable grasses (Chapter 3).

Seasonal fluctuations in species composition are a result of food availability and presence of grass cover after rainfall, and migratory season. During post monsoon and winter, migratory population was added in the existing biomass. Harvesting in the past winter period was responsible for the decline in species number. Harvesting reduces vegetation cover and increases disturbance by human and feral dog presence. Harvesting also affects the breeding habitat of some bird species (Murphy, 2003).

The basic unit that contributed to similarity in bird species composition appeared to be land use and geographical difference. If it was vegetation, then two transects with similar vegetation (as observed in present study) showed higher similarity in their bird species composition even if these were separated by longer distances of 50km, but it did not show similarity of species composition in three areas (Figures 4.25, 4.26). Although rarity and passive sampling could have had their influence, such distribution pattern was shown even by some of the most abundant species such as White Throated Munia, and Common Babbler.

The above patterns indicated that the distributions on transects were brought about by differences in location and geographic distance. The role of vegetation should be discussed to justify the statement.

Bird studies such as that of Raman (2001), highlighted the role of vegetation structure as compared to physical distance as a determinant of bird species composition in fragmented rainforest habitat of southern Western Ghats. Worah (1991) documented that in Dangs, protected forest areas and plantations showed two different clusters grouping together areas with similar vegetation features. Javed (1996) documented the importance of vegetation structure along with other key factors such as foraging behavior and body size of the birds in determining the guild and community structure of the area. Jaypal (1997) found significant difference between guild compositions of different habitat types.

Prince *et al.* (2003) attributed the observed differences in avifaunal composition of two sites (Manali and Overa Sanctuaries) separated by 250 km in the Himalayas to replacement by similar sized congeners, specific habitat requirement (e.g. presence of particular tree species), patchy distribution and unexplained patterns. They, however, did not consider the role of climatic and structural variation in habitat in detail, but indicated the likely role of vegetation in these observed differences. Jayson and Matthew (2002) attributed differences in bird species composition between rainforest and moist deciduous forest at two sites separated by 20 km in southern Western Ghats to variation in vegetation, mainly high diversity index. At their sites, the bird species richness did not show great variation but species composition varied. Trivedi (2006) also documented that the role of vegetation seemed to be more important than the distance effect.

In grassland bird studies, Wang *et al.* (2002) concluded that different vegetation types provide different habitat condition to birds, and the structure of bird community differs with habitat condition. Similar attributes were given by Scott *et al.* (1998) suggesting role of habitat characteristics in determination of bird richness. In their study, similar results were found as compared to my study, as common species were abundant in every habitat type. Scott *et al.,* (1998) concluded that similarity might be partly due to the loss of grassland habitat.

Thus, vegetation in terms of microhabitat has a key role in determination of species richness but land use and anthropogenic activities which disturb such microhabitat, are important factors.

In the present study, it can be concluded that in small grassland patches of Saurashtra, anthropogenic pressures and land use induced geographical isolation are more influencing factors than vegetation (microhabitat) in determination of species richness.

Thus, despite the apparent role of vegetation at local level, the possible role of history needs to be considered for species composition of bird communities at my study sites.

4.8.3 Foraging guilds: A guild is defined as a "set of species that exploits the same class of environmental resources n a similar way" (Root 1967 in Weins 1989). Guilds have high functional utility in understanding the organization of communities (Terborgh and Robinson, 1986). The guild signatures of my study sites did not vary much on the whole, except for few noticeable differences among some guilds. All three sites had few

specialized composition. There were several guilds at site 2and site 3 respectively and six guilds at site 1. Due to the presence of an irrigation reservoir in close proximity to each site, species of aquatic guild were observed. My observations indicate that omnivorous guild was dominant in site 1 and 2, whereas insectivorous guild was dominant at site 3. The possible reason is the presence of arthropods throughout the study period at site 3 which was not exploited by human presence and activity. Thus it suggests that insectivores are the indicators of disturbance on a grassland ecosystem. Kar (1980) outlined influence of specific abiotic factors in shaping the guild signatures. The guild was found highly sensitive to the changes induced by extrinsic factors. As pressure increased, omnivores were found dominant with high fluctuation. Fluctuation in omnivores can also be linked with anthropogenic pressures as it was high in site 1 as compared to site 2. The guild contains opportunistic birds, which utilize the resources at different strata during different time and fluctuations in their composition indicate various degrees of pressure on a system.

Thus, from guild in the study it was found that composition of insectivores indicates stressors in the system whereas fluctuations in omnivores indicate its intensity. The outcome can be used as an important tool in rapid assessment for determining the health of the grassland area. But there are certain features related to variability in guild structure which I wish to make a remark on. The variation arises as a particular species could belong to two different guilds at different times of the year. Thus, it is mandatory to evaluate resource use of individuals at a given moment in order to assign them to a guild, instead of obtaining single measure purporting to represent a species fixed attribute. Species showing temporal switches between guilds add still more complexity to the

process behind community organization, because they will overlap in resource use (and interact) with different members of the assemblage at different times, building up a diffuse, temporally variable network of species.

Granivorous guilds remain more or less constant with the least fluctuation at all sites. This suggests that it is a robust group with adaptability to utilize resources at different strata. As the group consisted of grassland specialist species of Alaudidae and Phasianidae, it was important to investigate their role in the system to understand the complete dynamics of the semi arid grasslands.

4.8.4 Species diversity and taxonomic distinctness

Diversity indices reflex seasonal variation as by food and cover availability during post monsoon followed by addition of migratory population. It remains fluctuating in site 1 and site 2 whereas it shows gradual increase at site 3 throughout the study period (figures 4.5, 4.13, 4.21). This suggests that if the area is not disturbed, diversity remains constant or exhibits gradual increase, irrespective of the mentioned factors. Thus, disturbance gradient is the principal component in the determination of species diversity of these grassland patches.

No final conclusion could be drawn on the nature of the relationship between alpha and taxonomic diversity in the absence of strong evidence. But if the value at which taxonomic distinctness peaks (51 species in the present study), is considered as an empirical measure of phylogenetic stock/reservoir of ecological communities [i.e., the minimum number of species required to maintain the taxonomic integrity of local

assemblages], it can be used as a potential optimality indicator in biodiversity assessment and monitoring surveys.

4.8.5 Species Abundance – Correlates of Commonness and Rarity: The trends of species abundance indicated a high similarity between the patterns observed in the bird communities of the three sites. The distribution-abundance curves showed that all the sites possessed even bird communities (Terborgh *et al*., 1990). Although distribution of abundance has not received much attention at the regional and continental scales, many local and habitat scale studies have focused on this aspect. Three models depicting local patterns of distribution of species abundance have been described. These are geometric, lognormal and broken stick (Wiens, 1989). Magurran (1988) has discussed their ecological relevance though there is considerable debate and discussion regarding the ecological implications and validity of these models, particularly the commonest – lognormal model (Magurran, 1988). The distribution observed in the bird communities of all study sites is a universal feature among communities of varying taxa and in sizes ranging from dilatometer slides to continents (Sugihara, 1980). However, there is no agreement on whether this is a mathematical artifact or has a biological basis. Sugihara (1980) explained this pattern in terms of a hierarchical community structure represented by a sequentially divided niche space.

It appears that several species in communities are rare and that rarity has different connotations. For instance, Karr (1977) studied rarity in rainforest birds in Panama. He described five forms of rarity that included species associated with other habitats, species which could not be sampled well (i.e. canopy species, nocturnal species), species showing seasonal movements, species visiting the area for specialized resources and

unknown form of rarity. He indicated that some species exhibited more than one form of rarity and in all 62% of the species were rare in his study area. Terborgh *et al*. (1990), while documenting the Amazonian bird community found about 42% of species to be rare using Karr's criteria. They re-interpreted Karr's work to reduce rarity to two chief forms – local rarity and inherent or constitutional rarity. The latter type includes species that are habitat specialists, the largest sized species within certain guilds, woodpeckers, raptors and owls. Such species are more vulnerable to changes in habitats (Terborgh *et al*., 1990) and require more attention from the conservation point of view. In their study, 10% of the species showed such rarity.

Half the species (50.3%) encountered on transects at the three sites were rare or very rare. Among these, species common to all sites (33%) belonged to the category of 'common elsewhere' i.e. in other habitats as shown by Terborgh *et al.,* (1990) or these were migrants. My result showed that there were 32 constitutively rare species (for all sites combined) on transects. This category did not include migratory species. The above indicates that patchy distribution of bird species and their apparent rarity are normal for grassland bird communities. However, such species need to be viewed in light of factors such as their habitat specificity, body size, guilds and endemism for conservation purposes.

Conservation of Avifauna: Threats, Recommendations and Research Needs.

From the foregoing, it is clear that fragmented grassland patches are of high conservation significance for avifauna. All the sites were found to become more fragmented habitat and isolated patches due to agriculture and forestry practices of the past. The anthropogenic activities (major threats) that could affect the avifauna of the study sites, which are representative for grassland patches of the peninsula, include poaching, fires, unsustainable and careless harvesting of resources, construction of roads, industrialization, overgrazing and harmful agricultural practices.

5.1 Threats to Avifauna

1. Poaching/hunting: During the study period, twenty one poaching incidents were recorded at site 2 and seven at site 1. All were during daylight hours. There were three common methods of hunting observed. At site 2 the commonest methods was using small traps and catapults to hunt birds and small mammals. The other method observed at site 1 was hunting with help of dogs. This was specifically targeted to hunt hares.

Interviewing these people (15 individuals) revealed that birds of family Phasianidae, Owls, lesser mammals such as hare and reptiles like *Uromastrix* and *Varanus* were their prime targets. Birds hunted are also consumed at the site itself.

Although a survey of hunting was not carried out, these observations indicated that few people were involved in hunting and that too not as a major subsistence activity or as an

occupation. Rather, most people did it seasonally (in late winter to summer when there were no farm related work) or in absence of employment (labors in these case).

2. Fires: Data of fire incidences of last ten years at site 2 showed that 5-8 percentage of total area experience fire every two years (Anon. 2006). Most fires were manmade and often intentional on three occasions. Fire was observed from January to March. These fires were mainly affecting the litter and undergrowth both important habitats for birds. Fires destroyed ground vegetation. Ground nesting and terrestrial birds are vulnerable to fires, particularly because the highest occurrence of fire coincides with the nesting season of these birds. In addition, the fires would also reduce the availability of food resources such as insects in the pinch period.

3. Agricultural Practices: Ill planned agricultural practices are the main reason for deterioration of native grasslands in the peninsula. Encroachment of grasslands and their fragmentation are a direct effect of these practices, influencing the grassland avifauna.

4. Past Forestry Practices: In the past, plantation activity by government in grasslands of the peninsula is a short visional step. The target species were *Acacia senegal* and *A. auriculiformis*. In some regions, *Boswellia serrata*, *Butea monosperma, Terminalia* crenulata, *Lannea corromandelica* and *Diospyros melanoxylon* were also planted. These forestry operations led to change in the quality of grassland in terms of reduce grass diversity, horizontal heterogeneity and microhabitat therein.

5. Harvesting of Fodder: Harvesting of fodder is a major practice employed in the grassland patches. Every year 9, 481, 44.25 kg of fodder is collected from grasslands of the peninsula (Annon. 2006). Such repeated harvesting of fodder could affect the health

of the grasslands. Further, movement of large number of people for the purpose causes physical disturbance. Instances of fire and poaching also occur.

6. Grazing by Livestock: Illegal and uncontrolled grazing by livestock caused damage to vegetation, especially to regenerating saplings. Long term exposure to overgrazing results in degradation of ecosystem particularly in shrub-dominated habitats (Dean and MacDonald 1994, Ward and Ngairoae 1999). Grazing causes replacement of perennial grass species to annuals with inferior quality (Chapter 3).

7. Disturbance by Roads, Trespassing and Vehicular Traffic: In sites 1 and 2, roads passing through and on periphery have uncontrolled trespassing and vehicular traffic. All types of vehicles including heavy transport ply on these roads throughout the day and even at night. The roads which cause more disturbances located in peripheral of areas include: Rajkot – Kalawad, Khirasara – Lodhika, Balasar – Munjka, Raiya – Munjka, and Munjka – Ishwariya.

8. Mining, Industrialization and Urbanization: Illegal soil mining was reported from site 1. Almost 40% of the land suffers the malpractice due to lack of proper policies. Mining alters the landscape permanently making it unsustainable for conservation efforts.

A major industrial estate is located near site 2. It creates pollution. Moreover, the laborers were reported conducting malpractices which are poaching, and firewood-fodder collection.

Urbanization at site 1 is a major issue. In addition to mining, it is the main factor responsible for deterioration of the grassland ecosystem. More than 60% of the area was fenced and utilized as farm houses, residence and for educational purposes.

5.2 Recommendations

(I) General Measures:

1) There is a urgent need to review the possibilities of protecting the area by regulating the land use pattern and the process of urbanization.

2) Give high priority to development and strengthening of corridors between grassland patches. This would ensure long term viability of the populations of the grassland bird species affiliated to the Saurashtra.

3) Regular patrolling and presence of Forest staff would eliminate the direct threats to wildlife such as poaching, illegal grazing and trespassing.

(II) Habitat Management Measures:

Introduction: Each grassland bird species has a particular range of habitat conditions (Weins 1969). As grassland bird requirements are diverse, effective management should produce a diverse spectrum of habitats across the peninsula taking into account amount of habitat, habitat size and shape, habitat distribution, surrounding land use, edge issue, habitat structure, disturbance patterns and the impacts of land management practices.

1) Grassland bird habitat should be managed at three different scales: Large landscapes of more than 2500 hectares, medium landscapes of around 700-1000 hectares and small blocks of 80-400 hectares.

A. Large landscapes:

(a) These Large landscapes should incorporate extensive areas of open treeless grasslands, along with some shrubs and savannah habitats that are consistent with pre settlement conditions (ex. Wastelands of present study).

(b) In present day situation, it is not possible to design and manage large grasslands as PA in Saurashtra, thus most of the land in these can remain in combination of public and private land. Following measures can be adopted to secure large area under management plan.

(i) Design an area by combining mosaic of lands of different land use which are consistent with each other (for example, PA-RF-PF, RF-Panchayat *vidi*, Panjarapol *vidi*-RF, Private *vidi*-RF etc.).

(ii) Other areas which can be included are historical native grasslands which take advantage of the land formations, climate and ecological features that naturally support management of open grassland habitat (ex.Wastelands and degraded Panchayat *vidis*). Some areas of cleared forest or former wetlands that are currently important to grassland birds should be identified and considered.

(iii) In designing large landscapes, privately owned grasslands, agricultural land and other landforms (as in Bhavnagar and Rajkot division, Chapter 3) with compatible agricultural uses which could stay in active crop production, ideally in small grains and hay are also useful.

(c) The core of the project should be an area of permanent grassland at least 1200 hectares in size. Securing this core grassland, 25% of the management area should be in long term grass cover including pastures, harvesting plots, grazing plots etc., 75% of which should be in blocks of 60-80 hectares or scattered throughout the area.

(d) The remaining land, if it is under agriculture should remain compatible with cropping pattern i.e. producing small grains, hay or cereal crops. In Saurashtra, most of the farmers follow a practice of growing fodder in farmlands for cattle and plant trees on edges. In this case, the agriculture land act as corridor for birds between isolated grassland patches. It is possible if and only if it meets the above criteria.

The role of agricultural practice in such prospective is not yet clear, thus further research is require to justify the hypothesis.

(e) Removal of tree and shrub cover, especially in fence lines and roadsides, should be encouraged throughout the management area, especially around the core grassland area. It reduces the amount of predator habitat.

(B) Medium scale Landscape: Medium scale management areas should be at least 700 to 1000 hectares in size. These areas should have 200-400 hectares of permanent

grassland, with 35% of the remaining land in permanent grass cover and the rest in productive agriculture.

