RANGING, ACTIVITY PATTERNS AND HABITAT USE OF BLACKBUCK AND NILGAI IN VELAVADAR NATIONAL PARK, GUJARAT, INDIA.

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT, IN PARTIAL FULFILMENT OF THE MASTER'S DEGREE IN WILDLIFE SCIENCE, JULY 2001

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CERTIFICATE

This is to certify that Ms. H. Dhanushki R. Sahabandu of the Wildlife Institute of India has carried out original research titled **"Ranging, Activity Patterns, and Habitat Use by Blackbuck and Nilgai in Velavadar National Park, Gujarat, India"** towards the partial fulfillment of the Master of Science (Wildlife Science) degree from Saurashtra University, Rajkot, India. These investigations were carried out under our supervision from November 2000 to June 2001. We also certify that this research has not been submitted for any other degree to any university.

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To

Thathi and Ammi

for their love and support

To laugh often and much; to win the respect of intelligent people and the affection of children; to earn the appreciation of honest critics and endure the betrayal of false friends; to appreciate beauty, to find the best in others; to leave the world a bit better, whether by a healthy child, a garden patch, or a redeemed social condition; to know even one life has breathed easier because you have lived. This is to have succeeded.

-Ralph Waldo Emerson

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SUMMARY

I studied the activity patterns, ranging and habitat use of blackbuck (*Antelope cervicapra rajputanae*) and nilgai (*Boselaphus tragocamelus*) in Velavadar National Park from November 2000 to April 2001.

Scan sampling was used to record blackbuck and nilgai activity patterns. Herds were also followed from sunrise to sunset to study the diurnal movements. Satellite imagery was used for vegetation mapping. Habitat availability and usage of both species were examined by plotting the grazing circuit on the satellite imagery.

Activity patterns were found to differ amongst the various social groups, habitats and seasons. Temporal variations in foraging time and resting time were found in all the groups studied. Blackbuck had three foraging peaks and two resting peaks as compared to nilgai, which had two, and one peaks respectively. Diurnal distances were not found to differ in any of the different blackbuck or nilgai groups or between the two species.

Differences between blackbuck herds in different seasons and habitats were attributed to the nutritional levels and the spatial dispersion of vegetation. Foraging behaviour decreased in summer supporting results of previous studies that blackbuck reduced foraging due to lower nutrition levels. Male blackbuck was found to forage 67% compared to 58% by females. This difference was attributed to larger body size in males, and the upcoming rutting/lekking season. No difference was found between nilgai males and females, except usage by females was slightly more in high nutritional areas. Female

nilgai were found to become more selective in summer, by increasing their foraging time from 43% to 55%. But no difference in habitat usage was found, possibly due to sustenance from *Prosopis juliflora* pods.

Blackbuck were found to spend more time foraging (53%) compared to nilgai (43%). This was due to blackbuck being more selective in the prevailing drought conditions, while nilgai were possibly supplementing their diet with *P.juliflora* pods. Differences between the two species in temporal allocation of foraging time was found which was ascribed to difference in gut capacity. No seasonal differences were found between the two species, except that nilgai were found to be using high nutrition areas. Nilgai were found to be more selective nutritionally than blackbuck, possibly due to nilgai being an intermediate feeder compared to blackbuck, which are coarse bulk feeders.

CHAPTER 1

INTRODUCTION

1.0 GENERAL INTRODUCTION

Energy demands in animals is indicated by the amount of time that is spent foraging (Fancy and White 1985, Bunnell and Gillingham 1985). Its survival and reproduction depends on how this energy is obtained and time spent (Bunnell and Harestad 1989). Thus time spent in foraging is an insight into the strategies that animals adopt to survive and reproduce (Bunnell and Gillingham 1985). Allocation of foraging time is faced with a number of constraints such as body size, diet, digestive system capabilities and mode of locomotion (Bunnell and Harestad 1989).

Differing resource selection is one of the principle factors, which permit species to coexist (Rosenzweig 1981). The differences are determined by factors including body size, gut morphology and function, sex and reproductive state and a variety of other environmental factors (Demment and Van Soest, 1985, Jarman 1974, Hanley 1982). The habitat use patterns as influenced by these factors is a comparison that provides insight into the factors affecting choices made by animals.

The aim of this study was two fold, firstly to attempt to examine the flexibility of foraging strategies taking in to account constraints such as body size, digestive differences and sex differences. And secondly to determine the variation in patterns of habitat use with body size, digestive differences, sex differences and differences between species.

1.1 LITERATURE REVIEW

An extensive body of literature exists on ungulate activity budgets, foraging behaviour and its relationships with body weight, habitat patchiness. However in the present study I have attempted to review literature that is most relevant to my study objectives. This review largely pertains to, ungulate activity budgets; foraging strategies and its relations to factors such as body size. And the second part overviews sympatric ungulate habitat use and differences in habitat use between seasons and sexes.

1.1.1 BLACKBUCK AND NILGAI

A large number of descriptive studies exist on blackbuck (*Antelope cervicapra rajputanae*), in wild free ranging conditions and also as an introduced exotic (Dharmakumarsinhji 1978, Jerdon 1874, Mungall 1978, Ranjitsinh 1982,). Mungall (1978) described blackbuck life history, behaviour and food habits. The study described 24 hour activity budgets, and it was concluded that the activity was polyphasic, with its basic form being predictable. Environmental parameters supposedly contributed to change. Nocturnal activity was found to be minimal, since it was dominated (65%) by 'lying' behaviour. In India, they are said to start show a two foraging peaks, one in the morning till noon and the other in the late evening (Bohra *et al.* 1992, Pandey *et al.* 1986).

A long term study conducted on blackbuck nutritional ecology in Velavadar National Park, determined that blackbuck primarily used grasslands with *Dicanthium annulatum* and *P. juliflora* pods contributing 35% and 9.5% to the annual dry matter intake respectively (Jhala 1997). Estimated seasonal forage consumption and digestibility suggested that consumption was high in the monsoon and winter seasons, and low in summer.

Ecological studies on nilgai (*Boselaphus tragocamelus*) covered different aspects such as ranging and food habits (Sankar 1994, Haque 1990, and Sheffield *et al.* 1983). A study on the social behaviour, home range and movement patterns, population dynamics and food habits of nilgai was conducted in Texas (Sheffield *et al.* 1983). The data showed two diurnal activity peaks with one 1-2 hours after sunrise with a steady decline to a minimum in early after noon. Evening activity approached a peak at sunset and continued into the night. Nocturnal activity was high in the first two hours after dark and then subsided to a sporadic level during the remainder of the night. Home ranges were found to be on average 4.3 km^2 (n=9). In Rajasthan, home ranges of male and female nilgai in winter were found to be 7.3 and 2.3 km^2 (Sankar 1994). A study conducted in Nepal also describes two peaks of activity, at 0700 and 1800 hours (Dinerstein 1979).

Habitat preference in nilgai was shown towards root plowed areas with scattered ponds and cover (Sheffield *et al.* 1983). It was also seen that when forage became sparse nilgai increased their woodland feeding, seeking evergreen browse and acorns. By rumen analysis and bite studies it was determined that nilgai consumed 60% grass, 25% forbs and 15% browse and 65% grasses 26% forbs and 9% browse respectively. Here, the habitat preferred was found to be subclimax vegetation, with vegetation in middle successional stages, spending more time in short grass savannas rather than tall grass riverine forests where visibility was poorer, escape difficult and predators numerous.

