FEEDING ECOLOGY AND HABITAT NEEDS OF WOLVES (*Canis lupus pallipes*) IN THE BHAL AREA OF GUJARAT

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CERTIFICATE

This is to certify that the thesis titled **'Feeding Ecology and Habitat Needs of Wolves (*Canis lupus pallipes*) in the *Bhal* Area of Gujarat'** submitted for the award of degree of **Doctor of Philosophy** in Wildlife Biology to the Forest Research Institute, Deemed University, Dehradun, Uttaranchal, is a record of bonafide research carried out by **Shri Bharat D. Jethva** under my guidance and supervision. No part of this thesis has been submitted for any other degree and it fulfils all the requirements specified in the ordinance of Forest Research Institute for this purpose.

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SUMMARY

Present study was conducted in the *Bhal* region of Gujarat between 1996-2000 to study the feeding ecology and habitat needs of wolves. Food habits of wolves in the *Bhal* were studied by analyzing 1246 wolf scats from 5 packs. Standardization of scat analysis technique suggested that minimum of 20 hair should be scanned per scat to get complete representation of mammalian prey species in that scat. Minimum number of scats that need to be analyzed per pack were different for different wolf packs (ranging from 165 scats needed for Velavadar National Park (VNP) pack to 40 scats from Mithapur pack and 180 scats for the wolves of entire *Bhal*) because of different diet diversity. Mammalian prey species dominated in the diet of wolves and 80.5% scats were found with only one prey species.

Blackbuck constituted majority of wolf's diet in 5 packs followed by cattle, and nilgai where as other species occurred in low proportion (<5%) e.g. rodents, hare (*Lepus nigricollis*), water buffalo, birds, wild pigs (*Sus scrofa*), insects such as locusts, vegetable matter, and others. Percent occurrence of wild prey species and domestic prey species differed significantly (X^2 = 11.02, df=2, P ≤ 0.001) in the diet of wolves inhabiting protected area (VNP) and non-protected area. There was no significant seasonal difference in prey items eaten by wolves (F=0.29, df=2, 17, P=0.749) of the *Bhal*. Three groups could be differentiated in order of importance of prey species a) blackbuck, b) cattle and c) nilgai, hare, birds and rodents.

Four wolves from three packs were live trapped, radio collared and monitored between 1996-2000 for collection of data on home range, habitat use and predation. Wolves of three packs were continuously monitored for periods ranging from 5-16 days (total 1994 hrs) in two seasons between 1998-2000. During these continues monitoring periods data on total of 29 feeding events resulted in average feeding interval of 3.62 days (SE = 0.73), kill interval of 4.54 days (SE= 0.63) and average consumption/wolf/day of 1.84 kg (SE = 0.29). Adult male blackbuck contributed maximum (70%) to biomass consumption of wolves where as scavenging on cattle contributed 14% and cattle predation 8%. Data on predation suggests that wolves in the study area subsist primarily on wild prey and by scavenging dead livestock; livestock predation constitutes less than 4% of feeding events. Wolf depredations on livestock were unlikely to result in significant economic loss to the local villagers. Feeding interval, kill interval and consumption/wolf /day did not differ across two seasons (Mann–Whitney U test, feeding interval P=0.517, kill interval P=0.571 and consumption/wolf/day P = 0.267). Annual

consumption by 3 wolf packs was estimated at about 262 adult blackbuck male, 17 adult female blackbuck, 67 blackbuck fawns and 25 vulnerable cattle.

Radio collared wolves were located by homing in, minimum 3 times a week covering day and night hours for estimation of home ranges. Home ranges of lone wolves were found to be larger (227.6 to 181.0 km^2) than that of wolves associated with the packs (average of 3 packs, 113.4 ± 24 (SE) km^2). Home ranges of wolf packs were exclusive and they seemed to optimize territory boundaries to incorporate villages, which were rich in resources for scavenging. Wolf pack inhabiting higher blackbuck (*Antelope cervicapra*) density area (protected area) had smaller territory (65.2 km^2) in comparison to packs (136.3 to 138.7 km^2) inhabiting areas of lower blackbuck density (located outside protected area).

Sixteen habitat types were classified by supervised classification of satellite imageries (standard LISS-III 1:50,000 IRS-1C, FCC) of the study area. Compositional analysis and regression analysis showed that dense *Prosopis juliflora* patches, grassland and sparse *Prosopis* patches were preferred habitat types by wolves.

Core areas of 3 wolf territories estimated by using 50% harmonic mean method (Dixon and Chapman 1980) were found to be exclusive and small (7.9 ± 1.3 (SE) km^2) these areas were used primarily for denning, rendezvous sites and lying up sites. These areas appeared to be ideal spatial optimization of the availability of vegetation cover in the form of *Prosopis juliflora,* close proximity to fresh water and avoidance of human disturbances such as villages and roads.

Comparative account on feeding ecology provided in the present study by scat analysis and monitoring of radio-collared wolves suggests that wolves depends primarily on wild prey species (blackbuck being major prey) and predation on domestic livestock results in minimal economic loss to the local people. It emphasizes the importance of protected areas for the conservation of wolves. Use of radio-telemetry in the present study provided critical information on territorial behavior of wolves, their population density, size of home range and their relation with prey abundance, habitat use and the size and characteristics of core areas.

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Chapter-1 INTRODUCTION

The *Bhal* region of Gujarat is one of the important high wolf density areas where the interaction of an endangered predator, wolf (*Canis lupus pallipes*) and endangered prey species blackbuck (*Antelope cervicapra*) makes this region a unique ecosystem (Jhala 1991). However, recent surveys suggest that only 550 km^2 area is important for wildlife and total of about 40 wolves were estimated (Jhala and Giles 1991) to be in this ecologically important part of the *Bhal* ecosystem.

Like other important wildlife regions of the country, the *Bhal* ecosystem is also not an exception where wildlife is under a state of siege by developmental activities. Present rate of increase in developmental activities and increase in saltpan industries suggests major habitat loss from the *Bhal* ecosystem and intense human wildlife conflict in the future. Part of the *Bhal* ecosystem (34.08 km^2) predominantly composed of grazing grassland (locally known as 'vidi') is protected in the form of Velavadar National Park with primary purpose of protecting the largest surviving herd of blackbuck in the wild. Fortunately, some attention is given in terms of management based on scientific research (Jhala 1991, 1993a 1993b,) since last few years in Velavadar National Park (Singh and Rana 1995). However, other parts of the *Bhal* ecosystem excluding Velavadar National Park varies in their ecological set up in terms of prey population, human disturbance, water availability, biomass production etc. The information on the number of wolf packs, the size and spatial distribution for territories, food habits and habitat use by wolves inhabiting areas outside the Velavadar National Park area were lacking. Wolf being a top carnivore in this ecosystem is likely to be affected by any changes in natural ecological processes in this ecosystem. Preservation of wolf population in such circumstances would need careful management efforts with an in-depth knowledge of the basic ecological parameters as well as other ecological processes. In many cases, management policies fail due to lack of sufficient knowledge of ecological and economical consequences. Information on number of packs, their home range, habitat use and preference, food habits etc., would be of great importance to make any long-term management decision for conserving the *Bhal* wolf population.

Food habits of animals determine a number of life history strategies like habitat selection, movement and success of reproduction (Krebs 1978). The magnitude and the role of wolf predation on prey population provide useful information on the species such as food habits, human-wolf relationships and the wolf-prey population dynamics (Jhala 1991). Very few studies have focused on predator prey interaction and on the feeding ecology of the Indian wolf (Jhala 1991,1993a, Kumar 1998). The information on preferred and intensively used habitats by wolves i.e. the denning area, rendezvous sites and lying up sites is of great importance. This information is essential for the managers when an endangered predator species preys on an endangered prey species in an ecosystem that is maintained by management and aid in making conservation and management decisions (Jhala 1993a).

This study was conducted as a part of an ongoing long-term research project on Indian wolf ecology by Wildlife Institute of India, which addresses the above-mentioned aspects and aims to collect basic ecological information using radio telemetry. The present study was specifically aimed at providing comparative accounts of food habits, home range, spatial distribution of wolf territories and their habitat uses, in relations to the prey abundance. Information on above-mentioned ecological parameters would provide better insight in the ecology of wolves of the *Bhal* and would not only help the management of the *Bhal* ecosystem but also add to the basic knowledge on the species.

Chapter-2 STUDY AREA

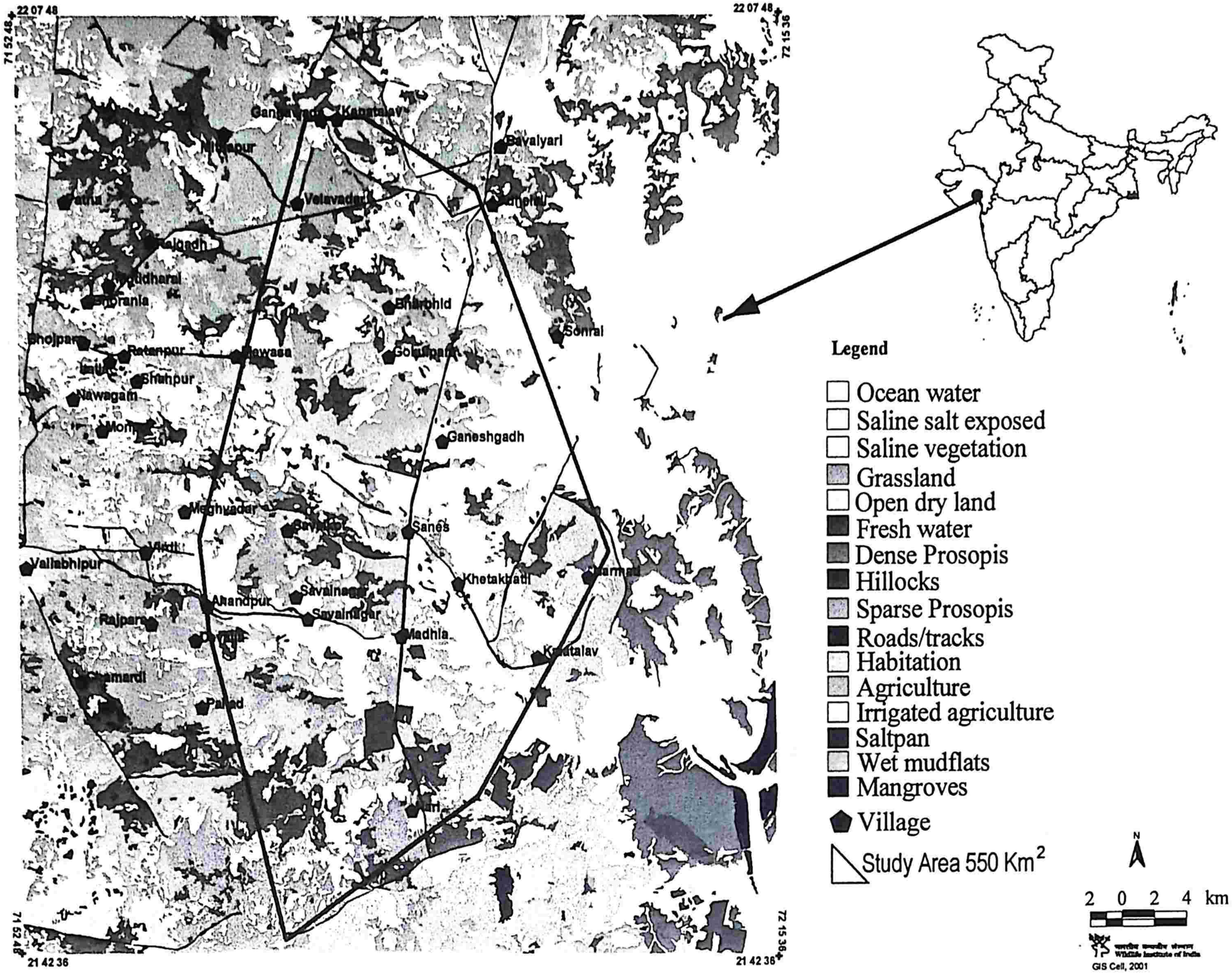
2.1. Location:

The present study was conducted in a part of the *Bhal* area of Saurashtra region in the state of Gujarat in western India. *Bhal* is situated just above sea level covering an area of 2590 sq. km^2 and bordered on the south by the Kalubhar river, on the northern side it extends to Dholka and Dhandhuka towns and the town of Limbdi marks its limits on the north west border (Dharmakumarsinhji 1978). The present study covered the *Bhal* of Bhavnagar district (21° 07′ to 21° 42′ N and 71° 52′ to 72° 15′ E). It extends from the eastern cost of 'Gulf of Cambay' on the western side the National highway connecting Dhandhuka-Vallabhipur and Bhavnagar marks its boundary. The city of Bhavnagar marked the southern limits. The villages of Adhelai, Mithapur and Rajgadh marked its northern limits. Approximately 550 km^2 of *Bhal* of Bhavnagar district known to have a good wolf and blackbuck population was considered as the intensive study area (Plate-1) The boundary of this intensive study area was generated by connecting the extreme location of radio collared wolves in the *Bhal* between 1996-2000.

2.2. History:

Before the India's independence (1947) the major part of the present *Bhal* belonged to the princely state of Bhavnagar. Grasslands of Velavadar and Mithapur were private grazing land (locally known as *'vidi'*) of the Maharaja of Bhavnagar. Large concentrations of blackbuck lived on these *'vidis,'* and the maharaja of Bhavnagar used to hunt them with the help of trained captive cheetah. After independence the government of Saurashtra allowed wildlife to be killed on sight for the protection of crops during the severe drought conditions. Due to hunting and habitat loss, blackbuck population was decimated. Efforts by R.K.S Dharmakumarsinhji, R.K. Shivbhadrasinhji and Dr. M.K. Ranjitsinhji succeeded in convincing the Government regarding the endangered status of the *Bhal* blackbuck. As a result a small part of the *'vidi'* (890 ha.) composing one of the rich grazing grassland near the village Velavadar was given the status of a sanctuary 1969 (Ranjitsinh 1982, Mungall *et al*. 1981:20).

Plate1. Different habitat types and distribution of villages in the study area, Bhal region, Gujarat. (Classified LISS- III Satellite Image of Dec. 1995).



Later on in 1976, the area was increased to 1,783.88 ha and the status upgraded to a National Park (Rashid 1977). In 1980 another 1,624.23 ha. were added to the park (Prasad 1985:14) and recently in 2000 an area of 44ha cropland was acquired and merged in the Park, thus currently the National Park covers an area of 3,452.11 ha (34.52 km^2).

2.3. Characteristics:

The *Bhal* (literally meaning forehead) is a flat alluvial plain made up of a mosaic of croplands, saline wastelands, grazing grasslands and marshes (Dharmakumarsinhji 1978). The *Bhal* is believed to have emerged from the sea during the late Tertiary and early Quaternary, much later than the rest of Saurashtra, which appeared during the Cretaceous (Dharmakumarsinhji 1978, Raychaudhari *et al.* 1963). The *Bhal* soil is highly saline and alkaline in nature, which is mainly due to its origin from sea, semi-arid climatic condition (Ranjitsinh 1982:23-24) and waterlogginng during monsoon. The *Bhal* soils are silt deposits from the rivers Narmada, Mahi, Sabarmati, Sukhbhadar, the Bhogavas, and rivulets like Kalubhar and Alang draining the basalt Kathiawar highlands into the Gulf of Cambay (Dharmakumarsinhji 1978). The tidal water from “Gulf of Cambay” invades in to the main land through several creeks as far as 20 km into the Velavadar National Park.

2.4. Climate:

Bhal falls under the semi-arid region as one of the broadly classified five different biogeographical regions of India. Droughts, floods, water logging salinization and marine inundation are inherent natural process in this region (Bhattacharya 1997). Three different seasons can be distinguished as winter (November-February), summer (March - June) and monsoon (July- October). The winter temperature ranges from 1° C to 38° C in winter (Jhala 1997). Rare showers (locally known as *'Mavthu'*) sometimes occur during winter. Due to high moisture content of the sea breeze, dew and low fog occurs during early morning hours (Ranjitsinh 1982:24). Summer is relatively hot day temperatures ranges between 37° C and 44° C but can be as high as 48° C. In summer dust storms, hot wind called *'loo'* and mirage are common feature of *Bhal* in midday (Jhala 1991). The average annual precipitation at Velavadar National Park recorded is

518 mm (standard deviation 215, minimum 90mm and maximum 776.5mm) (Jhala 1997) most of it occurs during monsoon. Due to low elevation than its surroundings the *Bhal* area remains submerged and becomes a large swamp during heavy monsoon rains (Jhala 1991). Habitat loss, poaching pressures severe droughts and cyclones in the *Bhal* are the major reasons for decline of blackbuck population.

2.5. People and Occupation:

Koli, Bharvad and *Darbar* are the major communities among the people in the *Bhal*. Cultivation of wheat, sorghum and cotton as well as cattle rearing is major occupations of the people of the *Bhal*. Cultivation of sorghum and cotton is done during the monsoon where as wheat is grown in winter. Cattle and water buffaloes are reared solely for dairy products. Due to salinity of ground water the vegetation growth is entirely dependent on the rainfall, which occurs during the monsoon and early winter. The livestock remains in the *Bhal* during monsoon and winter where as in summer the quantity and quality of forage in the *Bhal* deteriorates therefore the cattle herds are moved from the *Bhal* to regions of South Gujarat for better grazing and for marketing dairy products.

2.6. Flora and Fauna:

The *Bhal* area was an open treeless habitat as recently as 40 years ago (Dharmakumarsinhi 1978, Mungall *et al.* 1981). Present day the *Bhal* is dominated by large patches of *Prosopis juliflora* an exotic, native of Southwestern America (Muthana and Arora 1983) plant species. *This* exotic species was planted in the *Bhal* about 70-80 years ago for the purpose of fuel wood. Invasion of this exotic shrub into the main grassland is the major problem faced by the managers of the Velavadar National Park ecosystem (Jhala 1991). The other tree species found in comparatively in very low proportions are *Salvadora oliodes, Prosopis cineraria,* and *Acasia nilotica.* The major grass species found in grasslands of the *Bhal* are *Dicantium anulatum, Sporobolus virginicus, Sporobolus madraspatensis, Sporobolus coromendialis* (Jhala 1991).

The *Bhal* is known for its large concentration of blackbuck (*Antelope cervicapra rajputani*) and wolves. Present day the interaction of an endangered predator the Indian wolf with endangered prey blackbuck makes this region a unique ecosystem. The important wild herbivores of the *Bhal* include blackbuck, nilgai (*Boselaphus tragocamelus*), wild pigs (*Sus scrofa*) and hares (*Lepus nigricollis*). Where as among important carnivores the Indian wolf, golden jackal (*Canis aureus*) Indian fox (*Vulpes bengalensis*), jungle cat *(Felis chaus*) and rarely the stripped hyena (*Hyena hyena*) and leopard (*Panthera pardus*) have been reported in this region (Jhala pers.comm.). The part of the *Bhal*, Velavadar National Park is one of the biggest winter roosts of Harriers, which numbers around 2000-3000 birds (Clarke *et al.* 1998). The grasslands of *Bhal* provide important breeding ground to one of the four most critically endangered bird species of India the Lesser Florican (*Sypheotides indica*) (Jhala 1991, Sankaran 1997). The Houbara bustards *(Chalamydotis undulata)* are winter migrants in the *Bhal* (Jhala 1991). Three species of crane i.e. common crane (*Grus grus*), demoiselle Crane (*Grus virgo*) and sarus crane (*Grus antigone*) are found in the *Bhal*. In monsoon the shallow water swamps attracts many monsoon-winter migratory birds such as white stork (*Ciconia ciconia*).

The location, topography, climatic condition and the biological components i.e presence of important endangered *fauna* make the *Bhal* a unique ecosystem. However, in present day, invasion of exotic shrub *Prosopis* juliflora in the important grasslands and the loss of wasteland to industrial saltpans and increasing salinization of soil are the two major threats to the highly fragile ecosystem of the *Bhal*.

Chapter –3 LITERATURE REVIEW

Predators are crucial elements of ecosystems for maintaining and shaping the structure of communities (Glasser 1979) by regulating the prey population and maintaining biodiversity of the ecosystem (Stacey and Berger 2000). Recent studies have described systems where extinction of apex predators has caused trophic cascades that have influenced community structure and ecosystem function (Palomares *et al.*1995; Romer 2000; Stacey and Berger 2000).

Canids and felids have specialized to become the most successful top predators in many terrestrial ecosystems. Among canids, wolves are top predators on large ungulates in many ecosystems across the world and their role as big-game predator can be seen in all aspects of their life i.e. intelligence, social structure, travel, hunting methods and numerous sensory perception (Mech 1970).

Wolf control or help control number of large herbivorous, they also tend to cull out animal that are the least healthy and vigorous and those that are most poorly adapted for survival (Mech 1970). By doing this, they help ensure the balance of the community and the ecosystem (Mech 1970). Several studies have supported this statement such as study by Carbyn (1983) showed that wolves killed a larger proportion of young and old elk in Riding Mountain National Park in Manitoba. Another study by Bergerud *et al.* (1983) on Moose and Gray wolf between 1975 to 1979 showed that wolf predation was limiting the increase of the moose population. Larsen *et al.* (1989) between 1983-85 in southwest Yukon, and Adams *et al.* (1995) between 1984-87 in Denaili Caribou herd in Alaska suggested that predation by grizzly bears and wolves limited the growth of moose and caribou populations respectively. However, a study in Nelchina of south central Alaska suggested that caribou calf mortality was correlated with winter severity, not wolf predation (Van Ballenberghe 1985) but (Bergerud and Ballard 1988) using the same data came to the opposite conclusion, by re-analysis of the data they suggested that predation by wolves on young animals was the most consistent natural limiting factor in the dynamics of the caribou herd. These studies clearly state the role of wolf as an important predator. However, in areas where wild prey species are not abundant, wolves tend to kill domestic livestock and causes economic loss to the people (Shahi 1982). In these areas they have earned an unpleasant relationship with humans. Human-wolf conflict is the main reason for the shrinkage of historical range of the wolf.

Total three species of wolves are known today, Grey wolf (*Canis lupus*) (Nowak 1995, Wayne *et al.* 1995), Red wolf (*Canis rufus*) (Nowak *et al.* 1995) and the most recently classified Ethiopian wolf (*Canis simiensis*). Total of 32 sub-species of Grey wolves (*Canis lupus* Linnaeus 1758) that are widely distributed in diverse habitats in different ecosystems across the world (Mech 1970) exist today. There are two sub-species of Grey wolves found in India *Canis lupus chanco* also known as the Tibetan wolf found in Trans-Himalayan range and *Canis lupus pallipes* (Sykes 1831) in peninsular part of India (Mech 1970; Fox and Chundawat 1995). *C. l. pallipes* is considered endangered in India and features on schedule 1 of the Indian Wildlife Protection Act (1972) and CITES (Shahi 1982). This species is protected by law and killing or trading of this species is prohibited in India. Shahi (1982) estimated about 800 Indian wolves (*C. l. pallipes*) distributed in patchy habitats in peninsular India. Ginsburg and McDonald (1990) estimated about 2000-3000 wolves for the Indian peninsula. This population is found to occur in three biogeographic zones 1) the hot desert, 2) semi-arid zones and 3) the Deccan Plateau of India (Rodgers and Panwar 1988). Jhala and Giles (1991) suggests that Indian wolf is continuously distributed in the states of Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh and they estimated 450-620 wolves continuously distributed in the semi-arid tracts of Gujarat and Rajasthan states of western India. Geographical ranges of wolves and dholes are found to overlap considerably in central Indian highlands (Johnsingh and Yoganand 2000, Yoganand 1998). Status surveys suggests that Indian wolf is still far from safe in most of its range and occurs at very low densities (about 1 wolf/ per 100 km^2) and the high-density wolf populations are found to occur in some habitat pockets and preserves (Jhala and Giles 1991). Such high-density habitats are extremely important for wolf conservation since these pockets serve as successful breeding and recruitment areas from where wolves disperse to occupy marginal habitats (Jhala 1991).

As Durward Allen (1979) emphasized, "studies must span decades if we are to fully understand the wolf and it's relation to its prey and environment". Over half a century of research on wolves has provided in depth knowledge on their basic behavioral ecology and since the early 1940s North America has been the focus for studies of free-ranging wolves (Harrington and Paquet 1982:2). The use of radio-telemetry technique for studying animals increased during the 1970s and today virtually all studies employ it (Harrington and Paquet 1982:3). More and more accurate statements about the activities of particular wolves or packs under a variety of conditions are now possible (Harrington and Paquet 1982). Unfortunately no such long-term studies had been conducted to understand the ecology of wolves in India.

I attempt to familiarize the reader with the research done to date on topics relevant to my dissertation, various methods used for such studies and on the Indian wolf (*Canis lupus pallipes*) in compared to the research done on other sub-species of wolves in other part of the world.

3.1. Wolves:

Wolf (*Canis lupus*) has been one of the most studied of all wild species (Mech 1995). The first study of the wolf was published in 1938, and since then several books and monographs and thousands of articles have been published about the animal (Mech 1995). Two major long-term studies on wolves include study on wolf-moose system started in 1959 (Mech 1966, Jordan *et al.* 1967, Peterson 1977, Allen 1979, Peterson and Page 1988) and the wolf-deer system in the Superior National Forest of northeastern Minnesota (Mech and Frenzel 1971, Mech and Karns 1977, Nelson and Mech 1981).

A book by Mech (1970) "*The wolf*" was the first attempt to provide complete account and understanding of wolf ecology and was referred most during this study. A compilation of papers presented at the 1979 Portland International Wolf Symposium in the form of a book "*Wolves of the World*" (1982) provided useful information on status of *C. l. pallipes* in Iran (Joslin 1982), and food habits and other facets of wolf ecology in Israel (Mendelssohn 1982). Another *compilation* of selected research papers presented at the 'Second North American Symposium on Wolves' held in Edmonton in August 1992 in the form of "*Ecology and Conservation of Wolves in a Changing World*" (1995) provided recent account of wolf ecology, behavior, conservation, management, control, dispersal, movements, predator-prey dynamics, status, wolf-human relationships and the gaps in the knowledge of wolf ecology and behavior.

However, in comparison to studies *done* on wolves in other parts of the world, very few studies have been done on Indian wolf subspecies (*C. l. pallipes*). The earlier studies available on *C. l. pallipes* in India includes paper by Shahi (1982) discussing primarily on the attacks by wolves on children in the state of Bihar (India), who also suggested that there were only 800 wolves left in India which was much lower number then number of tigers in India. However, Ginsberg and Macdonald (1990) reported that there are 2000-3000 wolves in Indian peninsula. Later Jhala and Giles (1991) estimated about 450-620 wolves continuously distributed in the semi-arid tracts of Gujarat and Rajasthan states of western India and proposed a conservation strategy which included 1) public support and education, 2) enforcement of legal protection, 3) paying compensation for wolf killed livestock, 4) survey of wolf population and research on dynamics of select population, 5) protection of breeding habitat, and 6) eradication of feral dogs. The only scientific information available on Indian wolf (*C. l. pallipes*) is in the form of blackbuck wolf population dynamics in Velavadar National Park in the *Bhal* of Gujarat (Jhala 1991) and some information on ecology and behaviour of wolves in the Deccan grasslands of Solapur Maharashtra (Kumar 1998). Jhala and Sharma (1997) studied the incidences of child lifting by wolves in eastern Uttar Pradesh and concluded that most child-lifting events were related to some form of neglect by their parents who belonged to poor section of the society. They recommended ways to specifically target the child-lifter wolf and avoid unnecessary killing of other wolves. Kumar (2000) based on his Ph.D. research published a paper on livestock depredation by wolves in the Great Indian Bustard Sanctuary in Nanaj and suggested that compensation after preliminary investigation should be provided with least delay if the wolf is to be preserved in the Sanctuary and some other protected areas in India. Sawarkar (1986) stated that one of the most important questions to be considered for wolf conservation is the payment of adequate compensation by the government. Afik and Pinshow (1993) studied how wolves (*C. l. pallipes*) are adapted to meet the physiological challenge posed by the hot climate in the desert of Israel. Though some ecological information on the same subspecies is available from Iran (Joslin 1982) and Israel (Mendelssohn 1982, Afik and Pinshow 1993) the ecology of the Indian wolf is likely to be somewhat different due to the diversity of habitats in which the wolf is known to live (Shahi 1982).