Medium scale grassland areas are best suited to landscapes where large areas are not feasible (as in Junagadh division, Chapter 3).

(C) Small Blocks: Blocks of grassland should be of 90 hectares in size. Blocks of 100-250 hectares are preferable and blocks of 250-500 hectares are the most desirable in this size category. Small blocks should not be isolated on the landscape, but concentrated as closely together as possible, preferably adjacent to or connected by other suitable habitat such as PA (*vidis* of Maliya Hatina taluka, Junagadh division, Chapter 3).

(2) Shape of the habitat block should be approximate circle or square to minimize the edge to interior ratio.

(3) Habitat distribution: It is important to consider the predominant land uses and development patterns of the area along with ecological factors, when planning for large grassland landscapes. Considering these, there are two major ways to distribute habitat: consolidated (clumped) and scattered.

Scattered habitat blocks where the predominant surrounding land uses are dominated by suitable grassland habitats are recommended.

Consolidation of habitat blocks can be done in two kinds of landscapes.

(a) Landscapes that is intensely agricultural or primarily urban and suburban (as in surrounding grasslands of the Rajkot).

(b) Landscapes that offer special opportunities for the preservation of large areas of existing grasslands (as in Bhavnagar, Rajkot and Jamnagar division, Chapter 3).

In the case of intensely agricultural areas, little suitable habitat already exists. It is necessary to initiate grassland restorations (at least 300-600 hectares) to create quality grassland habitat. However, such landscapes are then inappropriate for social or economic uses.

So, large landscapes with suitable grasslands will be appropriate for the purpose with either scattered or clumped habitat distribution.

(4) Surrounding Land use: As grassland birds are influenced by land uses adjacent to patches of managed habitat, effective habitat size is grassland block plus the amount of suitable grassland habitat adjacent to or very near the patch.

The placement and configuration of habitat blocks in relation to other habitat types become important determinant of effective habitat size and of the species composition, species richness, and density of grassland birds that use the site.

Idealized arrangements of grassland patches on a typical agricultural region (in case of Rajkot division) or wildlife areas are presented below (in case of Dhari Gir east and Junagadh division)

Figure 5.1: Example of idealized arrangement of habitat in agricultural region

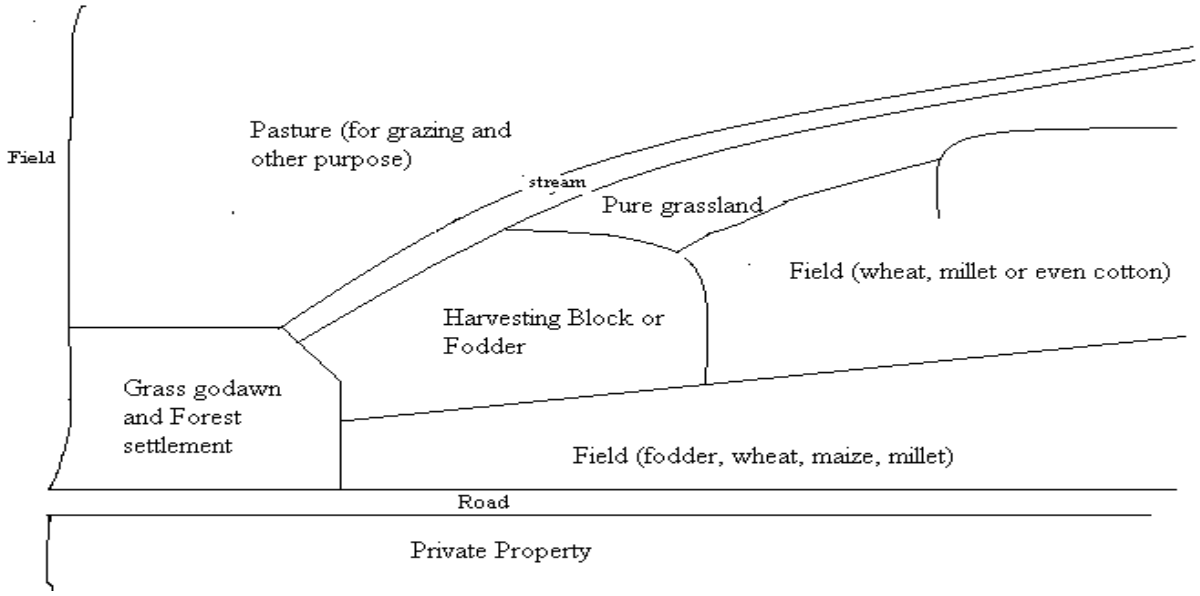
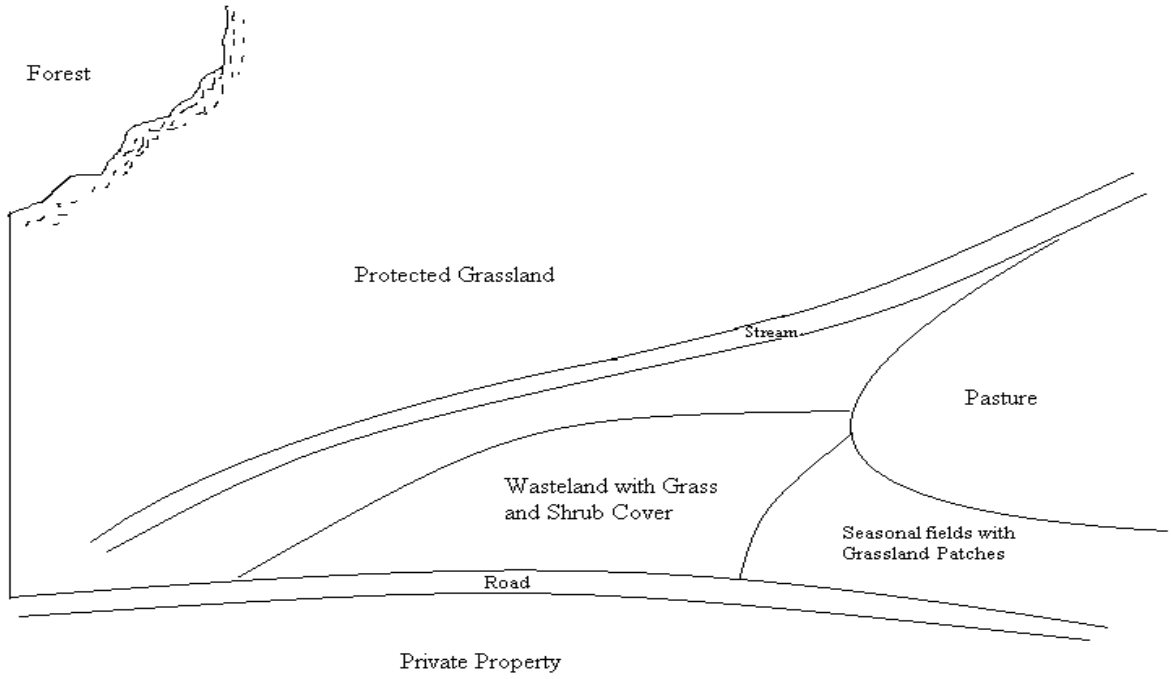


Figure 5.2 Idealized arrangement of habitat on a part of a wildlife area managed for grassland birds possible in case of Dhari-gir east and Junagadh division grasslands adjacent to Gir PA.



Buffer of grassland vegetation between managed grassland habitat increase effective size.

III. Grassland Management for Birds: Grassland bird habitats in existing grasslands, whether unfragmented patches, improved pastures, regenerated wastelands or other grassland system, can be maintained and improved through various management actions.

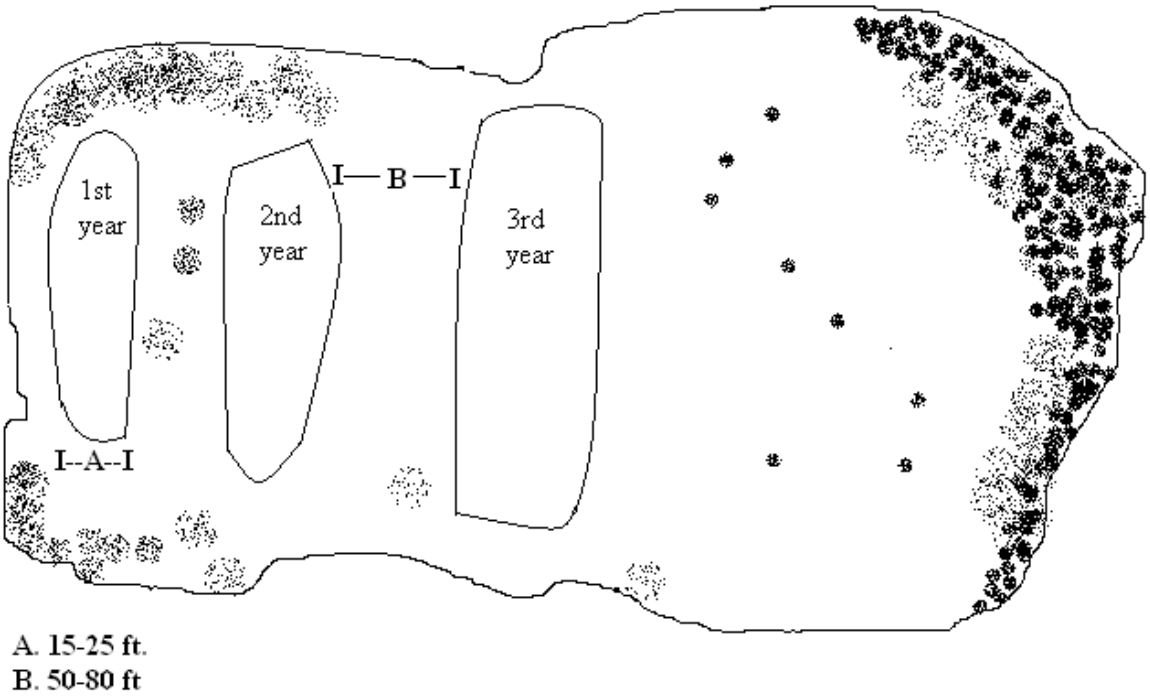
1). Rotational Mowing: Rotational moving can be used to maintain grassland communities in various stages of growth and diversity.

This can be conducted by dividing an area into 15 to 25 feet wide strips (depending on the area's size) that is separated from one another by 50 to 80 feet (Figure 5.3). A single strip is mown to a height of four to eight inches either once or twice a year depending on the species of nesting birds present in the area.

Smaller areas can be divided into 3 strips; mown one strip in early post monsoon when grass was in its younger stage and again in early summer (February end to March) after nesting activities are completed.

The following year, the second strip would be mowed in the same months. The third strip would be mowed in year three, and the process begins again in year four. Larger areas evenly divided into six or more strips can be rotationally mown in pairs, so that strip one is worked with strip three, strip two with strip four, strip three with strip six and so forth.

Figure 5.3 Rotational mowing configurations to provide various grassland growth forms for grassland birds



The concept can also be employed on site basis. If overall turnover of grass is properly managed, and the needs are satisfied with requisite quantity, few of the *vidis* are left unharnessed by rotation improves quality ecologically (Soni and Jadav, 2006).

While mowing following measures can be taken to minimize impacts on birds.

(1) Vidis should be mowed from the center outward to provide cover that allows fledgling birds to escape to the edge (Figure 5.4)

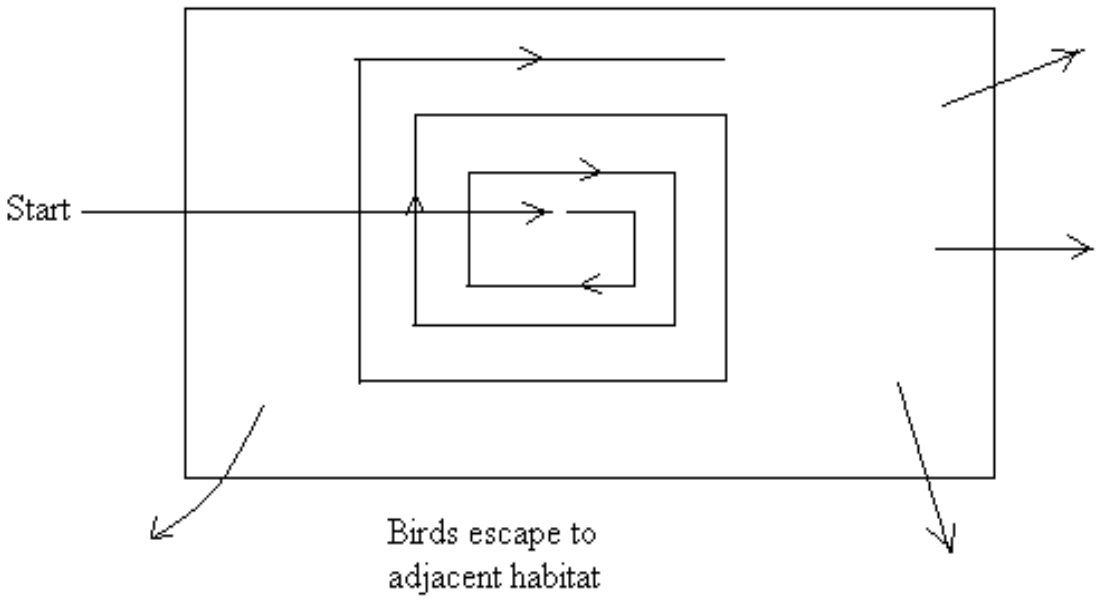


Figure 5.4 *Vidis* should be mowed from the center outward to allow birds to escape to adjacent habitats.

(2) Adult nesting birds and roosting individuals are less likely to flush from cover during night. Therefore night mowing should be avoided to present adult bird mortality.

(3) Some cover should be left undisturbed until well after the nesting season (till late January) to allow birds to rebreed that failed or breed late.

2) Prescribed Grazing: As grazing is the main issue for grassland of the peninsula, it is strongly recommended to terminate grazing in all *vidis* in monsoon and post monsoon season. It will provide a scope for grasses to get mature and shed their seeds, which is important for regeneration.

As in present situation, the practice is not possible in majority of the *vidis* due to high dependency of cattle rearing community for fodder needs. In such case rotational, deferred or continuous grazing can be conducted to benefit both forage quality and grassland bird habitat. Depending on the region, grassland composition, and bird species managed for grazing types and practices may vary.

Grassland can be managed in good condition, providing quality forage and suitable bird habitat for many species by one or more of the following measures:

a) Provide one month or month and a half days of rest between grazing periods in each paddock.

b) Defer grazing in some nesting areas until late in the nesting season.

c). Restrict livestock from sensitive nesting area.

d) graze the entire pasture at a light rate (allowing grass height to maintained at least 10 inches tall) all summer and put the entire herd on just one half of the pasture during the late season.

e) Avoid heavy continuous grazing.

3) Prescribed Burning: Burning is used to maintain grassland communities in various growth stages and diversity. It maintains grasslands as open habitat.

Prescribed burns should be conducted on a three to five year rotational basis. most prescribed burning should be done in late summer (April-June). Dividing the burn area into strips or plots is important in order to leave undisturbed habitat adjacent to burned plots.

4) Woody vegetation removal: In areas managed for birds that are intolerant of woody vegetation, manual removal of trees and shrubs may be necessary. However, some species of grassland birds are benefited by scattered trees, shrubs and woody fence rows (e.g., Grey shrike, Larks, Muniyas etc.). In addition, in some areas, birds that use shrub habitats (e.g., stone chat, grey headed bunting) may be in greater decline than maintenance of some scrub habitat become necessary.

Thus, bird species habitat objectives should be carefully considered before proceeding with woody vegetation removal.

5.3. Further Research Need: The following common themes are important information needs for conservation of grassland birds in the peninsula.