The classification is also important to define the questions at hand as the foraging strategies also depend on body size, diet type (Jarman 1974). Blackbuck is a semi arid plain's species. They thrive in places where the vegetation is not too dense, the climate is

not too moist, the temperature does not fall too low and the topography is not too rugged (Jerdon 1874). In the semi arid zone, such as in Velavadar National Park, plant growth is restricted to the monsoon season. Thus for the remaining months the grass is dry and mature. Thus according to Hoffman and Stewart 1972) they would classify as a roughage feeder, but a selective one. On the other hand blackbuck is a small sized antelope of approximately 26-35kg (Mungall 1978) and a social gregarious species with mixed herd size of more than 100+ on average (Ranjitsinh 1982). Thus according to Jarman's (1974) classification of African antelopes, it would fall in the category 'C' based on its small body size and larger groups sizes. According to Hoffman and Stewarts (1972) classification of nilgai, it would classify as an intermediate feeder. And vaguely fall in class D, with its larger body size and smaller group sizes. Group sizes of nilgai in Velavadar National Park vary from two to 20+ (Jarman 1974). The nilgai is widely considered a browser or mixed feeder (Rodgers 1988, Sankar 1994). But in the Sheffield study (1983) nilgai were seen to be mainly grazers in a system where browse was less available. Thus the classification of an intermediate feeder probably best defines the nilgai.

1.1.2 Activity Pattern

The flexibility of the basic activity patterns with regards to day and night time activity, seasonal variations, its relations to social status and the costs of territorial activities on the male, was brought out in a study on impala (*Aepyceros melampus*) (Jarman and Jarman 1973). Another study in gerenuks (*Litocranius walleri*) and giraffes (*Giraffa camelopardalis*) showed high degrees of variation in the activity pattern, being influenced by such factors as the social environment, reproductive status, predators and weather (Leuthold and Leuthold 1978). They also found that the daily pattern showed alternation between ruminating and feeding periods but found it difficult to substantiate quantitatively though evident qualitatively.

1.1.3 FORAGING STRATEGIES AND ITS RELATION TO BODY SIZE, DIET TYPE, SEX AND DIFFERENT HABITATS

Basal metabolic rate (kcal/kg/day) decreases nonlinearly with increasing body weight and the total metabolic requirement (MR kcal/day) of herbivores increases as

$$MR = 70\ W^{.75}$$

Where W is weight in kg (Kleiber 1975). MR increases with weight at a decreasing rate, thus large animals require more total energy, while smaller herbivores require more energy relative to their body weight (Demment and Van Soest 1985). Gut volume is a constant proportion of body weight (Demment 1982, Demment and Van Soest 1985). And both these factors affect the retention time of food in the gut and the extent of digestion of the diet. Thus body size has been considered as a possible mechanism for interspecific differences in diet (Van Soest 1982). Thus large herbivores should have a greater food requirement than smaller ones and would thus need to spend a larger proportion of time feeding than the latter (Bell 1971). But a study across mammals showed a tendency for mammals to allocate the same amount of time to foraging or total activity unhindered by body size (Bunnell and Harestad 1989). Herbivores were found to increase the time spent in active behaviour, foraging as well as their moving:foraging ratio when forage quality is the major difference in foraging conditions. Medium sized mammals were found to be mainly diurnal, due to the larger gut capacity and increased foraging efficiency. The larger mammals were found to be less constrained by predators but due to their higher absolute energy requirements tend to be more active over 24 hours.

Underwood (1983) described the variation of foraging behaviour with body size, feeding specialization and seasons in a range of African ungulates. Bulk/roughage feeders and intermediate feeders were found to differed in the relative amounts of time or energy

that is spent on food search and ingestion. Bulk/roughage feeders were found to spend more time feeding per site and accepted more feeding sites. While intermediate feeders spent less time feeding per site and accepted few sites. The main distinction between the species was found to be between the bulk/roughage feeders and the intermediate feeders and that the effect of body size is secondary to this. Seasonal differences in feeding patterns were found to be distinct between two areas as well. Blackbuck and nilgai being of two different size classes, and should be expected to follow the general trends, except for the confounding problem of their feeding strategy. Blackbuck are small bodied bulk coarse feeders and nilgai are large bodied browser/intermediate feeders.

Differences in foraging efficiency between sexes was found in red deer (*Cervus elaphus*) that the allometric relationship between foraging efficiency and incisor arcade was found to reduce the foraging efficiency in male calves and stags when feeding on depleted resources (Illius and Gordon 1990). Another study on Soay sheep (*Ovis aries*) showed female bite sizes to be smaller than males but female bite rates were higher (Perez-Barberia and Gordon 1999). It was determined that males show changes in activity during the breeding period. The time costs for males for facilitating reproduction during the breeding period was found to be quite substantial (Bunnell and Harestad 1989).

Foraging strategies were found to differ between habitats in dorcus gazelle (*Gazella dorcus*) (Lawes and Nanni 1993). Where food is more clumped and abundant gazelles were found at higher densities and have a complex social structure. It was determined that they adopt an energy maximising foraging strategy and are less selective feeders. Schoener (1969, 1971) suggested two possible types of foraging, that of time minimises, which stops foraging after obtaining some net energy requirement and energy

maximizes, which forages through out the entire period. The shortcomings of such a description is outlined in detail by Stephens and Krebs (1986) and Hixon (1982). How foraging strategy relates to habitats with varying patchiness to a small bodied coarse feeder and to a large bodied intermediate/browse feeder

Seasonal differences pulls the comparison into another dimension, that of resource scarcity. The study was conducted over that of winter and the beginning of summer. A point to be noted is the on going drought in the land and that the growth period after monsoon might have been minimal. And that due to time constraints the summer sampling was conducted during the very beginning of summer. Differences in foraging strategies either as time minimizes or energy maximizes should occur considering the depleted resources. According to Jhala (1991) blackbuck in Velavadar blackbuck considerably decrease their total forage consumption, as it becomes more and more unprofitable to process, losing more proteins than it gains. How this depletion affects nilgai is unknown, except that it is speculated to raid crops largely. But during this season, the dearth of crops outside the park, leaves us only with speculations about its impending strategy. Comparing the two strategies that the two species take up with the approaching resource crunch will be revealing. Considering all the differences of the two species, its flexibility and adaptability to cope under such stressful conditions will be interesting.

1.1.4 HABITAT USE AND AVAILABILITY

Differential resource selection is one of the principle factors, which permit species to coexist (Rosenzweig 1981). It is generally assumed that animals will select a habitat that will be best able to satisfy its requirements and thus high quality resources will be

selected more than low quality resources. But since availability is not uniform, use may change accordingly. Therefore to determine resource selection used resources should be compared to available resources. When resources are used out of proportion to their availability it is said to be selective (Manly *et al.*1993). Preference differs from selection in that if it is offered on an equal basis and it is selected then it is said to be preferred (Johnson 1980).

Sympatric ungulates tend to use their environment in differing ways, which are determined by factors such as body size, gut morphology and function, sex, and reproductive state and a variety of others (Hoffman and Stewart 1972, Hanley 1982, Jarman 1974, Demment and Van Soest 1985). A large number of studies have also been conducted on ungulate habitat use and its relation to sympatric ungulates (Cairns and Telfer 1980, Carson and Peek 1987, Ben-Shahar 1990, Ben-Shahar and Skinner 1988, Shannon *et al.* 1975, Doergeloh 1998, Tufto *et al.* 1996, Latham *et al.* 1997, Putman 1986).