3.2. Feeding Ecology:

Knowledge of wolf feeding ecology is critical not only in an ecological context but also in terms of economics and *conservation* (Ciucci *et al.* 1997), particularly in light of the increasing human-wolf conflict in India due to cattle depredation and child lifting by wolves. Mech (1970: 168p) explained how wolf's digestive system from one end to another is adapted to its carnivore way of life, for catching, tearing, digesting and eliminating animal matter. It seems logical that the wolf would prey mainly on large animals, because of its size, its habit of traveling in packs, and its ability to consume and digest great quantities of food in short periods (Mech 1970: 172p). Predators that feeds consistently on small animals usually are much smaller, and they hunt alone, many studies have supported this conclusion (Mech 1970: 172p).

The studies on feeding ecology of wolves are carried out by various means such as by analyzing stomach contents, scat analysis, kill investigation, and following radio collared wolves continuously to estimate kill rate and consumption rate by wolves. Reynold and Aebischer (1991) provided critiques with recommendations, based on a study of the Fox (*Vulpes vulpes*) for comparison and quantification of carnivore diet by fecal analysis. Ciucci *et al.* (1997) compared six methods of scat analysis and concluded that interpretation of scat analysis data in order to assess the diet of wolves, as well as other carnivores, would be greatly enhanced by comparing results obtained with two or more methods. Mukherjee *et al.* (1994 a, b) refined and standardized the method of scat analysis for Asiatic lion (*Panther leo persica*) and leopard (*Panthera pardus*). Johnson and Hansen (1978) estimated biomass intake by coyote from undigested residues in scats. Using scat analysis, most information regarding the diets of carnivores has been based on frequency of occurrence of prey species, biomass of ingested prey and relative frequency of prey found in proportion to prey consumed (Floyd *et al.* 1978, Corbett 1989). To address the problem of small prey being over represented as mass and underrepresented in numbers (Mech 1970), Floyd *et al.* (1978), Ackerman *et al.* (1984), and Weaver (1993) derived liner regression models to convert scat data to relative biomass and relative number of prey consumed.

Fuller and Novakowski (1955) analyzed 49 stomachs of poisoned wolves in Wood Buffalo National Park in Canada, *Makridin* (1962) analyzed 33 stomachs of wolves in Russia, Kelly (1954) also analyzed 131 stomachs from various part of Alaska and Stenlund (1955) analyzed fifty-one stomachs collected in winter from Minnesota. Studies on food habits of wolves based on scat analysis are increasing in numbers, Salvador and Abad (1987), Jhala (1991,1993a), Muszynska (1996), Patalano and Lovari (1993), Spaulding *et al.* (1997) and Jedrzejewski *et al.* (2000) studied food habits of wolves by analyzing the remains of prey species.

Paquet (1992) studied prey use strategies of sympatric wolves and coyotes in Riding Mountain National Park, Manitoba by examining kills made by both the species. Other studies by Carbyn (1983), Jhala (1991,1993a), Boyd *et al.* (1994), Mech (1977), Kumar (1998), Kunkel *et al.* (1999) and Hayes *et al.* (2000) has examined the kills made by wolves for studying kill rate of different ungulates. Holleman and Stephenson (1981) studied prey selection and consumption by Alaskan wolves by an alternate method, the fallout radiocesium method.

3.3. Radio- Telemetry:

Radio telemetry has become one of the most versatile techniques to study wildlife ecology especially when a species is *nocturnal,* illusive or shy in nature. It enables the biologist to collect information on the daily movements, activities and use of habitat and space, which are of critical importance for formulating effective conservation strategies for any species. Use of radio telemetry on wolves started in 1960s in Ontario and Minnesota since then information on wolves started accumulating (Harington and Paquet, 1982, Mech 1983).

Home range is defined as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943). Jewell (1966) discussed the concept of home range in mammals and restated the definition given by Burt (1943) that " home range is the area over which an animal normally travels in pursuit of its routine activities." Swihart *et al.* (1988) related body size of 23 species of terrestrial mammals to the rate of home range use and indicated that the existence of a size dependent time scale governing the rate of home range use. Gittleman and Harvey (1982) studied the carnivore home range size, metabolic needs and ecology and found carnivores with a large proportion of flesh in their diets have particularly large home ranges and home range size of carnivores increases with their metabolic needs.

Several methods are applied for estimation of home range estimation. Kernel Method (Worton 1989) for the nonparametric estimation of the utilization distribution from a random sample of locational observations made on an animal in its home range. Harmonic mean method (Dixon and Chapman 1980) explained a method of calculating centers and areas of animal activity. Although one of the earliest and simplest techniques for home range calculation, the Minimum Convex Polygon method Mohr (1947) is still the most frequently used (Harris *et al.* 1990) probably because this the only technique which is strictly comparable between studies. Harris *et al.* (1990) reviewed and critically evaluated 93 papers on home range analysis done using radio tracking data and discussed the problems advantages and disadvantages of the most frequently used methods of home range analysis. A book by White and Garrot (1990) "Analysis of wildlife radio-tracking data" was most useful for understanding the radio-telemetry technique, for designing sampling strategies, collection of data and analysis of home range.

3.4. Habitat Use:

Analysis of habitat selection is an important aspect of wildlife ecology for better understanding, how an animal makes use of its environment. Several methods have been applied to analyze resource selection data. Chi-square goodness of fit test is a common statistical approach for testing if observed habitat use is equal to expected use (Neu *et al.* 1974 and Bayers *et al.* 1984), Johnson (1980) described the general problems of determining selection when resources use is compared to availability and suggested a new technique where results do not depend upon the array of habitats considered. Friedman (1937) test for the randomized complete block design also has been used in recent studies of resources utilization (Johnson and Montalbano 1984). Alldrege and Ratti (1986) compared four statistical methods of habitat selection using 50,000 computer simulation of field data and concluded that studies with few observation from few animals should be avoided because of unacceptable Type-II error rates and the number of habitats considered should be limited. Aebischer *et al.* (1993) advocated compositional analysis to overcome the problem of non-independence of proportions and suggested proportional habitat use by individual animals as a basis for analysis of habitat use by radio collared animals.

3.5. Studies in the *Bhal*:

Information available on the *Bhal* ecosystem is in the form of papers published by Dharmakumarsinghji (1978). Ranjitsinh (1982) for his Ph.D. dissertation studied ecology of the blackbuck and published with updated information in the form of a book "The Indian Blackbuck". Studies by Mungall *et al.* (1981, 1983) and Ranjitsinh (1982, 1989) in Velavadar National Park identified critical areas where research is needed to guide management decisions. Satyanarayan (1985) and Prasad (1985) quantified the vegetation and *carrying* capacity of the Velavadar grasslands for their M.Sc research project. Jhala (1991) in his Ph.D. dissertation studied habitat and population dynamics of wolves and blackbuck in Velavadar National Park studied wolf- blackbuck population dynamics and provided mathematical optimization model for critical management decisions. Jhala *et al.* (1992) published research on water requirement of the blackbuck in its natural environment and its physiological response to water stress. Jhala (1993 a) provided information on predation on blackbuck by wolves in Velavadar National Park and suggested that removal of the exotic shrub *Prosopis juliflora*, minimizing human disturbance to wolves at kills and reducing predation on blackbuck by feral dogs as ways to ensure continued viability of wolf-blackbuck system. Jhala (1993b) provided the economics of crop damage by blackbuck in the *Bhal* and discussed measures to reduce prophylactic measures to ameliorate the problems and methods and criteria to decide on monetary compensation to farmers. Jhala (1996) published the optimization model for the management of an endangered predator and prey system at Velavadar National Park in the form of a research paper. Jhala (1997) studied the seasonal effects on the nutritional ecology of blackbuck. Isvaran (1995) and Isvaran and Jhala (2000) studied variation in lekking costs in blackbuck in relation to female mating patterns and tested the hypothesis that central males had a higher mating success and faced higher cost than peripheral males. Recently, Iiyadurai (2001) estimated home range, ranging patterns and abundance of jackals in the *Bhal* for her M.Sc., research project. Sahabandu (2001) estimated ranging, activity pattern and habitat use of blackbuck and nilgai in Velavadar National Park and tried to test several hypothesis related to nilgai and blackbuck activity pattern and habitat utilization patterns.

Since the wolf is shy and nocturnal in nature, information collection with the help of radio telemetry technique on their home *range*, habitat use and feeding ecology based on continuous monitoring would provide more precise information on these less known facts of wolf ecology in India. Information on wolf ecology in the *Bhal* is based on only one pack from Velavadar National Park (Jhala 1991). However, there was no information available on the wolf packs found outside Velavadar National Park which differ in their ecological set up in terms of status (non-protected area), prey availability and human disturbance etc. Hence the present study was taken up to add knowledge on the wolf and provide comparative account of feeding and habitat needs of wolf packs in the *Bhal* of Gujarat.

Chapter-4 METHODS

4.1. Feeding Ecology

Food habits of five wolf packs from the *Bhal* were studied by analyzing scats and by continues monitoring of radio collared wolves of three packs. And data on feeding events by wolves such as predation rate, consumption and scavenging on different prey species etc were recorded.

4.1.1. Scat Analysis:

Scat analysis is indirect, non-invasive and unbiased techniques for recording frequency of occurrence of prey in the diet *hence* it is most widely used (Johnson *et al.* 1983, Spaulding *et al.* 1997, Leopold and Krausman 1986, Mukherjee *et al.* 1994 a, b). In this study wolf scats from five wolf packs in the *Bhal* namely; 1) Velavadar National Park Pack, 2) Vegad pack, 3) Mithapur pack, 4) Narmad pack and 5) Adhelai pack were collected for analysis between 1996-2000.

4.1.1.a. Identification of Wolf Scats:

Carnivore scats are often identified by *size*, shape, odour, colour and signs associated with scats such as scrapes and footprints (Quinn and Jackman 1994). Wolf scats in the *Bhal* could likely be confused with dog and jackal scats. Wolves often use scats for marking territory, lying up sites, rendezvous sites and denning areas (Mech 1970). Relatively fresh wolf scats have a peculiar odour (Jhala 1991). Monitoring of three radio collared wolf packs provided information on the frequently used areas by wolves in the *Bhal*. We identified wolf scat by combinations of characteristics like associated signs, odour and location. Scats of ambiguous identity were discarded.

4.1.1.b. Collection and Preservation of Scats:

Total of 1,247 wolf scats from five wolf packs was collected between 1996-2000. The scats were collected in paper bags or polythene bags, labeled and sun-dried in the field. Information on date and location were recorded. Scats were oven dried at 60° in the laboratory and stored for a month to two years before further analysis.

4.1.1.c. Identification of Prey Remains From Scats:

Standard procedures for scat analysis reported by Reynolds and Aebicher (1991), Korschgen (1980), John *et al* (1996), Johnson *et al.* (1983), Spaulding *et al.* (1997), Leopold and Krausman (1986), Mukherjee *et al.* (1994a,b) was followed. Following steps explain the procedure in brief.

1) Scats were crushed and carefully observed for the presence of indigestible macro components such as bones, claws, feathers, beaks, scales, hooves etc.

2) After identification of macro components the hair remains were washed in warm water over a sieve to remove soil and calcium part present in the scat.

3) The washed scats were dried for further preparation of slides for microscopic observation of hair to identify prey species.

4) Hair were thoroughly mixed and randomly picked for slide preparation.

5) Reference slides for cuticular pattern; cross section and medulla were prepared for all potential wolf prey species occurring in the study area.

6) The combination of hair characteristics such as medullary and cuticular pattern, were primarily used for the identification of most of the mammalian species from the wolf scats. However, medulla to hair width ratio and the cross section of hair were also occasionally used to identify species represented in scats.

Microscope slides of whole mount of hair randomly picked from scats were prepared in DPX medium for examining medullary characteristics. Cuticular imprints of hair were made on a gelatin layer prepared on microscope slides and observed under 100X and 450X magnifications.

4.1.1.d. Sample Size Estimation for Minimum Number of Hair/Scat:

A total of 50-60 hair from a scat were randomly picked and the proportion of prey species detected by scanning a hair was calculated for each additional hair. Then the cumulative proportions of prey species detected from a scat were calculated for all the hair analyzed. This procedure was repeated for a total of 32 scats randomly picked for the analysis. The cumulative proportions of total prey items in a scat were plotted against number of hair scanned. Ninety five percent lower bounds for all the cumulative proportions were computed. We followed the result of this analysis for number of hair that need to be scanned per scat for further analysis of all the scats from all the packs from the *Bhal*.

4.1.1.e. Sample Size Estimation for the Minimum Number of Scats/Pack:

To determine the minimum number of scats that need to be analyzed for an accurate estimate of food habits of wolves, the cumulative percent frequencies of occurrences of different prey species were calculated for each increment of five scats and were plotted against number of scats. The number of scats sampled was considered sufficient when the plots of major prey items (>4% occurrence in the wolf's diet) prey items leveled off.

4.1.1.f. Data Analysis:

A year was divided into three seasons; summer (March-June) Monsoon (July-October) and winter (November-February). Number of scats in each season from each pack varied between 30 to 200. The frequency of occurrence of a prey item was calculated as number of times a specific prey item was found to occur in wolf scats expressed as a percentage of all prey occurrences (Ackerman *et al.* 1984; Floyd *et al.* 1978). Food habits of wolves of entire *Bhal* were determined by pooling all the scats from all five packs for analysis. Only prey species that comprised > 4% occurrences in scats were used for comparisons between packs and seasons. The data on percentage of occurrences of prey items were tested for normality using Kolmogorov-Smirnov test (Sokal and Rolf 1981). When data were found not to conform with normality they were transformed by using Arcsine transformation (Sokal and Rolf 1981) prior to further statistical analysis. The food habit of Velavadar National Park wolf pack was compared with the packs inhabiting areas outside the protected area using Two-Way-Analysis of Variance with main effects being pack location and prey species in scats. Data were also compared to see the seasonal difference in the food habits of the wolf packs of the *Bhal* using Two Way Analysis of Variance (between factors seasons and species found in scats) for this analysis data were pooled pack wise seasonally for all years i.e. 1996-2000.

4.1.2. Feeding Interval and Predation:

4. 1.2.a. Trapping and Radio Collaring:

We surveyed the entire study area using the baseline information from earlier studies (Jhala 1991) for the presence of different wolf packs. Wolves from three different wolf packs were live-trapped using 'McBride' soft catch, rubber padded leg hold traps (Gese and Mech 1991; Linhart and Dasch 1992; Kuehn *et al.* 1986). The wolves were then chemically immobilized using Telazol or Ketamine, Xylazine mixture and radio-tagged with 'Telonics' radio collars of different individual frequencies (Table-1).

4. 1.2.b. Continuous Monitoring and Quantification of Predation:

Each wolf pack (VNP pack, Vegad pack and Narmad pack) was monitored continuously for a minimum of 132 hrs and a maximum of 360 hrs per pack once in winter and summer between 1999-2000 (Table-2).

The radio collared wolves were continuously monitored using either a two-element H antenna or three elements 'Yagi antenna' and Telonics TR-2 radio receivers. Wolves were kept in constant radio contact ranging from distance between 200 meters to 1 kilometer. Care was taken not to disturb the animals during their normal movement and resting period. The routes taken by wolves and the places where wolves had spent sufficient time during their peak activity period were checked for the presence of kills or carcass. Whenever feeding events were recorded, data were collected on species, sex, age class, weight of the kill remains, location of the kill, time, date, proportion and parts of kill eaten. The loss of carcass mass to other scavengers such as dogs and jackals was estimated by observing scavengers feeding and/or by interpreting signs left at the feeding site. This estimate was deducted from the estimated carcass weight. Feeding interval, kill interval, and consumption/wolf/day were calculated from this data.

Table 1. Radio-locations between 1996-2000 from the following wolves were used for home range and habitat use analysis.

PACK	SEX	AGE	SOCIAL ORDER
Vegad	Male	Adult	Loner
Vegad	Male	Adult	Alpha
Vegad	Female	Adult	Alpha
VNP	Female	Adult	Alpha
VNP	Female	Adult	Alpha
Narmad	Female	Adult	Alpha

Table 2. Continuous monitoring sessions of wolf packs in the *Bhal* between 1999-2000 (in hrs).

Pack	1	2	3	4	Total
Velavadar	148	342			**490**
Narmad	175	182.2	331	199	**888**
Vegad	159.8	132.7	157	167	**616**
Total. hours.					**1994**

4. 2. Prey Availability:

We estimated the availability of major prey species, i.e. Blackbuck (*Antelope cervicapra*) and domestic cattle (*Bos taurus*) that constitutes more than 70% of the total diet of wolves in the *Bhal* in different wolf territories between 1998-2000.

4.2.1. Estimation of Blackbuck Population:

The estimation of blackbuck population in the *Bhal* was done in December 1998. We divided the study area in total 7 different zones based on ecological boundaries such as tidal water creeks, mudflats or physical barriers such as roads, which temporarily separates the blackbuck populations in below mentioned zones. Total counts were done, since the area is quite "open" with good visibility. The total counts were done three times in each block for the blackbuck and nilgai populations. Position coordinates were taken for each blackbuck herd sighting using a Global Position System. The position coordinates of blackbuck herds were superimposed on the wolf territories maps prepared in GIS domain for the calculation of blackbuck population availability in different wolf territories.

1. VNP block
2. Adhelai block
3. Mithapur Alang block
4. Narmad Kumbharwada block
5. Gokulpara Vegad-North block
6. Vegad-South Savaikot Savainagar block
7. Paliad Devalia Nari Undavi block

4.2.2. Cattle Population Estimation:

Estimation of the vulnerable cattle such as weak cattle and calves that can potentially be killed by wolves was done between 1999-2000 in three different seasons in the study area. The cattle herds from different villages wandering in and around the wolf territories were sampled for vulnerable cattle. Except for summer, cattle herds are mostly taken to graze during the daytime and very rarely left unattended. The total cattle numbers were also counted by visiting the villages and the proportion of vulnerable cattle were extrapolated using the total cattle population. Since the cattle herds return to the village after a grazing bout for milking purpose etc., the distance they move away from the village is limited. Three kilometers buffer area was created (based on the average distance of the grazing circuits of cattle around the village) around the villages, which were located in and around the wolf pack home range in the study area. Density of cattle was calculated for each buffer based on the cattle population in the villages. The buffer areas were then superimposed on the wolf territories maps prepared in GIS domain and the areas of buffer falling within the home range of wolves were used for estimation of cattle abundance in that particular home range.

4.3. Home range and Habitat Analysis:

4.3.1. Home range:

We calculated the home ranges of different wolf packs in order to test the hypothesis of relative importance of prey availability on territory size. Radio collared wolves (Table-1) from the *Bhal* were monitored. Minimum of two to three radiolocations per week was taken during different hours of the day and night (randomly selected). The location of the animal was determined by following the 'homing-in' method (White and Garrott, 1990) i.e. by following the transmitted signals increasing strength until the instrumented animal is actually observed or the presence was confirmed by circling the animal at considerably close radius (100-500 m.) without disturbing the animal. The position coordinates of radio collared animals were taken after the animal moved from the located place by using Global Positioning System (GPS). The Home ranges of different wolves of different social hierarchy were calculated using computer program CALHOME (Kie *et. al.* 1994). The 95% and 100% Minimum Convex Polygon (MCP) method was used for calculating home ranges. Core areas of individual wolves and pack were estimated by using method suggested by Harris *et al.* 1990. Areas of harmonic mean home range of different wolf/pack were estimated at different isopleths values and were plotted against the home range size.

4.3.2. Habitat Analysis:

For habitat analysis, remotely sensed standard LISS-III 1:50,000 IRS-1C, FCC imageries of winter 1995 were used. Different habitat classes i.e. vegetation, habitation, cultivation, saline patches, grassland, shrubland etc. were classified by visual interpretation of satellite imageries and ground truth using GPS location of various habitat types. The polygons of different habitat classes were digitized in GIS/ARC INFO domain and the maps for the landuse patterns were generated (Plate-1) .The analysis for habitat use and availability was carried out using compositional analysis (Aebischer *et al.* 1993) and regression analysis.

4.3.2.1. Compositional Analysis:

Compositional analysis (Aebischer *et al.* 1993) was carried out for habitat preference analysis at different scale of availability and use 1) 100% MCP versus Radiolocation, 2) 100% MCP versus core area and 3) intensive study area Vs Radio location points. A 100% MCP was created by pooling all the radiolocations of all radio collared wolves for delimiting the intensive study area. Habitats falling in this polygon were considered as available habitats to the wolves and the habitats in which wolves were located were considered as used habitats.

4.3.2.2. Regression Analysis:

Habitat use/availability analysis was done using regression analysis (LaGory *et al.* 1985) with a techniques to incorporate a 95% confidence interval. Proportion of all the habitat types present in the home range (100% MCP) were considered as available habitats to the wolf/pack. If wolves had no preference of habitats then they are expected to use habitats randomly within their home range. Random points equivalent to number of radio-locations were generated within 100% MCP home range to simulate random habitat use by radio collared wolf. Proportions of different habitat types randomly used by wolves within its home range were calculated using GIS domain and regressed with the proportions of habitats in 100% MCP. Since random points should sample habitat types in proportion to their availability the regression was expected to have a 45 ^{0} slope. A 95% Confidence Interval was generated on the regressed line. The variability responsible for the 95% CI was essentially a function of the number of random points and these points were considered to capture the error variability of radiolocations in case they were non-selective of habitat type.

Proportions of habitat types used by radio collared wolf were calculated by frequency of their radiolocations falling in different habitats. These actual habitat use recorded by radiolocations were plotted on the above mentioned regression. The habitat types falling within 95% CI were considered as habitats used in proportion to availability and habitat types falling above 95% CI were considered as preferred where as those falling below were considered as avoided habitats.

Chapter-5 RESULTS

5.1. Feeding Ecology

5.1.1. Scat Analysis

5.1.1.a. Sample Size Estimation for Minimum Number of Hair/Scat

The number of mammalian hair needed to be scanned per scat to detect all the mammalian prey species in a particular scat with 95% certainty of detecting all mammalian prey were between 19-20 (Fig.1). Maximum scats were found with only one prey species (80.5%) where as very few scats were found containing four species (Fig.2).

5.1.1.b. Sample Size Estimation for Minimum Number of Scats/Pack

Cumulative percent occurrences of major prey species stabilize at around 125 scats (Fig.3) for Velavadar National Park pack, 165 scats for Vegad pack (Fig.4), 75 scats for Narmad pack (Fig.5), 40 scats for Mithapur pack (Fig.6). Due to a low sample size of only 52 scats for the Adhelai Pack I was not certain if an asymptote for percentage occurrence of different prey species was achieved. However, the cumulative percent occurrence of major prey seem to stabilize at around 45 scats (Fig.7). For a random sample of scats from all the five packs of the *Bhal* the cumulative percentage occurrence stabilizes at around 180 scats (Fig.8). The diet of Vegad pack was most diverse (Shannon-Wiener index- H' = 2.59) while that of Narmad pack was least diverse (H' =0.25) (Fig.9).

Fig.1. Number of hair scanned for each scat versus cumulative percentage of prey items detected in wolf scats of the *Bhal* region studied between 1996-2000. Error bars represent 95 % lower bounds (n=32 scats).

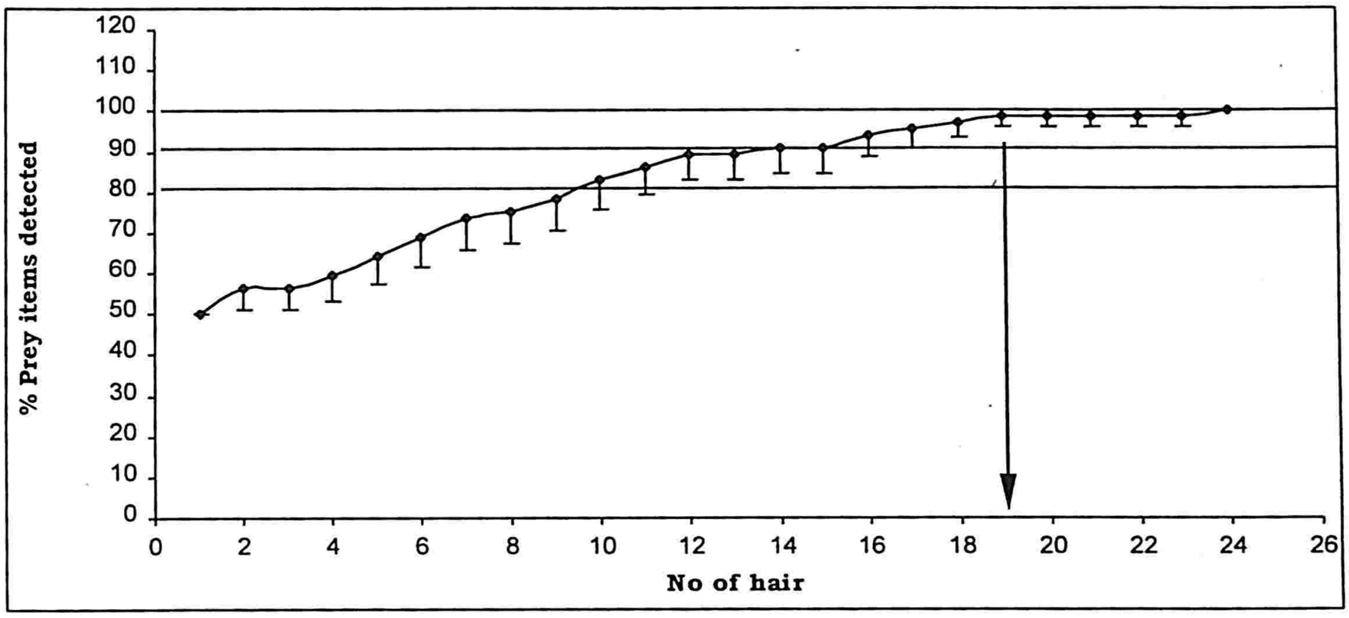


Fig.2. Number of prey items detected in wolf scats (n=1246) between 1996-2000 in the *Bhal* region.