(1) Effects of habitat and landscape features on grassland birds:-

(a) Habitat variables: The research and synthesis activities in this relation should focus primarily on the effects of vegetative structure and vegetative species composition on avian communities.

(b) Landscape variable: It should focus primarily on the effect of habitat block size and landscape context. The latter includes block distribution, surrounding land uses, and proximity to "Hostile Environments" (e.g., roads, suburban developments, trees, industries etc.).

(c) Management Practices: Research activities related to management practices should focus on the most important driving forces acting in particular grassland. For ex. Grazing, and harvesting are some common practices along with plantation of woody species and prescribe fire.

Issues to be addressed regarding the use of prescribed fire include effect of block size for burning, frequency of burn, timing of burn and importance of providing refugia for wildlife displaced by burning.

Issues related to grazing include timing, frequency, size of pasture and intensity of grazing. The effect of agricultural practices includes effect of pesticides, crop rotation, timing of blowing and harvest.

The effect of alien species, especially plants represent an information need for grasslands and on the wintering grounds, with the focus on different species in each area. Research should focus on mechanisms by which alien species invade effects of such invasions, development of methods for controlling alien species and the effects of control method on avian community.

(2) Development/Expansion of Species Status Assessment Reports

Documents that synthesize diverse technical information on individual grassland bird species and present the information in a usable form for managers are critical. Such synthesis documents should summarize the status of a species (population numbers and trends, distribution, etc.), its ecology and natural history, and threats to it, and should provide management guidelines that will result in the species' conservation. These documents should also determine whether additional information, such as a range wide survey, is needed.

(3) Range wide surveys of target grassland bird species

There are many grassland bird species for which few data exist on distribution and abundance on the breeding and/or wintering grounds because of their low densities, cryptic behavior, or difficulty in identification (ex. Larks, migratory Pipits, Harriers, Chats etc.). There is a need to develop standard methods for gathering population data and to apply range wide survey method to species of concern.

(4) Monitoring Issues

There are several grassland bird monitoring issues that should be addressed by additional research, literature synthesis, and technical assistance. Of key importance is: what species are inadequately monitored and how can we develop new methods to address these deficiencies? Managers want to know how to monitor birds, which species and habitats to monitor, and how their local monitoring efforts fit into broader monitoring programs.

(5) Effects of Agricultural Policies and Programs

The needs addressed here are to be distinguished from issues related to specific agricultural management practices as discussed above. What are referred to here are large scale farm policies and programs (e.g., the Conservation Reserve Program) and their effects on avian habitat and landscape features.

(6) Wintering Ground issues

There are several additional information needs that are focused on the wintering grounds. The need for information about the distribution of wintering grassland bird extends beyond the need for range wide surveys; it is also important to know how much spatial and temporal variability occurs in their distribution. There is also a need to develop survey methodologies and a training curriculum for identifying grassland birds on the wintering grounds. Finally, there is a need for information about the effects of contaminants on wintering birds.

In a conclusive statement future research priorities should focus in three sectors, in continuation of the baseline information provided by the present study.

1. Improving documentation of species, their status and distribution.

2. Research on grassland birds across seasons and across grassland types.

3. Testing of management options for improving grassland bird habitat.

Summary and Conclusion

Biodiversity assessment and impact of disturbance on distribution of species in space constitute one of the fundamental themes in ecological research. It is being increasingly recognized that studies on ecological status and factors determining species diversity are essential to understand the mechanism of maintenance of biological diversity. Tropical scrubland savanna of Saurashtra called "*Vidis*" were overexploited and neglected, where no efforts are being made to assess their role in conservation of native wildlife. This study highlight the ecological importance of degraded and exploited "*vidis*" in conservation of wildlife considering avifauna as an indicator group.

At the outset, it becomes important to know the status of the biological community of the "*vidis*" in an ecological perspective, to evolve a conservation strategy for the region. The avifauna profile and effects of human activities on avifaunal assemblages remain largely unknown for the region. A few past studies were conducted which either provided avifaunal checklists (Ali, 1954-55, Dharamkumar Singhji, 1956) or were specific to the region (Naik, *et al*,1990., Singh and Tatu, 1992).

Thus, the present study evaluates the ecological status of grassland biome and structure of the avian fauna assemblages in the grasslands having varied anthropogenic pressures and management practices. It was intended to fulfill gaps in knowledge about biodiversity of semi arid grasslands and impact of use.

An outcome of the study provides useful baseline information to understand the grassland avifauna, its structural and functional aspects. It also highlights effects of human activities on birdlife. This information proves useful to design a management strategy for the native grasslands and its avifauna, and provide platform for the further research in the area.

To evaluate ecological status of grasslands, the study was conducted in two phases from July 2007 to 30th September 2007, and 1st July 2008 to 31st October 2008 at eighty nine sites covering an area of 30,402.017 hectares. The avifaunal studies were conducted from 1st August 2006 to 31st May 2007 at three grassland patches near Rajkot city in the central Saurashtra.

Primary data of vegetation and composition suggest a total of 58 grass species from Saurashtra penninsula, of which 38 species were perennial, 17 species were annual and three species were annual-perennial in habit. Sub-family Panicoideae is well represented in the area with all its tribes while the sub-family Pooideae has poor distribution. The tribes Andropogoneae and Paniceae are dominant tribes of the region.

Jamnagar division- B-"RJT" posses the highest number and diversity of grass species (51), followed by Surendranagar division (48), Jamnagar division- A-"Jam"(41), Bhavnagar division(31), Junagadh division(29) and Dhari- Gir east division with 24 species which was least among all.

All the grasslands in Junagadh division are in ecologically healthy condition, but deteriorating factors such as fragmentation, over grazing and encroachment were observed. In Bhavnagar division factors that affect annual grass production and biomass

turn over are high grazing pressure, invasion of weed species and encroachment. Ill planned management practices by forest department and categorization of land as special economical zone (SEZ) is direct threat to the grassland areas of the division. Special emphasis should be given to restore and protect grasslands namely Ranigalo, Karjala, Gebar, Beda, Kundhada, Rajasthali, and Sangadasar which harbors satellitic meta population of Asiatic lions and face issues related to human wildlife conflicts. Grasslands of Dhari Gir east Division are under immense pressure of human activities. Agricultural expansion and encroachment are the main issues, along with high grazing, illegal fodder harvesting and poaching.

These grasslands are important for wildlife conservation as they act as a corridor between setellitic meta population of Asiatic lion and the core population in Gir P.A. Thus, their conservation and management should be ensured in the long term conservation planning of a species.

In Surendranagar division and Jamnagar division main issues are, invasion of *Prosopis juliflora.*, high grazing pressure, soil erosion, uncontrolled mining of lignite, graphite and gypsum, land exploitation by small scale industries of ceramics, and developmental activities. In Rajkot district, landscape heterogeneity was greatly disturbed in the recent past due to grazing pressure and urbanization. It requires immediate attention.

The cover type was *Sehima-Dicanthium.* The finding is consistent with earlier observations Dabadghao and Sankaranarayan (1973) and Whyte (1964). Total nine grassland communities were recognized, in relation to different habitats, micro-geomorphic conditions and factors of use.

Succession studies suggest that the grasslands on hills which are subjected to annual harvesting and soil erosion, favor the appearance of a *Cymbopogon, Heteropogon, Andropogon* community, either pure stand or in combination. The erosion and continuous leaching of soil nutrients occurring in the hills along with grazing, appears to restrict grassland development to the stage of dominance of *Cenchrus ciliaris* along with inferior species such as *Aristida* and *Eragrostris* species with *C. ciliaris* as the principal species.

Dabadghao and Sankaranarayan (1973) reported that erosion and continuous leaching of soil nutrients in the hills give emergence to *Themeda/ Pseudanthistiria* community, but in present study it was observed that *Cymbopogon, Heteropogon* followed by *Cenchrus* community dominate in these conditions. The difference in the findings are due to geographical scale of study area, as the work conducted by Dabadghao and Sankaranarayan evaluated succession trend in entire *Sehima-Dicanthium* cover type which spreads over the whole of Peninsular India, whereas this study was focused only on Saurashtra region. Thus, the local trend emerges, which may not be significant or applicable at large scale. Other hypothetical reason may be that it was an anti deteriorating tactic exhibited by grassland to reduce pressure from the patch to regulate further deterioration, but it has to be justified with proper scientific tools.

On level soils with increasing moisture availability, the *Dichanthium* community is replaced partially or wholly by an *Iseilema* community, with *I. laxum* as the chief species. Further increase in moisture conditions appears to favor the establishment of an *Ischaemum* and *Eremopogon* community with *Ischaemum rugosum* and *Eremopogon foveolatus* as the main species. This, when subjected to grazing, is replaced by

Echinociloa, Dactyloctenium aegyptium and *Cynodon communities* which give rise to *Chloris virgata* under sever grazing. If the factors continue, inferior species such as *Aristida* and *Eragrostris* appear and dominate.

When the *Sehima-Dichanthium* cover is subjected to grazing, these communities are replaced by *Chrysopogon, Bothriochloa, Bracharia, Heckelochloa* and *Bothriochloa, Cenchrus* communities, respectively. The main species of the former was *C. fulvus, B. ramose* and that of the latter was *B. pertusa* and *C. celiaris*. With further grazing at this stage, these communities are replaced by *Heteropogon* and *Eremopogon communities*, with *H. contortus* and *E. foveolatus*, respectively as the chief species. Further grazing at this stage brings about the appearance of *Cynodon dactylon*, which under the influence of sever grazing gives rise to *Cenchrus, Brachiaria* community and depending upon the soil condition, *Urochloa* and *Tragus biflous* appear along with. These, when subjected to further deterioration give rise to essentially annual communities represented mainly by *Aristida, Eragrostis* and *Melanocenchris*. Appearance of *Cynodon dactylon* is also influenced by proximity to agriculture land and encroachment in the grassland.

Within the limited scope of the avifauna study, a habitat hypothesis was not tested. The study areas are relatively small in size and geographically similar so no significant change in the habitat structure was observed. A lack of vegetation records for a specific region in the past and limited time, man power and monetary funds restricted the scope of the study.

Line transects data were used to estimate month wise species richness, species distribution and feeding guild composition on the basis of food preference. Indices like

abundance, density, diversity, and encounter rates were worked out to understand the community structure and to observe the effect of various changes.

In all, 79 species belonging to 34 families were recorded at the three study sites. Of these, 32 species (40.6%) and 22 families (64.7) were common between all the sites. Seven (8.9%), eleven (13.9%), and six (7.6%) species were exclusive of fifty species of birds at site 1, sixty-six at site 2 and fifty-one at site 3 respectively. One family at site 1, five at site 2 and three at site 3 were exclusive, whereas 3 families were common between sites 2 and 3. Eleven species each were common in sites 1 and 2 and between 2 and 3 respectively. Only one species was common between sites 1 and 3. More migratory species were recorded at site 2 than sites 3 and 1 respectively. All sites had a higher proportion of resident species. Proportions of terrestrial, arboreal and mixed niche species were different at the three sites.

A total of 7,775 individuals of 79 species were encountered with a frequency of 4,126 on nine transects at the three study sites. None of the study area could be considered as very rich area in terms of bird species richness in the grassland biome of the peninsula. Exploitation of resources and long exposure to ill planned management strategies resulted into impoverishment of avifauna.

There appeared to be an ascending bird species richness gradient from site with higher disturbance to the site with minimum disturbance. It suggests the impact of anthropogenic pressure.

Bird species composition is found to be preliminary determined by land use and geographical difference. In small grassland patches of Saurashtra, anthropogenic

pressures and land use induced geographical isolation are more influencing factors than vegetation (microhabitat) in determination of species richness.

Thus, despite the apparent role of vegetation at local level, the possible role of history needs to be considered for species composition of bird communities at my study sites. Species area relationship study also reveals that in addition to patch size, protection has a key role in determining avifaunal diversity in these grassland patches.

The study suggests that insectivores are the indicators of disturbance on a grassland ecosystem. Thus composition of insectivores indicates stressors in the system whereas fluctuations in omnivores indicate its intensity. The outcome can be used as an important tool in rapid assessment for determining the health of the grassland area. Granivorous guilds remain more or less constant at all sites. It suggests is a robust group with adaptability to utilize resources at different strata. As the group consisted of grassland specialist species of Alaudidae and Phasianidae, it was important to investigate their role in the system to understand the complete dynamics of the semi arid grasslands.

No final conclusion could be drawn on the nature of the relationship between alpha and taxonomic diversity in the absence of strong evidence. But if the value at which taxonomic distinctness peaks is considered as an empirical measure of phylogenetic stock/reservoir of ecological communities [i.e., the minimum number of species required to maintain the taxonomic integrity of local assemblages], it can be used as a potential optimality indicator in biodiversity assessment and monitoring surveys.

My result showed that there were 32 constitutively rare species (for all sites combined). This category did not include migratory species. However, such species need to be viewed in light of factors such as their habitat specificity, body size, guilds and endemism for conservation purposes.

The first null hypothesis proposed was found true and hence accepted. The second null hypothesis was false and rejected. Thus it can be concluded that *vidis* are important for wildlife conservation, considering avifauna as indicator group and all the *vidis* have different cover and composition with different pressures.

REFERENCES

Albertson, F. W. 1958. How they are improving grasslands in Saurashtra. Govt. India/ICA/Kansas State College Bulletin. IICAKSC. Kansas. pp. 131.

Ali, S. 1954-55. The Birds of Gujarat- I and II. *Journal Bombay Natural History Society* 52: 374-458 and 735-802.

-- 2002. The book of Indian Birds, Thirteenth edition. Bombay Natural History Society publication. Mumbai. pp. 1-326.

Ali, S., G. R. Rao, K. M. Divakar, Sreekantha, V. D. Mukri, M. D. Subhash Chandran, K.V. Gururaja, N. V. Joshi, and T. V. Ramchandra. (2007). Ecological Status of Sharavathi Wildlife Sanctuary. Prism Books Pvt. Ltd. New Delhi. pp.1-5.

Anonymous. 1998. Gazetteer of India: Gujarat State Gazetteer, Part-I. Government of Gujarat, Gandhinagar. pp. 1-607.

Anonymous. 2000. Gazetteer of Government of Gujarat.

Anonymous. 2006. Gujarat Forest Statistics. Forest Department, Gujarat State. pp.1-130.

Austin, M. P. 1981. Permanent quadrates: An interface for theory and practice. *Vegetatio*. Spinger publication, Nedherland. 40: 1-10.

Bakker-Gabb, D. J., and I. D. Lunt. 1990. Conservation program for Native Grasslands and Grassy Woodlands in Victoria. Department of Conservation and Environment. Melbourne.

Bal, D. V., and C. R. Athavale. 1935. An investigation into effects of manuring and stage of maturity on the yield and mineral composition of pasture grass and their

bearing on the mineral requirements of the cattle of the Central Provinces. Nagpur University Journal. Nagpur. 1: 11-27.

Barkman, J. J. 1989. A critical evaluation of minimum area concepts. *Vegetatio,* Springer Publication, Netherlands. 85: 89-104.

Bole, P. V., and J. M. Pathak. 1988. Flora of Saurashtra, Part-II. Botanical Survey of India, Calcutta. pp. 1-301.

Bor, N.L. 1960. The Grasses of Burma, Ceylon, India and Pakistan (Excluding Bambuseae). Pergamon Press. Paris, France.

- 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press. Oxford.

Brooks, T. M., S. L. Pimm, and J. O. Oyugi. 1999. Time lag between deforestation and bird extinction in tropical forest fragments. *Conservation Biology,* Blackwell publication, Hoboken, NJ. USA. 13: 1-11.

Burns, W. 1929. Further studies of Indian Grasses and Grasslands. Memorendum of Department of Agriculture, Indian Botanist. Bombay. 16: 101-143.