Selection can occur at a number of levels for habitat, plant species or for plant parts (Jarman and Sinclair 1979). The present study was conducted as per design one (Manly *et al.* 1993) at a population level, where resource availability and use was sampled for the entire study area and most animals within it. Individual animals were not identified. The other two levels at which resource selection studies have been conducted is when individual animals have been identified and the resource use is measured for each, but availability is measured for the population. Or when resource use as well as availability is measured for individually identified animals.

Selection was found to change with body size, the largest grazers studied, buffalo (*Syncerus caffer* Sparman) and zebra (*Equas bruchelli*), hardly selected for plant parts or

species at all in the wet season (Jarman and Sinclair 1979). These species have relatively less requirements of dietary protein so that even without selection buffalo consume twice the food quality they require. By contrast small species such as impala select habitat, plant species and plant parts in all seasons. Despite this selection their protein intake is relatively less rich in quality that the buffalo's but does not decline as rapidly or as much in the dry season.

Differential habitat use by sexes has been reported in roan antelope; where bachelor males were spatially segregated from the breeding herds (Dorgeloh 1998). Spatial segregation was also found between non burnt areas and also in newly burnt areas.

Patterns of habitats use is found to also change between seasons in bighorn sheep, and was related to a number of environment variables (Shannon *et al.* 1975). Home range size variations has been related to body size dependent metabolic requirements (McNab 1963). And declining rates of utilizable energy in the environment with increasing body weight (Harestad and Bunnell 1979). It was also found that the differences in weight alone account for a large portion of the differences between male and female home ranges (Harestad and Bunnell 1979).

Other studies that examine patterns in habitat use amongst sympatric ungulates, also found that a considerable amount of selection occur for habitat types depending on the needs and specialisation of the species (Cairns and Telfer 1980, Ben-Shahar 1990). Putman (1986) studied the niche overlap and competition between five species of ungulates and found that the most significant overlap was in the diet.

1.2 OBJECTIVES

1.2.1 BROAD OBJECTIVES

- To estimate the time activity budgets of nilgai and blackbuck between different social groups, habitats and seasons.
- To estimate the resource availability and utilization patterns of blackbuck and nilgai.

The above broad objectives were used to generate specific hypothesis to be tested with field data.

H_1: Do blackbuck and nilgai differ in activity patterns?

H_2: Are there differences in activity pattern between habitat in blackbuck and nilgai?

H_3: Is there a difference in activity patterns between sexes in blackbuck and nilgai?

H_4: Is there a difference in activity patterns between seasons in blackbuck and nilgai?

H_5: Do blackbuck and nilgai differ in the utilization pattern of their habitats?

H_6: Is the habitat use patterns different between habitats in blackbuck and nilgai?

H_7: Are the habitat use patterns different between sexes in blackbuck and nilgai?

H_8: Is the habitat use patterns different between seasons in blackbuck and nilgai?

1.3 Study Area

Velavadar National Park (21° 56'N, 72° 10' E) in the region of Saurashtra, Gujarat (Fig. 1.1) harbours one of the largest wild populations of blackbuck of approximately 1300 animals in 1990 (Jhala 1991). VNP is a 34.08km^2 park of semi- arid grasslands, shrublands and bare saline regions. The park is just above sea level and is only 18km from the Gulf of Cambay (Ranjitsinh 1982). It is located in the *Bhal* region, which covers an area of about 2590 km2. It is a saline flat tract of land formed by the natural reclamation of riverine silt of the various rivers opening into the Gulf of Cambay and the

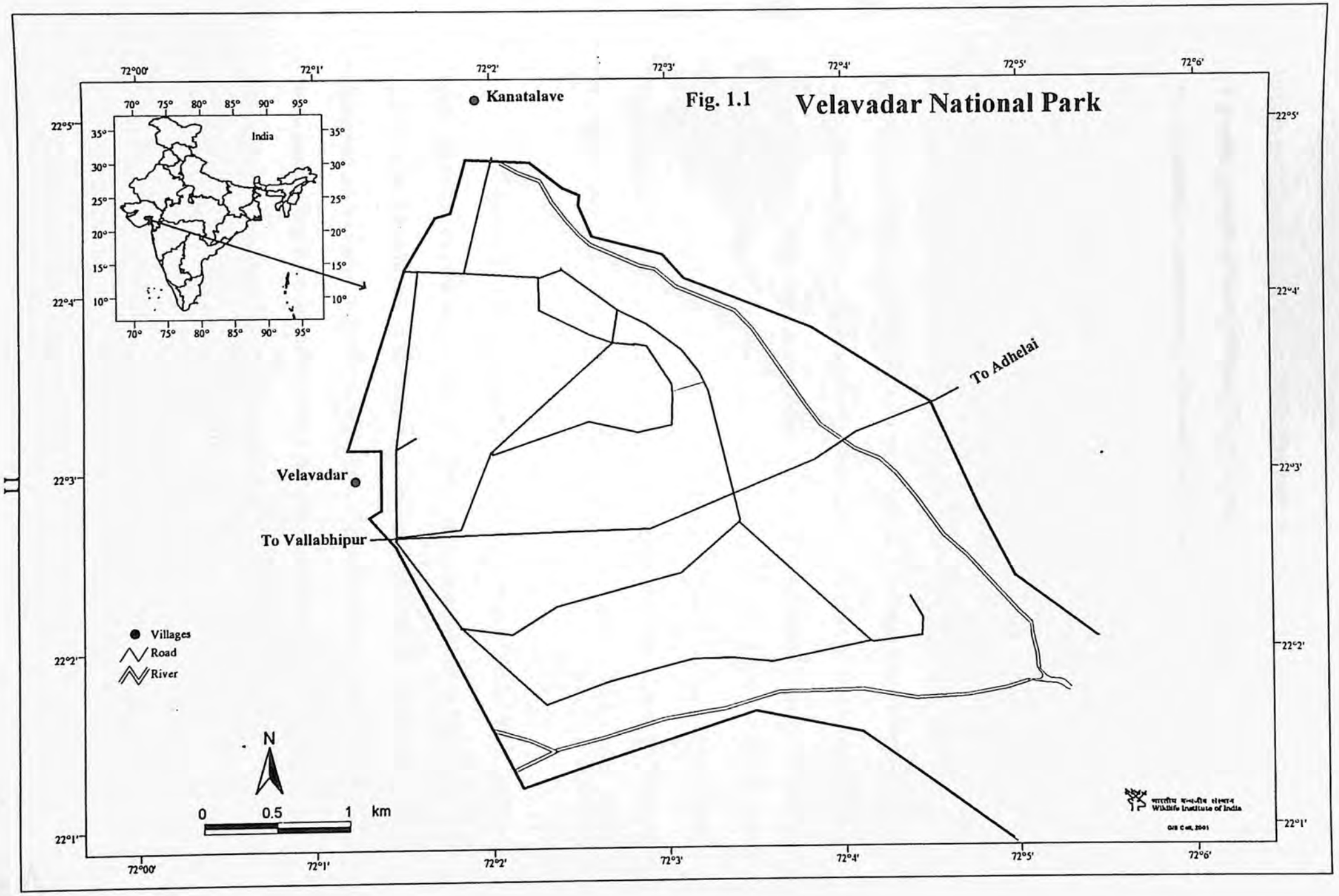
Fig. 1.1 Velavadar National Park
Kanatalave
India
To Adhelai
Velavadar
To Vallabhipur
Villages
Road
River
N
0 0.5 1 km
72°00'
72°1'
72°2'
72°3'
72°4'
72°5'
72°6'
22°5'
22°4'
22°3'
22°2'
22°1'
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Wildlife Institute of India

Arabian sea (Dharmakumarsinhji, 1978). The park is surrounded by agricultural fields and grazing grounds of five villages. The *Bhal* alluvium which composes one of the richest grasslands, is mainly now a cultivated tract (Dharmakumarsinhji, 1978).