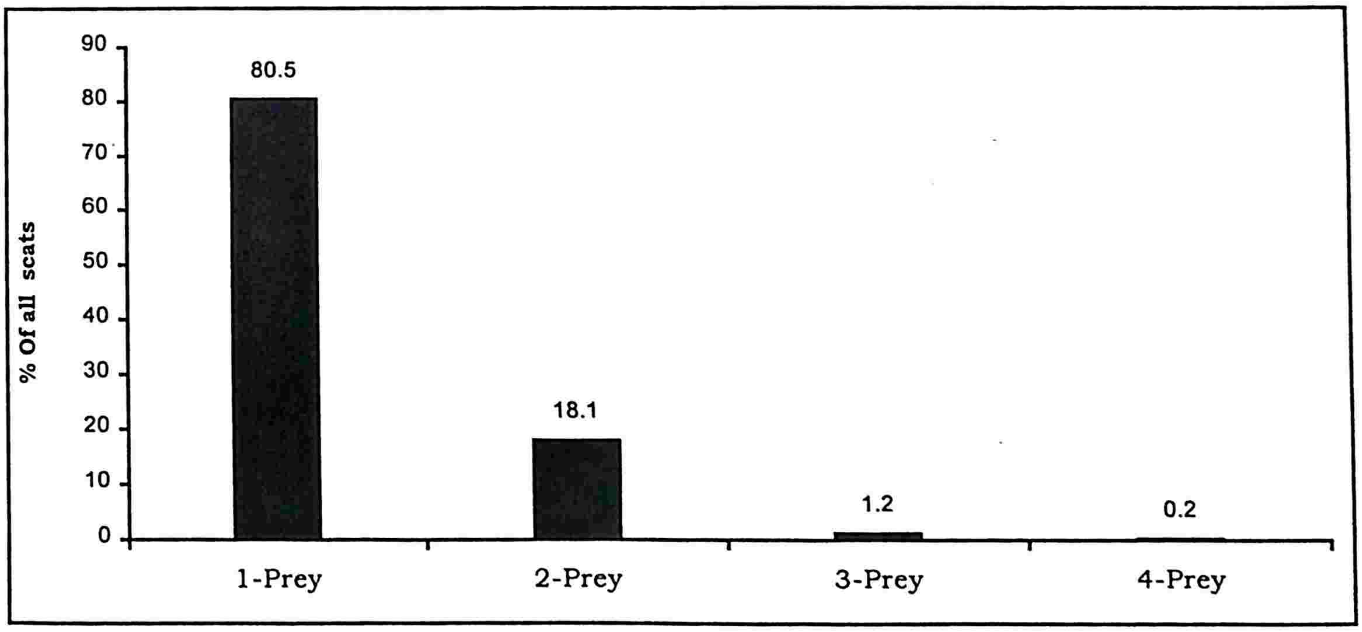


Fig.3. Estimation of minimum number of scats that need to be analyzed for studying annual food habits of Velavadar National Park (VNP) wolf pack of the *Bhal* (n= 365 scats).

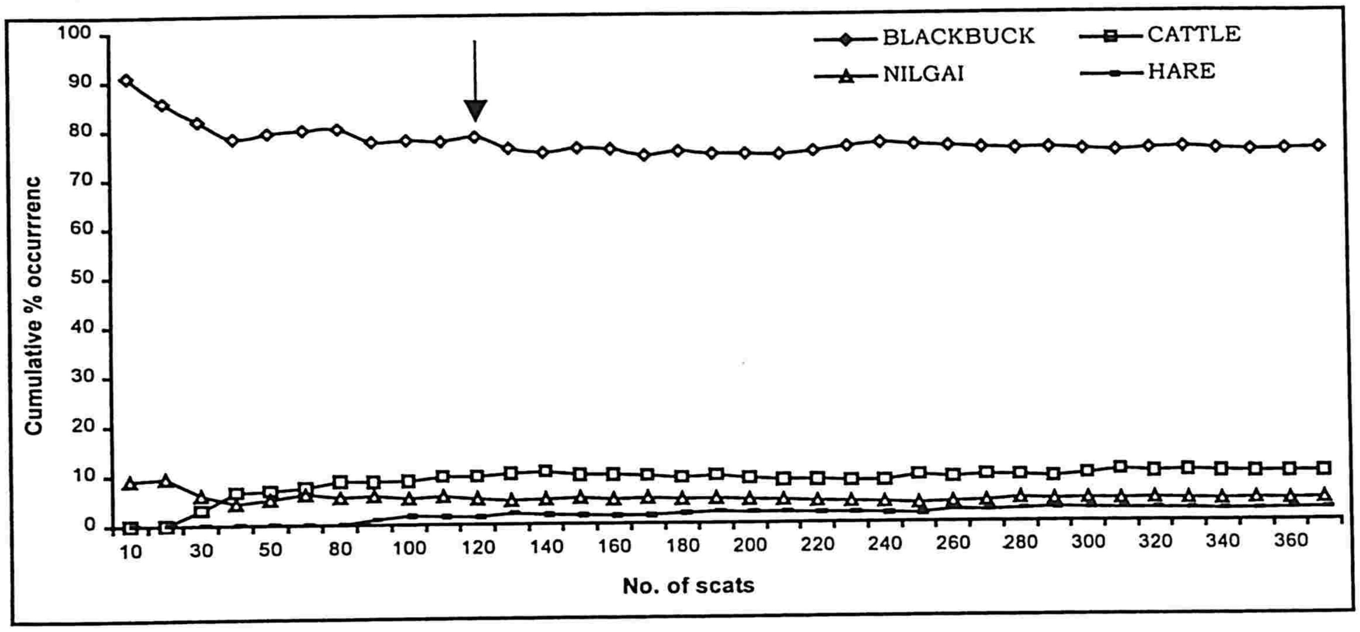


Fig.4. Estimation of minimum no of scats that need to be analyzed to study annual food habits of Vegad wolf pack of the *Bhal* region between 1996-2000 (n=464 scats).

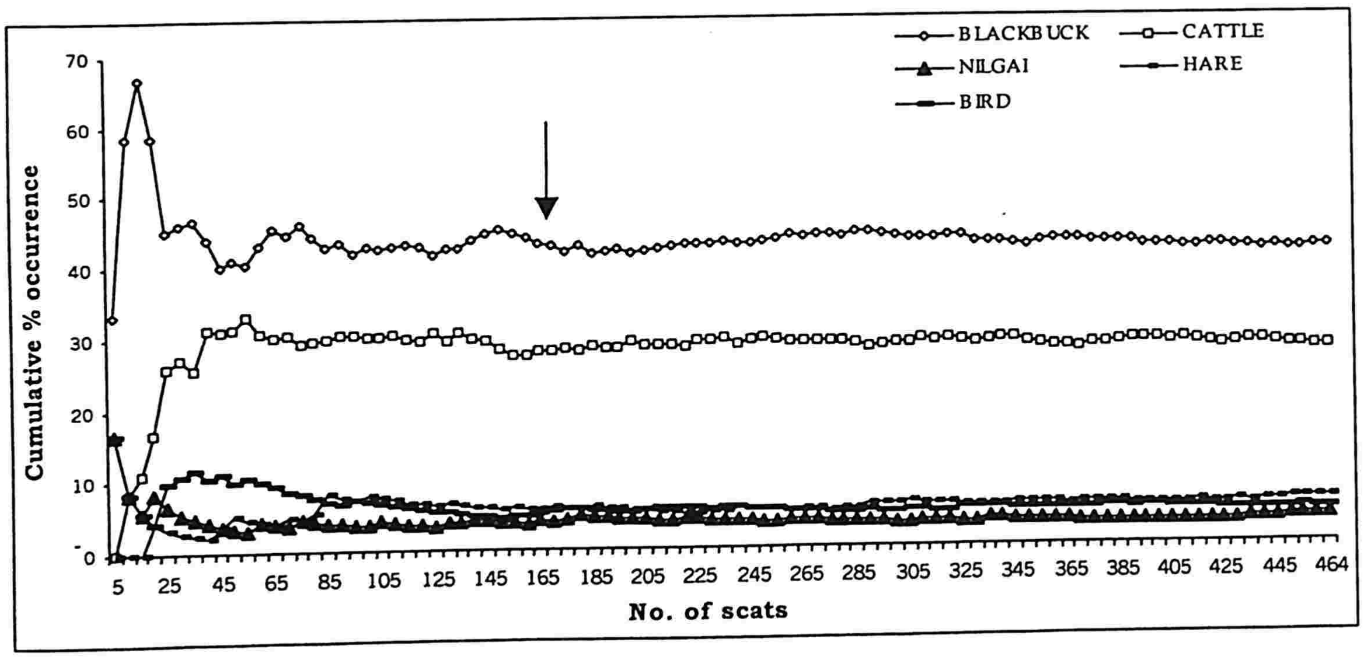


Fig.5. Estimation of minimum no of scats that need to be analyzed to study annual food habits of Narmad wolf pack of the *Bhal* region between 1996-2000(n=254 scats).

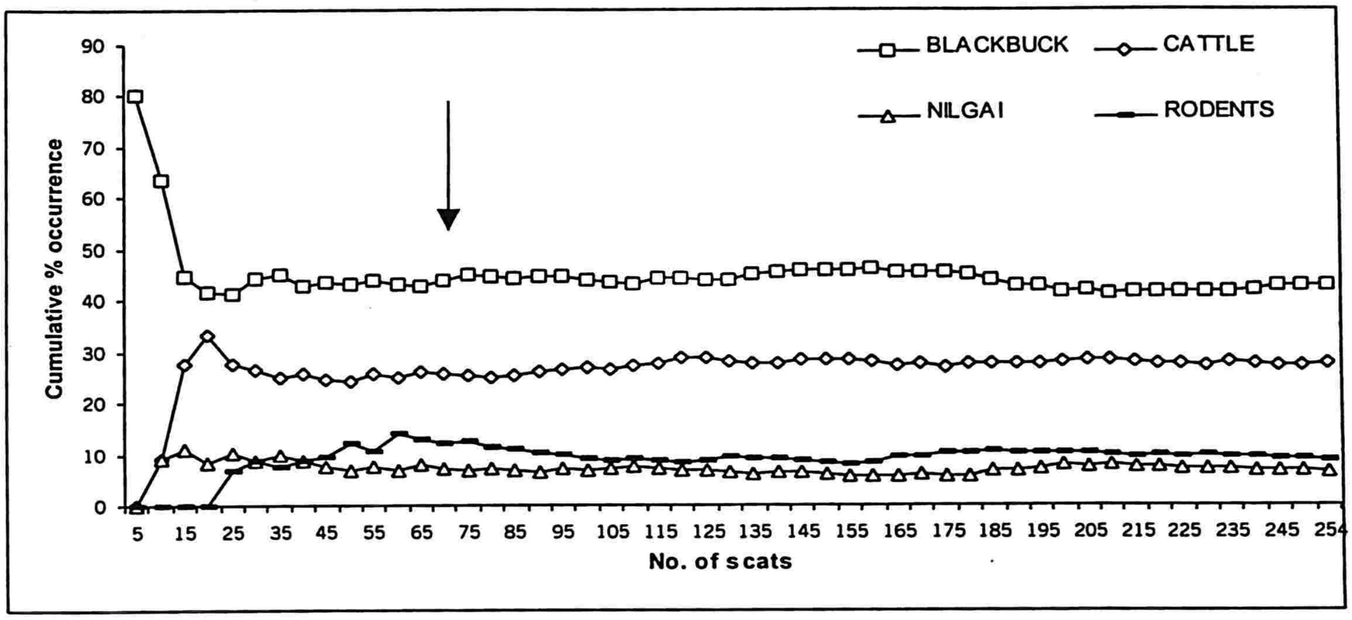


Fig.6. Estimation of minimum no of scats that need to be analyzed to study annual food habit of Mithapur wolf pack of the *Bhal* region between 1999-2000 (n=109 scats).

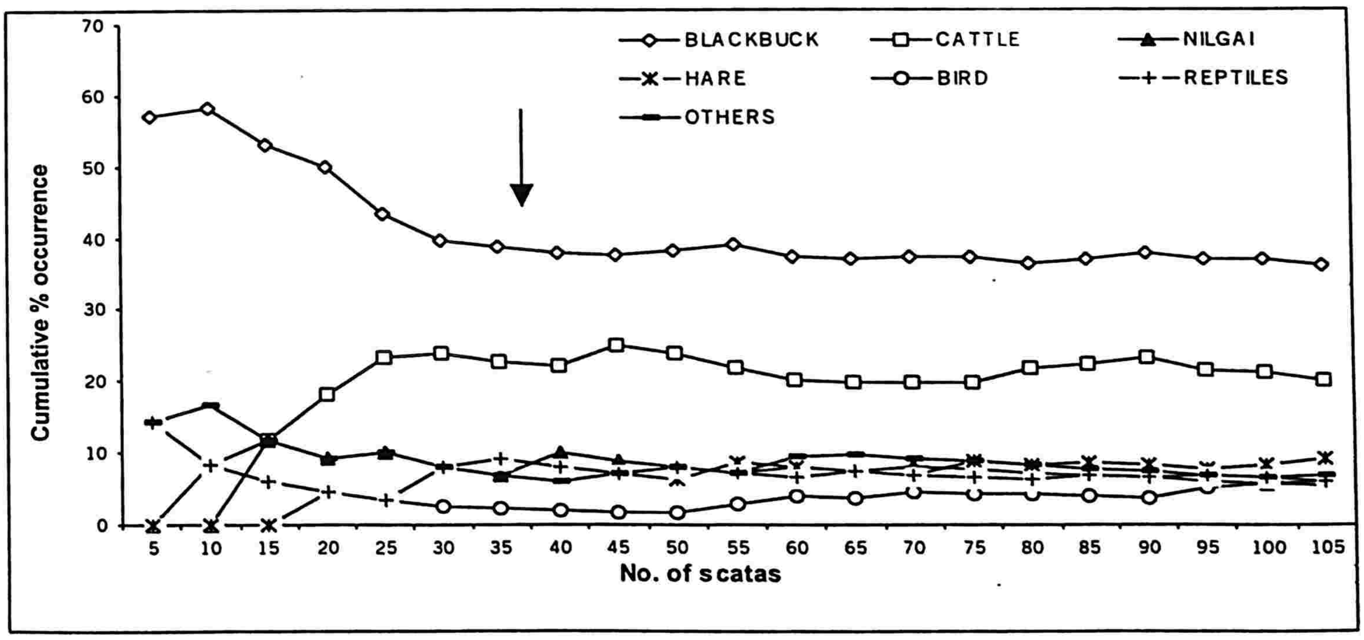


Fig.7. Estimation of minimum number of scats that need to analyze for studying food habits of Adhelai wolf pack of the *Bhal* region between 1999-2000 (n=51).

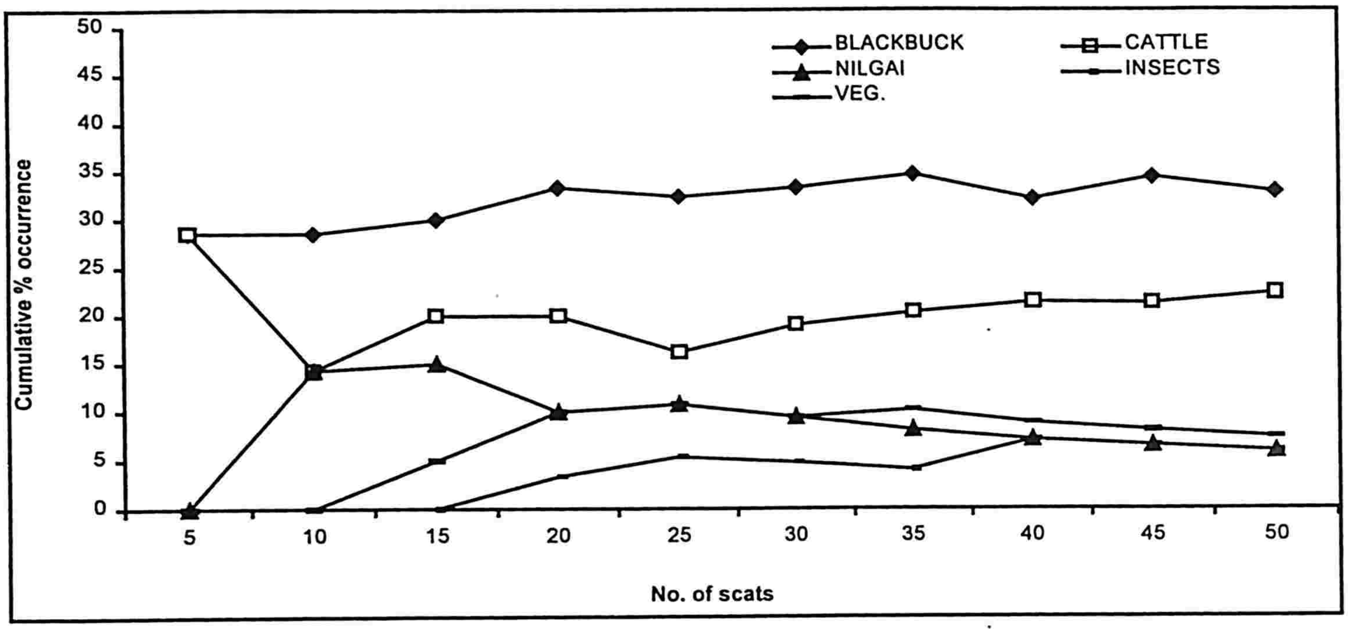


Fig.8. Estimation of number of scats that need to be analyzed for studying the annual food habits of wolves of the *Bhal* region between 1996-2000 (n=1240 scats).

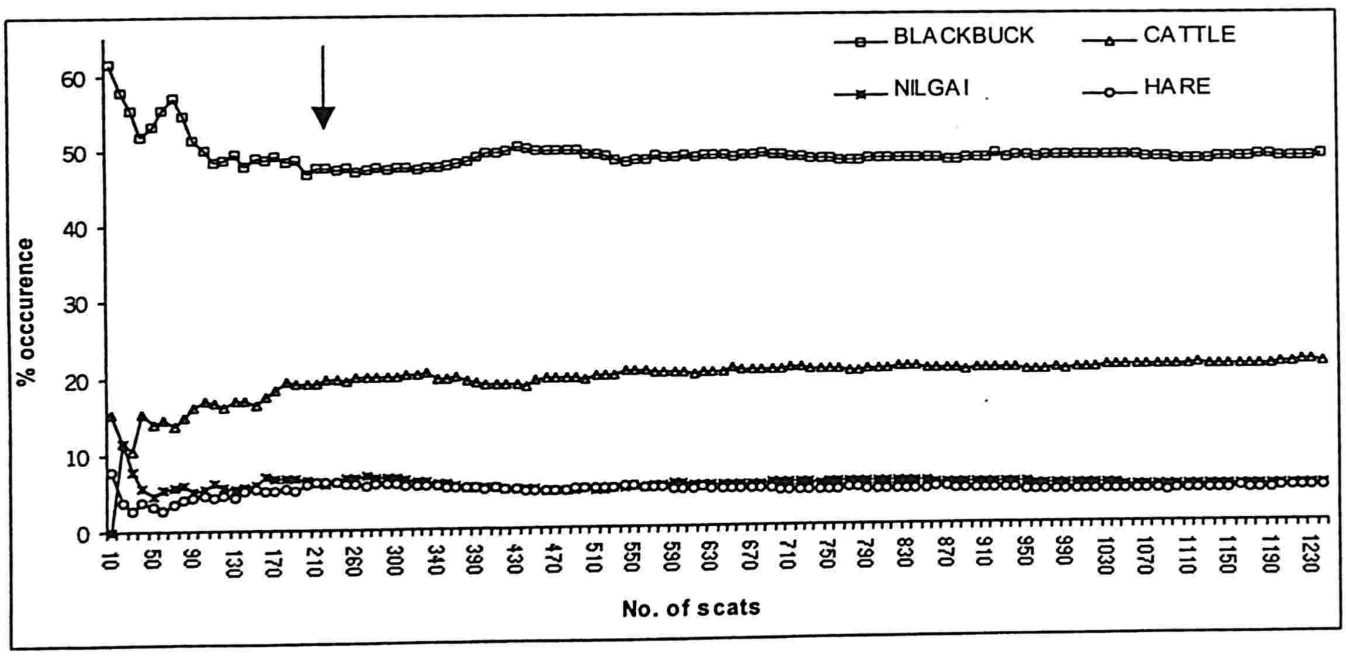
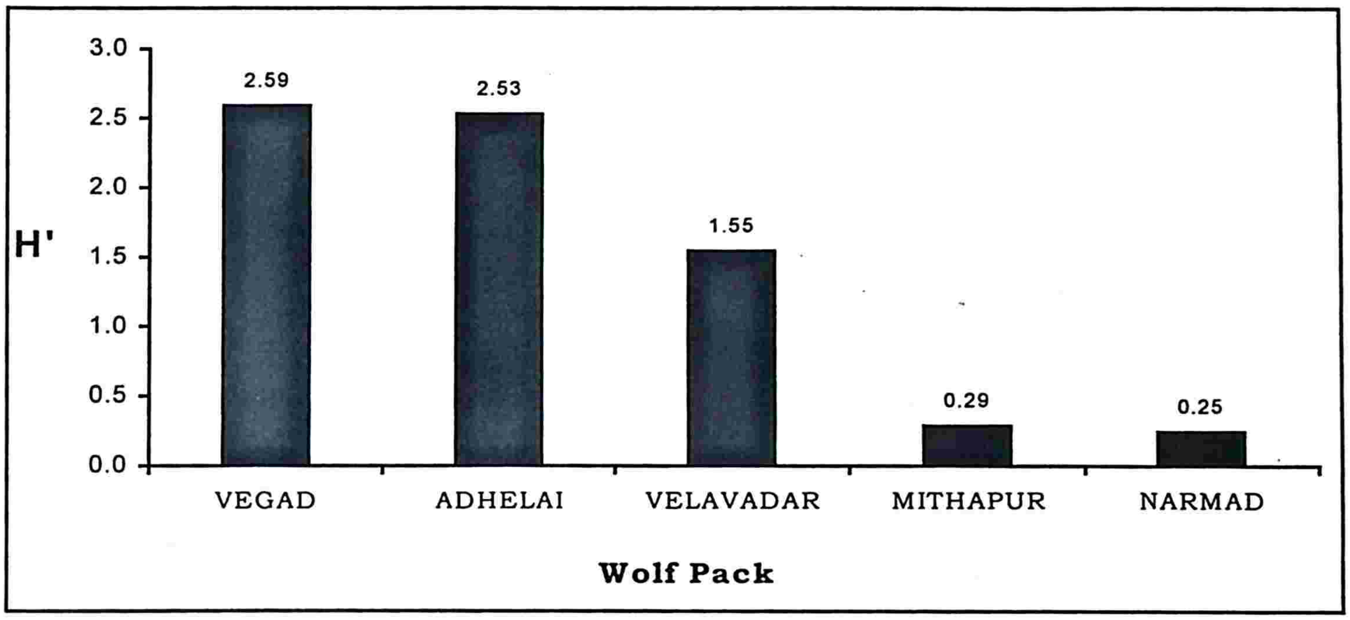


Fig.9. Diet diversity as estimated by Shannon-Wiener index- H' of 5 wolf packs in the *Bhal* region between 1996-2000.



5.1.1.c. Annual Food Habits:

Percent occurrence of different prey items in the wolf scats of VNP pack suggest that blackbuck (*Antelope cervicapra*) constitute a major portion of their diet (87%) followed by domestic cattle (*Bos taurus*) (11.5%) and nilgai (*Boselaphus tragocameleus*) 5% where as other species occurred in low proportion (< 5%) e.g. rodents, hare (*Lepus nigricollis*), water buffalo, birds, wild pigs (*Sus scrofa*), insects such as locusts, vegetable matter, and others. The others category includes jungle cat (*Felis chaus*), dogs and unidentified (Fig.10)

A total of 464 wolf scats that were analyzed from Vegad pack show that blackbuck constitute a major portion of their diet (50%), followed by cattle (33.5%), nilgai (4.5%), rodents (5.0%), hare (7.0%), and birds (6.0%). Where as buffalo, wild pig, insects, reptiles, goat, sheep and others occurred in low percentages i.e. < 5%. Other category includes mongoose (*Herpestes edwardsi*), fox (*Vulpes bengalensis)*, jungle cat, dog and unidentified species (Fig.11)

Blackbuck (51.5%) and cattle (33.5%) make the major portion of the diet of wolves of Narmad pack, where as Nilgai (8%) and rodents (11%) contributed moderately. Hare, birds, buffalo, wild pigs, insects, reptiles, goat, sheep, vegetable matters and others occurred in low percentages (<5%). Other category includes jungle cat and garbage (containing plastic bag) (Fig.12).

Blackbuck also constitutes a major portion (45%) of the diet of the Mithapur wolf pack (Fig.13). Cattle (23.0%), nilgai (6.0%), rodent (9.0%) hare (11.0%), birds (6.0%), and reptiles (7.0%) were other important components of the diet. Where as buffalo, wild pig, insects, goat, sheep, vegetable matter, others occurred in low proportions (< 5%).

The food habit of wolves of the Adhelai wolf pack studied from 51 scats (Fig.14) shows that blackbuck make a major portion of their diet occurring 45.0% followed by cattle 29.0%, nilgai 8.0%, rodent (8.0%), hare (12.0%), reptiles (6.0%) and vegetation occurred in (10.0%). Whereas birds, buffalo, and insects, occurred in low percentages (<5%).

Considering the overall diet of wolves of the *Bhal*, blackbuck constitutes the major portion (55.5%) followed by cattle (26.0%) nilgai (6.0%), rodents (8.0%) and hare (7.0%). Whereas birds, buffalo, wild pig, insects, reptiles, goat, sheep, vegetable matters occurred in, and others occurred in low percentages (< 5%). Others category includes jungle cat, dog, mongoose, fox, unidentified species and garbage (Fig.15).

Fig.10. Food habits of the Velavadar National Park wolf pack between 1996-2000 in the *Bhal* region. Error bars shows 95 % bootstrap confidence intervals (n= 368).

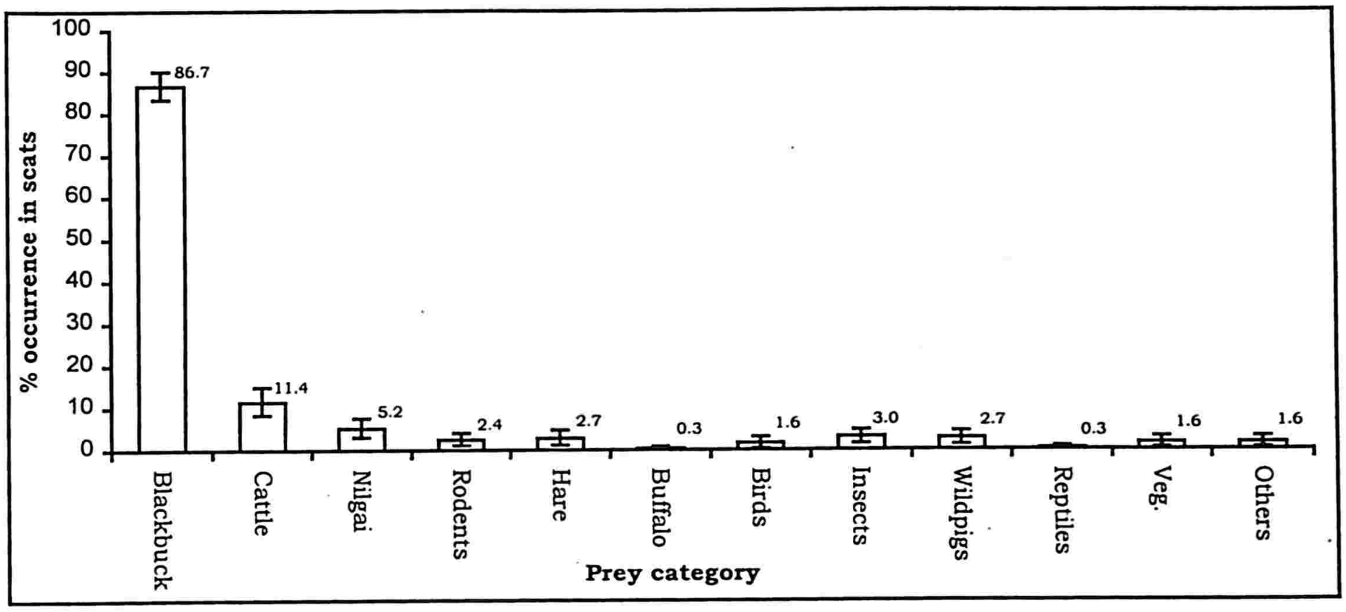


Fig.11. Food habits of the Vegad wolf pack between 1996-2000 in the *Bhal* region. Error bars shows 95% bootstrap confidence intervals (n=464).