- 1932. Grassland problems in Western India. *Buleteen of Department of Agriculture*. Bombay. pp.171.

Burns, W., L. B. Kulkarni, and S. R. Godbole. 1932. A study of some Indian grasses and grasslands. Memorendum of Department of Agriculture, Indian Botanist. Bombay 14: 1-57.

Canfield, R. H. 1941. Application of the line-intercept method in sampling range vegetation. *Journal of Forestry*, American Fester Society. New York. 39:388–394.

Clarke, K. R., and R. M. Warwick. 1998. A taxonomic distinctness index and its statistical properties. *Journal of Applied Ecology*. British Ecological Society. London. 35: 523-531.

Clements, F. E. 1916. Plant succession: an analysis of the development of vegetation. *Publication no.* 242. Carnegie Institute. Washington, D.C.

Clements, F. E., and V.E. Shelford. 1939. Bio-ecology. J. Wiley and Sons, New York. Computing, John Wiley and Sons Publication, USA.

Coupland, R.T. 1978. Grassland Ecosystems of the world, (edi), Cambridge University Press, London. pp. 401.

Crozier, R. H. 1992. Genetic diversity and the agony of choice. *Biological Conservation*, Elsevier Publications, Amsterdam. 61: 11-15.

Dabadghao and Sankaranarayan. 1973. The grass cover of India, ICAR, New Delhi.

Dabadghao, P. M. 1954. A field experiment on natural grassland in the former Baroda State. Journal of Agricultural Sciences. Bombay. 24: 229-242.

Dean, W.R.J and MacDonald, I.A.W. 1994. Historical changes in stocking rates of domestic livestock as a measure of semi-arid and arid rangeland degradation in the Cape Province, South Africa. *Journal of Arid Environments.* 26, 281-298.

Dharmakumarsinhji, K. S. 1956. Birds of Saurashtra (India). Dilbahar, Bhavnagar.

Diamond, J. M. 1972. Biogeographic kinetics: Estimation of relaxation times for avifaunas of Southwest Pacific Islands. *Proceeding of National Academy of Science. USA.* 69: 3199-3202.

Dillon, S., and J. Fjeldsa. 2005. The implications of different species concepts for describing biodiversity patterns and assessing conservation needs for African birds. *Ecography*, Blackwell publication, Hoboken, NJ. USA. 28: 682-692.

Drury, W. H., and Nisbet, I.C.T. 1973. Succession. *Journal of the Arnold Arboretum*, Haward University press, Haward. UK. 54:331-368.

Ellingsen, K. E., K. R. Clarke, P. J. Somerfield, and R. M. Warwick. 2005. Taxonomic distinctness as measure of diversity over a large scale: the benthos of the Norwegian continental shelf. *Journal of Animal Ecology.* British Ecological Society. London. 74: 1069-1079.

Elton, C. 1927. Animal Ecology. Sidgwick and Jackson. London.

Emlen, J. T. 1971. Population density of birds derived from transect counts. In *Auk* 58.

Flather, C. H. 1996. Fitting species-accumulation functions and assessing regional land use impacts on avian diversity. *Journal of Biogeography,* Blackwell publication, Hoboken, NJ. USA. 23: 155-168.

Gandhi, A. P., and A. S. Yusufzai. 1999. Grasses of Gujarat. Watershed Devlopment Project series. Junagardh Agricultural University, Junagardh.

Gleason, H. A. 1917. The structure and development of the plant association. *Bulletin of the Torrey Botanical Club.* 44: 463-481.

Gleason, H. A. 1926. The individualistic concept of plant association. *Bulletin of the Torrey Botanical Club.*53: 7-26.

Goriup, P. D., and Z. Karpowiz. 1985. A review of the past and recent status of the lesser florican. Bustard Studies. NHBS, Devon, UK. 3: 163-182.

Groombridge, B 1992. 1994 IUCN Red List of Threatened Mammals. IUCN Gland, Switzerland, and Cambridge, UK. pp.286.

Gujarat Ecological Commission (GEC). 2005. Ecoregions of Gujarat. A final report. GEC, Baroda.

Haffer, J. 1969. Speciation in Amazonian forest birds. *Science*. 165: 131-137.

Hammer, O., D. A. T. Harper, and P. D. Ryan. 2004. PAST –Paleontological Statistics. Version 1.32. http://folk.uio.no/ohammer/past/.

He, F., and P. Legendre. 1996. On species-area relations. *Americana Naturalist,* The American Society of Naturalists, Chicago. 148: 719-737.

Humphreys, W. F., and D. J. Kitchener. 1982. The effect of habitat utilization on species-area curves: implications for optimal reserve area. *Journal of Biogeography*, Blackwell publication, Hoboken, NJ. USA. 9: 391-396.

Isaac, N. J. B., and A. Purvis. 2004. The 'species problem' and testing macroevolutionary hypotheses. *Diversity and Distributions,* Journal of Conservation Biogeography, Blackwell publication, Hoboken, NJ. USA 10: 275-281.

Javed, S. 1996. Study on bird community structure of terai forest in Dudhwa National Park. Ph. D. Dissertation, Aligarh Muslim University.

Jayapal, R. 1997. A study on bird communities-habitat structure relationships in Pench National Park, (M. P). M. Sc. Dissertation. Saurashtra University.

Jayson, E. A., and D. N. Matthew. 2002. Structure and composition of two bird communities in the southern Western Ghats. *JBNHS.* 99 (1): 8-25.

Johnson, R.W., and J.C. Tothil. 1985. Ecology and Management of world Savannas, edi, Common Wealth Agriculture Bureau, Australia. pp. 279-291.

Karr, J. R. 1977. Ecological correlates of rarity in a tropical forest bird community. *Auk.* 97: 283-298.

Karr, J. R. 1980. Geographical variation in the avifauna of tropical forest undergrowth. *The Auk.* 97: 283-298.

Khosoo, T.N. 1994. India's biodiversity, Task ahead. *Current Sciences.* 67 (25). pp. 577-582.

Koellner, T., A. M. Hersperger, and T. Wohlgemuth. 2004. Rarefaction method for assessing plant species diversity on a regional scale. *Ecography,* Blackwell publication, Hoboken, NJ. USA., 27: 532-544.

Krajewski, C. 1994. Phylogenetic measures of biodiversity: a comparison and critique. *Biological Conservation*, Elsevier Publications, Amsterdam. 69: 33-39.

Krishnamani, R., A. Kumar, and J. Harte. 2004. Estimating species richness at large spatial scales using data from small discrete plots. *Ecography,* Blackwell publication, Hoboken, NJ. USA. 27: 637-642.

Kumar, L. S. S., and S. R. Godbole. 1932. Rational system of grazing in Bombay Province. Agriculture and livestock. Bombay. 9: 667-67.

La Sorte, F. A., and W. J. Boecklen. 2005. Changes in the diversity structure of avian assemblages inn North America. *Global Ecology and Biogeography.* Blackwell publication, Hoboken, NJ. USA. 14: 367-378.

Landers, P. B. and MacMohan, J. A. 1980. Guilds and community organization: analysis of an oak woodland avifauna in Sonora, Mexico. *The Auk*. 97: 371-260.

Lawrey, J. D. 1991. The species-area curve as an index of disturbance in saxicolous lichen communities, *Bryologist,* JSTOR publications. The American Bryological and Lichenological Society, USA. 94: 377-387.

Leafe, E.L. 1988. The history of improved grasslands in the grass crops, edi. M.B.Jones and A. Lazenby. Chapmann and Hall. pp 1-20.

Likens, G. E., F. H. Borman, R. S. Pierce and W. A. Reiners. 1978. Recovery of a deforested ecosystem. *Science*. 199:492-496.

Lomolino, M. V. 2001. The species-area relationship: new challenges for an old pattern. *Progresses in Physical Geography,* USA. 25: 1-21.

Ludwing J. A., and Reynolds J. F. 1998. *Statistical Ecology* - A Primer of Methods and

Computing, John Wiley and Sons Publication, USA.

MacArthur, R. H., and MacArthur, J.W. 1961. On bird species diversity. *Ecology.* 42 (3): 594-598.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton.

Manakadan, R. and Pittie, A. 2001. Standardized English and Scientific names of the birds of the Indian subcontinent. Buceros 6(1): 1-38.

Mani, M.S. 1974. Ecology and Biogeography in India. The Hague. Dr. W. Junk b.v. Publication. Old Delhi.

Martin, T. E. 1981. Species-area slopes and coefficients: a caution for their interpretation. *American Naturalist,* The American Society of Naturalists, Chicago. 118: 823-837

Matter, S. F., I. Hanski, and M. Gyllenberg. 2002. A test of the metapopulation model of the species-area relationship. *Journal of Biogeography,* Blackwell publication, Hoboken, NJ. USA. 29:977-983.

McGuinness, K. A. 1984. Equations and explanations in the study of species area curves. *Biological Reviews,* Blackwell publication, Hoboken, NJ. USA. 59: 423-440.

Menhinick, F. F. 1964. A comparison of some species-individuals diversity indices applied to samples of field insects. *Ecology.* 45: 859-861.

Mondor, C., and S. Kun. 1982. The long struggle to protect Canada's vanishing prairies. *Ambio* 2: 286-291.

Moreno, C. E., and G. Halffter. 2001. On the measure of sampling effort used in species accumulation curves. *Journal of Applied Ecology.* British Ecological Society. London. 38:487-490.

Murphy, M.T. 2003. Avian population trends within the evolving agrarian landscape of eastern and central United States. *The Auk.* 120(1): 20-34.

Naik, R. M., M. S. Murthy, Y. N. Rao, T. Mundkur, and P. Rishad. 1990. WWF-India Sponsored research Project on the Ecology of Hingolgardh Nature Education Sanctuary, Final Report. Department of Biosciences, Saurashtra University, Rajkot.

Overton, W.S., and Devis, D.E. 1969. Estimating the number of animals in wildlife population. In: Wildlife management Techniques (Edited by R. H. Giles). The Wildlife Society, Washington D.C.

Palmer, M. W. 1990. The estimation of species richness by extrapolitan. *Ecological Society of America. USA.* 71: 1195-1198.

Parasharya, B.M., C.K. Borad and D. N. Rank 2004. A checklist of the birds of Gujarat. Bird Conservation Society, Gujarat. pp. 26.

Pathak, B.J. 2002. Biodiversity conservation plan for Gir. (A management plan for Gir and Pania sanctuaries, Gir National Park and peripheral forests, volume 3). Supplementary management plan, 2002–2003 to 2006– 2007. Gujarat Forest Department, Gujarat, India. pp. 407.

Patunkar, B. W. 1980. Grasses of Marathwada. Scientific Publisher, Jodhpur. India.

Polasky, S., B. Csuti, C. A. Vossler, and S. M. Meyers. 2001. A comparison of taxonomic distinctness versus richness as criteria for setting conservation priorities for North American birds. *Biological Conservation*, Elsevier Publications, Amsterdam. 97: 99-105.

Polasky, S., J. D. Camm, A. R. Solow, B. Csuti, D. White, and R. Ding. 2000. Choosing reserve networks with incomplete species information. *Biological Conservation*, Elsevier Publications, Amsterdam. 94: 1-10.

Pomeroy, D. 1993. Centers of high biodiversity in Africa. *Conservation Biology*, Blackwell publication, Hoboken, NJ. USA. 7: 901-907.

Premadasa, M.A. 1990. Tropical grasslands of Sri Lanka and India, *Journal of Biogeography.* 17: 395-400.

Prince, T., J. Zee, K. Jamdar, and N. Jamdar. 2003. Bird species diversity along the Himalaya: A comparison of Himachal Pradesh with Kashmir. *JBNHS.* 100 (2 and 3): 394-410.

Rafe, R. W., M. B. Usher, and R. G. Jefferson. 1985. Birds on reserves: the influence of area and habitat on species richness. *Journal of Applied Ecology.* British Ecological Society. London. 22: 327-335.

Rahmani, A.R. 1989. Grassland Birds of the Indian Subcontinent: A review. ICBP technical Publication No. 7. 187-204.

Ramachandra, T. V., M. D. Subash Chandran, Gururaja, K. V. and Sreekantha. 2006. Cumulative Environmental Impact Assessment, Nova Science Publishers, Inc., New York.

Raman, T. R. S. 2001. Community ecology and conservation of tropical rainforest birds in the southern Western Ghats, India. Ph. D. Thesis. Indian Institute of Science. Bangaluru.

Ricklefs, R. E. and Schluter, D. 1993. Species Diversity in Ecological Communities: Historical and Geographical Perspectives. The University of Chicago Press, Chicago.

Ricotta, C. 2004. A parametric diversity measure combining the relative abundances and taxonomic distinctiveness of species. *Diversity and Distributions,* Journal of Conservation Biogeography, Blackwell publication, Hoboken, NJ. USA. 10: 143-146.

Risser, G.P. 1991. Diversity in and among grasslands. Biodiversity, ed., Wilson National Academy Press, Washington, D.C. pp 176-181.

Rodgers, W. A. 1991. Techniques for Wildlife census in India: A Field Manual Wildlife Institute of India, Dehradun.

Rodgers, W. A., H. S. Panwar, and V. B. Mahur. 2002. Biogeographic classification of India: Provinces. Wildlife Institute of India, Dehradun.

Rodrigues, A. S. L., and K. J. Gaston. 2002a. Maximizing phylogenetic diversity in the selection of networks of conservation areas. *Biological Conservation,* Elsevier Publications, Amsterdam.105: 103-111.

- 2002b. Optimisation in reserve selection procedures – why not? *Biological Conservation,* Elsevier Publications, Amsterdam. 107: 123-129.

Root, R.B. 1967. The niche exploitation pattern of the Blue-Grey Gnatcatcher. *Ecological Monograph.* 37: 317-350.

Sarmiento, G. 1992. Adaptive strategies of perennial grasses in South American Savannas. *Journal of Vegetation Science.* 3: 325-336.

Scott, N. K., F. P. Neil, and D. R. Ludwig. 1998. Habitats/ Area Relationships, Abundance, and Composition of Bird Communities in 3 Grassland Types. *Transections of the Illinois State Academy of Science,* Vol. 92, 1 and 2. pp. 109-131.

Shantz, H.L. 1954. The place of the grasslands in the Earth's cover of vegetation, *Ecology*. 35: 143-151.

Sibley, C. G., and B. L. Monroe Jr. 1990. *Distribution and Taxonomy of Birds of the World.* Yale University Press, New Haven, USA.

Singh, H. S., and K. Tatu. 1992. Biodiversity Study on Rampara Wildlife Sanctuary. Technical report BIODIV/20/99. GEER Foundation. Gandhinagar.

Singh, H.S. 2001. Natural Heriage of Gujarat (Forest and Wildlife). GEER foundation, Gandhinagar. pp. 8-37.

Singh, K.S. 1994. The scheduled Tribes. Oxford University Press. Delhi. pp. 833-842.

Singh, P. 1988. Rangeland Reconstruction and Management for optimizing biomass production. (ed.). Rangeland Resources and Management. IGFRI, Jhansi. pp. 20-37.

Skerman, P. J., and F. Riveros. 1990. Tropical grasses. FAO Plant Production and Protection series, no 23. Rome, Italy. pp. 181- 752.

Soberon, J. M., and J.B. Llorente. 1993. The use of species accumulation functions for the prediction of species richness. *Conservation Biology.* Blackwell publication, Hoboken, NJ. USA. 7: 480-488.

Soni, V. C., J. P. Suchakar, and V. Vijaykumar. 1995. Studies on den ecology of the Golden Jackals (*Canis aureus aureus*) in Saurashtra region of Gujarat-India. Tiger paper. 22(2). pp. 27-28.

Southwood, T. R. E. 1987. The concept and nature of community. In: Organization of communities: past and present (Ed.) Gee, J.H.R., and P.S. Giller. 27th Symposium of British Ecological Society, Aberystwyth. Blackwell Scientific Publication.