Climatic extremes are normal for the *Bhal*. The land is baked in summer and drenched in monsoon. Three seasons can be distinguished in Velavadar: the Monsoon (end June- mid September) October is a transition period with sporadic showers, winter (November-February) and summer (March-June) (Jhala 1991). The study was conducted from November 2000 to April 2001, covering winter and the beginning of summer. The area is prone to droughts occurring two to four years out of ten years and flooding during monsoon (Jhala 1992). Gujarat has been experiencing a continuing drought for the last two years (1999-2000). But on average the rainfall for the *Bhal* is 468 mm and temperatures fluctuate between -1° to 38° in winter and 37° to 48° in summer (Ranjitsinh 1982, Raychaudhari et al. 1963, Jhala 1991). Hot winds called 'loo' sweep the land and dust storms, dust devils and mirages are common (Jhala 1991).

Plant growth is restricted to the monsoon and early winter (Jhala 1991). Crops are solely dependent on rains are the ground water is saline. Crops such as wheat (*Triticum* sp.), Cotton (*Gossipyum* sp.), Sorghum (*Sorghum* sp) and Kasumbi (*Carthamus tinctorius*) are the major crops of the *Bhal* (Jhala 1991). Due to the ongoing drought most of the surrounding fields are fallow, with a few areas growing cotton, and small plots for cattle feed. The crops are known to be raided by blackbuck and nilgai (Jhala 1993 and pers. comm. Y. V. Jhala).

The vegetation of Velavadar N. P. can be classified into 3 types (Jhala 1991)

- Grasslands: dominated by grasses, forbs and sedges.
- Scrublands: areas colonised by *Prosophis juliflora*
- Saline or halophytic regions: Characterised by sparse vegetation and dominated by halophytes and devoid of perennial grasses and shrubs.
- Tidal and flood plains: Devoid of any vegetation. Often flooded in the monsoon season.

The *Bhal* area was an open treeless habitat as recently as 70 years ago (Dharmakumarsinhi 1978, Mungall 1978). *P. juliflora* an exotic, native of Southwestern America (Muthana and Arora 1983) was planted in the *Bhal* region 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)

CHAPTER 2

METHODS

2.1 FIELD METHODS

2.1.1 Activity Pattern

The behaviours recorded in the present study were 'foraging', 'resting', 'moving', 'standing' and the rest of the activities such as social activity, suckling, aggression were clubbed into 'other' activities. Jarman's (1974) definition of a herd was adopted as a criterion to distinguish herds. Groups of animals were distinguished into two herds when the two herds were separated by an approximate distance of 50-100m in blackbuck and 200-300m in nilgai. Mixed herds comprised of females, males and calves. The occurrence of males and calves in this class was irregular; for instance males were found in mixed nilgai herds mainly when they were courting a female. Bachelor herds were defined as those in which only male individuals were found. Sampling was done for five different categories in winter and two in summer (Table 2.1).

The behaviours of interest were foraging, resting, and moving. These being behavioural states they were sampled using scan sampling (Altman 1974), at fifteen minute intervals for blackbuck and five minute intervals for nilgai. The scan sessions were determined based on the herd size of the two species Blackbuck were found in large herds of 100-200 animals while nilgai were found in smaller herds of 10-20 animals, which allowed scans to be more regular.

Table 2.1: **The different blackbuck and nilgai categories sampled along with the number of herds and number of hours sampled in Velavadar National Park from November 2000 to April 2001.**

Groups	# of herds	Hours of sampling
Blackbuck mixed herds in grassland habitats during winter	14	48
Blackbuck mixed herds in saline habitats during winter	14	57
Blackbuck bachelor herds during winter	10	39
Blackbuck mixed herds in grasslands during summer	10	44
Total for Blackbuck herds	48	188
Nilgai mixed herds during winter	17	66
Nilgai bachelor herds during winter	11	46
Nilgai mixed herds in grasslands during summer	13	53
Total for Nilgai herds	41	165

Scans were taken using a Bushnell spotting scope, of 25x-45x magnification, from varying distances and view points. The day was divided in to 3 sessions morning, afternoon and evening and one or two sessions were sampled every day.

One of the problems faced by the observer was the visibility of resting blackbuck. When observing the animal from a height, it was possibly to account for decreases in number, from the total herd size. And the validity of this assumption was assured as the number of animals in and around the herd could be tracked due to the advantage of height. The problem arose mainly in saline habitats and in summer. In saline habitats, work was conducted on foot from the ground level, and thus visibility was limited. Thus animals resting in and around *P. juliflora* shrubbery escaped observations. During summer, the herd structure itself was not as consistent as winter. Herds were constantly forming and breaking up. Thus herd structure in a scan varied from 30-300 animals at times. Also the numbers of animals moving in and around the scanning herd was constantly varying. Thus it was not possible to assume the numbers of animals resting as the herd size was never constant. Thus there is a possibility of numbers of animals resting being underestimated, especially in summer.

2.1.2 Habitat Analysis

2.1.2.1 Grazing Circuits

A herd was chosen and continuously followed from sunrise to sunset. The herd was observed from a view point, such as that given from a watch tower or from elevated roads and followed on foot. Care was taken that the observer does not approach the herd too close to avoid bias, such as causing the herd to move more due to the observer's presence. The route taken by the herd was mapped using Global Positioning System (GPS)

(Garmin II). Four to five readings were taken for each location. Other details such as herd size, time at different positions were noted down. Circuits were done for mixed herds of blackbuck in grasslands and in saline habitats and bachelor herds in grasslands during winter (Table 2.1 and Fig 2.1). Mixed herds of blackbuck were also followed in grasslands during summer. Nilgai mixed herds and male herds were followed in grasslands during winter and mixed herds in grasslands in summer (Table 2.1, Fig. 2.2).

2.1.2.2 Spatial Analysis

The remote sensing data of Indian remote sensing satellite-ID (LISS III) was acquired for vegetation mapping. The satellite acquired the digital imagery of the *Bhal* region, of path 092 and row 056 on 23rd January 2001 at 11:40:55 hours (Indian standard time). The image has four bands; two bands are in the visible (green 0.52-0.59μ and red 0.62-0.68μ) and one in near infrared region (0.77-0.86μ), and the fourth in infrared region (1.55-1.70μ). All bands have a spatial resolution of 23.5m except the infrared band, which is of 70.5m.

The digital image processing was done with Erdas Imagine 8.3 (1997) and Arc/ Info 7.1.2 (1998). The remotely sensed digital data was rectified to Survey of India Toposheets of 1:50,000 scale. The image was georectified to geographical latitude; longitude and polyconic plane coordinate system. The linear transformation and nearest neighbour method was used for resampling the image. The total root mean square error per point was 7 m.