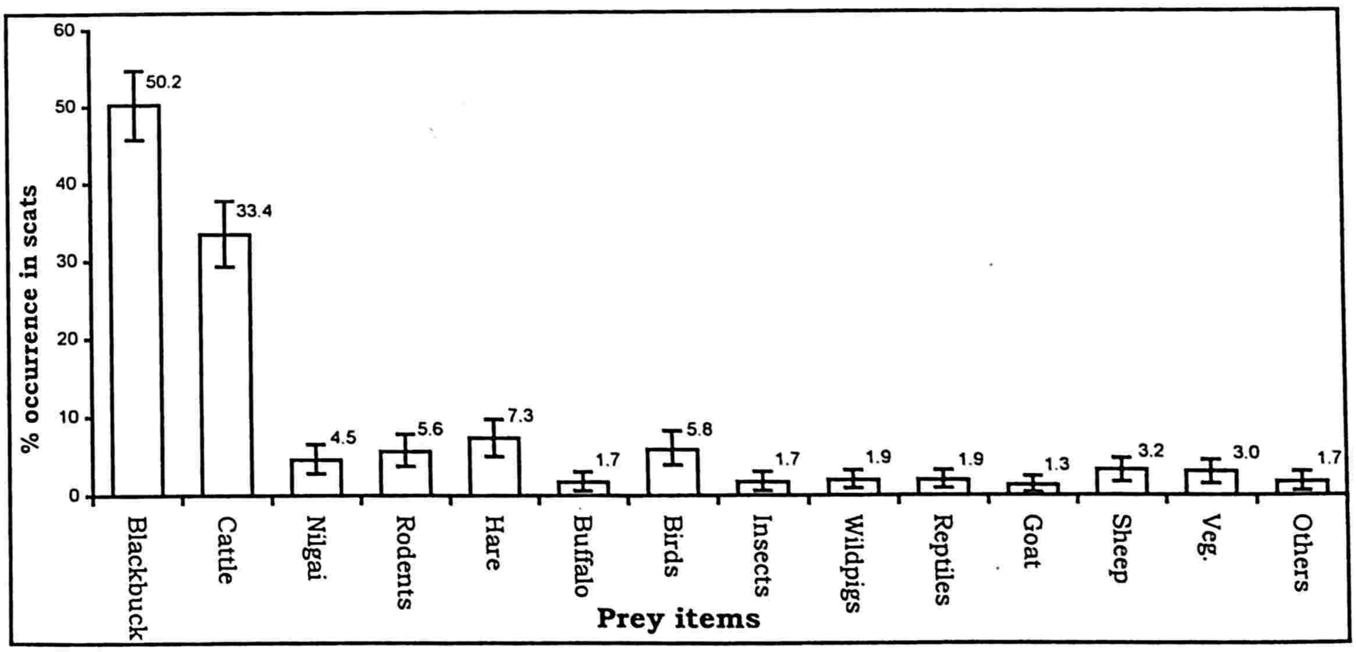


Fig.12. Annual food habits of Narmad wolf pack in the *Bhal* region between 1996-2000. Error bars shows 95 % bootstrap confidence intervals (n= 254).

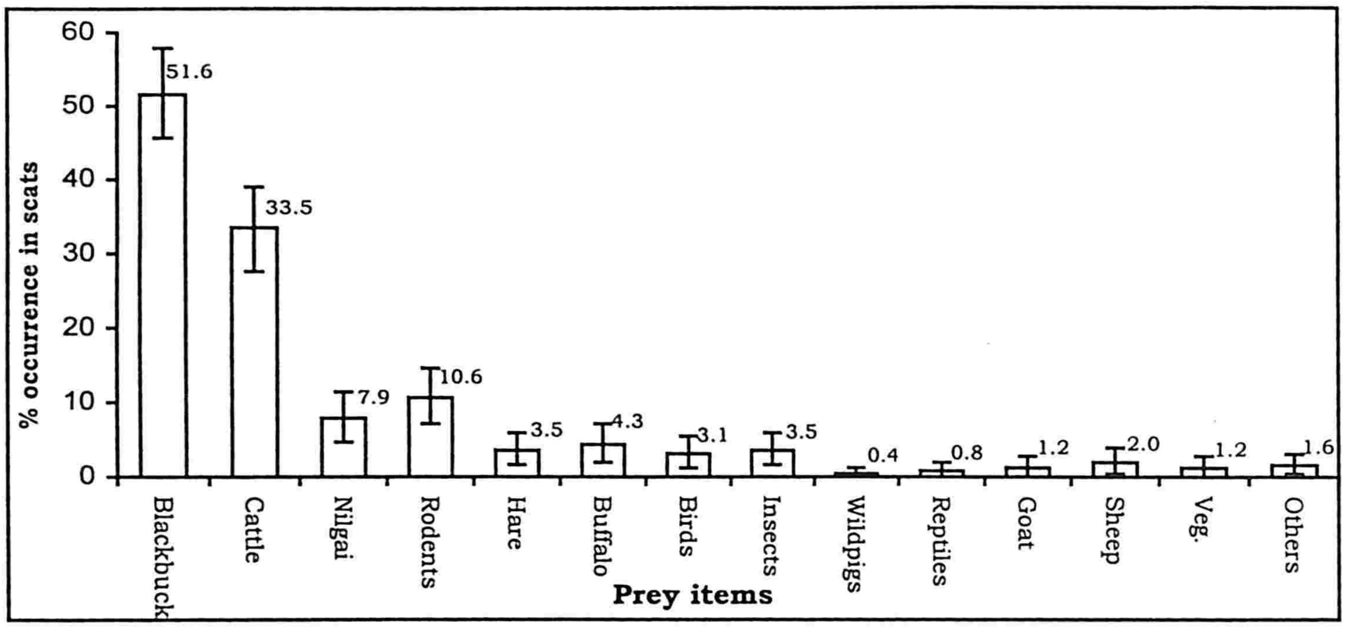


Fig.13. Food habits of wolves of Mithapur wolf pack in the *Bhal* region between 1999-2000. Error bars shows 95 % bootstrap confidence intervals (n= 109 scats).

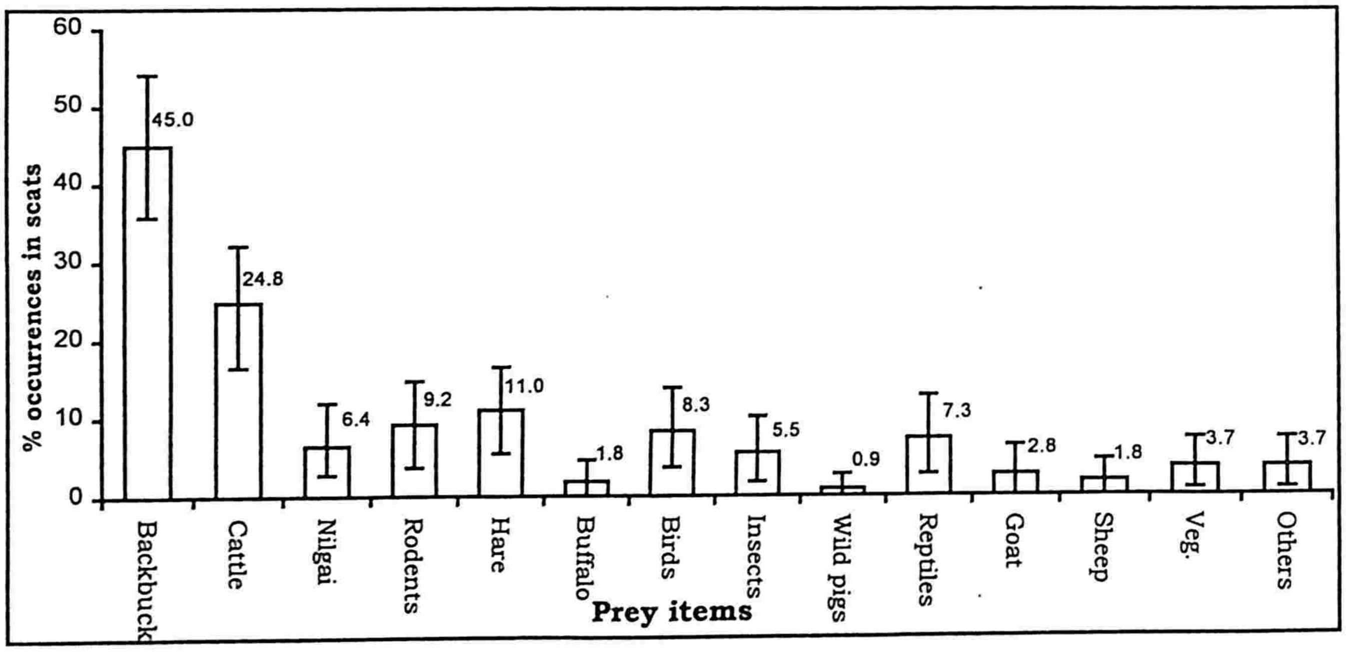


Fig.14. Food habit of wolves of Adhelai wolf pack in the *Bhal* region in 1999-2000. Error bars shows 95% bootstrap confidence intervals (n=51 scats).

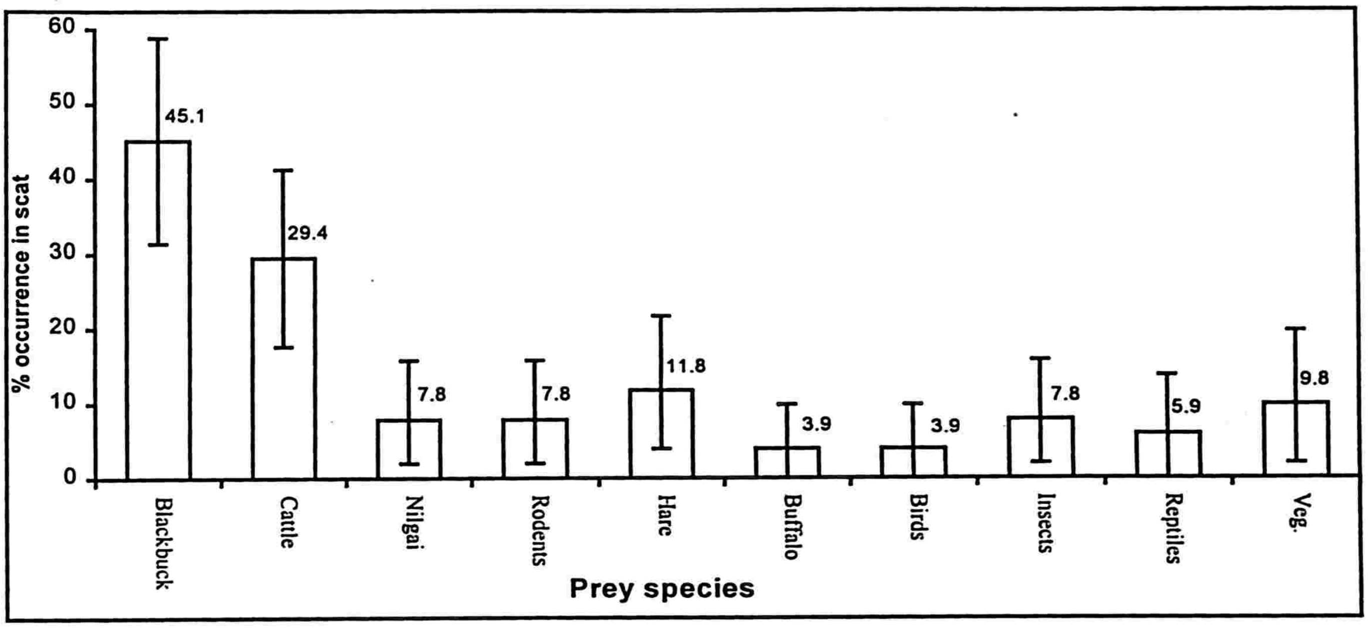
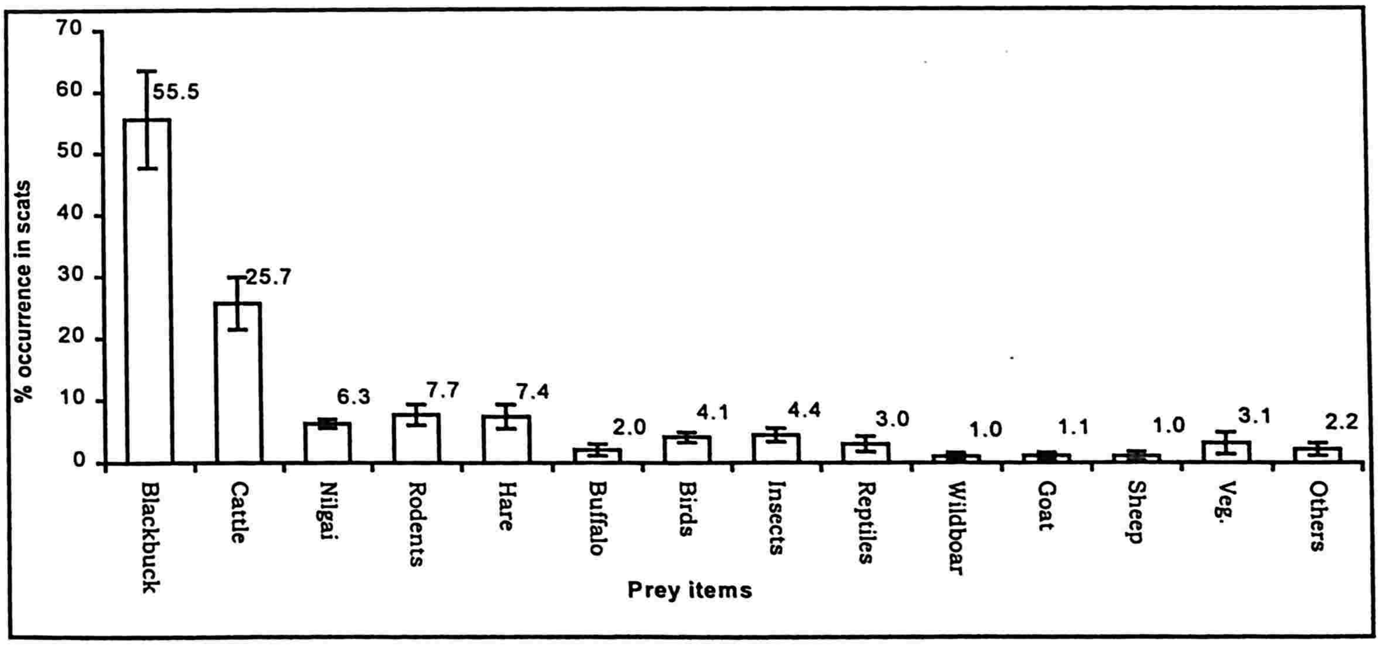


Fig.15. Food habits of wolves of the *Bhal* region (1996-2000). Error bars shows 95 % bootstrap confidence intervals (n=1246 scats from five packs).



5.1.1.d. Seasonal Food Habits:

Seasonal food habits of wolves of Velavadar National Park were studied in three different season using 195 winter (November-February) scats, 61summer (March-June) scats and 112 monsoon (July-October) scats (Fig.16). In all three seasons blackbuck occurred in large percentages. However, 95% bootstrap confidence interval generated on the percentage occurrences on different food items suggests that percentage occurrence of blackbuck in summer (72.0%) was significantly lower than in winter (88.0%) and monsoon (92.0%). Occurrence of cattle in monsoon was significantly higher (26.0%) in compared to winter (4.0%) and summer (10.0%). Where as percentages of occurrences of other species did not differ significantly within species across seasons.

The 95% bootstrap confidence interval generated on the percentage occurrences on different prey items occurring in scats suggests that there is no seasonal difference in the percentage occurrences within the species across three seasons (winter-167 scats, summer-190 scats and monsoon-107 scats) in the diet of Vegad wolf pack (Fig.17).

There were no seasonal differences in percentage occurrence of different prey items in the diet of wolves of Narmad pack (studied using 116 winter scats, 58 summer scats and 80 monsoon scats) as suggested by 95% bootstrap confidence intervals generated on the percentage occurrences on different prey items occurring in scats. However, buffalo did not occur in summer, wild pigs did not occur in summer and in monsoon, sheep did not occur in winter and insects in summer (Fig.18)

Seasonal food habits of wolves of Mithapur wolf Pack were studied using 45 winter scats, 34 summer scats and 30 monsoon scats (Fig.19). The bootstrap 95% confidence interval generated on the percentage occurrences on different species occurring in scats suggests that there is no seasonal difference in the percentage occurrences within the major prey species across three seasons in Mithapur wolf pack. However, buffalo did not occur in summer, wild pigs did not occur in winter and summer, goat did not occur in winter and sheep did not occur in winter and summer.

Fig.16. Comparison of seasonal food habits of Velavadar National Park wolf pack in the *Bhal* (1996-2000). Error bars shows 95 % bootstrap confidence intervals.

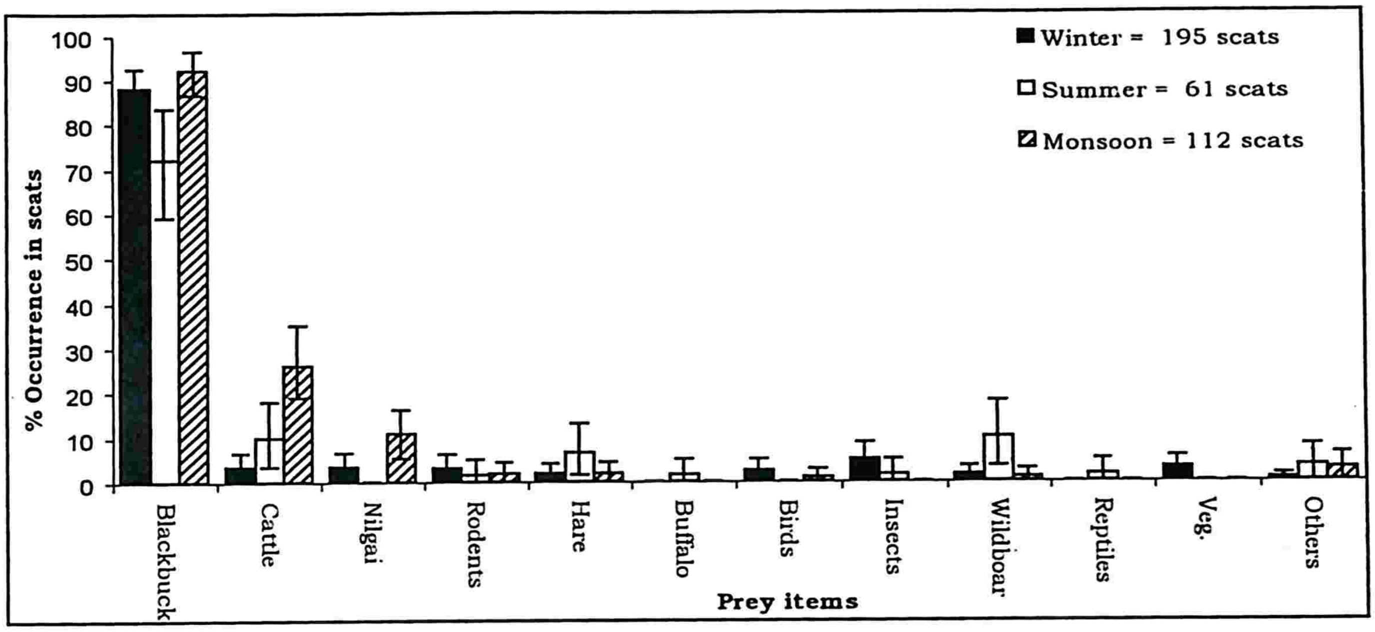


Fig.17. Comparison of seasonal food habits of Vegad wolf pack of the *Bhal* region between 1996-2000. Error bars shows 95 % bootstrap confidence intervals.

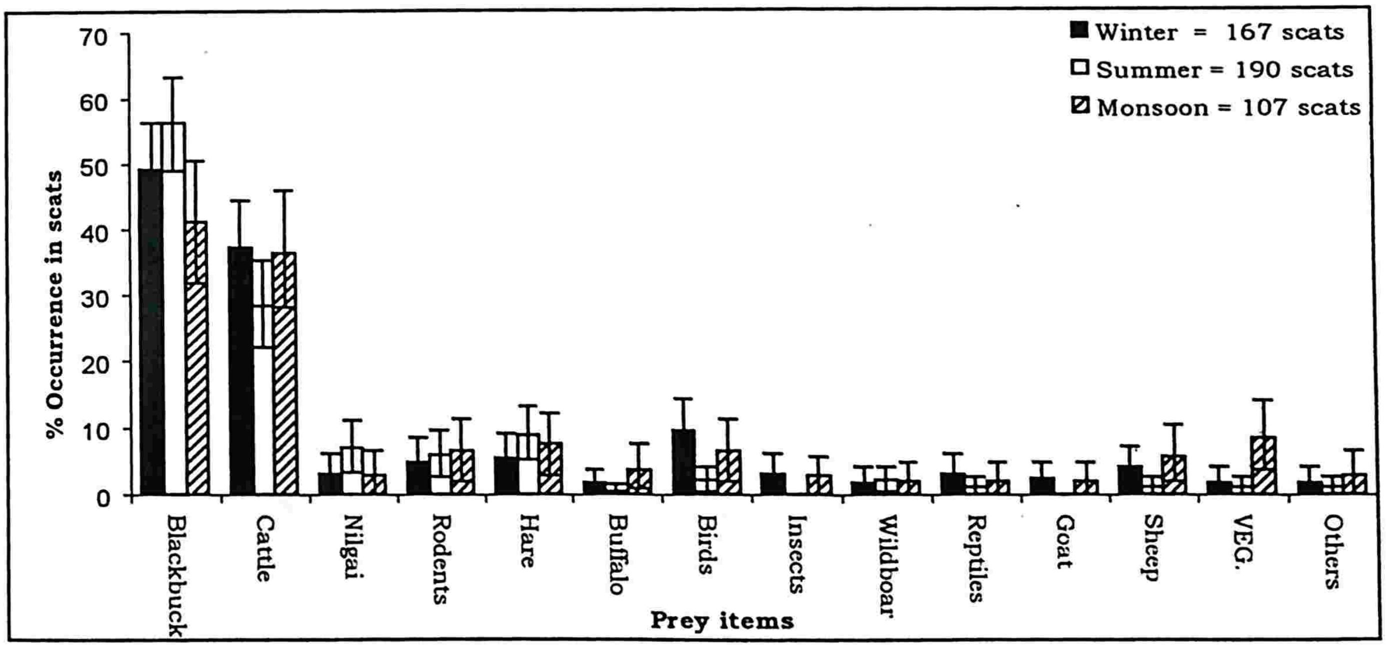


Fig.18. Comparison of seasonal food habits of wolves of Narmad wolf pack of the *Bhal* region between 1996-2000.Error bars shows 95 % bootstrap confidence intervals.

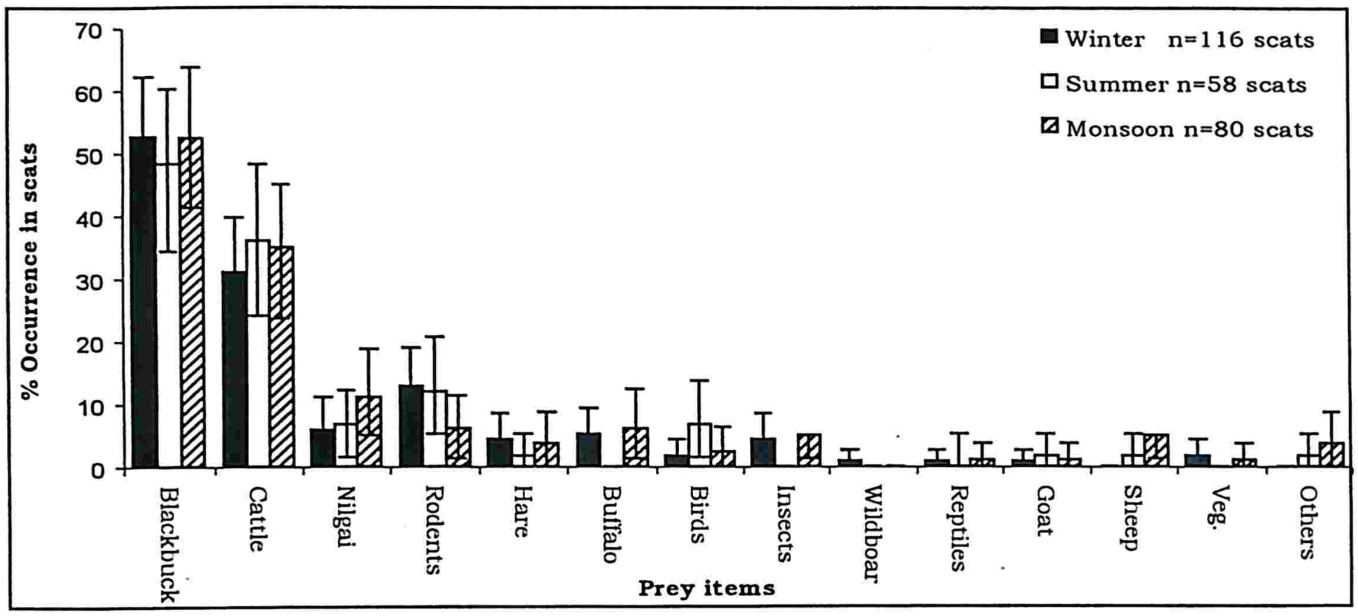
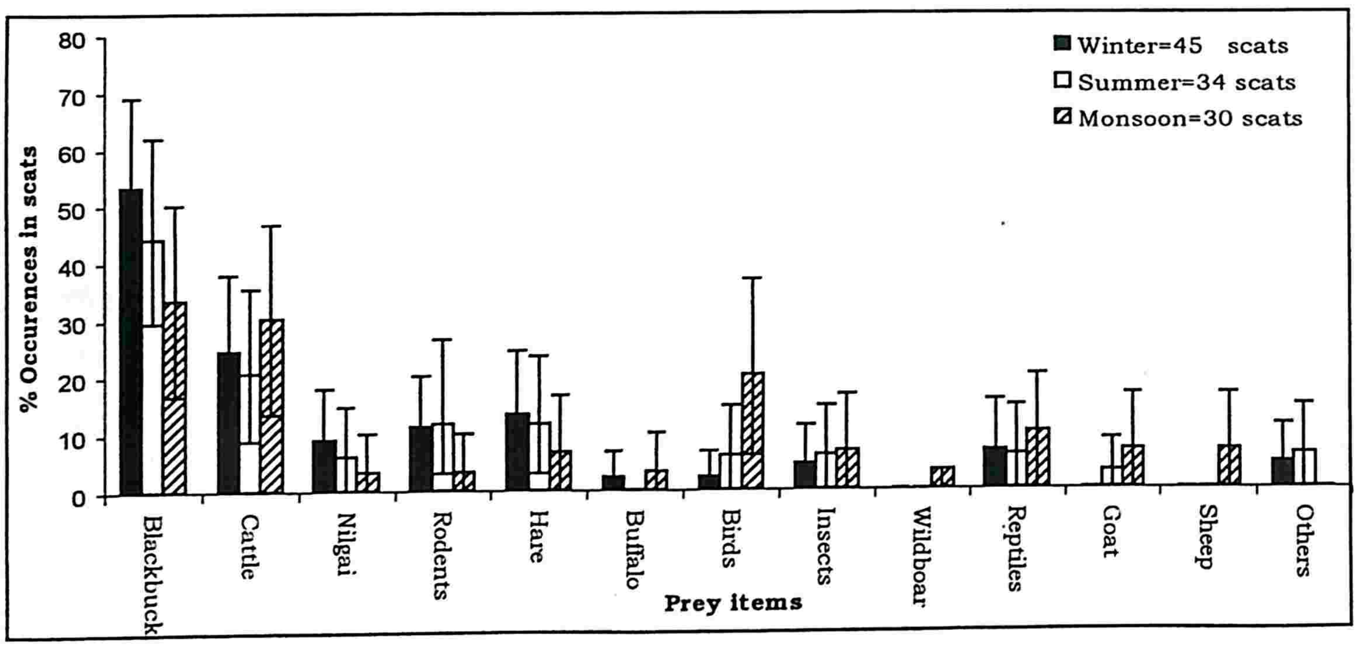


Fig.19. Comparison of seasonal food habits of wolves of Mithapur wolf pack of the *Bhal* region (1996-2000). Error bars shows 95 % bootstrap confidence intervals.