Space application center (SAC). 2001. Quantification of Grassland areas of Gujarat by Remote sensing and GIS. Final Report. Ahmedabad.

Stoke, W. J. 1942. The Observer's Book of Grasses, Sedges and Rushes. Frederick Warne and Co. London. pp. 173.

Storch, D., A. L. Sizling, and K. J. Gaston. 2003. Geometry of the species-area relationship in central European birds: testing the mechanism. *Journal of Animal Ecology*. British Ecological Society. London. 72: 509-519.

Sugihara, G. 1980. Minimal community structure: an explanation of species-abundance patterns. *The American Naturalist.* 116(6): 770-787.

Terborgh, J. 1990. Mixed flocks and polyspecific associations: costs and benefits of mixed groups to birds and monkeys. *American Journal of Primatology.* 21: 87-100.

Terborgh, J. and Robinson, S. K. 1986. Guilds and their utility in ecology. In: Community Ecology: Pattern and Process. *Eds.* Kikkawa, J., and D. J. Anderson. Blackwell Publications Hoboken, NJ. USA. pp. 65-90.

Terborgh, J. H. 1974. Preservation of natural diversity: the problem of extinction prone species. *Bioscience.* 24: 715-722.

Terborgh, J. W., S. K. Robinson, T. A. Parker, C. A. Munn, and N. Pierpont. 1990. Structure and organization of an Amazonian forest bird community. *Ecological Monographs* 60(2): 213-238.

Trivedi, P., and V. C. Soni. 2006. Significant bird records and local extinctions in Purna and Ratanmahal Wildlife Sanctuaries, Gujarat, India. *Forktail.* 22: 39-48.

Verner, J. 1985. Assessment of counting techniques. In: Current Ornithology Vol.2 (ed.) Richard F. Johnston. Plenum Press, New York.

von Euler, F. 1999. An objective indicator of functional integrity in avian communities. *Forest ecology and Management.* Elsevier Publications, Amsterdam. 115: 221-229.

von Euler, F., and S. Svensson. 2001. Taxonomic distinctness and species richness as measures of functional structure in bird assemblages. *Oecologia.* Springer Publications, Berlin, Germany. 129: 304-311.

Wang, W., N. Maruyama, LIU. Bo-wen, H. Morimoto, and G. Zhong-xin. 2002. Relationships between bird communities and vegetation structure in Honghua'erji, northern Inner Mongolia. *Journal of Forestry Research.* 13(4): 294-298.

Ward, D. and Ngairorue, B.T. 1999. Are Namibia's grasslands desertifying? *Journal of Range Management,* 40, 357-371.

Whyte, R. O. 1964. The Grassland and Fodder Resources of India. Scientific Monograms. ICAR, New Delhi. 3rd edition.

Wiens, J. A., Rotenberry, J. T. and Horne, B. N. 1987. Habitat occupancy patterns of North American shrub steppe birds: the effects of spatial scale. *Oikos.* 48: 132-147.

Wiens, J. A. 1989. The ecology of bird communities. Vol – 2, Cambridge University Press, Cambridge.

Wilcox, B. A. 1978. Supersaturated island faunas: A species-area relationship for lizards on post-Pleistocene land-bridge islands. *Science.* 199: 996-998.

Wilson, E. O., and E. O. Willis. 1975. Applied biogeography. In: M. L. Cody and J. M. Diamond (eds.), *Ecology and Evolution of Communities,* Harvard University Press, Cambridge, USA. pp.522-534.

Worah, S. 1991. The ecology and management of a fragmented forest in south Gujarat India: The Dangs. Ph. D. thesis submitted the University of Poona, Pune.

Yadava, P. S. and J. S. Singh. 1986. Progress in Ecology Vol. 2. Grassland Vegetation. Today and Tomorrow Printers and Publishers. New Delhi. pp. 132.

Zende, G. R., and O. G. Kundalkar. 1954. Primary trials on the manuring of grasslands in Bombay State. *Indian Journal of Agricultural Sciences*. Bombay. 24: 244-253.

Plate 1. Threats to grassland biome in Saurashtra : Destuction of native vegetation by manual clearence, encroachment for agriculture and burning.

Plate 2. Threats to grassland biome in Study area: Grazing

Plate 3. Threats to grassland biome in Study area: Harvesting

Plate 4. Threats to grassland biome in Study area: Mining and Development.

Plate 5. Wildlife in Grassland *vidis* of Study area - Super Predator, Asiatic Lion and Leopard.

Plate 6 Wildlife in Grassland *vidis* of Study area - Carnivorous (L-R), Hyanea, Wolf, Golden Jackel, Jungle Cat, and Indian fox.

Plate 7. Wildlife in Grassland *vidis* of Study area - Herbivorous (L-R), Bluebull, Blackbuck, Wildboar and Chinkara.

Plate 8. Wildlife in Grassland *vidis* of Study area - Raptors (L-R), Shikra, Montuga's harrier, Indian hobby, King Vulture, Barn Owl, Short toed eagle, Black sholdered kite, and Spotted owlet.

Plate 9. Wildlife in Grassland *vidis* of Study area - Granivores (L-R), Ashy Crowned Finch Lark, Jungle Bush Quail, Red winged Bush Lark, Indian silver bill, Crested Skylark, and Rufous tailed Finch Lark.

Plate 10. Wildlife in Grassland *vidis* of Study area - Insectivores (L-R), Black Redstart, Indian Robin, Common Stone Chat, Small green bee-eater, and Pied Chat.

Plate 11. Wildlife in Grassland *vidis* of Study area - Omnivores (L-R), Jungle Babbler, Large grey babbler, Grey Shrike, Sirkeer Malkoha, and Greater Coucal.

Plate 12. ***Themeda quadrivalvis and Apluda mutica*** **grasses at Babra cluster, Junagadh.**

Plate 13. Woody vegetation of ***Butea monosperma*** **and** ***Terminalia crenulata*** **at Mohabattgadh cluster, Junagadh.**

Plate 14. Successive regeneration of forest and profuse growth of *Acacia senegal* at Paturan, Junagadh.

Plate 15. Prestine *Sehima-Dicanthium* grassland of Gebar-Ranigado-Beda cluster and invasion of *Prosopis juliflora,* Mahuva, Bhavnagar.

Plate 16. Degradation of grassland due to excessive grazing at Sanjanasar, Palitana. Bhavnagar.

Plate 17. Grass growing on hillocks, Rajesthali, Palitana, Bhavnagar.

Plate 18. Erroneous Plantation causes loss of native grassland Paval vidi, Ghogha, Bhavnagar.

Plate 19. High grass density at Kalthochapro, Ghogha surrounded by buffer grasslands.

Plate 20. *Heteropogon contortus*: less palatable grass species common in the region .

Plate 21. *Heteropogon- Cymbopogon* community type Babra cluster, Junagadh.

Plate 22. *Sehima- Aristida* Community, dominant on slopes and hill top.

Plate 23. Grassland in undulating terrain along Lambidhar Hill , Gir East.

Plate 24. *Boswellia cerata* and *Euphorbia Species,* major vegetation in Gir east region.

Plate 25. Grassgrowth under tree cover effecting the biomass production.

Plate 26. Pure stand of *Iselima laxum* on water logged patches, interepted by *Salvadora persica* at Santhave *vidi*, Surendranagar.

Plate 27. Grassland Management plots maintained by State Forest department as a part of restoration project.

Plate 28. Degraded grassland consisting *Eragrostris- Aristida* cover type at Chorvira cluster, Surendranagar.

Plate 29. Pure *Dichanthium annulatum* stand at Moti majethi *vidi*, Surendranagar.

Plate 30. *Sehima- Dichanthium* cover type associated with *Aristida species.*

Plate 31. Invasion of Prosopis juliflora, a major threat to grassland habitat

Appendix-I Grass species recorded from Study area during study period.

Sr. no.	SPECIES	HABIT	LOCAL NAME	PALATIBILITY
1	*Andropogon pumilius*	A	Zinzu,Govindvel, Baerki	P
2	*Apluda mutica*	PR	Bhangoru	P(young)
3	*Aristida adscensionis*	A or PR	Uth-Lampdo	NP
4	*Arundinella setosa*	PR	Bajariyu, Kotir,Tordia, Vad-bajariyu	P
5	*Brachiaria eruciformis*	A	Shimpi, Wag-hakt	P
6	*Brachiaria ramosa*	A	Chapar,Chapsura	P
7	*Cenchrus biflorus*	A	Motu-dhramanu,Sandbur,Anjan	P(young)
8	*Cenchrus ciliaris*	PR	Anjan, Dhraman	P
9	*Chionachne koenigii*	PR	Garolu,Karang	NP
10	*Coix lacryma-jobi*	A or PR	Kahudo	P
11	*Cymbopogon martinii*	PR	Rosha grass, Pama- rosa, Roh	NP
12	*Heteropogon contortus*	PR	Dabhsuliyu,Kagadi,Ratad,Kusali	NP
13	*Ischaemum rugosum*	A	Barodi,Tiki-ghas, Gandharu	P
14	*Iseilema prostratum*	PR	Achi-ghas	NP
15	*Panicum antidotale*	PR	Dhansado,Dhuns-ghas, Karkariyu	P(young)
16	*Panicum turgidum*	PR	Taman, Mor-kuba, Gunchi	P(young)
17	*Paspalidium flavidum*	PR	Jinko samo, Goriu,Jungli barvat	P
18	*Paspalidium germinatum*	PR	samo, Goriu, barvat	P
19	*Saccharum spontaneum*	PR	Kans,Thatch,Chia	P
20	*Sorghum halepense*	PR	Baru	NP
21	*Sporobolous helovolous*	PR	Velari-marmar	P(young)
22	*Sporobolous indicus*	PR	Velari-marmar	NP
23	*Sporobolous marginatus*	PR	Marmar	NP
24	*Sporobolous verginicus*	PR	Marmar	NP
25	*Cynodon dactylon*	PR	Dharo, Dhrokhad	NP
26	*Dichanthium annulatum*	PR	Zinzvo, Marvel	P
27	*Eragrostis cilianensis*	A	Kalagi marmar	NP
28	*Eremopogon foveolatus*	PR	Saniyar	P
29	*Eulaliopsis binata*	PR	Sabai ghass	NP

30	*Hackelochloa granularis*	A	Kasiyu, Kasiyu ghass	NP
31	*Halopyrum mcronatum*	PR	Kans	P(young)
32	*Themeda cymbaria*	PR	Ratadun-ghas	P
33	*Themeda quadrivalvis*	A	Bhati, Glader grass	P
34	*Tragus biflorus*	A	Vandhariyu ghass	P
35	*Urochondra setulosa*	PR	Khariyu	P(young)
36	*Vativeria zizanioides*	PR	Vetiver, Valo, Khas ghass	P
37	*Paspalum distichum*	PR	Moti Kodari, Kodri	P
38	*Sehima nerosum/sacculatum*	PR	Shaniyar, Sheda	P
39	*Iseilema laxum*	PR	Ghavlu,Shata,Dadhel	P
40	*Bothriochloa intermedia*	PR	Dharfo	P
41	*Bothriochloa pertusa*	A or PR	Khetravjinjvo	P
42	*Bothriochloa ischaemum*	PR	Dungarijinjvo,Jenjavo	P
43	*Cenchrus setigerus*	PR	Dhamnu	P
44	*Cenchrus penniseriformis*	PR	Motu Dhamnu	P
45	*Chloris barbata*	PR	Mindaliyu ghass	P(young)
46	*Chloris virgata*	A or PR	Nanu mindaliyu	P
47	*Desmostachya bipinnata*	PR	Dharbh, Kusha	NP
48	*Dactyloctenium aeypticum*	A	Dharo	P(young)
49	*Digitaria adscendens*	PR		P
50	*Dinebra retroflexa*	A		P
51	*Echonochloa colonum*	A		P
52	*Echonochloa crusgalli*	A		P
53	*Elyonurus royleanus*	A		NP
54	*Themeda triandra*	PR		P
55	*Arthraxon lancifolius*	A		P(young)
56	*Melenocenchris jacquemontii*	A		P(young)
57	*Aeluropus lagopoides*	P		P
58	*Chrysopogon fulvus*	P	Dharaf	P

Abbreviations: P- Palatable, NP- Non-palatable, P (young) - Palatable in early stage of life cycle, PR- Perennial species, A- Annual species.

Appendix-II Grassland communities recorded from Study area during study period.

Sr. No	Dominant grassland community/ cover type	Number of vidis of grassland diviosns						
		Junagadh	Bhavnagar	Gir- (E)	Surendranager	Jamnagar "A" JAM	Jamnagar "B" RJT	Total
1	*Sehima- Dichanthium*	5	8	3	0	7	11	34
2	*Sehima- Aristida*	0	8	7	0	4	6	25
3	*Dichanthium*	0	0	0	2	0	0	2
4	*Heteropogon- Cymbopogon*	3	0	0	0	1	0	4
5	*Bothriochloa-Aristida*	3	0	0	0	4	0	7
6	*Eragrostris- Aristida*	0	5	0	5	1	0	11
7	*Cenchrus– Dichanthium*	0	0	0	0	1	2	3
8	*Cenchrus- Eragrostris- Aristida*	0	0	0	2	0	0	2
9	*Aleuropsis- Halopyrum- Urochondra*	0	0	0	1	0	0	1
	Total	11	21	10	10	18	19	89

Appendix-IIa: - A list of sites represents the community type and associated grass species in Junagadh division.

Sr.No.	Name of Vidi	Cover type	Associated species
1	Paturan Tarsuliya	*Sehima – Dichanthium*	*Apluda mutica, Heteropogon contortus, Hackelochloa granularis, Brachiaria ramosa, Paspalidium flavidum, Cenchrus ciliaris*
2	Mota babra	*Heteropogon-Cymbopogon*	*Aristida adscensionis, Sehima nerosum, Cynodon dactylon, Apluda mutica, Paspalidium flavidum*
3	Nana babra	*Sehima – Dichanthium*	*Cymbopogon martinii, Hackelochloa granularis, Aristida adscensionis, Paspalidium flavidum, Heteropogon contortus, Apluda mutica*
4	Amridhar	*Bothriochloa-Aristida*	*Sehima nerosum, Heteropogon contortus, Cymbopogon martinii, Apluda mutica, Sporobolous marginatus, Dactyloctenium aeypticum*
5	Chuldi(Jalondra)	*Sehima – Dichanthium*	*Cymbopogon martinii, Heteropogon contortus, Hackelochloa granularis, Aristida adscensionis, Brachiaria ramosa, Echonochloa colonum*
6	Mohabatgadh Kadiya	*Heteropogon -Cymbopogon*	*Sehima nerosum, Aristida adscensionis, Dichanthium annulatum, Hackelochloa granularis, Apluda mutica, Paspalidium flavidum*
7	Kalibhda Lakkaddhar	*Sehima – Dichanthium*	*Borhriochloa pertusa, Hackelochloa granularis, Brachiaria ramosa, Heteropogon contortus, Cymbopogon martinii, Dactyloctenium aeypticum*
8	Amalgadh Charakhda	*Heteropogon- Cymbopogon*	*Sehima nerosum, Apluda mutica, Aristida adscensionis, Dichanthium annulatum, Hackelochloa granularis, Paspalidium flavidum*
9	Khageshri Madhva	*Bothriochloa-Aristida*	*Dichanthium annulatum, Sehima nerosum, Themeda cymbaria, Panicum antidotale, Brachiaria ramosa, Eragrostis ciliaris*
10	Dhruvala Dudiya	*Bothriochloa-Aristida*	*Brachiaria ramosa, Sehima nerosum, Dichanthium annulatum, Themeda triandra, Cenchrus ciliaris, Paspalidium flavidum*
11	Naliyadhar	*Bothriochloa-Aristida*	*Sehima nerosum, Eremopogon foveolatus, Dichanthium annulatum, Cenchrus ciliaris, Themeda cymbaria, Echonochloa crusgalli*

Appendix-IIb: - A list of sites represents the community type and associated grass species in Gir east division.