The study area image subset was extracted and was classified using unsupervised classification for 25 categories. The signatures were extracted for 25 classes. The means

Fig. 2.1 **Diurnal Ranging Pattern of Blackbuck Herds through different Vegetation Communities**

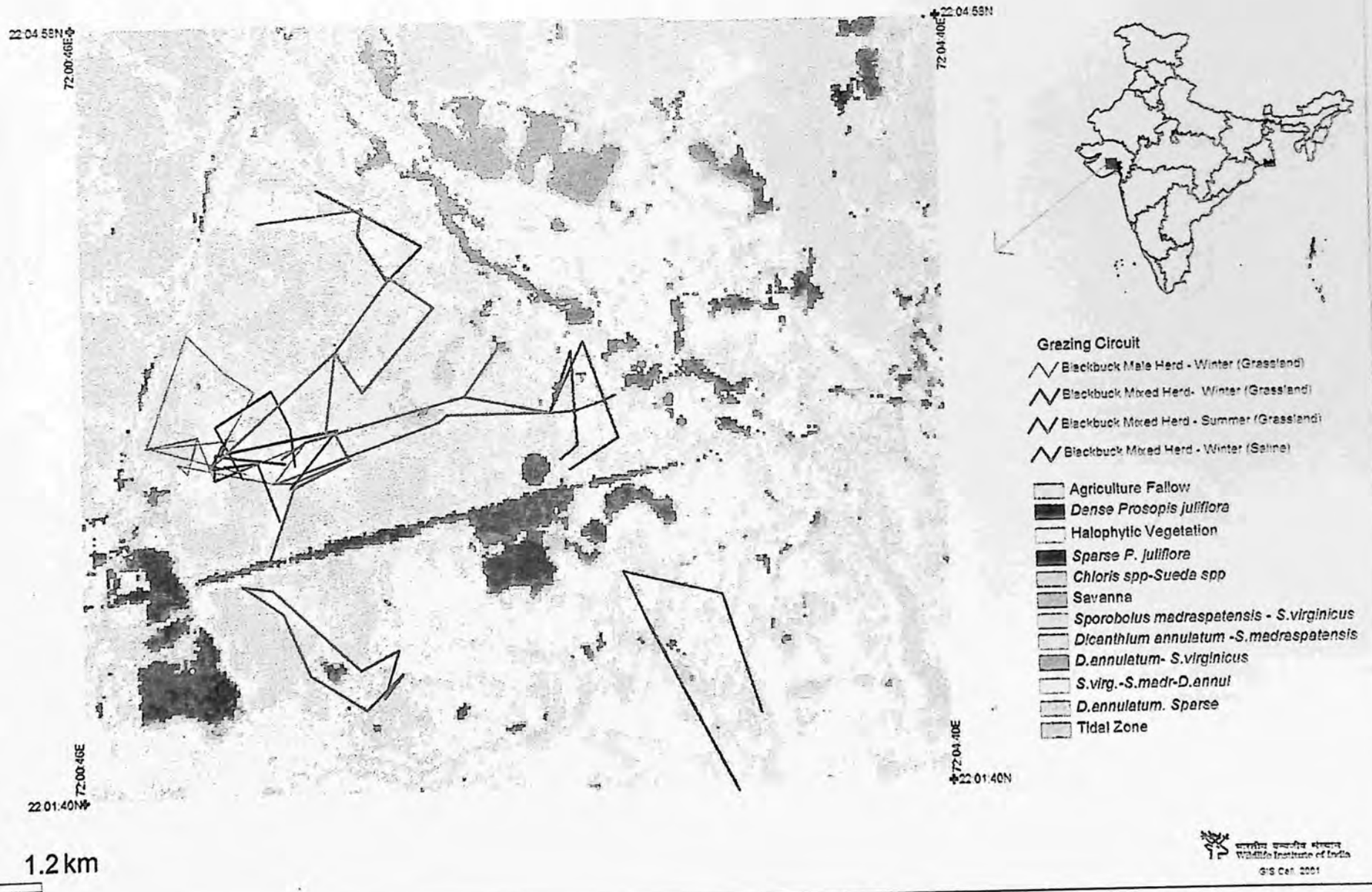


Fig. 2.2 **Diurnal Ranging Pattern of Nilgai Herds through different Vegetation Communities**

for class signatures were initialized with one standard deviation along the diagonal axis. The convergence was achieved at a threshold of 0.95 after 10 iterations. The point location for vegetation classification was collected with the help of a GPS. The classes were evaluated with field data and merged (Fig. 2.3).

The study area subset covers the most of the park and a small proportion outside the park. The amount of area under different vegetation types was estimated from the imagery (Fig. 2.3). This was determined to be the vegetation type available for the animals found in the park. On this vegetation map the grazing circuits were laid and buffered to quantify the 'utilized' vegetation types. Taking in to consideration the different herd sizes, herds less than 100 animals were buffered by a 30m buffer (15m on either side). Those consisting of more than 100 animals were buffered by 50m (25m on either side). A 30m buffer was considered the minimum taking in to account spatial errors due to the GPS and georectification errors of the imagery. The buffered area was composed of different vegetation communities in varying proportions along the length of the circuit. The amount of area under each vegetation class per circuit was extracted using Arc View Version 3.1 (1996) and thus quantified for all the circuits.

To determine selection based on nutrition, a nutritional layer and nutritional index was derived. The index was a composite of three factors, crude protein and lignin levels of each plant species (Jhala 1991) and the normalised differential vegetation index (NDVI). The vegetation ratio indices demonstrated their usefulness in estimating above ground biomass (Jensen 1986, Schowengert 1997). The biomass index was derived by (Fig 2.4),

$$NDVI = \frac{\text{Infrared band - red band}}{\text{Infrared band + red band}}$$