Two-way analysis of variance with seasons and prey as main effects showed that there was no significant difference in occurrence of the major prey species in the diet of wolves of the *Bhal* between seasons ($F = 0.290$, df = 2, 17 and $P \geq 0.749$) (Fig.20). However, species were differentially eaten ($F = 50.55$, df = 5,17 and $P \leq 0.001$) in three major prey groups (Tukeys post hoc test $P \leq 0.05$) i.e. group 1(birds, buffalo, hare, nilgai and rodents) contributed least, group 2 (domestic cattle) contributed moderately and group 3 (blackbuck) had maximum contribution.

5.1.1.e. Comparison of Food Habits of Wolves Inhabiting Protected Area and Non- Protected Area in the Bhal:

Comparison of the diet of the wolf pack inhabiting protected area (VNP) with packs located outside the protected area shows a significant interaction between the location of the pack and species (Two way ANOVA, $F=18.46$, df = 5, 11 and $P = 0.000$). This is due to the percentage occurrence of a single species (blackbuck) contributes major portion (87.0%) of the diet of wolves inhabiting protected area and occurrence of other species (cattle, nilgai, buffalo, birds, rodents etc.) was comparatively lower (ranged between 11.0% to 2.0%). While for packs living outside of protected area the drop in blackbuck consumption was compensated for an increase in consumption of cattle, thereby showing significant interaction (Fig.21).

Percent occurrence of wild prey species and domestic prey species differed significantly ($X^2 = 11.02$, df=2, $P \leq 0.001$) in the diet of wolves inhabiting protected area (VNP) and non-protected area (Fig.22) However, the average percent occurrence of wild prey species in the diet of wolves of the *Bhal* (includes five packs) was 75.0% and domestic prey species was 25.0% (Fig.22).

Fig 20. Seasonal comparison of major prey species that occurred in the diet of wolves of different packs in the *Bhal* region between 1996-2000. The error bars are standard errors.

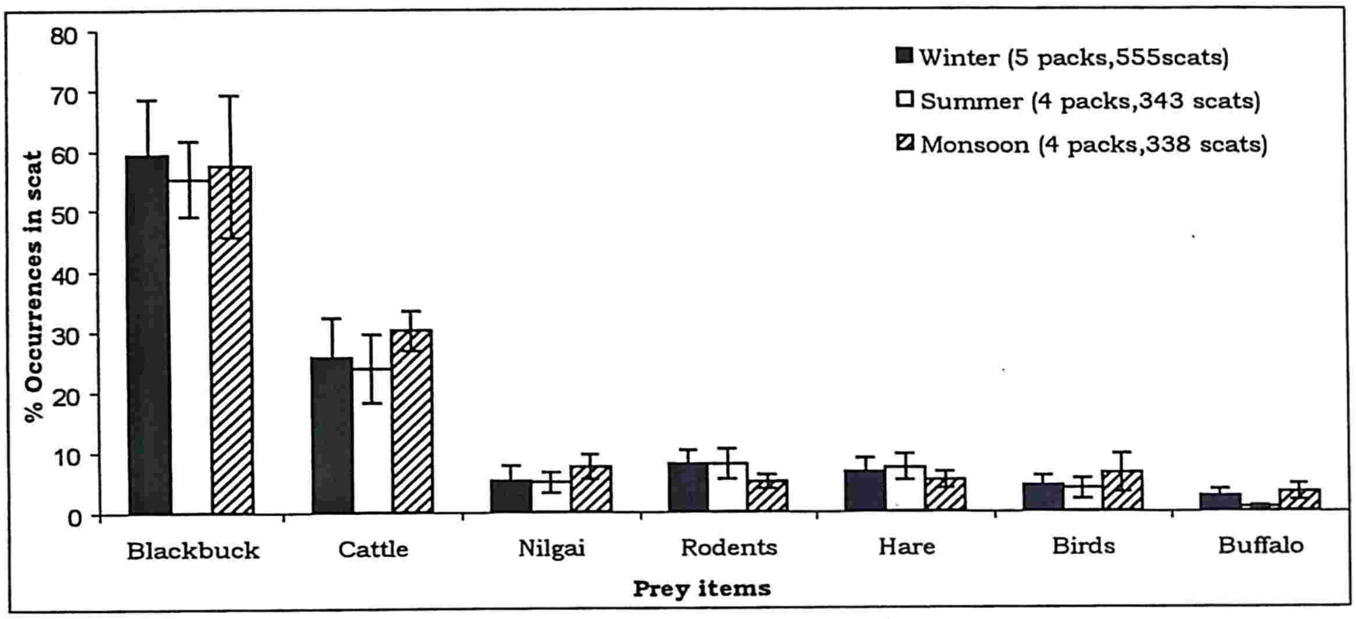


Fig 21. Comparison of major prey species that occur more than 5% in the diet of wolves of different packs in the *Bhal* region between 1996-2000. The error bars are 95% bootstrap confidence intervals.

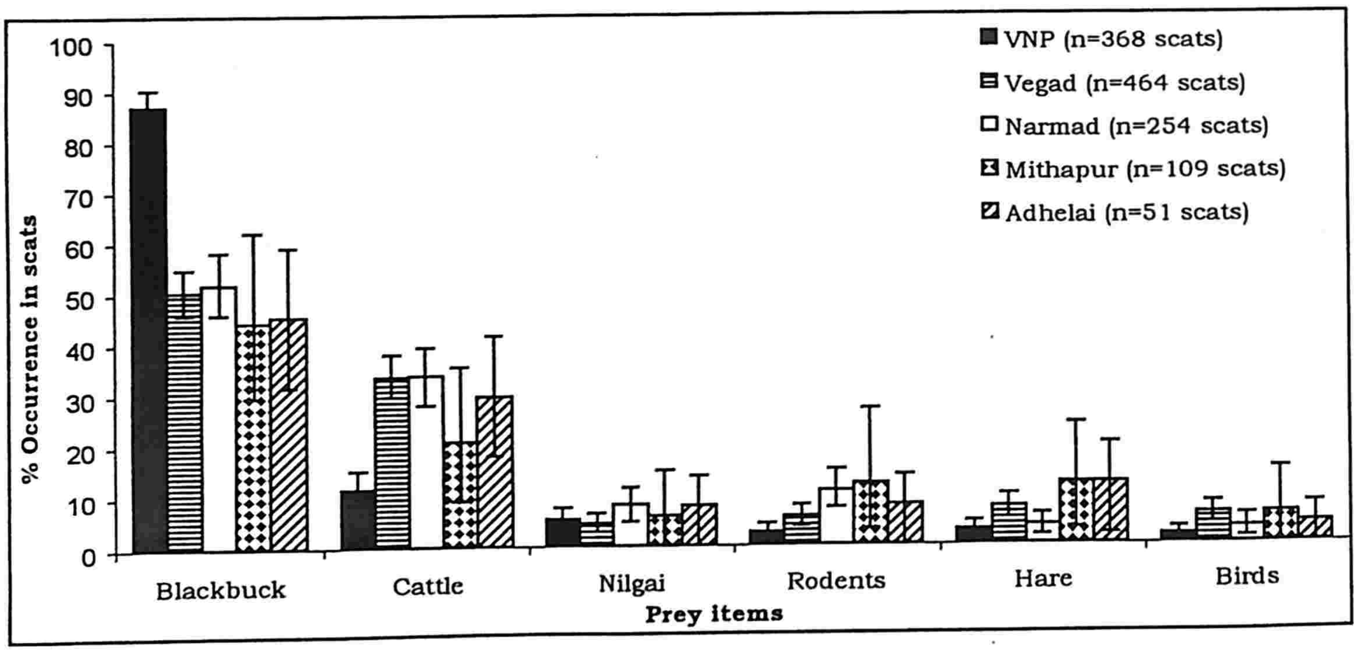
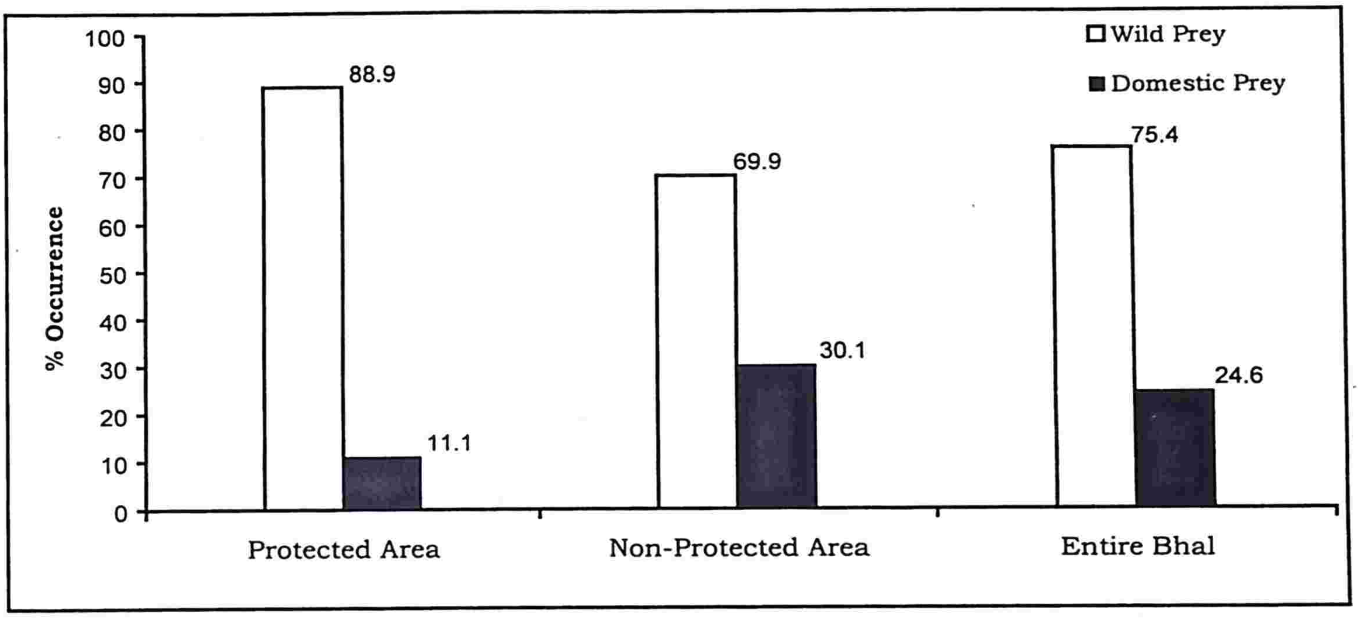


Fig.22. Comparison of occurrence of wild and domestic prey species in the scats of wolves inhabiting protected area, non-protected area and all packs combined in the *Bhal* region between 1996-2000 (Protected area n=1pack and non-protected area n=4 packs. In the entire *Bhal* n= 5 packs).



5.1.2. Feeding Interval and Predation:

5.1.2.a. Contribution of Different Prey Species:

During 1994 hrs of continuous observation of 3 wolf packs a total of 29 feeding events were recorded. Of all feeding events adult male blackbuck contributed 48.0%, adult female blackbuck contributed 3.0% and blackbuck fawn were 14 %, 21.0 % of the events were scavenging on domestic cattle and 7.0% were predation on cattle, where as feeding events on others contributed 7.0%. Feeding events on others include feeding on a harrier (*Circus sp.*) and a snake (*Naja naja*) (Fig.23). Total 72.0% of feeding events were predation on wild prey species where as only predation on domestic livestock contributed 7.0% and scavenging on domestic prey species contributed 21.0%.

5.1.2.b. Biomass Consumption:

The 29 feeding events corresponded to an estimated 582-kg of consumption. Of these, adult male blackbuck accounted for 70.0% where as adult blackbuck female 4.0% and blackbuck fawns contributed 4.0%. Scavenging on cattle contributed 14.0% and cattle predation 8.0% where as others contributed only 0.3% (Fig.24). Total 75.0% of biomass was consumed by predation on wild prey species where as 9.0% of the biomass was consumed by predation on domestic prey species and 16.0% by scavenging on domestic prey species.

5.1.2.c. Feeding Interval:

Average 'feeding interval' of three wolf packs in the *Bhal* calculated between 1998-2000 was 3.62 days (SE = 0.73). There was no significant difference (Kruskal Wallis Test, Chi-square =4.582, df=2, P = 0.101) in feeding intervals of the three wolf packs studied in the *Bhal* between 1998-2000.

Fig.23. Contribution of different prey species to the wolf's diet as observed during continuous monitoring of three different wolf packs in the *Bhal* region between 1998-2000. The bars show data means with jackknife standard errors, (n=1994 hrs; 29 feeding events).

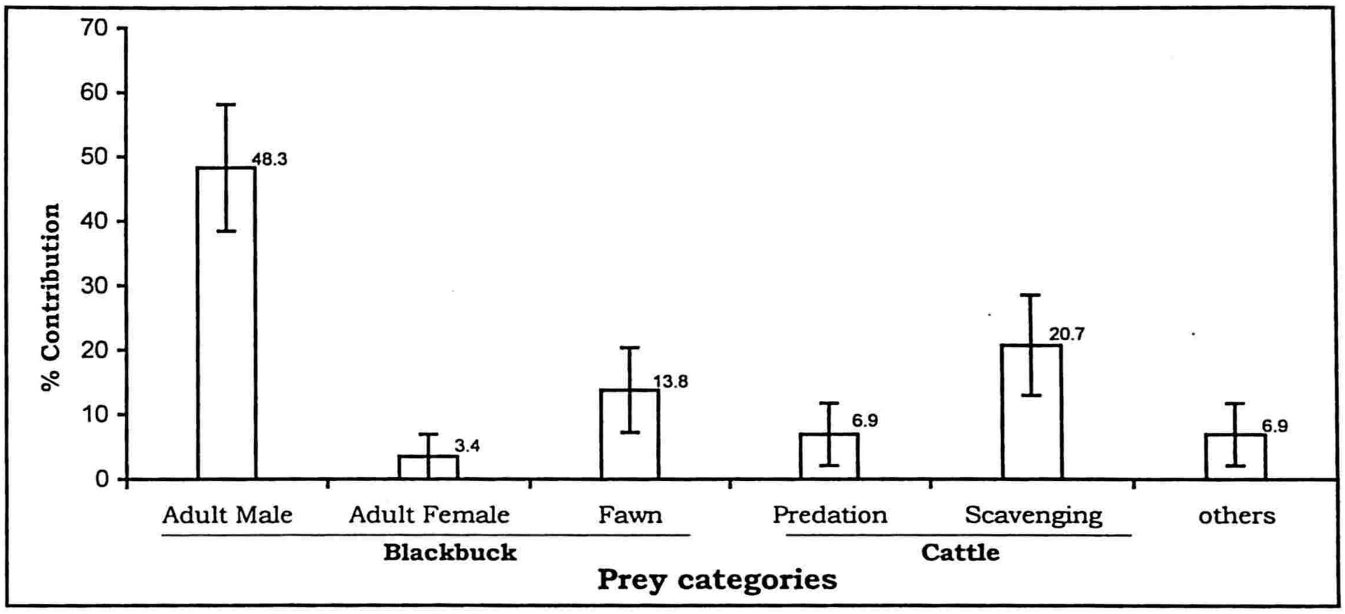
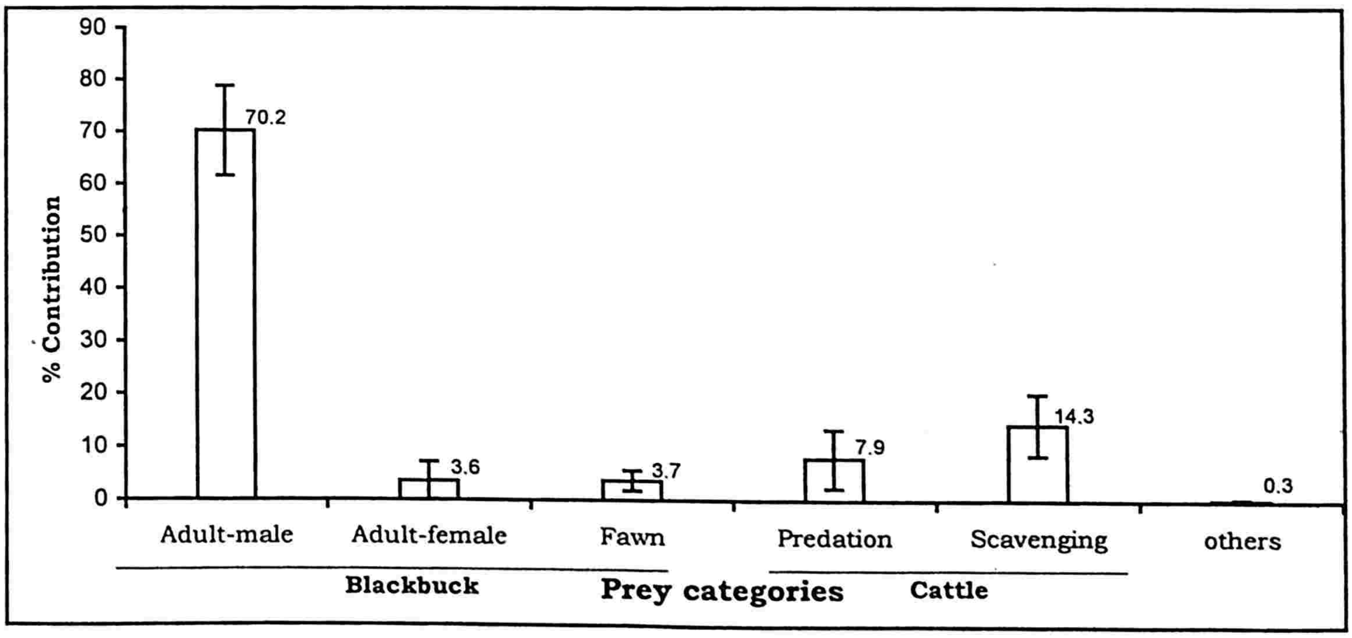


Fig.24. Biomass contribution to the consumption of wolves by different prey species as observed during continuous monitoring of three different wolf packs of the *Bhal* region between 1998-2000. The bars show data means with jackknife standard errors. (n= 1994 hrs of observations; 29 feeding events; 582kg of food consumption estimated.)



5.1.2.d. Kill Interval:

Average 'kill interval' of three wolf packs calculated in the *Bhal* was 4.54 days (SE= 0.63). There was no significant difference (Kruskal Wallis test, X^2= 3.764, df=2, P = 0.152) in kill intervals by wolves of three different packs studied in the *Bhal* between 1998-2000.

5.1.2.e. Consumption /wolf/day:

Average consumption /wolf/day calculated from continuous monitoring of three wolf packs in the *Bhal* was 1.84 kg (SE = 0.29) (Table-3). Considering the average weight of the *C. l. pallipes* 18-kg (Joslin 1982, Mendelssohn 1982. Shahi 1982 and the present study) the estimated consumption was 0.1 kg/kg of wolf/day. There was no significant difference (Kruskal Wallis test, X^2=1.718, df=2, p= 0.424) in the consumption/wolf /day of three different wolf packs studied in the *Bhal* between 1998-2000.

5.1.2.f. Seasonal Comparison:

Feeding interval, kill interval and consumption/wolf /day did not differ across two seasons (Mann–Whitney U test, feeding interval P=0.517, kill interval P=0.571 and consumption/wolf/day P = 0.267).

5.1.2.g. Number of Different Prey Killed Annually:

Since there was no significant seasonal difference in food habits across five packs in three seasons showed by scat analysis and no seasonal difference in feeding interval, kill interval and consumption/wolf/day it would be safe to use above data to calculate annual consumption of total number of different prey species by wolves of three packs.

The biomass consumption of 1.8 kg /wolf/day by 3 wolf packs with 4.5 wolves average pack size would correspond to an annual consumption of biomass about 9067 kg by three packs. The average consumption of adult blackbuck by wolves on kills is 80%, blackbuck fawn100 % and vulnerable cattle to be around 60%. Average weight of adult blackbuck 38 kg (Mungall 1978, Jhala 1993) adult female blackbuck 30 kg, Table- 3, Estimation of biomass consumption by wolves by continuous monitoring of three different wolf packs of the *Bhal* region between 1998-2000.

Session	Pack	Total Hrs.	continuous Observation in days	Mode of feeding	Species	Age / Sex	Est. Weight Kg.	% Eaten	Est. consumption kg.	No. of Wolves fed	Kg. cons./ wolf	Total cons/wolf per session	cons/wolf/day per session
Jan.-99	Vegad	159.8	6.7	pred.	blackbuck	Ad./ M	38	70	26.60	5	5.3	15.82	2.38
				pred.	cattle	calf	40	70	28.00	5	5.6		
				scav	cattle	calf	35	70	24.50	5	4.9		
Apr-99	Vegad	167.0	7.0	pred.	blackbuck	fawn	5	98	4.90	5	1.0	3.98	0.57
				pred.	cattle	calf	60	30	18.00	6	3.0		
May-99	Vegad	157.0	6.5	pred.	blackbuck	fawn	5	98	4.90	6	0.8	5.82	0.89
				pred.	blackbuck	Ad./ M	40	75	30.00	6	5.0		
May-00	Vegad	96.0	4.0	pred.	blackbuck	Ad./ M	35	80	28.00	5.5	5.1	5.89	1.47
Feb-00	Narmad	175.5	7.3	pred.	blackbuck	Ad./ M	38	70	26.60	2	13.3	13.30	1.82
May-99	Narmad	182.4	7.6	pred.	blackbuck	Ad./ M	35	75	26.25	2	13.1	16.07	2.11
				pred.	blackbuck	fawn	6	98	5.88	2	2.9		
Jun-99	Narmad	199.0	8.3	scav.	cattle	calf	35	40	14.00	2	7.0	9.85	1.19
				pred.	blackbuck	fawn	6	95	5.70	2	2.9		
May-00	Narmad	188.5	7.9	pred.	blackbuck	Ad./ M	35	85	29.75	2	14.9	30.63	3.90
				pred.	blackbuck	Ad./ M	35	90	31.50	2	15.8		
Feb-99	VNP	148.0	6.2	pred.	blackbuck	Ad./ M	38	80	30.40	5	6.1	13.20	2.14
				pred.	Harrier	Adult	0.6	35	0.21	1	0.2		
				pred.	blackbuck	Ad./ M	38	85	32.30	5	6.5		
				pred.	cobra	Adult	1.5	90	1.35	3	0.5		
May-99	VNP	342.0	14.3	pred.	blackbuck	Ad./ M	38	85	32.30	5	6.5	27.38	1.92
				pred.	blackbuck	Ad./F	28.0	75	21.00	5	4.2		
				pred.	blackbuck	Ad./ M	38	80	30.40	5	6.1		
				pred.	blackbuck	Ad./ M	38.0	65	24.70	5	4.9		
				pred.	blackbuck	Ad./ M	38	75	28.50	5	5.7		
												Average	**1.84**
												Standard Error	**0.29**

Est.= Estimated, Cons= Consumption
Ad= Adult, M= Male, F=Female
Pred.= Predation, Scav.= Scavenging

blackbuck fawn 5kg and vulnerable cattle to be around 60 kg. Use of data on percentage of biomass contribution to wolf's diet by different prey species results in annual consumption of total 262 adult blackbuck male, 17 adult female blackbuck, 67 blackbuck fawns and 25 vulnerable cattle by 3 packs of wolves (Table-4).

5.2. Prey Availability:

5.2.1. Cattle:

Availability of vulnerable domestic prey (cattle and buffalo) was higher in the home range of Vegad pack (625 individuals) which was followed by Narmad pack home range (328 individuals) and was minimum in VNP pack home range (263 individuals) (Plate-2).

5.2.2. Blackbuck:

Availability of blackbuck was higher (1092 ± 112, SE) in the home range (100% MCP) of VNP pack in compared to Vegad pack (512 ± 81, SE) and Narmad wolf pack (401 ± 38, SE) (Plate-3).

5.3. Home range and Habitat Use:

5.3.1. Home range:

5.3.1a. Adequacy of Sample and Home range Estimates:

Home range calculated for different wolves/packs at each 10 sequential radiolocations were plotted against home range size (Fig.25). The home ranges wolves reached asymptote at different sample size in accordance to their social status. These ranged between 70 to 200 radio-locations spanned over one to two years.

Home-ranges (100% MCP) of four wolves in their various social status and pack associations were between 38 to 228 km^2 (Table-5).

Table-4. Estimation of annual number of prey consumed by 3 wolf packs in the *Bhal* region between 1998-2000.

Prey species	Age Sex	Aveg. Weight *	Average % of weight available for consumption	Average weight available	Aveg.% Utilization of Carcasses	Average weight eaten in kg. /carcass	Aveg.% in wolf's diet (±SE)	Corresponding biomass consumption in kg.	Total no. of animals predated /annum (± SE range)
Blackbuck	Adult Male	38	80	30.4	80	24.3	70.2 ± 8.6	6364.8	262 (230 - 294)
Blackbuck	Adult Female	30	80	24	80	19.2	3.6 ± 3.6	326.4	17 (0 - 34)
Blackbuck	Fawn	5	100	5	100	5	3.67 ± 1.9	332.7	67 (32 - 101)
Cattle	Calf	60	80	48	60	28.8	7.9 ± 5.6	716.3	25 (7 - 42)

Average no of wolves/pack= 4.5
Total no of packs = 3
Total no of wolves=13.5
Average consumption /wolf/day=1.8
Annual consumption by 3 packs = 9067
* From Mungall 1978 and Jhala 1993.

Plate 2. Blackbuck abundance and wolf territories in the intensive study area in 1999.