Sr.No.	Name of Vidi	Cover type	Associated species
1	Sarasiya	*Sehima – Dichanthium*	*Bothriochloa pertusa, Aristida adscensionis, Eremopogon foveolatus, Iseilema laxum, Apluda mutica, Andropogon pumilius*
2	Mota Sosariya	*Sehima-Aristida*	*Dichanthium annulatum, Borhriochloa pertusa, Chrysopogon fulvus, Themeda quadrivalvis, Hackelochloa granularis, Heteropogon contortus*
3	Nani Vadal	*Sehima-Aristida*	*Dichanthium annulatum, Hackelochloa granularis, Heteropogon contortus, Apluda mutica, Ischaemum rugosum, Themeda quadrivalvis*
4	Vasiyadi	*Sehima-Aristida*	*Heteropogon contortus, Dichanthium annulatum,Hackelochloa granularis*
5	Katrodi	*Sehima-Aristida*	*Cymbopogon martini, Heteropogon contortus,Themeda quadrivalvis, Paspalidium flavidum, Hackelochloa granularis, Chrysopogon fulvus*
6	Hipavadli	*Sehima – Dichanthium*	*Aristida adscensionis, Eremopogon foveolatus, Chrysopogon fulvus, Andropogon pumilius*
7	Kedariya	*Sehima – Dichanthium*	*Aristida adscensionis,Cymbopogon martini, Apluda mutica, Iseilema laxum, Themeda quadrivalvis, Heteropogon contortus*
8	Zadkala	*Sehima-Aristida*	*Dichanthium annulatum, Cymbopogon martini, Heteropogon contortus, Themeda quadrivalvis, Hackelochloa granularis, Chrysopogon fulvus*
9	Bhekara	*Sehima-Aristida*	*Dichanthium annulatum, Chrysopogon fulvus, Themeda quadrivalvis, Hackelochloa granularis, Heteropogon contortus, Cymbopogon martini, Apluda mutica*
10	Pilaniya	*Sehima-Aristida*	*Dichanthium annulatum, Chrysopogon fulvus, Themeda quadrivalvis, Hackelochloa granularis, Heteropogon contortus, Cymbopogon martini, Apluda mutica*

Appendix-IIc: - A list of sites represents the community type and associated grass species in Bhavnagar division.

Sr.No.	Name of Vidi	Cover type	Associated species
1	Navkukri (Mandva)	*Eragrostis-Aristida*	*Cynodon dactylon, Eulaliopsis binata, Urochondra setulosa, Elyonurus royleanus, Desmostachya bipinnata*
2	Hamirpara	*Sehima-Aristida*	*Dichanthium annulatum, Bothriochloa pertusa, Eremopogon foveolatus, Eragrostis ciliaris, Cynodon dactylon, Eulaliopsis binata, Heteropogon contortus*
3	Kundhada	*Sehima-Aristida*	*Dihcanthium annulatum, Bothriochloa pertusa, Eremopogon foveolatus, Eragrostis ciliaris, Cynodon dactylon, Eulaliopsis binata, Heteropogon contortus, Themeda quadrivalvis*
4	Beda-Gebar-Ranigalo	*Sehima – Dichanthium*	*Andropogon pumilius, Paspalidium flavidum, Eremopogon foveolatus, Heteropogon contortus, Bothriochloa pertusa, Aristida adscensionis, Cymbopogon martinii*
5	Karjala	*Sehima – Dichanthium*	*Andropogon pumilius, Paspalidium flavidum, Eremopogon foveolatus, Heteropogon contortus, Bothriochloa pertusa, Aristida adscensionis, Themeda quadrivalvis, Cymbopogon martinii*
6	Rajasthali	*Sehima-Aristida*	*Dichanthium annulatum, Themeda quadrivalvis, Heteropogon contortus, Apluda mutica, Eremopogon foveolatus, Cenchrus ciliaris, Eulaliopsis binata*
7	Sarod-Anida	*Sehima – Dichanthium*	*Dichanthium annulatum, Themeda quadrivalvis, Heteropogon contortus, Apluda mutica, Eremopogon foveolatus, Cenchrus ciliaris, Aristida adscensionis,*
8	Charvadla	*Eragrostis-Aristida*	*Cenchrus ciliaris, Brachiaria eruciformis, Sehima nerosum, , Heteropogon contortus, Dactyloctenium aeypticum, Elyonurus royleanus*
9	Rojmala	*Sehima-Aristida*	*Dichanthium annulatum, Heteropogon contortus, Apluda mutica, Cenchrus ciliaris*
10	Pavla	*Sehima-Aristida*	*Paspalidium flavidum, Bothriochloa pertusa, Heteropogon contortus, Eragrostis ciliaris*
11	Kalathochhapro	*Sehima – Dichanthium*	*Apluda mutica, Heteropogon contortus, Bothriochloa pertusa, Aristida adscensionis, Hackelochloa granularis*

Appendix-IId: - A list of sites represents the community type and associated grass species in Surendranagar division.

Sr.No.	Name of Vidi	Cover type	Associated species
1	Sharana	*Aeluropus- Halopyrum-Urochondra*	*Sporobolous indicus, Sporobolous verginicus, Saccharum spontaneum, Coix lacryma-jobi, Sporobolous marginatus*
2	Santhava	*Dichanthium*	*Apluda mutica, Iseilema laxum, Ischaemum rugosum, Saccharum spontaneum, Chrysopogon fulvus, Eremopogon foveolatus*
3	Moti majethi	*Dichanthium*	*Heteropogon contortus, Vativeria zizanioides, Ischaemum rugosum, Bothriochloa pertusa, Brachiaria ramosa*
4	Sangadhra	*Cenchrus- Eragrostis-Aristida*	*Heteropogon contortus, Desmostachya bipinnata, Dactyloctenium aeypticum, Cenchrus biflorus, Chloris virgata*
5	Mandav	*Cenchrus- Eragrostis-Aristida*	*Sehima nerosum, Themeda triandra, Bothriochloa pertusa, Heteropogon contortus, Elyonurus royleanus, Eulaliopsis binata*
6	Chorvira	*Eragrostis- Aristida*	*Heteropogon contortus, Cenchrus ciliaris, Cenchrus biflorus, Arthraxon lancifolius, Desmostachya bipinnata, Dactyloctenium aeypticum*

Appendix-IIe: - A list of sites represents the community type and associated grass species in Jamnagar division.

Sr.No.	Name of Vidi	Cover type	Associated species
1	Moti Vidi	*Heteropogon-Cymbopogon*	*Sehima nerosum, Aristida adscensionis, Dichanthium annulatum, Themeda triandra, Bothriochloa pertusa, Hackelochloa granularis*
2	Mahika-Varvada	*Sehima – Dichanthium*	*Aristida adscensionis, Andropogon pumilius, Bothriochloa pertusa, Cenchrus ciliaris, Heteropogon contortus, Brachiaria ramosa*
3	Sadodar	*Bothriochloa-Aristida*	*Sehima nerosum, Cenchrus ciliaris, Cenchrus biflorus, Heteropogon contortus, Paspalidium flavidum, Themeda cymbaria, Hackelochloa granularis*
4	Khatiya-Samana	*Sehima – Dichanthium*	*Paspalidium flavidum, Panicum antidotale, Heteropogon contortus, Cynodon dactylon, Bothriochloa pertusa, Aristida adscensionis, Cenchrus ciliaris*
5	Pipartoda	*Sehima – Dichanthium*	*Cenchrus ciliaris, Bothriochloa pertusa, Aristida adscensionis, Desmostachya bipinnata, Dactyloctenium aeypticum, Apluda mutica, Bothriochloa pertusa*
6	Khad-Khambhala	*Sehima – Dichanthium*	*Cenchrus ciliaris, Panicum antidotale, Paspalidium flavidum, Bothriochloa pertusa, Heteropogon contortus, Aristida adscensionis,*
7	Modpar	*Sehima – Aristida*	*Cenchrus ciliaris, Heteropogon contortus, Dactyloctenium aeypticum, Andropogon pumilius, Chloris barbata, Brachiaria ramosa*
8	Jamvadi	*Sehima – Dichanthium*	*Paspalidium flavidum, Hackelochloa granularis, Cenchrus ciliaris, Heteropogon contortus, Bothriochloa pertusa, Aristida adscensionis, Cynodon dactylon*
9	Apaiya	*Eragrostis - Aristida*	*Sporobolous helovolous, Chloris barbata, Elyonurus royleanus, Cenchrus biflorus, Desmostachya bipinnata*
10	Sanosari	*Cenchrus - Dichanthium*	*Sehima nerosum, Heteropogon contortus, Eremopogon foveolatus, Aristida adscensionis, Eragrostis ciliaris, Bothriochloa pertusa*

Appendix-IIf: - A list of sites represents the community type and associated grass species in JAM "B" (Rajkot) division.

Sr.No.	Name of Vidi	Cover type	Associated species
1	Vansthali	*Cenchrus - Dichanthium*	*Sehima nerosum, Aristida adscensionis, Eragrostis ciliaris, Bothriochloa pertusa, Heteropogon contortus, Tragus*
2	Valadhari	*Cenchrus - Dichanthium*	*Sehima nerosum, Aristida adscensionis, Eragrostis ciliaris, Bothriochloa pertusa, Heteropogon contortus, Tragus*
3	Dungarpur	*Sehima – Dichanthium*	*Aristida adscensionis, Andropogon pumilius, Chrysopogon fulvus, Heteropogon contortus, Hackelochloa granularis, Cenchrus ciliaris*
4	Rampara	*Sehima – Aristida*	*Dichanthium annulatum, Eragrostis ciliaris, Eremopogon foveolatus, Heteropogon contortus, Cenchrus ciliaris, Cenchrus biflorus*
5	Umath	*Sehima – Dichanthium*	*Aristida adscensionis, Apluda mutica, Heteropogon contortus, Dactyloctenium aeypticum, Dichanthium annulatum*
6	Khirasara	*Sehima – Dichanthium*	*Cenchrus ciliaris, Cenchrus setigerus, Apluda mutica, Eragrostis ciliaris, Heteropogon contortus, Aristida adscensionis, Cymbopogon martinii*
7	Kalikanagar	*Sehima – Dichanthium*	*Heteropogon contortus, Vativeria zizanioides, Cenchrus setigerus, Aristida adscensionis, Paspalidium germinatum, Cymbopogon martinii*

Appendix-III a- List of Reserve and Non-reserve *vidis* surveyed, in Junagadh Forest Division

Sr.No.	Name of District	Name of Taluka	Name of Village	Name of vidi	Area in hectares
1	Junagadh	Junagadh	Paturan Tarsuliya	*Paturan Tarsuliya vidi	651.41
2		Maliya Hatina	Mota Babra	*Mota Babra *vidi*	405.18
3			Nana Babra	*Nana Baba *vidi*	117.06
4			Chuldi (Jalondra)	*Chuldi Jalondra *vidi*	177.33
5			Mohobatgadh	*Mohobatgadh Kadiya vidi	142.75
6			Amrapur	*Amridhar	163.93
7			Amalgadh	Amalgadh Charakhda vidi	197.36
8			Kalibhda	*Khlibhda Lakkaddhar vidi	101.61
9		Kutiyana	Khageshri	*Khageshri Madhva vidi	648.30
10			Druvala	*Dhruvala Dudiya vidi	734.30
11		Ranavav	Naliyadhar	*Naliyadhar vidi	1151.80

Reserve *vidi

Appendix-III b- List of Reserve and Non-reserve vidis surveyed, in Bhavnagar Forest Division.

Sr.No.	Name of District	Name of Taluka	Name of vidi	Area in hectares
1	Bhavnagar	Bhavnagar	Rajmala(bhanbariya)*	195.22
2		Gadhada	Vavdo nanosariyo*	105.98
3		Ghogha	Kalathochhapro*	141
4			Paval*	263.55
5			Khatdi	155.61
6		Mahuva	Beda*	730.23
7			Gebar*	727.67
8			Ranigalo(jesor)*	409.5
9			Karjala	182.65
10			Navkukri(mandava)	137.92
11		Palitana	Rajasthali*	562.55
12		Palitana	Sajanasar*	343.26
13			Sarod*	224.78
14			Vaknrriya(anida)	910.84
15		Shihor	Chorvdala*	886.17
16			Malvna*	246.87
17			Piparala*	687.98
18			Thala*	390.52
19			Sikotra ghodighado(chorvadla)	221.42
20		Talaja	Hamirpara*	107.35
21			Kundhada*	455.83

Reserve *vidi

Appendix-III c- List of Reserve and Non-reserve vidis surveyed, in Dhari-Gir east Forest Division

Sr no.	District	Taluka	Name of vidi	Area in ha.
1	Amreli	Dhari	Sarasiya vidi	1764.44
2		Savarkundla	Motasosaria(Nal)*	355.43
3			Nanivadal*	555.64
4			Vasiyadi	217.53
5			Katrodi	316.47
6			Hipavadli	208.94
7			Kedariya	247.2
8			Zadkala	206.77
9			Bhekara	256.62
10			Pilaniya(Vijaynagar)	199.85

Reserve *vidi

Appendix-III d- List of Reserve and Non-reserve vidis surveyed, in Surendranagar Forest Division

Sr. No	Name of District	Name of Taluka	Name of Village	Name of Vidi	Area of hectares
1	Surendranagar	Chotila	Thangadh	*Mandav vidi	1774.99
2		Muli	Khakharla	*Khakarla vidi	178.06
3			Sangadhra	*Sangadhra vidi	320.27
4			Rampara	Ramparda vidi	134.79
5			Umarada(Plasa)	Palsa vidi	127.88
6 7		Sayala	Chorvira	*Chorvira vidi, Lakhtardi vidi	1018.28
8		Dhrangadhra	Thada	*Santhava vidi	270
9			Moti Majethi	*Majethi vidi	121.18
10		Halvad	Tikar	Sharana vidi	232.69

Reserve *vidi

Appendix-III e- List of Reserve and Non-reserve vidis surveyed, in Jamnagar-A "Jam" Forest Division

Sr. No	Name of District	Name of Taluka	Name of Village/Town	Name of Vidi	Abbrivation	Area of hectares
1	Jamnagar	Jamjodhpur	Jamjodhpur	Moti vidi*	-	549.24
2 3				Mahika* Varvada*	-	512.44
4 5 6 7			Sadodar	Sadodar* Bharakhadi*, MundoAyar*, Bavdidad* cluster	SDR-BHK-MA-BVD CLUSTER	513.95
8 9		Lalpur	Samana	Khatiya-Samana*	Khatiya-Sam	349.55
10			Pipartoda	Pipartoda* vidi	-	404.55
11			Khad-Khambhala	Khambhala*	Khad-Khamb	404.21
12			Lalpur	Apaiya	-	229.84
13				Sanosari	-	158.38
14 15 16 17		Jamnagar	Modpar, Pasaya, Sapda, Vijarakhi	Modpar-Pasaya-Sapda-Vijarakhi Cluster*	MODPAR-PAS	525.88
18		Kalawad	Kalawad	Jamvadi*	-	486.58

Reserve *vidi

Appendix-III f- List of Reserve and Non-reserve vidis surveyed, in Jamnagar-B "RJT" Forest Division

Sr. No	Name of District	Name of Taluka	Name of Village/Town	Name of Vidi	Abbrivation	Area of hectares
1	Rajkot	Gondal	Gondal	Vanastali*	GND-VNS-VAL	215.89
2 3				Valadhari*		117.08
4 5 6 7		Rajkot/ Jasdan	Dungarpur, Halenda, Mesvada.	Dungarpur* Halenda*, Mesvada*, Bawan* cluster	DNG-HLD-MES-CLUSTER	413.28 129.99
8 9 10		Vakaner	Vakaner, Tithva, Jambudiya	Ramparda* Tithava* Mota Jambudiya* Cluster	VKN-RMP-TIV	3237.63
11		Jasdan	Fuljar/ Modhuka	Umath* vidi	-	1455.79
12		Morbi	Morbi	Kalikanagar*	-	1253.44
13 14		Lodhika	Khirasara/ Chidhada	Khirasara-Chibhada*	-	646.09
15 16 17 18 19		Kotda Sangani	Naranka	Naranka-Pirvadi, Sardhar, Aradoi, Bodipat Cluster*	-	215.28
20		Rajkot	Haripar-pal	Haripar	-	110.55

Reserve *vidi

Appendix -IVa - Checklist of birds encountered at three study sites.