Fig. 2.3 **Vegetation Classification of Velavadar National Park, Gujarat**

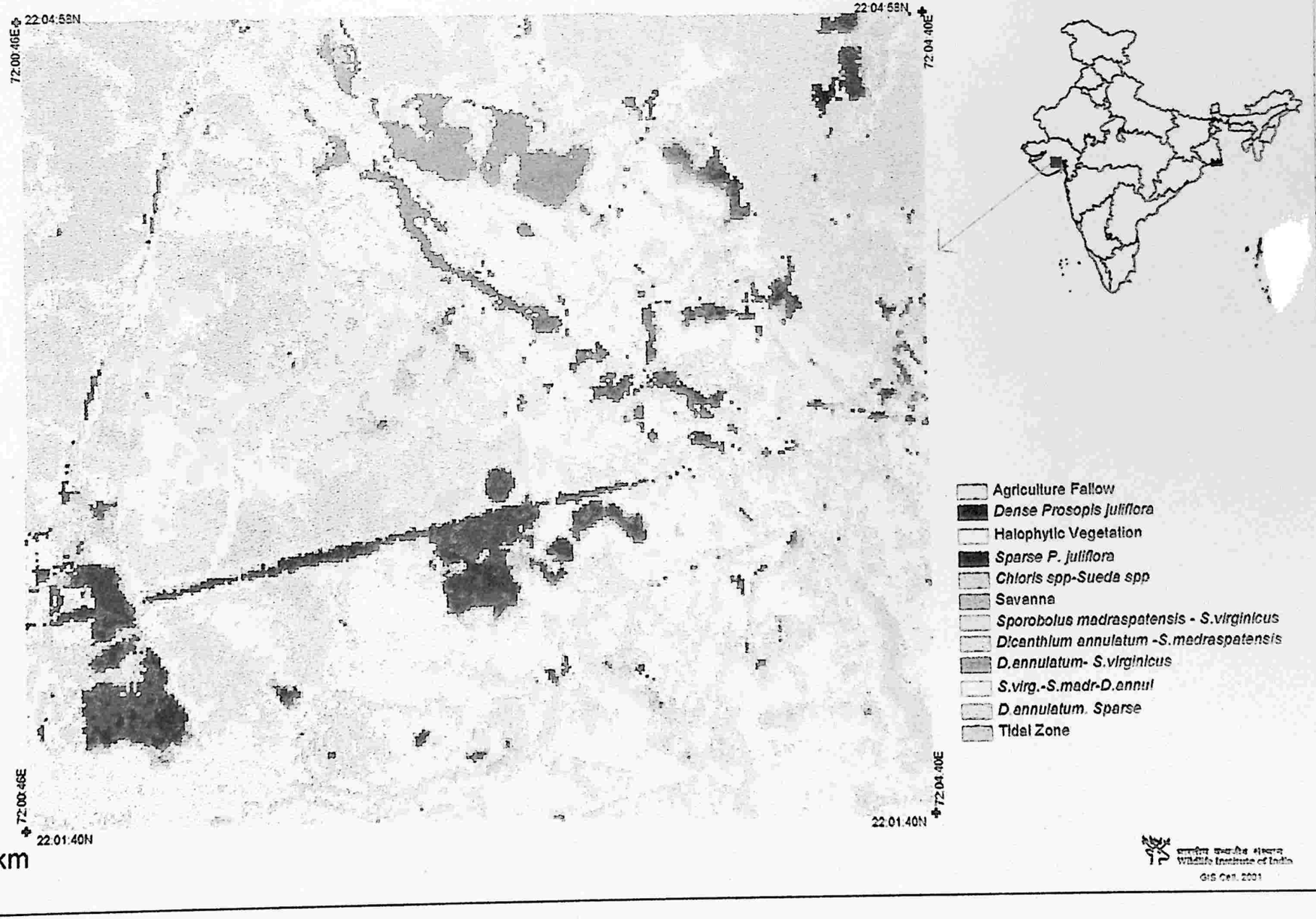


Fig. 2.4 **Winter Biomass Index (NDVI) of Vegetation Classes in Velevadar National Park**

NDVI = Normalized Difference Vegetation Index

Vegetation classes comprise of proportions of different species of plants. Per class, the crude protein and lignin levels in grams per m^2 for each species, were calculated as per the proportion it constitutes in the vegetation class (Fig. 2.7). The NDVI values range between –1 to +1, they were transformed to a positive scale and multiplied by hundred and then applied to the formula given below,

$$\text{Nutritional Index} = \frac{\text{Crude Protein}}{\text{Lignin}} * \text{NDVI (transformed)}$$

P. juliflora was an exceptional case, as high NDVI values were present, but only the pods are fed upon. Its index value was adjusted to compensate for nilgai being able to forage on more pods than blackbuck (Fig. 2.5 and 2.6).

The grazing circuits were laid on the nutritional layer and buffers of 30m and 50 m were laid around it, as per the previous classification. The mean nutritional value along with its standard deviation was obtained for the whole circuit. The mean nutritional value for blackbuck and nilgai in the whole park was obtained separately for comparison with the utilized nutritional means.

A problem with the nutritional index was that, plots were not laid for the sites where the peak feeding occurred, but along the whole circuit. Both species, especially nilgai feed at length in an area and then move straight to another site. Thus they pass through some areas, which are not actual foraging sites. Thus a lot of other habitats or patches are passed through, which dilutes the effect and increases the variability of the data.

Fig. 2.5 **Winter Grazing Circuits of Blackbuck Indicating Selection of Higher Nutrient Areas**

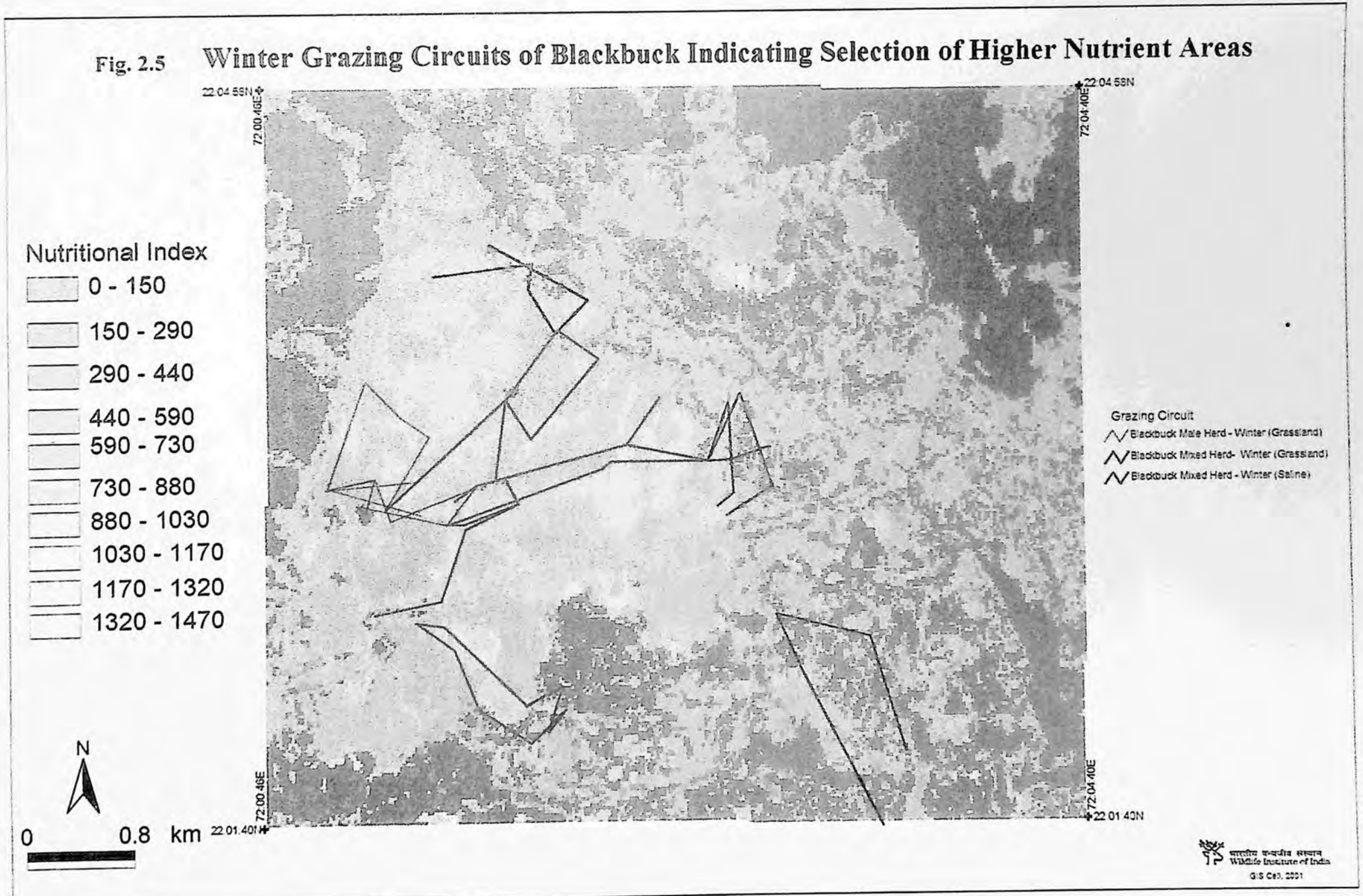


Fig. 2.6 Winter Grazing Circuits of Nilgai Indicating Selection of Higher Nutrient Areas