Plate 3. Distribution of villages, wolf territories and prey abundance in and around wolf territories in the Bhal. The villages are buffered by the average distince tavelled by livestock for grazing

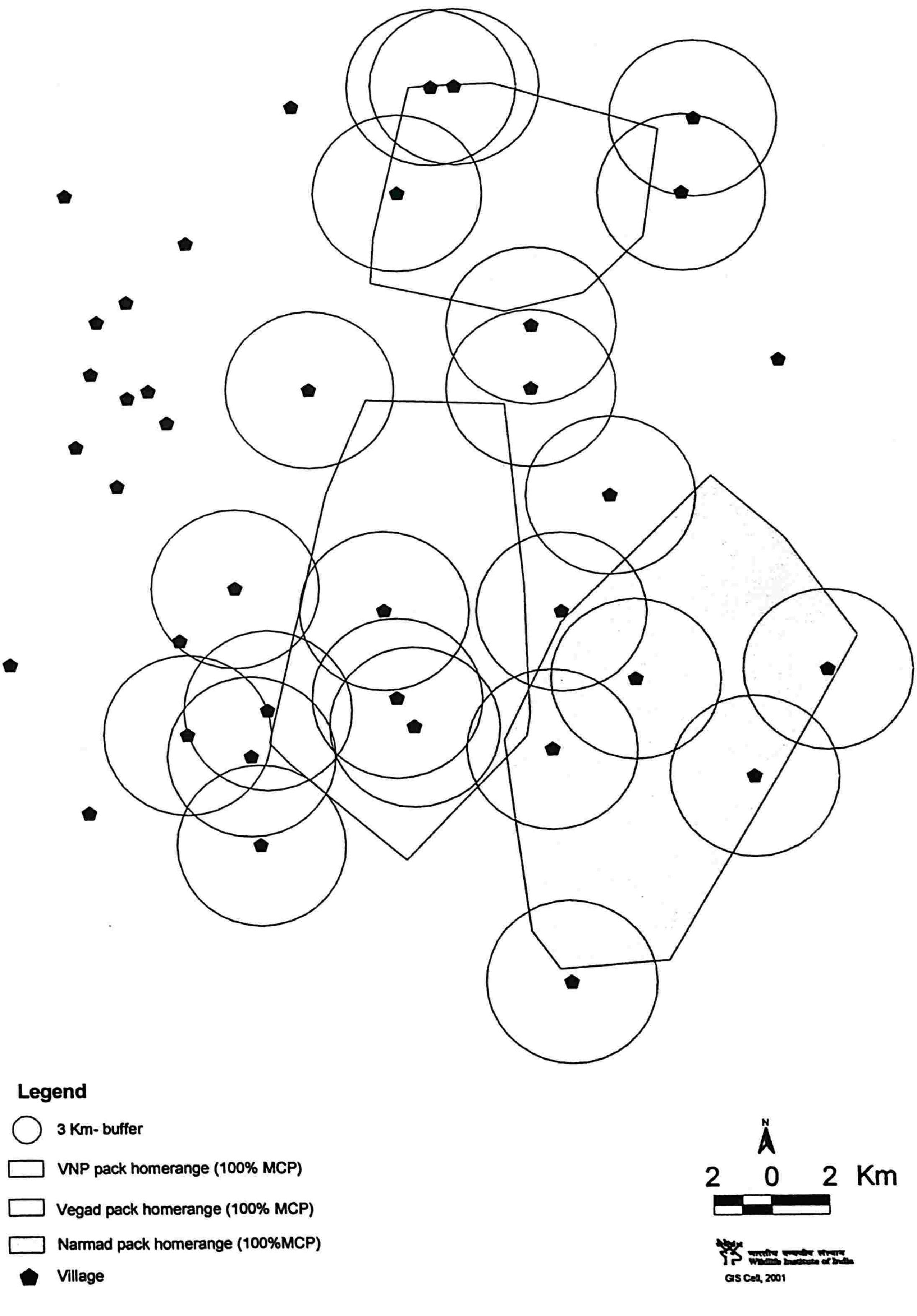
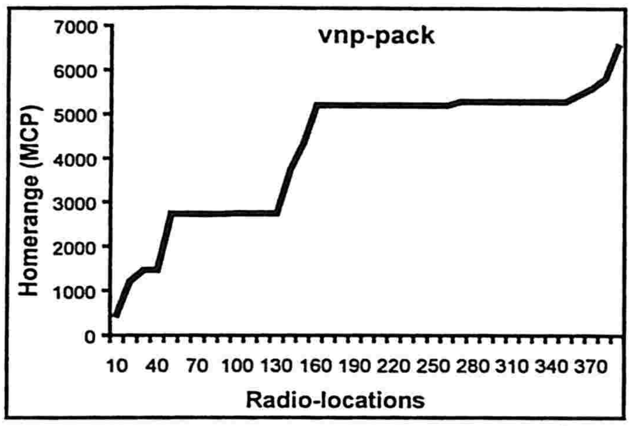
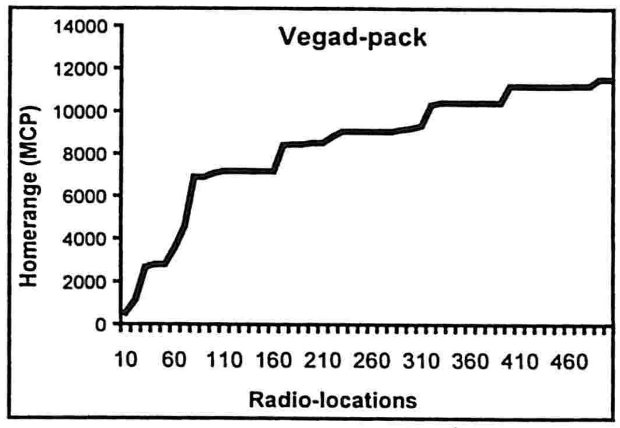


Fig.25. Cumulative area of 100% Minimum Convex polygon (ha.) plotted against sequential number of radio locations to determine sample size for home range estimation.





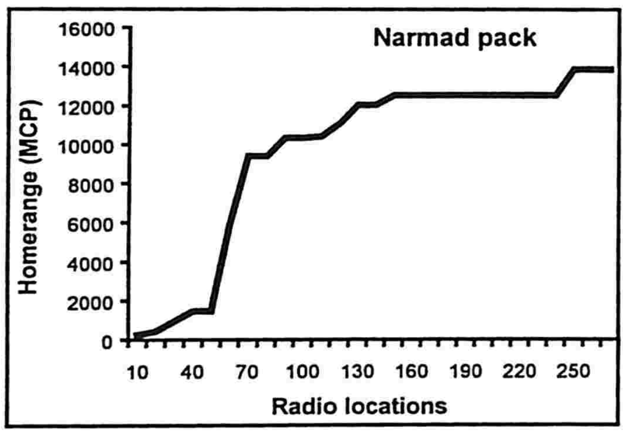


Table. 5, Home range and core areas (in km^2) of four wolves in various social status between 1996-2000 in the *Bhal*, Gujarat.

Wolf	Social Status	**100% MCP**	**95 % MCP**	**Core Area 50 % HM**
Male	Lone-wolf	227.60	196.80	
Male	Lone-wolf	181.00	181.00	
Male	Alpha status	92.22	74.42	12.12
Male	Alpha status	105.90	66.84	10.61
Female	Alpha status	51.98	18.10	4.44
Female	Alpha status	107.80	71.12	7.80
Female	Alpha status	38.38	19.65	3.96
Narmad-Pack		138.70	83.39	8.666
VNP- Pack		65.25	18.88	4.26.
Vegad-pack		136.30	110.20	11.66

MCP = Minimum Convex Polygon
HM = Harmonic Mean

Throughout the study a lone wolf was not located for 30 days and an alpha female was not found for 120 days. Thus minimum 100% MCP for wolves not associated with packs were larger than those associated with packs 204.3 ± 23 (SE) km^2 (Table-5, Plate-4).

Average home range estimated using 100% MCP for three different packs of wolves was found to be 113.4 ± 24 (SE) km^2. Where as average 95% MCP home range was 70.8 ± 27 (SE) km^2 (Plate-5).

Average individual wolf home ranges estimated using 100% MCP was 89.1 ± 15.3 (SE) km^2 (Plate-6). Where as average 95% MCP home range was 55.5 ± 11.8 (SE) km^2 (Plate-7).

5.3.1.b. Core Area Estimate Using Harmonic Mean Method:

The point of inflexion in the graphs suggesting uniform distribution of radiolocations ranged from 40% to 75% isopleths values hence on the average 50% Harmonic Mean was chosen to estimate the core areas for different wolf/pack home range (Fig.26)

Average core area estimated for individual wolves (50% Harmonic Mean) was 7.9 ± 1.3 (SE) km^2 (Table-5). Where as average core area (50% Harmonic Mean) estimated for three wolf pack was 8.2 ± 2.1 (SE) km^2 (Table-5, Plate-5).

Plate 4. Home ranges (100% MCP) of male lone wolves in the Bhal region studied between 1996 -2000.

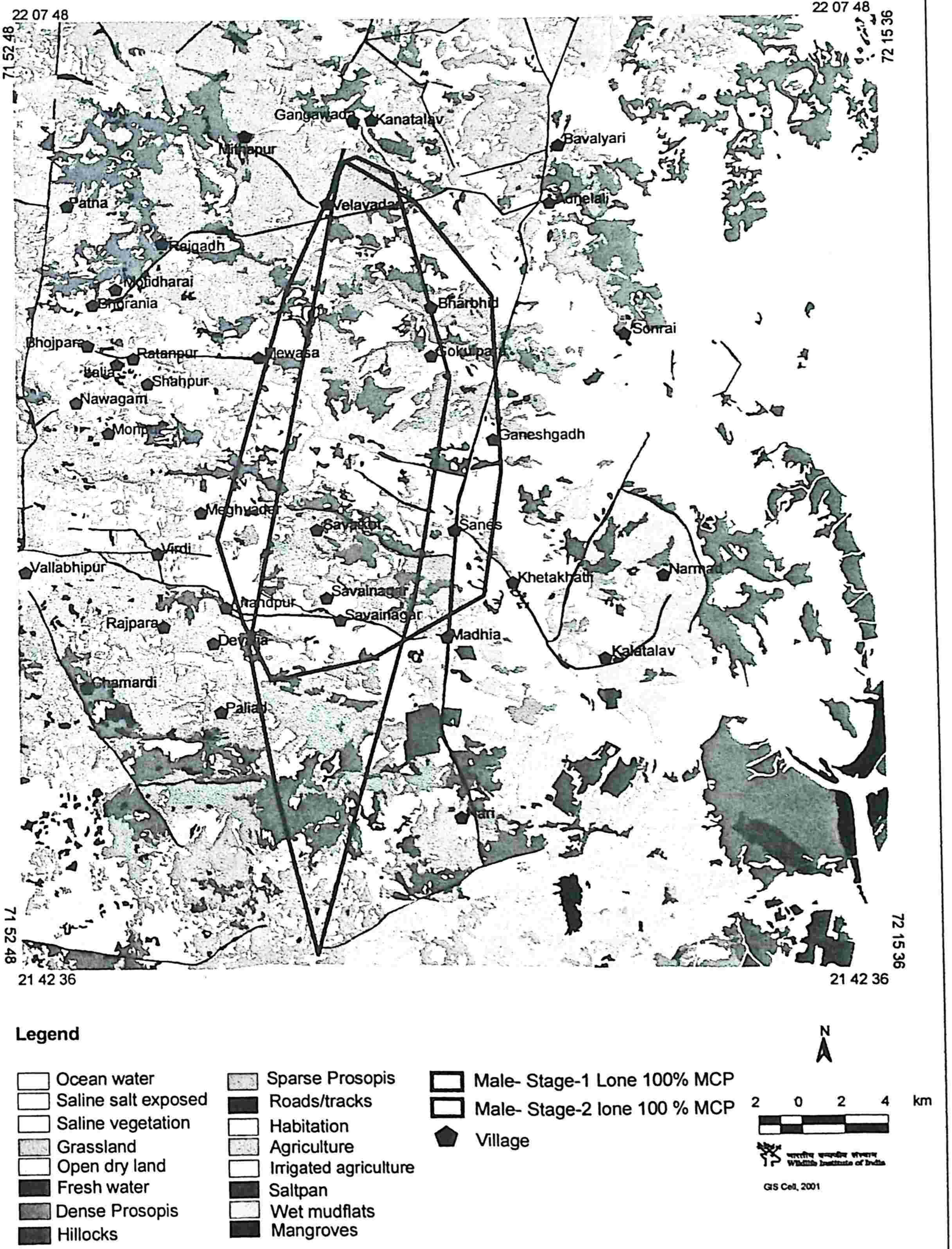


Plate 5. Spatial distribution of home ranges and core areas of 3 wolf packs in the Bhal region studied between 1995 -2000, on classified LISS-III image (1995 Dec.).

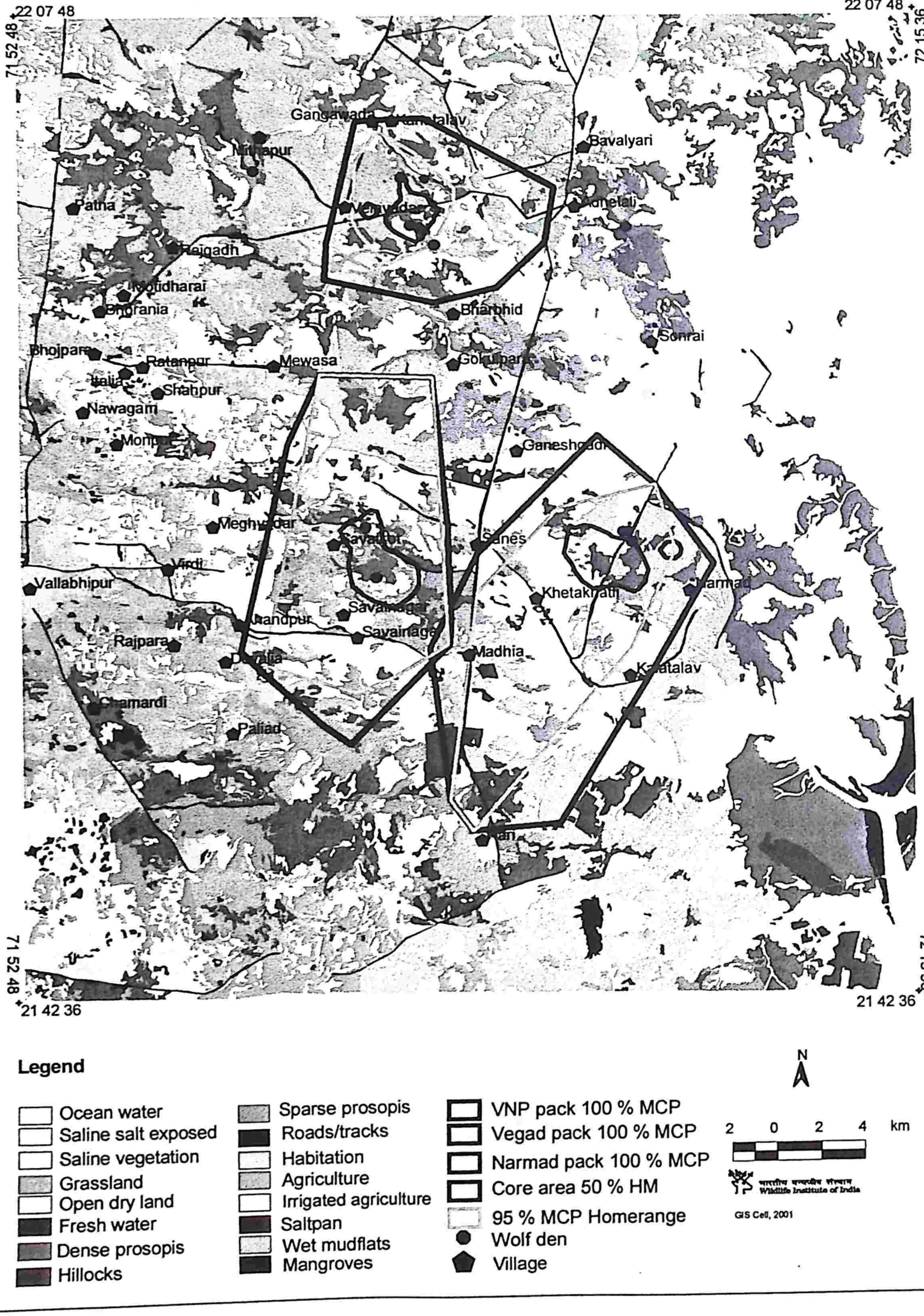


Plate 6. Spatial distribution of home ranges (100 % MCP) of radio collared wolves studied in the Bhal region between 1996-2000, on classified LISS-III image (1995 Dec.).

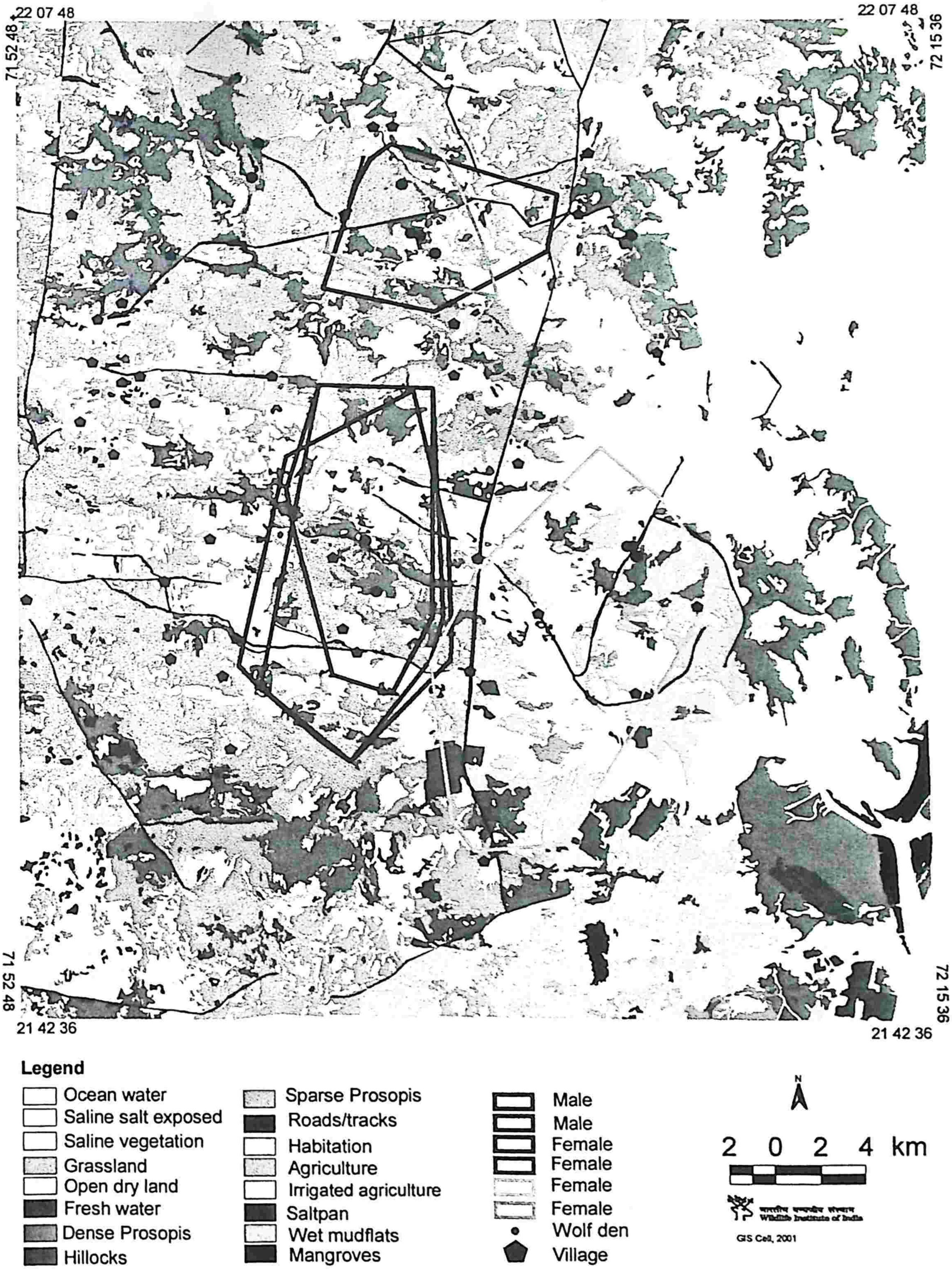


Plate 7. Spatial distribution of home ranges (95 % MCP) of radio collared wolves studied in the Bhal region between 1996-2000, on classified LISS-III image (Dec. 1995.).

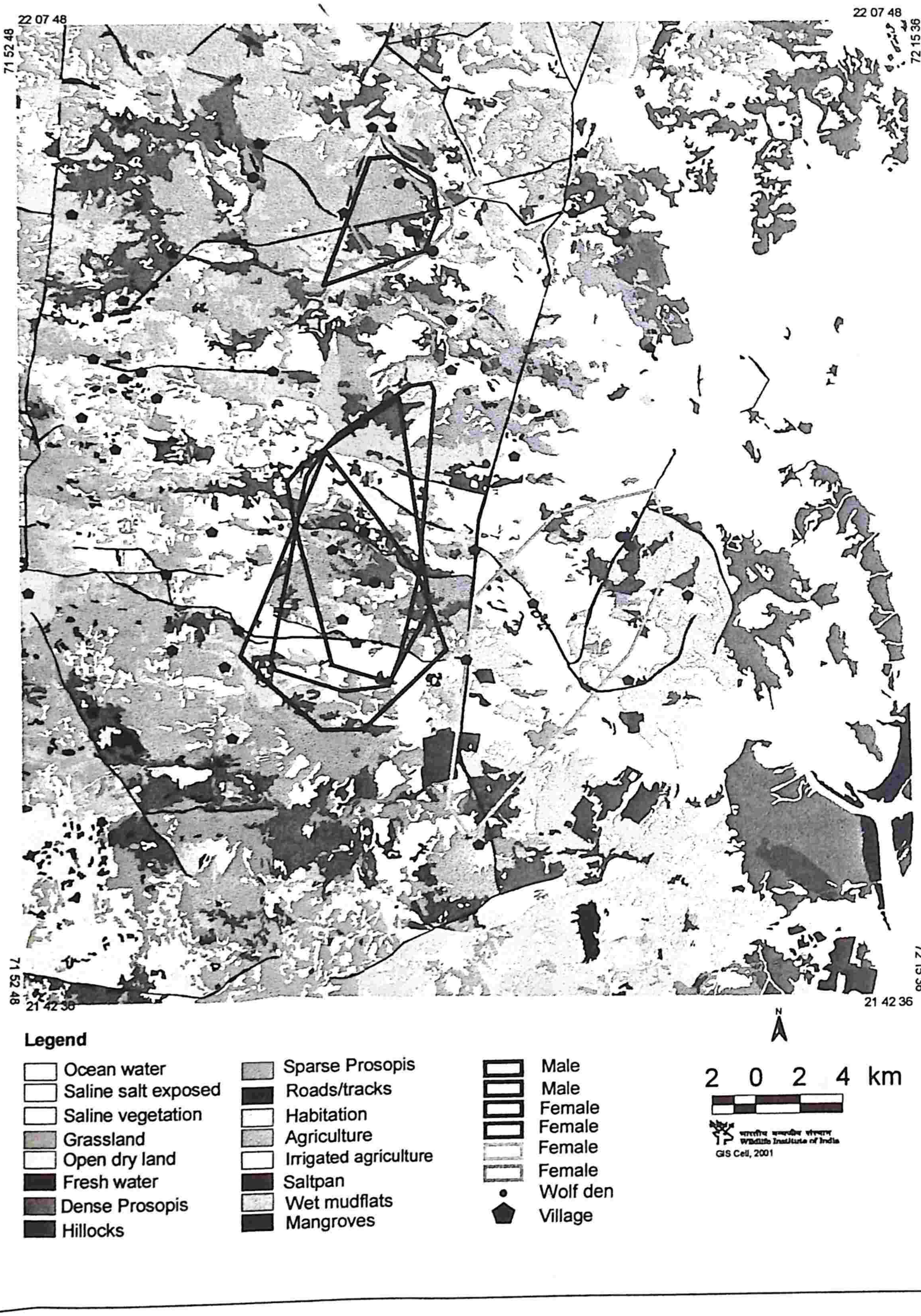
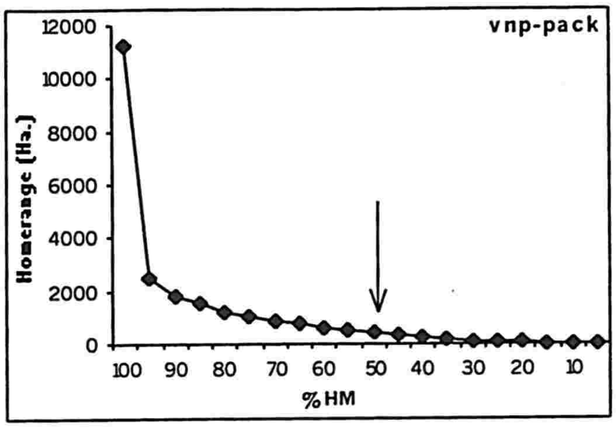
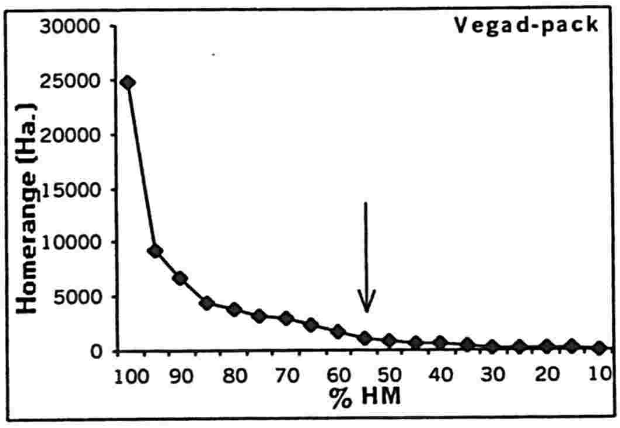
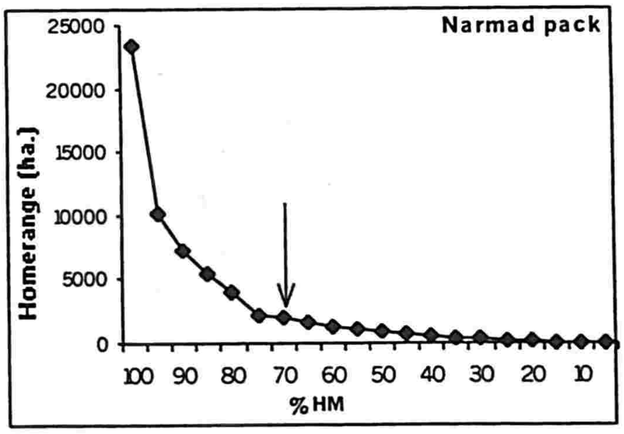


Fig.26. Harmonic Mean isopleths values were plotted against home range size to determine the core areas of the three wolf packs in the *Bhal* region.







5.3.2. Habitat Analysis:

5.3.2.a. Habitat Availability:

Sixteen different habitat types were identified in the entire study area using satellite imageries (Table-6, Plate-1). Different habitat types available in study area and within the home range areas of different wolf packs are mentioned bellow. Grasslands constituted major and important portion of VNP pack home range where as it was not present in the range of the Vegad pack and Narmad pack home range.

1) *Ocean water*: Saline water of "Gulf of Cambey" which penetrates the land of *Bhal* region through several creeks during high tide and remains for several days.

2) *Salt exposed land*: along the saline water creeks of Gulf of Cambey and some wasteland area with accumulated white salt on surface is classified as salt exposed land.

3) *Saline vegetat*ion: The area covered mainly by sparse halophytic vegetation species such as *Saueda nudiflora*, *Chloris*, and devoid of perennial grasses and shrubs.

4) *Grassland*: The flat grassland composed of major species such as *Dicanthium annulatum, Sporobolus madraspatensis, S. verginicus,* and *S. coromendalis.*

5) *Open dry area*: The barren areas devoid of any vegetation.

6) *Fresh water*: The rainy water accumulates in the low land area, rivers, harvested water in village ponds, check dams and puddles.

7) *Dense Prosopis*: The dense scrub patches of exotic plant *Prosopis juliflora.*

8) *Sparse Prosopis*: Area with sparse *Prosopis juliflora* clumps.

9) *Roads and tracks*: Tarmac roads, permanent rough tracks connecting villages and agriculture fields.

10) *Habitation*: The human habitation in the form of small villages, settlements and huts in the *Bhal* region.

Table 6. Percentage availability of different habitat types in the study area (550 Km^2), home range (100% MCP) and core area (50 % Harmonic Mean) of different wolf packs from remotely sensed standard LISS-III, 1:50,000 IRS-1C FCC classified imageries obtained in December 1995.