No.	Species Name(*Scientific name*)/Family	Site 1	Site 2	Site 3	Habit	Status	Guild
I	**Accipitridae**	**1**	**1**	**1**			
1	Black-shouldered Kite (*Elanus caeruleus*)	0	1	1	A	R	C
2	Shikra (*Accipiter badius*)	1	1	1	A	R	C
3	Tawny Eagle (*Aquila rapax*)*	0	1	0	A	R	C
4	Pale Harrier (*Circus macrourus*)*	0	1	1	A	M	C
5	Harrier(?)	1	1	1	A	M	C
II	**Alaudidae**	**1**	**1**	**1**			
6	Ashy Crowned Finch Lark (*Eremopterix grisea*)*	1	1	1	T	R	G
7	Bush lark (*Mirafra assamica*)	1	0	0	T	R	G
8	Red winged bush Lark (*Mirafra erythroptera*)*	1	1	1	T	R	G
9	Syke's Creasted Lark (*Galerida malabarica*)*	1	1	1	T	R	G
10	Sand Lark (*Calandrella raytal*)	1	0	0	T	R	G
11	Cristed lark (Galerida cristata)	1	0	0	T	R	G
12	Short-toed Lark (*Calandrell cinerea*)	1	0	0	T	R	G
III	**Anhingidae**						
13	Darter (*Anhinga melanogaster)*	0	0	1	AQ	RM	AQ
IV	**Alcedinidae**	**0**	**1**	**0**			
14	White-Brested Kingfisher (*Halcyon smyrnensis*)	0	1	0	AQ	R	AQ
V	**Apodidae**	**0**	**1**	**1**			
15	House Swift (*Apus affinis*)*	0	1	1	A	RM	I
VI	**Ardeidae**	**1**	**1**	**1**			
16	Cattle Egret (*Bubulcus ibis*)*	1	1	1	T	RM	O
VII	**Capitonidae**	**1**	**1**	**1**			
17	Coppersmith Barbet (*Megalaima haemacephala)*	1	1	1	T	R	F
VIII	**Charadriidae**	**1**	**1**	**1**			
18	Red-wattled Lapwing (*Vanellus indicus*)*	1	1	1	AQ	R	O
19	Yellow-wattled Lapwing (*Vanellus malabaricus*)	1	1	0	T	R	C
VIII	**Cisticolidae**	**1**	**1**	**1**			
20	Ashy Prinia (*Prinia Socialis*)	1	1	0	A	R	I
21	Plain Prinia (*Prinia inornata*)	1	1	1	A	R	I
22	Rufous-fronted Prinia (*Prinia buchanani*)	1	1	1	A/T	R	I
23	Streaked fantail Warbler (*Zitting Cisticoal*)	1	1	1	A	R	I
IX	**Columbidae**	**1**	**1**	**1**			

24	Euraian Collared Dove (*Streptopelia decaocto*)*	1	1	1	A/T	RM	G
25	Laughing Dove (*Streptopelia senegalensis*)*	1	1	1	T	R	G
26	Red Collared Dove (*Streptopelia traquebarica*)*	1	1	0	T	RM	G
X	**Corvidae**	**0**	**0**	**1**			
27	Indian Treepie (*Dendrocitta vagabunda*)	0	0	1	T	R	O
XI	**Coraciidae**	**0**	**1**	**0**			
28	Indian Roller (*Coracias benghalensis*)*	0	1	0	A	R	I
XII	**Cuculidae**	**1**	**1**	**1**			
29	Pied Crested Cuckoo (*Clamator jacobinus*)	0	1	0	T	M	O
30	Greater Coucal (*Centropus sinensis*)	1	1	0	T	R	O
31	Asian Koel (*Eudynamys scolopacea*)	0	0	3	T	R	O
XIII	**Dicruridae**	**1**	**1**	**1**			
32	Black Drongo (*Dicrurus macrocercus*)*	1	1	1	A	R	I
XIV	**Emberizidae**	**1**	**1**	**1**			
33	Grey headed Bunting (*Emberiza fucata*)	1	1	1	T	RM	G
XV	**Falconidae**	**0**	**1**	**1**			
34	Red-headed Merlin (*Falco chicquera*)*	0	1	0	A	R	C
35	Common Kestrel *(Falco tinnunculus)*	0	0	1	A	RM	C
XVI	**Hirundinide**	**1**	**1**	**1**			
36	Red-rumped Swallow (*Hirundo daurica*)*	0	1	1	A	RM	I
37	Swallow (*Hirundo rustica*)*	0	1	1	A	RM	I
38	Dusky Crag martin (*Hiriundo concolor*)	1	0	0	A	R	I
39	Wire Tailed Swallow (*Hirundo smithii*)	1	0	1	A	R	I
XVII	**Laniidae**	**1**	**1**	**1**			
40	Bay-backed Shrike (*Lanius vittatus*)	1	1	0	A	R	O
41	Rufous backed Shrike (*Lanius schach*)	1	1	1	A	RM	O
42	Grey Shrike (*Lanius emeridionalis*)	1	1	1	A	RM	O
XVIII	**Meropidae**	**1**	**1**	**1**			
43	Small Green Bee-eater (*Merops orientalis*)*	1	1	1	A	R	I
XIX	**Motacillidae**	**1**	**1**	**1**			
44	Yellow Wagtail (*Motacilla flava)*	1	1	1	AQ	RM	O
45	White Wagtail (*Motacilla alba*)	0	1	1	AQ	RM	O
46	Oriental Tree Pipit (*Anthus hodgsoni*)	0	1	0	T	RM	O
47	Paddyfield Pipit (*Anthus rufulus*)	1	1	1	T	RM	O
48	Pipit (?)	0	1	1	T	RM	O
XX	**Muscicapidae**	**1**	**1**	**1**			
49	Black Redstart (*Phoenicurus ochruros*)	0	1	1	T	RM	I
50	Common Stonechat (*Saxicola torquata*)	1	1	1	T	RM	I

51	Indian Robin (*Saxicoloides fulicata*)*	1	1	1	T	R	I
52	Pied Bushchat (*Saxicola caprata*)	0	1	0	T	RM	I
53	Brown Flycatcher (*Muscicapa latirostris*)	0	1	1	A/T	R	O
54	Desert Wheatear (*Oenanthe deserti*)	1	1	0	T	RM	I
XXI	**Oriolidae**	**0**	**0**	**1**			
55	Eurasian Golden Oriole (*Oriolus oriolus)*	0	0	1	A	RM	O
XXII	**Nectariniidae**	**0**	**1**	**1**			
56	Purpal Sunbird (*Nectarinia asiatica)*	0	1	1	A	R	N
XXIII	**Passeridae**	**1**	**1**	**1**			
57	Baya Weaver (*Ploceus philippinus*)*	1	1	0	A	R	G
58	Tailor Bird (*Orthotomus sutorius*)*	0	1	0	T	R	I
59	White-throated Munia (*Lonchura malabarica*)	1	1	1	T	R	G
XXIV	**Phalacrocoracidae**	1	0	0			
60	Little Cormorant *(Phalacrocorax niger)*	1	0	0	AQ	R	AQ
XXV	**Phasianidae**	**1**	**1**	**1**			
61	Indian Peafowl (*Pavo cristatus*)*	1	1	0	T	R	O
62	Jungle Bush Quail (*Pardicula asiatica*)*	0	1	1	T	R	G
63	Common Quail (*Coturnix coturnix*)*	1	1	1	T	R	G
64	Rain Quail (Coturnix coromandelica*)*	0	1	0	T	RM	G
65	Grey Francolin (*Francolinus pondicerianua*)	1	1	1	T	R	G
66	Painted Francolin (*Francolinus pictus*)*	1	1	1	T	RM	G
XXVI	**Psittacidae**	**0**	**1**	**0**			
67	Rose-ringed Parakeet (*Psittacula krameri*)*	0	1	0	A	R	F
XXVII	**Pteroclididae**	**0**	**1**	**1**			
68	Chestnut-bellied Sandgrouse (*Pterocles exustus*)	0	1	1	T	R	G
XXVIII	**Pycnonotidae**	**1**	**1**	**1**			
69	Red-vented Bulbul (*Pycnonotus cafer*)*	1	1	1	A	R	O
XXIX	**Scolopacidae**	**0**	**1**	**0**			
70	Common Sandpiper (*Actitis hypoleucos*)	0	1	0	AQ	R	AQ
XXX	**Strigidae**	**0**	**1**	**0**			
71	Spotted Owlet (*Athene brama*)	0	1	0	A	R	C
XXXI	**Sturnidae**	**1**	**1**	**1**			
72	Common Myna (*Acridotheres tristis*)*	1	1	1	A/T	R	O
73	Brahminy Starling(*Sturnus pagodarum*)	0	1	0	A/T	R	O
XXXII	**Timaliinae**	**1**	**1**	**1**			
74	Common Babbler (*Turdoides caudatus*)*	1	1	1	A/T	R	I
75	Large Grey Babbler (*Turdoides malcolmi*)*	1	1	1	T	R	O
76	Jungle Babbler (Turdoides straitus)	1	1	0	A/T	R	O
XXXIII	**Threskiornithidae**	**1**	**1**	**1**			

77	Black Ibis (*Pseudibis papillosa*)*	0	1	0	AQ	R	O
78	Eurasian Spoonbill (*Platalea leucorodia*)	1	0	1	AQ	RM	AQ
XXXIV	**Upupidae**	**1**	**1**	**1**			
79	Common Hoopoe (*Upupa epops*)*	1	1	1	T	RM	I

Abbreviations: A: Arboreal, T: Terrestrial, A/T: Arboreal/Terrestrial, AQ: Aquatic, R: Resident, M: Migratory, RM: Migrant with resident population, I: Insectivorous, O: Omnivorous, C: Carnivorous, G: Granivorous, N: Nectarivorous, F: Frugivorous.

Appendix – IVb - Frequency of encounters and abundance of bird species sighted on transects at study sites.

No.	Species Name	Site 1		Site 2		Site 3	
		Frequency	Number	Frequency	Number	Frequency	Number
1	Ashy Crowned Finch Lark (*Eremopterix grisea*)*	41	65	67	93	59	94
2	Ashy Prinia (*Prinia Socialis*)	2	2	2	3	0	0
3	Asian Koel (*Eudynamys scolopacea*)	0	0	0	0	4	5
4	Baya Weaver (*Ploceus philippinus*)*	15	36	40	102	0	0
5	Bay-backed Shrike (*Lanius vittatus*)	3	3	1	1	0	0
6	Black Drongo (*Dicrurus macrocercus*)*	35	58	46	76	49	75
7	Black Ibis (*Pseudibis papillosa*)*	0	0	11	24	0	0
8	Black Redstart (*Phoenicurus ochruros*)	0	0	6	7	11	19
9	Black-shouldered Kite (*Elanus caeruleus*)	0	0	8	8	4	4
10	Brahminy Starling(*Sturnus pagodarum*)	0	0	5	10	0	0
11	Brown Flycatcher (*Muscicapa latirostris*)	0	0	2	2	1	1
12	Bush lark (Mirafra assamica)	1	2	0	0	0	0
13	Cattle Egret (*Bubulcus ibis*)*	40	147	35	126	13	31
14	Chestnut-bellied Sandgrouse (*Pterocles exustus*)	0	0	6	10	6	10
15	Common Babbler (*Turdoides caudatus*)*	55	119	76	161	87	177
16	Common Hoopoe (*Upupa epops*)*	3	5	7	12	8	11
17	Common Kestrel *(Falco tinnunculus)*	0	0	0	0	1	1
18	Common Myna (*Acridotheres tristis*)*	22	36	17	26	18	32
19	Common Quail (*Coturnix coturnix*)*	7	11	8	17	29	52
20	Common Sandpiper (*Actitis hypoleucos*)	0	0	1	1	0	0
21	Common Stonechat (*Saxicola torquata*)	18	32	128	208	80	155
22	Coppersmith Barbet (*Megalaima haemacephala)*	1	2	2	3	4	6
23	Creasted lark	15	23	0	0	0	0

24	Darter	0	0	0	0	3	7
25	Desert Wheatear (*Oenanthe deserti*)	3	6	3	5	0	0
26	Dusky Crag martin (*Hiriundo concolor*)	3	4	0	0	0	0
27	Euraian Collared Dove (*Streptopelia decaocto*)*	49	88	55	80	68	108
28	Eurasian Golden oriole	0	0	0	0	1	2
29	Eurasian Spoonbill (*Platalea leucorodia*)	3	6	0	0	3	10
30	Greater Coucal (*Centropus sinensis*)	1	1	2	3	2	2
31	Grey Francolin (*Francolinus pondicerianua*)	21	31	38	50	32	43
32	Grey headed Bunting (*Emberiza fucata*)	14	47	125	288	79	306
33	Grey Shrike (*Lanius emeridionalis*)	6	6	8	8	5	6
34	Harrier(?)	1	1	4	6	6	8
35	House Swift (*Apus affinis*)*	0	0	4	12	30	54
36	Indian Peafowl (*Pavo cristatus*)*	11	16	11	15	0	0
37	Indian Robin (*Saxicoloides fulicata*)*	43	64	62	94	62	97
38	Indian Roller (*Coracias benghalensis*)*	0	0	1	2	0	0
39	Indian Treepie (*Dendrocitta vagabunda*)	0	0	2	3	0	0
40	Jungle Babbler (Turdoides straitus)	44	144	78	199	0	0
41	Jungle Bush Quail (*Pardicula asiatica*)*	0	0	23	56	37	60
42	Large Grey Babbler (*Turdoides malcolmi*)*	39	91	40	93	58	136
43	Laughing Dove (*Streptopelia senegalensis*)*	61	142	72	120	106	181
44	Little Cormorant *(Phalacrocorax niger)*	3	6	0	0	0	0
45	Oriental Tree Pipit (*Anthus hodgsoni*)	0	0	2	1	0	0
46	Paddyfield Pipit (*Anthus rufulus*)	3	5	3	5	10	16
47	Painted Francolin (*Francolinus pictus*)*	24	26	12	15	20	24
48	Pale Harrier (*Circus macrourus*)*	0	0	6	8	2	3

49	Pied Bushchat (*Saxicola caprata*)	0	0	1	1	0	0
50	Pied Crested Coucoo	0	0	1	1	0	0
51	Pipit (?)	3	5	8	16	5	8
52	Plain Prinia (*Prinia inornata*)	30	41	78	100	54	76
53	Purpal Sunbird (*Nectarinia asiatica)*	0	0	12	17	7	11
54	Rain Quail (Coturnix coromandelica*)*	0	0	12	26	0	0
55	Red Collared Dove (*Streptopelia traquebarica*)*	2	3	6	8	0	0
56	Red winged bush Lark (*Mirafra erythroptera*)*	71	114	123	210	89	132
57	Red-headed Merlin (*Falco chicquera*)*	0	0	1	1	0	0
58	Red-rumped Swallow (*Hirundo daurica*)*	0	0	2	5	9	15
59	Red-vented Bulbul (*Pycnonotus cafer*)*	26	43	47	74	51	92
60	Red-wattled Lapwing (*Vanellus indicus*)*	36	52	30	44	24	35
61	Rose-ringed Parakeet (*Psittacula krameri*)*	0	0	1	2	0	0
62	Rufous backed Shrike (*Lanius schach*)	7	8	2	2	8	9
63	Rufous-fronted Prinia (*Prinia buchanani*)	37	51	93	137	59	88
64	Sand Lark (*Calandrella raytal*)	7	11	0	0	0	0
65	Shikra (*Accipiter badius*)	4	4	3	3	3	3
66	Short-toed Lark (*Calandrell cinerea*)	6	8	0	0	0	0
67	Small Green Bee-eater (*Merops orientalis*)*	33	65	29	65	47	93
68	Spotted Owlet (*Athene brama*)	0	0	4	4	0	0
69	Streaked fantail Warbler (*Zitting Cisticoal*)	2	4	30	37	7	11
70	Swallow (*Hirundo rustica*)*	22	43	24	46	15	36
71	Syke's Creasted Lark (*Galerida malabarica*)*	42	71	73	124	72	99
72	Tailor Bird (*Orthotomus sutorius*)*	0	0	5	8	0	0
73	Tawny Eagle (*Aquila rapax*)*	0	0	2	2	0	0
74	White throted muniya	39	133	59	166	74	227

75	White Wagtail (*Motacilla alba*)	0	0	12	26	26	46
76	White-Brested Kingfisher (*Halcyon smyrnensis*)	0	0	2	2	0	0
77	Wire Tailed Swallow (*Hirundo smithii*)	6	14	0	0	7	12
78	Yellow Wagtail (*Motacilla flava)*	5	10	4	9	21	34
79	Yellow-wattled Lapwing (*Vanellus malabaricus*)	2	16	2	3	0	0
		967	1921	1685	3092	1476	2763

Appendix- IVc Relative Abundance of Species at Study sites.