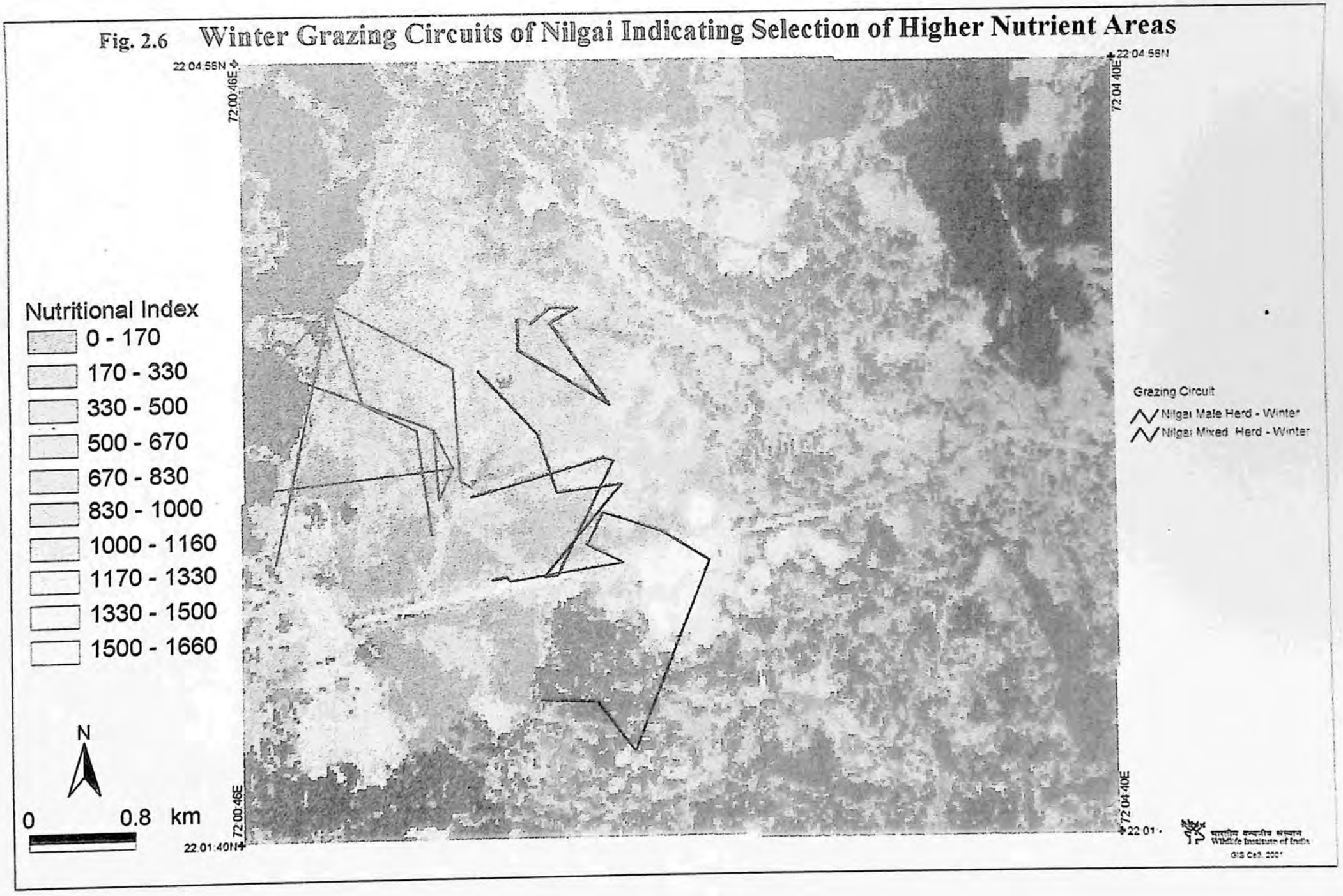
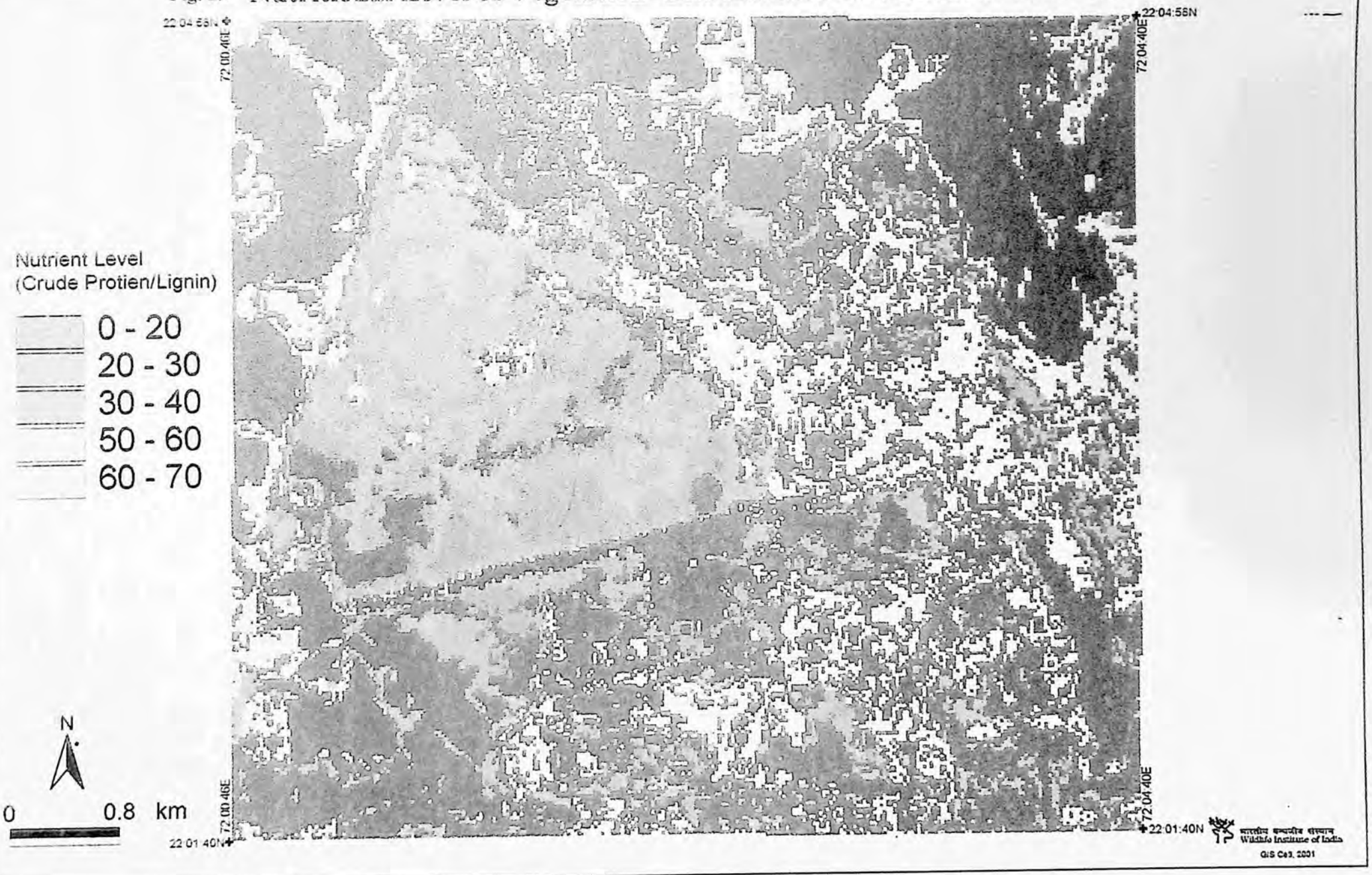


Fig. 2.7 Nutritional Level of Vegetation Communities in Velavadar National Park



2.2 ANALYTICAL METHODS

2.2.1 Activity budgets

The raw data was for every 15 minutes for blackbuck and 5 minutes for nilgai. The weighted mean of an hour of activity was used for analysis. The data was weighted to correct for varying group sizes in that time frame.