Habitats	Study area	VNP Pack	VNP Core area	Vegad Pack	Vegad Core area	Narmad Pack	Narmad Core area
Ocean water	0.76	0.12	NA	NA	NA	1.21	NA
Saline salt exposed land	11.01	2.91	NA	NA	NA	15.77	10.53
Saline vegetation	30.32	29.54	8.91	37.83	25.35	33.26	21.05
Grassland	1.41	13.63	34.65	NA	NA	NA	NA
Open dry area	13.44	17.43	21.78	13.95	5.07	25.54	21.27
Fresh water	0.35	0.25	NA	0.81	2.30	0.21	NA
Dense *Prosopis*	12.46	15.09	28.71	16.43	34.56	8.79	34.93
Sparse *Prosopis*	11.92	7.29	1.98	15.12	29.95	4.45	NA
Roads/tracks	1.41	1.83	3.96	1.02	NA	2.28	2.87
Habitation	0.74	1.20	NA	0.60	NA	0.74	NA
Agriculture	13.20	10.52	NA	13.92	2.76	3.62	3.35
Irrigated agriculture	0.72	NA	NA	NA	NA	NA	NA
Saltpans	1.51	NA	NA	0.28	NA	2.64	NA
Wet mudflats	0.69	0.12	NA	NA	NA	1.45	NA
Mangroves	NA	NA	NA	NA	NA	NA	NA
Hillock	NA	NA	NA	NA	NA	NA	NA

NA= Not available

11) *Agriculture*: Agriculture field with sorghum, cotton, and wheat in monsoon and part of winter and fellow fields in summer.

12) *Irrigated agriculture*: Fields, which are irrigated through ground water or canal water, are used for growing cotton, wheat and sorghum in all the three seasons.

13) Saltpans: Salt producing industries on the cost of "Gulf of Cambey".

14) Wet mudflats: Mudflats that remains wet are mainly situated on the edge of water creek carrying tidal water.

15) Mangroves: Community of woody plants that lives between the sea and the land in areas which is inundated by tides. They are found on the southern most part of the *Bhal* region of Bhavnagar district.

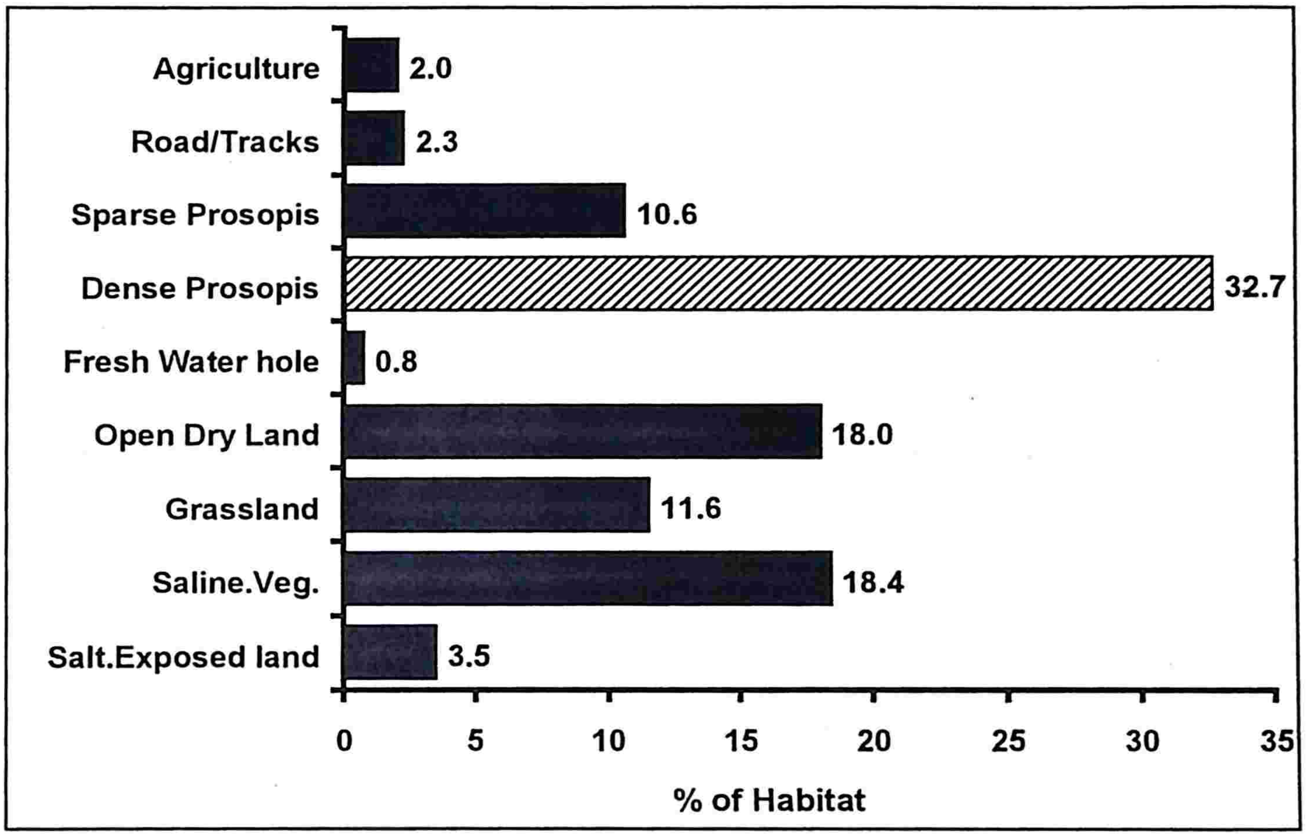
16) Hills: Hillocks of Chamardi, which is situated just outside the *Bhal* region.

5.3.2.b. Habitat Use / Preference:

5.3.2.b.1. Core Area Characteristics:

Most of the active wolf dens were located in cores areas. Core areas were devoid of human disturbances (no human settlements present inside the core areas) and had high percentage of dense *Prosopis* patches (32.7%) and had fresh water accessibility (Fig.27, Plate-5)

Fig. 27. Average composition of core areas of three wolf packs in the *Bhal* between 1996-2000.



5.3.2.b.2. Habitat Preference by Compositional Analysis:

5.3.2.b.2.1. 100% MCP vs. Radio Locations:

Dense *Prosopis*, grassland and sparse *Prosopis* are preferred habitat types as these habitat types obtained high rank (1-3) in compositional analysis (Table-7). However, saline vegetation, open dry land, fresh waterhole, and roads/tracks were moderately used where as agricultural fields, irrigated agriculture fields, wet mudflats, saltpans, salt exposed land and ocean water were avoided (Plate-5, 6).

5.3.2.b.2.2. 100 MCP vs. Core Areas (50% HM):

Compositional analysis was also done by using all the habitats present in 100% MCP as available habitats and core area (50% Harmonic Mean) as used habitats (Table-8). Grassland, dense *Prosopis*, freshwater, sparse *Prosopis* were found to be preferred habitat types for core areas whereas open dry land and saline vegetation were moderately used and agricultural fields, irrigated agriculture fields, wet mudflats, saltpan, salt exposed land and ocean water were avoided (Table-8, Plate-5).

5.3.2.b.2.3. Intensive Study Area vs. Radio Locations:

The grasslands, dense *Prosopis* were most preferred habitat types as they obtained high rank in compositional analysis, where as roads/tracks, sparse *Prosopis,* open dry land, saline vegetation, fresh water, wet mudflats were moderately used habitat types and salt exposed land, saltpan, irrigated agriculture and ocean water were least used habitats.

Table 7, Order of preference of different habitat types by wolves / packs in the *Bhal* region obtained by compositional analysis. All the habitats present in 100 % MCP were considered as available habitats and the habitats in which wolves were located were considered as used habitats. Habitat types are ranked on a 1-11 scale 1= highly used and 11 = least used.

Habitats	VNP Pack	Narmad Pack	Vegad Pack	Male	Male	Female	Female	Female
Ocean water	8	11	NA	NA	NA	8	NA	NA
Salt exposed land	11	4	NA	NA	NA	11	NA	9
Saline vegetation	6	5	3	3	4	5	3	5
Grassland	2	NA	NA	NA	NA	1	NA	2
Open dry area	4	6	4	4	3	4	5	4
Fresh water	10	2	5	6	5	10	4	8
Dense *Prosopis*	1	1	1	1	1	2	1	1
Sparse *Prosopis*	5	7	2	2	2	3	2	6
Roads and tracks	3	3	8	7	8	6	8	3
Habitation	–	–	–	–	–	–	–	–
Agriculture	2	8	6	8	6	7	6	7
Irrigated agricult.	7	NA	NA	NA	NA	NA	NA	NA
Saltpans	NA	10	7	5	7	NA	7	NA
Wet mudflats	9	9	NA	NA	NA	9	NA	NA
Mangroves	NA	NA	NA	NA	NA	NA	NA	NA
Hills	NA	NA	NA	NA	NA	NA	NA	NA

NA= habitat types not available in the animal/pack's home range.
Agricult. = Agriculture

Table 8, Order of preference of different habitat types by wolves / packs in the *Bhal* region obtained by compositional analysis. All the habitats present in 100 % MCP were considered as available habitats and core area (50 % Harmonic Mean) as used habitats. Habitat types are ranked on a 1-11 scale 1= highly used and 11 = least used.

Habitats	VNP Pack	Narmad Pack	Vegad Pack	Male	Male	Female	Female	Female
Ocean water	7	8	NA	NA	NA	7	NA	NA
Salt exposed land	10	5	NA	NA	NA	10	NA	8
Saline vegetation	5	6	3	5	4	5	4	5
Grassland	1	NA	NA	NA	NA	1	NA	3
Open dry area	4	2	5	6	5	4	5	4
Fresh water	8	7	1	3	3	8	2	7
Dense *Prosopis*	3	1	2	2	2	3	1	2
Sparse *Prosopis*	6	11	3	1	1	6	3	6
Roads and tracks	2	4	8	8	8	2	8	1
Habitation	–	–	–	–	–	–	–	–
Agriculture	11	3	6	4	6	11	6	9
Irrigated agricult.	7	NA	NA	NA	NA	NA	NA	NA
Saltpans	NA	10	7	7	7	NA	7	NA
Wet mudflats	9	9	NA	NA	NA	9	NA	NA
Mangroves	NA	NA	NA	NA	NA	NA	NA	NA
Hills	NA	NA	NA	NA	NA	NA	NA	NA

NA= habitat types not available in the animal/pack's home range.
agricult. = Agriculture

5.3.2.b.3. Use/Availability Analysis Using Regression Analysis:

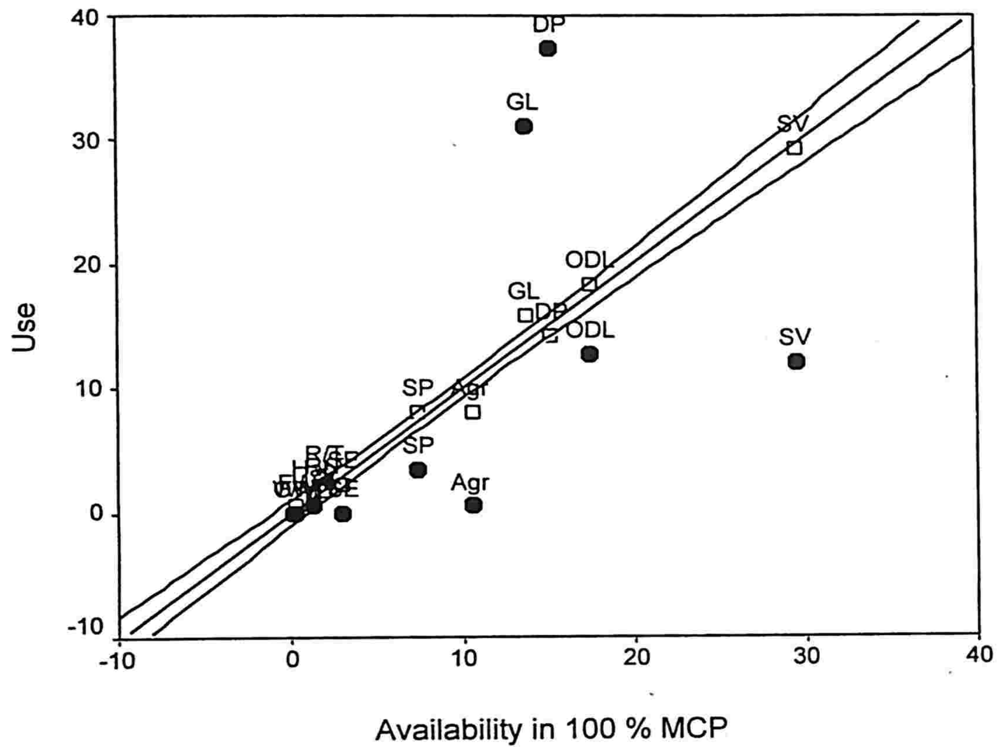
Regression analysis method also gave the similar order of preference of different habitat types by different wolves/packs studied in the *Bhal* (Fig.28 a-d). Dense *Prosopis*, grassland and sparse *Prosopis* were preferred habitats where as open dry land, agriculture fields, saline vegetation, saltpans, wet mudflats, salt exposed land were among the avoided habitat types (Table-9).

5.3.3. Home range Size and Prey Availability Relationship:

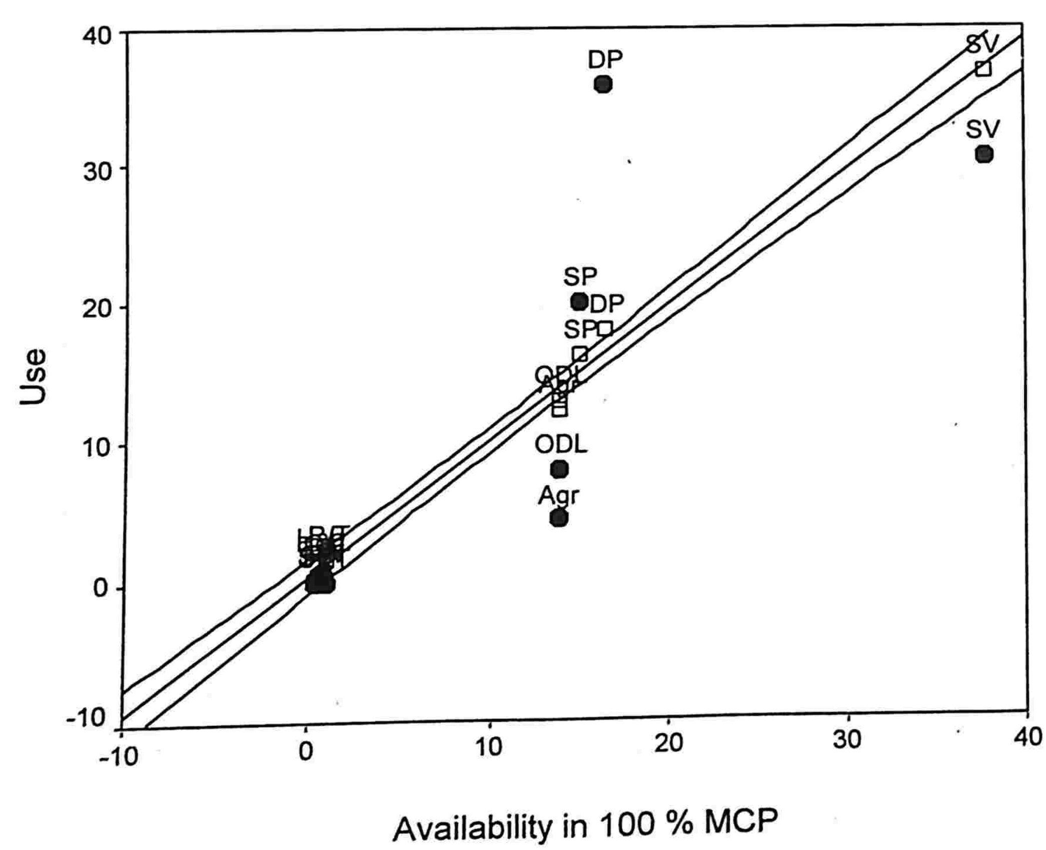
Home-range size of VNP pack (65.25 km^2) was found to be smaller in compared to Vegad pack (136.2 km^2) and Narmad pack (138.7 km^2). Availability of blackbuck (wild prey) was found to be higher (1092 individual blackbuck) in VNP pack home range compared to Vegad wolf pack's home range (512 individuals) and Narmad pack home range (401 individuals). However, domestic prey availability in VNP pack's home range was relatively lower (263 cattle) in compared to Vegad pack (625) and Narmad pack (328) (Fig.29).

Fig.28. Habitat preference and avoidance by wolf packs analyzed using regression method.

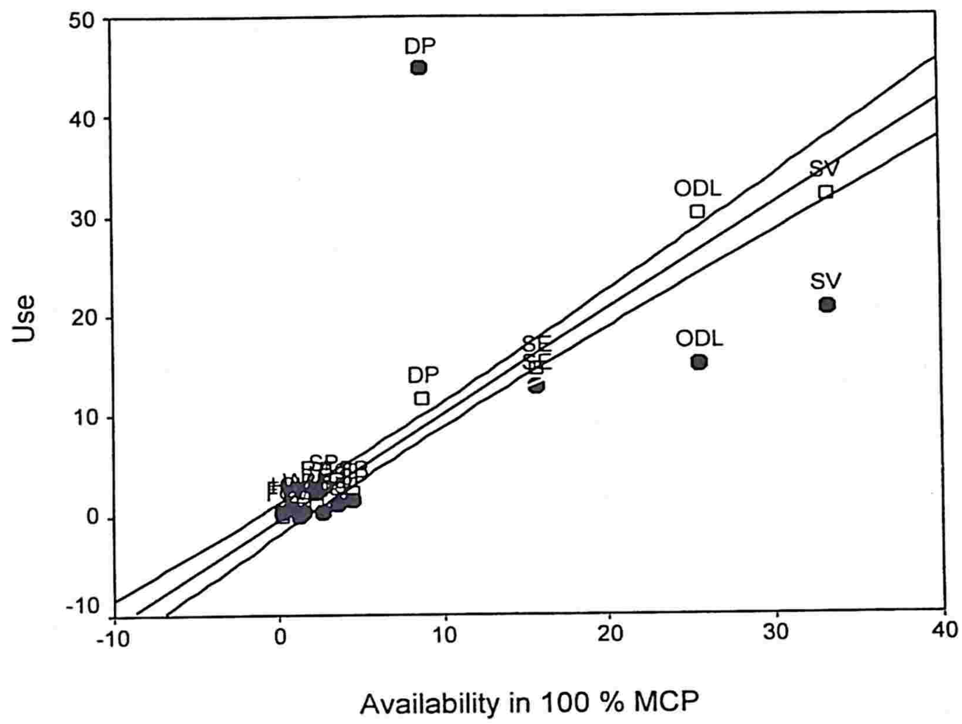
a) Regression analysis for habitat use by VNP wolf pack showing high preference for grassland and dense *Prosopis* where as avoidance of saline vegetation, open dry area, agriculture fields and sparse *Prosopis* OW= ocean water, SE= Salt exposed land, SV= Saline Vegetation, GL= Grassland, ODL= Open dry land, FW= Fresh water, DP= Dense *Prosopis, SP*= Sparse *Prosopis*, R/T= Roads/ Tracks, Hab= Habitation, Agr= Agriculture, IAGR=Irrigated agriculture, SP= Saltpan, WM= Wet mudflats



b) Regression analysis for habitat use by Vegad wolf pack showing high preference for dense *Prosopis* and sparse *Prosopis* where as avoidance of saline vegetation, open dry area and agriculture fields.



c) Regression analysis for habitat use by Narmad Pack showing high preference for dense *Prosopis* where as avoidance of saline vegetation, open dry land and salt exposed land.



d) Regression analysis for habitat use by All radio collared wolves vs their area (100 % MCP) of distribution shows high preference for dense *Prosopis*, grassland, where as avoidance of agriculture fields, salt exposed land, and agriculture fields. Wet mudflats and sparse *Prosopis*.

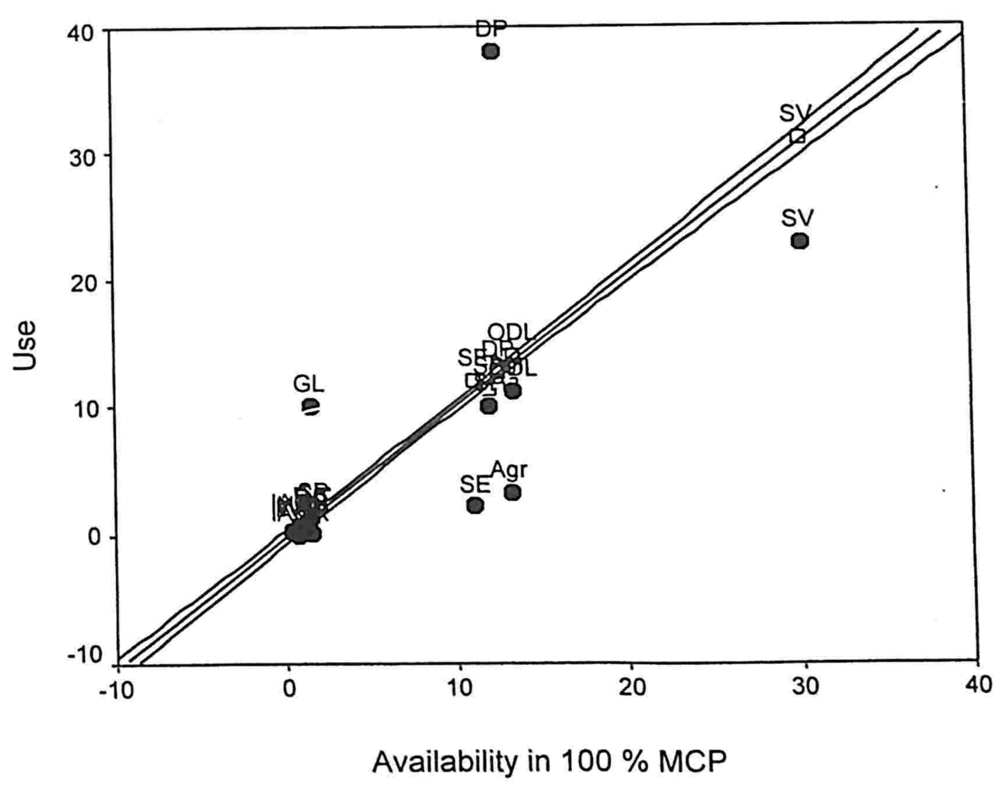
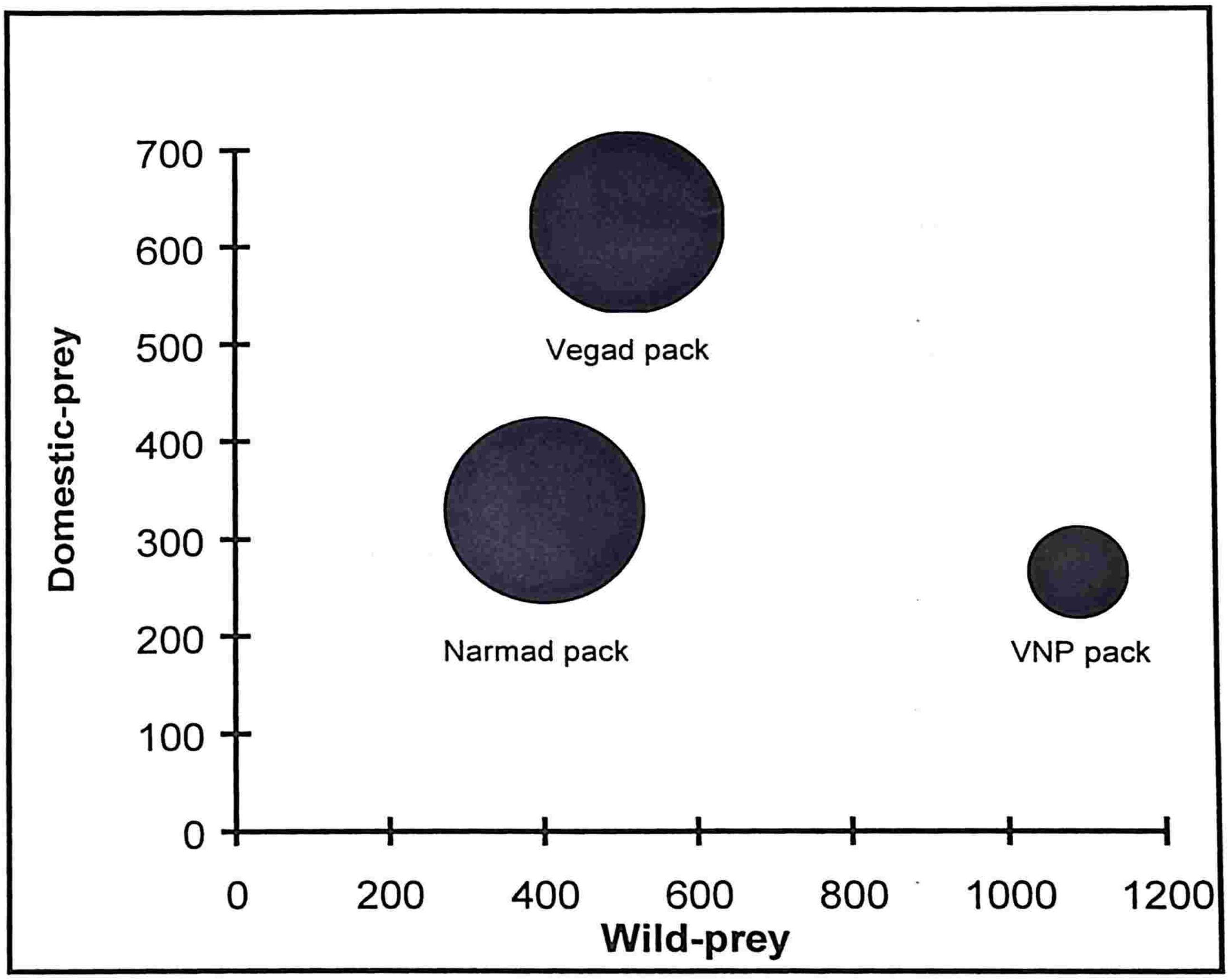


Table 9, Summary of preferred and least used habitats in home range of different wolves/packs obtained by regression analysis.

Animal	Preferred habitats	Least used habitats
Male	Dense *Prosopis*	Open dryland, agriculture fields
Male	Dense *Prosopis*, sparse *Prosopis*	Saline vegetation, open dryland, agriculture fields.
Female	Dense *Prosopis*, sparse *Prosopis*	Saline vegetation, open dryland, agriculture fields.
Female	Dense *Prosopis*, sparse *Prosopis*	Saline vegetation, open dryland, agriculture fields.
Female	Dense *Prosopis*	Saline vegetation, open dryland, agriculture fields.
VNP pack	Grassland, dense *Prosopis*	Saline vegetation, salt exposed land, open dry land, sparse *Prosopis*, agriculture fields.
Vegad pack	Dense *Prosopis*, sparse *Prosopis*	Saline vegetation, open dryland, agriculture fields.
Narmad pack	Dense *Prosopis*,	Saline vegetation, salt exposed land, open dry land, sparse *Prosopis*, saltpan, and wet mudflats
All wolves Pooled data	Dense *Prosopis*, grassland	Saline vegetation, salt exposed land, open dry land, sparse *Prosopis*, agriculture fields.

Fig.29. Home range of three wolf packs in relation to wild-prey and domestic-prey availability studied in the *Bhal* region between 1996-2000. Size of home range is depicted by the size of the object in the figure.