		Relative Abundance %		
		Site 1	Site 2	Site 3
1	Ashy Crowned Finch Lark (*Eremopterix grisea*)*	3.35	3.01	3.40
2	Ashy Prinia (*Prinia Socialis*)	0.10	0.10	0.00
3	Asian Koel (*Eudynamys scolopacea*)	0.00	0.00	0.18
4	Baya Weaver (*Ploceus philippinus*)*	1.86	3.30	0.00
5	Bay-backed Shrike (*Lanius vittatus*)	0.15	0.03	0.00
6	Black Drongo (*Dicrurus macrocercus*)*	2.99	2.46	2.71
7	Black Ibis (*Pseudibis papillosa*)*	0.00	0.78	0.00
8	Black Redstart (*Phoenicurus ochruros*)	0.00	0.23	0.69
9	Black-shouldered Kite (*Elanus caeruleus*)	0.00	0.26	0.14
10	Brahminy Starling(*Sturnus pagodarum*)	0.00	0.32	0.00
11	Brown Flycatcher (*Muscicapa latirostris*)	0.00	0.06	0.04
12	Bush lark (Mirafra assamica)	0.10	0.00	0.00
13	Cattle Egret (*Bubulcus ibis*)*	7.59	4.08	1.12
14	Chestnut-bellied Sandgrouse (*Pterocles exustus*)	0.32	0.00	0.36
15	Common Babbler (*Turdoides caudatus*)*	6.14	5.21	6.40
16	Common Hoopoe (*Upupa epops*)*	0.26	0.39	0.40
17	Common Kestrel *(Falco tinnunculus)*	0.00	0.00	0.04
18	Common Myna (*Acridotheres tristis*)*	1.86	0.84	1.16
19	Common Quail (*Coturnix coturnix*)*	0.57	0.55	1.88
20	Common Sandpiper (*Actitis hypoleucos*)	0.00	0.03	0.00
21	Common Stonechat (*Saxicola torquata*)	1.65	6.73	5.61
22	Coppersmith Barbet (*Megalaima haemacephala)*	0.10	0.10	0.22
23	Creasted lark	1.19	0.00	0.00
24	Darter	0.00	0.00	0.25
25	Desert Wheatear (*Oenanthe deserti*)	0.31	0.16	0.00
26	Dusky Crag martin (*Hiriundo concolor*)	0.21	0.00	0.00
27	Euraian Collared Dove (*Streptopelia decaocto*)*	4.54	2.59	3.91
28	Eurasian Golden oriole	0.00	0.00	0.07
29	Eurasian Spoonbill (*Platalea leucorodia*)	0.31	0.36	0.00
30	Greater Coucal (*Centropus sinensis*)	0.05	0.10	0.07
31	Grey Francolin (*Francolinus pondicerianua*)	1.60	1.62	1.56
32	Grey headed Bunting (*Emberiza fucata*)	2.43	9.32	11.07
33	Grey Shrike (*Lanius meridionalis*)	0.31	0.26	0.22
34	Harrier(?)	0.05	0.19	0.29
35	House Swift (*Apus affinis*)*	0.00	0.39	1.95

36	Indian Peafowl (*Pavo cristatus*)*	0.83	0.49	0.00
37	Indian Robin (*Saxicoloides fulicata*)*	3.30	3.04	3.51
38	Indian Roller (*Coracias benghalensis*)*	0.00	0.06	0.00
39	Indian Treepie (*Dendrocitta vagabunda*)	0.00	0.00	0.04
40	Jungle Babbler (Turdoides straitus)	7.43	6.44	0.00
41	Jungle Bush Quail (*Pardicula asiatica*)*	0.00	1.81	2.17
42	Large Grey Babbler (*Turdoides malcolmi*)*	4.70	3.01	4.92
43	Laughing Dove (*Streptopelia senegalensis*)*	7.33	3.88	6.55
44	Little Cormorant *(Phalacrocorax niger)*	0.31	0.00	0.00
45	Oriental Tree Pipit (*Anthus hodgsoni*)	0.00	0.10	0.00
46	Paddyfield Pipit (*Anthus rufulus*)	0.26	0.16	0.58
47	Painted Francolin (*Francolinus pictus*)*	1.34	0.49	0.87
48	Pale Harrier (*Circus macrourus*)*	0.00	0.26	0.11
49	Pied Bushchat (*Saxicola caprata*)	0.00	0.03	0.00
50	Pied Crested Coucoo	0.00	0.03	0.00
51	Pipit (?)	0.26	0.52	0.29
52	Plain Prinia (*Prinia inornata*)	2.12	3.24	2.75
53	Purpal Sunbird (*Nectarinia asiatica)*	0.00	0.55	0.40
54	Rain Quail (Coturnix coromandelica*)*	0.00	0.84	0.00
55	Red Collared Dove (*Streptopelia traquebarica*)*	0.15	0.26	0.00
56	Red winged bush Lark (*Mirafra erythroptera*)*	5.88	6.79	4.78
57	Red-headed Merlin (*Falco chicquera*)*	0.00	0.03	0.00
58	Red-rumped Swallow (*Hirundo daurica*)*	0.00	0.16	0.54
59	Red-vented Bulbul (*Pycnonotus cafer*)*	2.22	2.39	3.33
60	Red-wattled Lapwing (*Vanellus indicus*)*	2.68	1.42	1.27
61	Rose-ringed Parakeet (*Psittacula krameri*)*	0.00	0.06	0.00
62	Rufous backed Shrike (*Lanius schach*)	0.41	0.06	0.33
63	Rufous-fronted Prinia (*Prinia buchanani*)	2.63	4.43	3.18
64	Sand Lark (*Calandrella raytal*)	0.57	0.00	0.00
65	Shikra (*Accipiter badius*)	0.21	0.10	0.11
66	Short-toed Lark (*Calandrell cinerea*)	0.41	0.00	0.00
67	Small Green Bee-eater (*Merops orientalis*)*	3.35	2.10	3.36
68	Spotted Owlet (*Athene brama*)	0.00	0.13	0.00
69	Streaked fantail Warbler (*Zitting Cisticoal*)	0.21	1.20	0.40
70	Swallow (*Hirundo rustica*)*	2.22	1.49	1.30
71	Syke's Creasted Lark (*Galerida malabarica*)*	3.66	4.01	3.58
72	Tailor Bird (*Orthotomus sutorius*)*	0.00	0.26	0.00
73	Tawny Eagle (*Aquila rapax*)*	0.00	0.06	0.00
74	White throted muniya	6.86	5.37	8.21

75	White Wagtail (*Motacilla alba*)	0.00	0.84	1.66
76	White-Brested Kingfisher (*Halcyon smyrnensis*)	0.00	0.06	0.00
77	Wire Tailed Swallow (*Hirundo smithii*)	0.72	0.00	0.43
78	Yellow Wagtail (*Motacilla flava)*	0.52	0.29	1.23
79	Yellow-wattled Lapwing (*Vanellus malabaricus*)	0.83	0.10	0.00

Appendix -IVd -ER of Species met with on transects at three study sites.

		Site 1		Site 2		Site 3	
		Mean ER	Std dev	Mean ER	Std dev	Mean ER	Std dev
1	Ashy crowend finch lark	2.52381	0.989743	2.721429	1.967932	4.214286	2.343031
2	Ashy wren warbler	0.571429	0.824786	0.285714	0.412393	0	0
3	Coppersmith Barbet	0.142857	0.606092	0.142857	0.606092	0.571429	1.296253
4	Bay back shrike	0.285714	1.212183	0.142857	0.606092	0	0
5	Baya weaver	1.047619	0.576023	1.635714	0.926131	0	0
6	Rain quail	0	0	1	2	0	0
7	Black drongo	2.47619	1.155881	1.880952	1.018045	3.642857	1.619398
8	Black ibis	0	0	1.071429	0.822722	0	0
9	Black red start	0	0	1	1.414214	0.928571	1.451014
10	Black-shouldered Kite	0	0	0.857143	0.423783	0.571429	0.606092
11	Brahminy myna	0	0	0.714286	1.145829	0	0
12	Brown flycatcher	0	0	0.285714	0.412393	0.142857	0.606092
13	Bush lark	0.142857	0.606092	0	0	0	0
14	Cattle egret	2.642857	1.025193	1.885714	0.723443	1.857143	0.855554
15	Common Stonechat	1.285714	2.955452	4.952381	2.916788	5.714286	2.68051
16	Common babbler	2.452381	1.897466	3.483333	1.933436	6.571429	2.305716
17	Asian koel	0	0	0	0	0.571429	0.606092
18	Common hoopoe	0.571429	0.191663	0.328571	0.497408	0.857143	0.053995
19	Common Kestrel	0	0	0	0	0.142857	0.606092
20	Common myna	2.119048	1.287036	1.261905	0.571759	2.571429	1.399708
21	Grey Francolin	1.714286	1.005814	1.773809	0.583698	2.285714	0.958315
22	Common quail	0.571429	0.606092	0.690476	0.592039	2.428571	1.237179
23	Common sandpiper	0	0	0.142857	0.606092	0	0
24	Little Cormorant	0.714286	0.670059	0	0	0	0
25	Creasted lark	0.952381	0.775913	0	0	0	0
26	Greater Coucal	0.285714	0.412393	0.285714	0.412393	0.285714	0.412393
27	Darter	0	0	0	0	0.428571	0.285714
28	Desert wheatear	0.571429	0.606092	0.428571	0.795395	0	0
29	Dusky crag martin	0.428571	0.285714	0	0	0	0
30	Eurasian Golden oriole	0	0	0	0	0.142857	0.606092
31	Grey headed Bunting	1.214286	2.152755	4.880952	4.208691	5.642857	2.118753
32	Grey shrike	0.5	0.408248	0.785714	0.49125	0.714286	0.494872
33	Harrier (?)	0	0	0.5	0.408248	0.642857	0.305561
34	House swift	0	0	0.571429	0.606092	1.857143	1.063942
35	Indian robin	2.142856	0.923366	2.554762	1.190129	4.285714	1.55511
36	Indian Roller	0	0	0.142857	0.606092	0	0

37	Chestnut ballied Sandgrouse	0	0	0.857143	2.351725	0.714286	0.670059
38	Indian tree pipit	0	0	0.142857	0.606092	0	0
39	Jungle babbler	2.214286	0.651574	2.75	1.655798	0	0
40	Jungle bush quail	0	0	1.857143	0.95004	3.214286	1.665986
41	White breasted Kingfisher	0	0	0.285714	0.412393	0	0
42	Large gray babbler	1.857143	0.989743	1.5	0.83666	4.5	2.236068
43	Eurasian laughing dove	3.214286	1.100917	2.75	1.069045	7.571429	2.981234
44	Paddy field pipit	0.857143	0.996593	0.142857	0.606092	1.428571	1.574672
45	Painted partridge	0.8571	2.351	1.071429	0.480221	1.5	0.636209
46	Pale harrier	0.142857	0.606092	0.428571	0.285714	0.571429	1.296253
47	Indian Peafowl (call)	1.071429	0.480221	0.857143	0.28212	0	0
48	Pied bush chat	0	0	0.142857	0.606092	0	0
49	Pied creasted cuckoo	0	0	0.142857	0.606092	0	0
50	Pipit (?)	0.571429	2.424366	0.785714	0.814411	0.714286	1.145829
51	Plain wren warbler	1.785714	0.462648	3.269048	1.951443	3.857143	1.726149
52	Purple sunbird	0	0	1.285714	0.71173	1	0.816497
53	Red turtle dove	0.285714	0.412393	0.642857	0.305561	0	0
54	Red vented bulbul	0.904762	0.636075	1.119048	0.770717	3.642857	2.082483
55	Red watteld lapwing	2.479048	0.869099	1.6	0.67011	1.785714	0.361538
56	Red winged bush lark	2.714286	1.812028	4.571429	1.357247	6.357143	2.415934
57	Red-headed merlin	0	0	0.142857	0.606092	0	0
58	Red-rumped swallow	0	0	0.142857	0.606092	0.714286	0.346263
59	Ring dove	2.52381	0.663256	2.333333	0.931162	4.857143	0.788954
60	Roseringed parakeet	0	0	0.142857	0.606092	0	0
61	Rufous back shrike	0.571429	0.191663	0.142857	0.606092	0.785714	0.49125
62	Rufous-fronted wren-warbler	1.190476	0.920293	3.635714	1.807555	4.214286	2.118914
63	Sand lark	0.5	2.12132	0	0	0	0
64	Shikra	0.428571	0.285714	0.428571	0.285714	0.428571	0.285714
65	Short toad lark	0.285714	1.212183	0	0	0	0
66	Small green bee eater	2.261905	1.083268	2.066667	0.783561	3.357143	0.874818
67	Spoonbill	0.714286	0.670059	0	0	0.428571	0.795395
68	Spotted Owlet	0	0	0.571429	0.606092	0	0
69	Streaked Fantail Warbler	0.285714	1.212183	1.571429	1.550364	0.857143	0.996593
70	Swallow	2.142857	1.312421	1.642857	1.237729	2.142857	2.388322
71	Syke’s creasted lark	2.619048	1.150274	3.328571	1.17046	5.142857	2.215437
72	Tailor Bird	0	0	0.714286	0.494872	0	0
73	Tawny Eagle	0	0	0.285714	0.412393	0	0
74	Tree pie	0	0	0	0	0.142857	0.606092

75	White throated Munia	2.47619	2.273313	2.661905	2.006384	5.285714	1.55511
76	White wagtail	0	0	1.142857	0.895947	2	1.25499
77	Wire tailed swallow	0.285714	0.412393	0	0	1.142857	2.477106
78	Yellow wagtail	0.571429	1.296253	0.642857	0.591895	1.642857	1.760827
79	Yellow watteld lapwing	0.571429	1.296253	0	0	0	0