Chapter-6 DISCUSSION

6.1. Feeding Ecology

6.1.1. Scat Analysis:

6.1.1.a. Minimum Number of Hair/Scat and Scats/Packs:

Numerous studies have been done on the feeding ecology of carnivores (Joslin 1973, Johnsingh 1983, Norton *et al.* 1986, Palmer and Fairall 1989, Windberg and Mitchell 1990) based on identifying prey species by hair characteristics from the remains in the scats. But only few recent studies on coyotes (Windberg and Mitchell 1990), leopard and Asiatic lion by Mukherjee *et al.* (1994 a, b) have mentioned the minimum number of hair/scat that are required to be scanned and the minimum number of scats that need to analyze for studying the feeding ecology of the concerned carnivore species. The present study has also standardized the minimum number of hair that need to scan (19-20) and minimum number of scat that need to analyze for studying the annual feeding ecology of different wolf packs and for the wolves of the *Bhal*. Several studies have shown that majority of the wolf scats do not consist of more than one prey species (Murie 1944; Pimlott *et al.* 1969; Haber 1977 and Scott and Shackleton 1980). In the present study also majority of the wolf scats (80.5%) contained only one prey species. Like other food habit studies on wolves (Murie 1944; Pimlott *et al.* 1969; Haber 1977, Scott and Shackleton 1980, Jhala 1993a and Kumar 2000) in the present study also mammalian prey species were found to constitute the large portion of the wolf's diet.

The reason for variation in the number of scat that need to analyze for different wolf packs (164 scats for Vegad pack and 40 scats for Mithapur pack) is likely to their different food habits in terms of diversity of prey. Since mammalian prey constituted majority of the diet of wolves, standardization of the scat analysis technique for studying food habits of different pack of wolves of the *Bhal* would be of a great use for reducing efforts and cost for conducting further food habit studies on wolves in the *Bhal*.

6.1.1.b. Annual Food Habits of Wolves:

Probably every kind of backboned animal that lives in the range of the wolf has been eaten by the wolf (Mech 1970,178 p). Several studies mentioned below, conclude that wolves feed on variety of prey species throughout their range from large mammals to insects. However, one or two species of wild and/or domestic ungulate, which are larger than the wolf's body size, make up the majority of their diet. The present study shows that blackbuck and cattle constitute the majority of food items of wolves in the *Bhal*.

Wolves prey mainly on animals, which are larger than their own body size (mainly on wild ungulates) because of its habit of traveling and hunting in pack and its ability to consume and digest great quantities of food in short periods Mech (1970). Numerous studies have supported this conclusion, Murie (1944), Cowan (1947), Thompson (1952), Pimlott (1967), Pimlott *et al.* (1969), Bergerud (1974), Huston (1978), Holleman and Stephenson (1981), Van Ballenberghe and Hanley (1984), Salvador and Abad (1987), Bergerud (1988), Jhala (1991) Paquet (1992), Patalano and Lovari (1993), Jhala (1993 a), Boyd *et al.* (1994), Forbes and Theberge (1996), Eberhardt (1997), Bergerud and Elliot (1998), DelGiudice (1998), Eberhardt and Peterson (1999), Hayes *et al.* (2000), Wlodzimerz *et al.* (2000). Because the distribution range of the wolf as a species covers over a much larger distribution than any of its prey species, different populations of wolves must prey on different kinds of animals hence in different regions, only one or two species make up most of the wolf's diet (Mech 1970). Elk make up the single largest prey of wolves in certain areas of western Canada (Cowan 1947). White tailed deer composed greatest portion of wolf kills (83.0%) than Elk (6.0%) and Moose (2.0%) in and near Glacier National Park, Montana (Kunkel *et al.* 1999). Caribou and moose composed 51.0 and 42.0%, respectively of the kills observed in Northwest Alaska (Ballard *et al.* 1997). Deer remnants were found in 82.9% of the scats analyzed for studying diet of wolves in Bieszczady mountains of Poland (Muszynska 1996). Wolves in Velavadar National park subsist primarily on blackbuck (Jhala 1993a). The present study on food habits of five different wolf packs using total 1,247 scats in the *Bhal* also suggests that blackbuck, a wild ungulate make the major portion of wolf's annual diet in the *Bhal*, ranging from 86.5% occurrence in Velavadar National Park pack and 50% in Vegad and Narmad wolf pack where as 45.0% in other two packs.

As other studies have showed that if two or more species of large prey inhabit the same region, wolves apparently concentrate on the smallest or easiest to catch (Mech 1970). Several other ungulate species larger than blackbuck such as domestic cattle, buffalo and nilgai also inhabit the *Bhal*. However, wolves have been found to subsist primarily on blackbuck occurring in higher percentage of scats of all the five wolf pack studied in the *Bhal*. Where as the occurrence of cattle, nilgai and buffalo in the scats analyzed in the present study were comparatively lower than that of blackbuck, which confirms Mech (1970).

6.1.1.c. Seasonal Food Habits:

The significantly lower occurrence of blackbuck in summer scats of wolves in compare to winter and monsoon scats of wolves of Velavadar National Park could probably be due to dispersal of blackbuck herds in surrounding areas outside the park for foraging in the fellow fields after the crop harvesting period in summer. The significant higher occurrence of cattle in monsoon scats of wolves in compare to scats of summer and winter may be due to the large number of migratory cattle coming in from the surrounding villages of Velavadar National Park and increasing their availability to wolf predation. The cattle population is stable in monsoon and winter however, in summer productive cattle are taken away from the *Bhal* and weak, unproductive old cattle and male calves are left behind. Poor body condition of weak cattle, unescorted unproductive cattle and male cattle calves make them more vulnerable to wolf predation, this could be the reason for increased relative availability of cattle prey population in the *Bhal* in summer. However, there was no significant difference in occurrence of prey species across four packs in three seasons. This could be due to the consistent availability of prey species throughout year in all the four packs.

6.1.1.d. Comparison of Food Habits of Wolves Inhabiting Protected Area and Non- Protected Area in the Bhal:

In the present study, percent occurrence of wild prey species and domestic prey species differed significantly in the diet of wolves inhabiting protected area (VNP) and non-protected area. This was due to the percentage occurrence of a single species (blackbuck) contributes major portion (87.0%) of the diet of wolves inhabiting protected area due to higher availability of blackbuck in this pack's territory. However, occurrence of other species (cattle, nilgai, buffalo, birds, rodents etc.) was comparatively lower (ranged between 11.0% to 2.0%). While for packs living outside of protected area the drop in blackbuck consumption was compensated by an increase in consumption of domestic cattle. Jhala (1991) has reported that blackbuck, hare, and rodents together accounted for 93.6% of the wolf's diet where as cattle, and nilgai and sheep were rare occurrence and occurred in only one season in the diet of wolves of Velavadar National Park pack at that time nilgai population in the VNP and *Bhal* was very small compared to the current population (Jhala Pers Comm.). In the present study blackbuck, cattle, and nilgai were found to account for >95% of the occurrence in the diet of Velavadar National Park pack reflecting their high availability. The same pattern was also observed in wolf's diet of Vegad pack, Narmad pack, Mithapur pack, and Adhelai pack and in the wolves of entire *Bhal* but with relatively higher percentage occurrence of domestic cattle consumption.

6.1.2. Feeding Interval and Predation:

6.1.2.a. Contribution of Different Prey Species, Biomass and Numbers:

High predation on adult male blackbuck (48%) by wolves could be due to their poor body condition during rutting seasons and old age. Jhala (1991:96) has also reported that the major cause of mortality among blackbuck was wolf predation. Seventy five percent of the examined carcass were over 5 years of age and of these 76% were in poor body condition Jhala (1991:96). Among the males killed by predation, major portion (78%) were in poor body condition and 95% were killed during the rutting season (Jhala1991: 96). Another study by Kumar (1998) reported high predation of blackbuck especially the male blackbuck by wolves during their non-breeding season, however, wolves were found to kill more domestic livestock such as goats and sheep than blackbuck during their breeding season. The age distribution, condition and season during the deaths of these males suggest that energy investment for breeding (primarily establishing and maintaining territories) predisposes male blackbuck with depleted body reserves to predation (Flook 1970). In the *Bhal,* there are two major rutting seasons and two fawning peaks have been observed in the blackbuck population. During these peaks the vulnerability of adult male blackbuck and fawn to wolf predation may be high. In the present study most of the kill were made during night. Blackbuck are diurnal and rely on sight to avoid predation by quick flight (Mungal 1978), they are likely to be at a disadvantage to nocturnal hunters (Jhala 1991).

In the present study of the total blackbuck predation by wolves, fawn contributed 21% which suggests high availability/vulnerability to wolf predation during fawning peak. Jackals, dogs and jungle cat have also been reported to prey on blackbuck fawns in the *Bhal*. Ranjitsinh (1982) estimated that dogs were responsible for killing two to three fawns per day during peak fawning periods. During such period predation by wolves on fawns would be additive to the blackbuck fawn mortality. Predation by these predators on fawn could probably be the major cause for controlling blackbuck population in the *Bhal* (Jhala *et al.* 2001). Bergerud and Ballard (1988) suggests that predation by wolves on young animals was the most consistent natural limiting factor in the dynamics of the Nelchina caribou herd. Wolf predation is a major limiting factor and would retard the rate of increase of the blackbuck population, such an effect would be desirable in areas where blackbuck density reaches high levels causing conflicts with people due to substantial crop depredation. Another high-density population of blackbuck in Gujarat (Visatpura), in absence of the wolf as their chief predator seems to have intense conflict due to crop raiding (Jhala pers comm.).

Lower frequency of domestic livestock (cattle) kill by wolves in the present study could possibly be due to escorted diurnal movement of cattle herds, thus decreasing vulnerability to wolf predation in the wolf territories in winter and monsoon. However, vegetation type in the *Bhal* does not support the browsers such as goats and sheep like other regions (Jhala. Pers. Comm.). There is substantial temporal and spatial variation concerning livestock depredation by wolves, with wolves in some areas relying on domestic prey more heavily than others in certain years (Fritts *et al.* 1992). Most depredations in Minnesota (USA) occur in northcentral and northwestern counties where farm and livestock densities are highest within the wolf range (Fritts *et al.* 1992). Wolves will occasionally prey on livestock, including cattle (primarily calves), sheep, turkeys, swine, and goats, but generally, they occur in the wolf's diet in low amounts, both with respect to the number of individuals and biomass consumed (Fritts and Mech 1981, Fuller 1989, Fritts *et al.* 1992). The areas where wolves depends mainly on domestic livestock are likely to have higher magnitude of human-wolf conflict (Jethva and Jhala 2000 a, b), which would not be desirable for the long-term conservation of the wolf population in such areas. However, in the present study area during the study period very low magnitude of human–wolf conflict was observed in compared to Kutch region of Gujarat where humans persecute wolves, which could possibly be due to the cattle, which are killed by wolves, are mainly those cattle that are unproductive such as male calves and old aged cattle. The predation on such unproductive cattle does not result in significant economic loss to the people. The average cost of such vulnerable male cattle calf is only Rs. 500.0 ($ 10.4 US). Total number of such cattle calves predated per annum is 25 only which results in total economic loss of Rs. 12,500 ($ 260.4 US) annually (Table-5). Hence this could be the reason of no incidences of persecution by human to wolves observed in the *Bhal* during study period.

The carcass of domestic livestock are dumped outside the villages in the *Bhal*, they constitutes major portion of scavenging. The scavenging on cattle carcasses and predation on small animals such as hare and reptiles might supplement wolf's diet and act as buffer between blackbuck hunting intervals.

Biomass contribution of different prey species to wolf's diet also suggests that maximum biomass (70%) was contributed by predation on male blackbuck, however, blackbuck female and fawn contributed only 4.0% each where as scavenging on cattle contributed 14.0%, cattle predation 8.0% and others contributed only 3.0%.

6.1.2.b. Feeding Interval /Kill Interval:

Average feeding interval by wolf packs of the *Bhal* in the present study was estimated to be 3.62 days (SE = 0.73) however, kill interval was 4.54 days (SE = 0.63). However, a study conducted only on one pack, Velavadar National Park wolf pack in the *Bhal* was found to make kills at an interval of 3.5 days (SE = 0.5) Jhala (1991, 1993). Another study on Indian wolf in Nanaj (Maharashtra) (Kumar 1998) has also reported that wolves make kills on an average 3.65 days (SE = 0.58) in Nanaj (Maharashtra). The kill rate estimated in the present study is lower than reported by Jhala (1991,1993 a) and Kumar (1998). Wolves are well adapted to extended fasting as they are for feasting (Mech 1970:182). Of three pack monitored in the present study one pack (Narmad pack) had only two individuals through out the observation period the smaller number of individuals in the pack might have been the reason for less number of kills made by the pack. The kill interval of Narmad pack was relatively larger than that of other two packs, which might be the reason for, estimated larger kill interval for the wolf packs of the *Bhal*.

During the present study wolves of Velavadar National Park pack were not found to scavenge however, wolves of two other packs situated outside Velavadar National Park were observed to scavenge on domestic livestock. Wolves are potentially good scavengers (Mech 1970). Scavenging is an important component of wolf feeding behavior (Fox and Chundawat 1995, Boitani 1982, Mendelssohn 1982). The kill intervals mentioned in other studies (Jhala 1991, 1993a, Kumar 1998) and feeding interval in the present study were found to be similar, this could possibly be due to the supplementary food acquisition through scavenging events by other two wolf packs outside the Velavadar National Park in the *Bhal*.

6.1.2.c. Consumption /wolf/day:

Average consumption /wolf/day calculated from continuous monitoring of three wolf packs in the *Bhal* was 1.84 kg (SE = 0.29), which is higher than reported (1.33 kg.) for the same sub-species at Velavadar National Park (Jhala 1991,1993a) and (1 kg) in Nanaj, Maharashtra. Studies by Jhala (1991) and Kumar (1998) are likely to have underestimated the consumption/wolf/day, since these studies were not based on radio collared wolves they are likely to have missed feeding events on smaller prey and scavenging events. However, the consumption of 0.1 kg/kg of wolf/day is within the range reported (0.06 Fuller 1989 to 0.22 Peterson 1977) for other sub species of wolves of the world. Wolves of a breeding pack in captivity at Sakkarbaug Zoo, Junagadh were fed 1-1.2 kg meat/wolf/day (Bhuva pers. Comm.). Wolves were observed to have higher intake in the wild (Fuller and Keith 1980 and Mech 1970:184-185). Since wolves have distensible stomach and meat diets have high digestibility wolves can consume large quantities of meat when available (Mech 1970: 181-185).

6.2. Prey Availability:

6.2.1. Domestic Prey:

Vulnerable domestic prey e.g. cattle and buffalo availability was higher in the home range of Vegad pack as compare to Narmad and VNP pack home ranges. The higher vulnerable domestic prey availability could be due to presence of more number of villages (10) in and around the Vegad pack home range. The number of villages was few in and around the Narmad pack (7) and VNP pack (6) home ranges.

6.2.2. Wild Prey (Blackbuck):

Availability of blackbuck was higher within the home range of VNP pack when compared to Vegad and Narmad wolf packs. Velavadar National Park is protected grassland with higher biomass productivity is likely to support more blackbuck than unprotected areas outside Velavadar National Park. Narmad and Vegad pack home ranges are situated in the areas with high domestic livestock density, which could possibly compete with blackbuck population for food resources. Numbers of water sources with continuous water availability are more in Velavadar National Park than in the areas inhabited by other two packs outside the protected area.

6.3. Home range and Habitat Analysis:

6.3.1. Home range Analysis:

Information on the size, shape and spatial distribution of wolf / wolf pack home ranges and their core areas are extremely important for any conservation or management activities in the area where wolves inhabits. Present study has produced such information demarking the boundaries wolf / wolf packs home range and core areas in the *Bhal* based on data collected by using radio telemetry techniques.

Estimates for individual home ranges reach asymptotes at different values and with a variety of curves, depending on the pattern of home range utilization and range size for that particular animal (Harris *et al.* 1990). Some animals may never reach an asymptote; this may occur when the individual is a transient adult, a dispersing sub adult, or when the time interval for calculating the home range is inappropriate (Harris *et al.* 1990). In the present study the male wolf was old and loner wolf when trapped and after that he joined the pack (Vegad pack) and became an alpha male the reason for not reaching asymptote for this wolf could be due to its age.

The home ranges and core areas of three wolf packs were exclusive and there was very negligible temporary overlap between two pack's home ranges. Wolves rarely trespassed in to other wolf territories only one incidence resulted in overlap of wolf territories using 100% MCP, however 95% MCP showed completely exclusive territories.

Tress passing or overlap in home ranges of wolf packs results mainly due to lack of prey in the resident territories (Zimen 1976). Hoskinson and Mech (1976) and Mech (1977) found that wolves stayed within their resident territory until deer (major prey species) declined, wolves then trespassed but only into adjacent packs. Potvin (1987) believed that the lack of movement in Papineau-Labelle, Quebec was due to the continuous availability of small numbers of deer within territories. Data on food habits of wolves in the present study and Jhala (1991) have found that blackbuck is the major prey species and domestic cattle are second major prey species for wolves in the study area. The population estimations of blackbuck and cattle in three wolf territories in the present study have showed that there is substantial population of blackbuck and vulnerable cattle in their territories. Hence the reason for exclusive wolf territories could possibly be due to continuous availability of blackbuck and vulnerable cattle in the region throughout year.

Home ranges estimated in this study were not compared since present study is the first effort to quantify home ranges of wolves in India using radio collars. The average home ranges of wolf packs (using 100% MCP 113.4 ± 24 (SE) km^2 with range 65.2 - 138.70 km^2) was found to be higher than reported for the Ethiopian wolves (Sillero-Zubiri, and Gottelli 1995) having typical home range size 4-15 km^2. However, it was within the lower range of gray wolf's home ranges reported in North America (Mech 1970, Mech 1973, Van Ballenberghe *et al.* 1975, Fritts and Mech 1981, Berg and Kuehn 1982, Fuller 1989). Forbes and Theberge (1995) reported 63 km^2 to 387 km^2 with average home range size 149 km^2 in Algonquin between 1987-1992. Pimlott *et al.* (1969) reported home ranges between approximately 100-310 km^2 in Algonquin Provincial Park, Ontario, Canada. Much larger home ranges have been reported from Alaska 12,950 km^2 Burkholder (1959). Between these extremes there are reports of ranges around 1,400 km^2 from Alberta (Rowan 1950), 224 km^2 from Ontario (Kolenosky 1972), more than 110 km^2 from Minnesota (Mech *et al.*, 1971; Mech 1973, 1974), 1,050 km^2 from Finland (Pulliainen 1965) and 500 km^2 and 600 km^2 from Sweden (Haglund 1968 and Bjarvall and Isakson 1982). Variation in home range sizes is the result of differences in methodology and /or the duration of data collection, there are also differences, which reflect habitat or prey densities Mech (1970:164)

In the present study minimum estimated home ranges of lone male wolves (227.6 and 181 km^2) were higher than that of wolves associated with packs (98.1 km^2). The lone wolves cover much larger areas than packs or, restrict their movements to areas between established, pack territories (Mech *et al.* 1971, Ream *et al.* 1985). The movement beyond the resident territory has been confined to dispersal or pre-dispersal forays by sexually maturing individuals (Fritts and Mech 1981, Ballard *et al.* 1987, Fuller 1989, Gese and Mech 1991).

The home range size of VNP wolf pack was found to be much smaller than that of the other two packs. The VNP pack inhabits a protected area where as other two wolf packs inhabits area outside the protected area. The home range is an area with a certain productivity that meets the energy requirements of the individual or group that occupies it (Jewell 1966). Scott and Shackleton (1980) found that relatively small home range size of wolves on Vancouver Island suggests that their habitat supported high densities of their major prey. Hebert (1979) and Hebert *et al.* (1982) have reported high densities of black-tailed deer (major prey of wolves) on Vancouver Island. Ballard *et al.* (1997) suggested that winter territories were larger than those during summer due to large differences in density and distribution of prey, relatively low prey densities during winter caused wolves to range over larger areas to find vulnerable prey. The data on blackbuck population estimation in the present study across the three wolf pack home ranges has reveled that wolves inhabiting Velavadar National park have large number of blackbuck (major prey of wolves) available compared to two other wolf packs inhabiting outside the protected area. Hence prey abundance could be one of the major reasons for relatively small size of home range of VNP pack.

The spatial distribution of wolf packs suggests that wolves seem to have optimized their territory boundaries in order to include villages inside their territories, which are rich in resources for scavenging. Livestock rearing is one of the major occupations of people of the *Bhal* hence these villages are potential sources for scavenging on dead livestock carcass dumped outside the villages. Data on feeding events collected by continuous monitoring of radio collared wolves in the present study have revealed that scavenging on dead cattle carcasses outside villages form 21% of the total feeding events. In the present study most of the scavenging events happened during nights. Wolves are potentially good scavengers (Mech 1970) and scavenging is an important component of wolf feeding behavior (Fox and Chundawat 1995, Boitani 1982, Mendelssohn 1982). Wolves move toward urban centers, valleys and areas inhabited by humans in search of food (Boitani 1982). In many wolf areas of Italy there are two to three villages, which with their rubbish, can amply sustain a pack of wolves

(Boitani 1982) and the size of the pack home range was probably also a function of the number of rubbish tips required by the entire pack, their boundaries, appeared mostly delimited by topography and human settlements and infrastructures (Ciucci *et al.*1997). The *C. l. pallipes* population in Israel subsists to a considerable degree, by scavenging at garbage dumps (Mendelssohn 1982). Hence adjustment of villages within their home range would benefit wolves in food acquisition by scavenging and would serve as buffer between kills.

6.3.2. Habitat Use/Preference:

Wolves did not use their home ranges uniformly. Most of the radiolocations plotted were in the center of the home ranges. These areas of home ranges with high concentration of radiolocations were devoid of human disturbances, dominated by dense vegetation cover (*Prosopis juliflora* 32.7%) and had fresh water accessibility. These areas corresponded to core areas of wolf pack home ranges and used as lying up sites during daytime, den sites during breeding season and rendezvous sites post denning period for pup rearing. Ciucci *et al.* (1997) has also reported that core area of a wolf pack was located toward the center of home range where human disturbances and road densities were lowest but forest cover was highest. Distance from human settlements of wolf pack core areas help reduce disturbance from people (Boitani 1982 and Ciucci *et al.* 1997).

Wolves in the present study restricted themselves to dense *Prosopis juliflora* patches within their core area during the daytime in summer and winter to seek visual cover and protection from sun probably to regulate their body temperature and avoid human disturbances. Study on temperature regulation by C. *l. pallipes* in Israel (Afik and Pinshow 1993) have concluded that wolves are physiologically better equipped to survive in cold or temperate climates, rather than in hot, dry climates, therefore wolves can inhabit hot regions by behavioral temperature regulation i.e. by limiting activity to the cooler hours of the day and by non-frugal use of water for evaporative cooling. Jhala (1991) and Kumar (1998) have also reported that wolves used scrubland during the daytime hours for lying up, as rendezvous site, to protect them from temperature and to avoid human disturbances.

Almost all the active den sites were located within the core area and their locations appeared to represent ideal spatial compromise between the closest proximity to fresh water, avoidance of human disturbances such as villages and roads, and proximity to vegetation cover. Apart from blackbuck population, such core areas with combination of vegetation cover, less human disturbances and fresh water accessibility are becoming limiting in the *Bhal* therefore such areas are of great importance to manage the wolf population in this region. Present rate of increase in developmental activities in this region may result in loss of such important core areas for wolf pack and would certainly affect wolf population.

Dense *Prosopis*, grassland and sparse *Prosopis* were preferred habitat types as these habitat types obtained high rank (1-3) in compositional analysis using habitats present in 100% MCP as available habitats and the habitats in which wolves were located were considered as used habitats. Dense *Prosopis*, sparse *Prosopis* and grasslands provide visual cover and protection from harsh environmental conditions as also reported by studies on the similar wolf sub-species in India (Jhala 1991, and Kumar 1998). Wolves were considered 'migrant' visitors into Velavadar National Park (Mungall *et al.* 1981,1983 Ranjitsinh 1982) however, due to increase in cover in the form of *Prosopis juliflora* wolves have made Velavadar their home (Ranjitsinh 1989:64). *Prosopis* patches were not rich in food resources for wolves and grasslands were not present in the home ranges of two wolf packs (Vegad pack and Narmad pack). The reason for preference of grassland showed by VNP pack could possibly be due to the presence of two dens in the grassland during the study period which would have restricted the movement of breeding pair in proximity to dens and another factor could possibly be their repeated visits to blackbuck lekking ground situated in grassland for hunting and feeding. Evidently majority of blackbuck kills made by VNP wolf pack were in the lekking ground where rutting male blackbuck were easy to kill.

Compositional analysis done by using all the habitats present in 100% MCP as available habitats and core area (50% Harmonic Mean) as used habitats (Table-4) has also showed dense *Prosopis*, Grassland, freshwater, with sparse *Prosopis* as preferred habitat types. Preference of fresh water area as core areas of wolf pack territories again emphasizes the optimized selection of habitat. During monsoon rainy water is available throughout animal's range due to low elevation, flooding and flatness of the region, however, fresh sources starts decreasing in the beginning of winter (breeding season of wolves) and by the end of December and beginning of January depending on rainfall, fresh water availability decreases drastically in the region. For habitat analysis by wolves in the present study satellite imageries of winter were used therefore considering the smaller areas with fresh water as use in compared to entire home range resulted in high ranking of this habitat type in compositional analysis. Bigger canids, usually of the genus *Canis*, cannot fulfill their water needs without drinking and are dependent on free water for at least a part of the year (Golightly and Ohmart 1984, Meir and Shkolnik 1984). Hence fresh water availability is probably the key habitat characteristic for core area selection.

Habitats avoided by wolves were mainly those habitats, which had low productivity or prey availability, high human disturbances and more open without cover. Wet mudflats, saline salt exposed land and ocean water were among the avoided habitats probably because of very low prey availability, and are open and devoid of vegetation structure. Saltpans, agriculture fields and irrigated agriculture fields were also influenced by human disturbances hence these areas were avoided. Saline vegetation, open dry land and roads/tracks were used mainly for traveling during the nights to blackbuck hunting ground and drinking water.

Regression analysis with 95% confidence interval has also showed almost similar habitat preference pattern by individual wolves and wolf packs. Dense *Prosopis*, grassland and sparse *Prosopis* were among the preferred habitats where as other habitats open dry land, agriculture fields, saline vegetation, saltpans, wet mudflats, salt exposed land were among the avoided habitat types.

CONCLUSIONS

- Data on food habits studied by scat analysis of wolves of 5 packs and predation by continuous monitoring of radio collared wolves from 3 packs showed that wild prey species dominated in the diet of wolves in the study area, which is rare when compared to reported food habits of wolves else where in India.
- Higher occurrence of blackbuck in the diet of wolves of five packs suggests that blackbuck is an important prey species for wolves in the region. However, higher contribution of blackbuck in the diet of wolves in protected area (Velavadar National Park) having higher availability of blackbuck then that of wolf packs inhabiting outside protected area reflects the importance of protected area for conservation of such endangered species.
- Only 8.0% of the biomass to the diet of wolves was contributed by predation on cattle. The cattle, which were killed by wolves, were mostly unproductive resulting in a negligible economic loss to the local people.
- There are 5-6 wolf packs in the *Bhal* region of Bhavnagar district with an average territory size of 113 km^2, this region could serve as a source population for wolves.
- With average pack size 4.5 adult wolves/pack there are 13.5 wolves with density of 2 adult wolves/100 km^2 in the intensive study area (550 km^2) in the *Bhal* of Bhavnagar district.
- Territory boundaries of wolf packs were exclusive and showed optimization in order to include villages, which were rich in resources for scavenging.
- Core areas of wolf territories were identified and appeared to be ideal spatial optimization of the availability of vegetation cover in the form or *Prosopis juliflora*, closest proximity to fresh water and avoidance of human disturbances such as villages and roads.

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