The samples for each activity was averaged on an hourly basis and its standard error estimated. The number of samples ranged from a minimum of three to a maximum of five. The percent activity data was arc sine transformed to make it independent. The various categories to be compared were analysed using SIMSTAT (2000) and SPSS (1999). Students T test, One way ANOVA, Duncans multiple range test (Zar, 1984), were used for comparative analysis of different activities of blackbuck and nilgai, between seasons, sexes and species. The samples were also bootstrapped due to the low sample size. The comparisons were considered to be significantly different upto p=0.10 level.

2.2.2 Habitat Analysis

2.2.2.1 Grazing Circuits

The grazing circuits were mapped with a mean of five latitude and longitude values for each point in Arc Info 7.1.2 (1998) and the total distances of the circuits were extracted. One way ANOVA and Duncan's multiple range tests were used to compare grazing circuits of blackbuck and nilgai in different habitats, seasons, among sexes and species.

2.2.2.2 Habitat use and availability

The vegetation data was analysed first by Chi square (Neu *et al.*1974) to determine whether the utilized habitat was significantly different from the available habitat. After

determination of the circuits in which a significant choice was exerted, they were subjected to compositional analysis (Aebischer and Robertson 1993) to determine which habitats were used significantly.

The compositional analysis (Aebischer and Robertson 1993) was carried out by dividing each vegetation class by the least used class, which was fallow agricultural fields and barren soil and subsequently was removed from analysis. The compositional transformation was done for both available and utilized data sets (Appendix 1, 2). The difference matrixes of utilized - available was derived for further analysis (Table 2.2). The difference data for each group replicate was subtracted from each other, to give rise to a matrix. The preference ranking for each vegetation category was obtained by counting the number of positive values, in each column.

To determine whether the different categories of animals were exerting a choice in using habitats and habitats were used significantly differently amongst the different categories multiway blocked ANOVA was conducted.

Table 2.2: Utilized – available matrix after log transformation from compositional analysis

	2	3	4	5	6	9	10	12	13	14
Blackbuck male	-6.72004	-1.44613	-7.10398	-7.53793	-6.5452	1.839553	0.822501	2.35949	3.003932	3.26774
Blackbuck male	1.14676	8.351697	0.762815	0.328866	1.321601	0.741132	0.822693	10.55842	10.33536	11.75003
Blackbuck male	-4.64411	-6.13877	-5.02805	2.812243	-4.46927	4.988099	4.733187	4.524606	4.221009	5.187374
Blackbuck saline	-7.809	-0.16564	-8.19295	0.551945	-0.2879	1.271696	-1.47996	-7.89536	1.481633	-7.95651
Blackbuck saline	-7.77597	0.575703	-8.15991	1.058314	0.798286	0.440961	-8.10003	-7.86233	-0.10946	-7.92348
Blackbuck saline	-7.84489	0.184903	-0.04812	1.040362	0.105205	-0.0698	-8.16896	-0.44368	0.537236	-7.9924
Blackbuck summer	-6.27212	-7.76678	-6.65607	-7.09002	-6.09728	3.37989	-6.59619	2.446393	3.529091	3.196173
Blackbuck summer	-7.44227	-2.91173	-7.82622	-8.26016	-0.55029	1.813676	0.337092	1.753453	2.266559	1.692302
Blackbuck summer	-6.00985	-7.50451	-6.39379	-6.82774	-5.83501	3.631114	2.768213	3.139451	3.758575	2.385153
BB winter grassland	2.361105	-1.68262	-0.10228	-0.66976	-0.23664	0.974648	-0.33009	2.61567	1.887063	-0.15353
BB winter grassland	-7.11874	0.492809	-7.50269	0.533531	-6.9439	-0.55828	-7.44281	-1.33763	2.388727	2.849719
BB winter grassland	-6.73463	-1.04086	-0.74145	1.350328	1.896776	3.314403	2.537302	1.753357	1.905323	0.188129
BB winter grassland	-7.95407	-2.19343	-8.33802	-8.77197	-7.77923	0.687009	-0.73551	1.374001	1.904499	-0.55895
BB winter grassland	-7.07735	-2.94892	-0.7414	-0.19429	2.274125	2.94233	2.482549	1.230164	1.712087	-0.91043
Nilgai male	-5.95176	-7.44642	-6.33571	0.328866	-5.77692	4.141917	3.63569	3.052416	3.021729	2.790595
Nilgai male	-7.04835	-0.16558	-7.43229	0.798869	0.40531	2.532892	2.824173	2.01591	1.376337	-7.19586
Nilgai male	0.37357	-0.14026	-0.26169	0.30289	0.142946	1.408304	0.685492	0.48788	0.651349	1.073356
Nilgai summer	-5.61834	0.345535	-6.00228	2.597609	2.862046	4.267493	4.329251	3.545306	1.887163	-5.76585
Nilgai summer	-6.86228	-0.12492	-7.24622	1.683245	2.574198	3.183313	1.921139	-6.94864	1.193849	-7.00979
Nilgai summer	-6.53054	-0.19398	-0.33603	1.245017	2.787706	3.47093	2.814891	2.734144	1.561509	-6.67805
Ng winter grassland	4.008665	1.615454	1.861131	0.734034	1.72677	1.433983	2.614156	2.931905	1.106708	0.71127
Ng winter grassland	3.343095	-6.67993	1.860538	1.244267	3.959769	4.524432	4.650445	4.670427	2.984885	-5.33278
Ng winter grassland	-6.88289	-0.68454	-7.26684	0.328703	2.46657	3.272396	2.705261	2.44653	-0.05891	-7.0304

1-*Prosopis* dense and moderate;2-Saline sparse; 3-Sparse *Prosopis;* 4-Sueda & chloris 5-Savanna:*Prosopis juliflora*, *Sporobolus madraspetensis Sporobolus virginicus*; 6- *S.virginicus*; *S. madraspetensis* 7- *Dicantium annulatum & S. madraspetensis* ; 8- *Dicantium annulatum & S.virginicus*; 9- *S.virginicus*; *S. madraspetensis & Dicantium annulatum* 10- *Dicantium annulatum*
BB-Blackbuck; Ng- Nilgai.

CHAPTER 3

RESULTS

3.1 ACTIVITY PATTERN

3.1.1 Comparison of activity patterns in different habitat types in blackbuck

Grassland herds spent the most time in foraging (58.54%), and then resting (15.05%), with moving, standing and other activities contributing less than 15% (Fig 3.1). In the saline habitats, foraging took up 49.5% of the time, followed by moving (19.39%) and standing activity (16.5%). Resting and other activities contributed less than 15%.

The daily foraging pattern of both grassland herds and saline herds showed different variation in foraging and resting temporally (Fig 3.2 and 3.3). The saline herds showed a more consistent foraging rate throughout the day with a minor resting peak (<30%) at around 0900 hours and a greater peak (45%) at approximately 1500 hours. While the grassland herds showed three prominent foraging peaks (> than 60%), with resting peaks at around 1000 and 1600 hours.

Blackbuck mixed herds showed higher moving activity in saline habitats than that in grassland habitats ($p=0.001$, Table 3.1). Foraging activity on the other hand was found to be higher in grassland habitats than that in saline habitats ($p=0.072$ Table 3.1).

3.1.2 Comparison of differences between sexes in blackbuck

In bachelor herds foraging time was higher (67.06%) than mixed herds (58.54%), and resting occurred 19.37% of the time, while other activities were less than 15% of the

Figure 3.1: **The percent time spent in different activities with the standard error between blackbuck mixed herds in grasslands and mixed herds in saline during winter.**

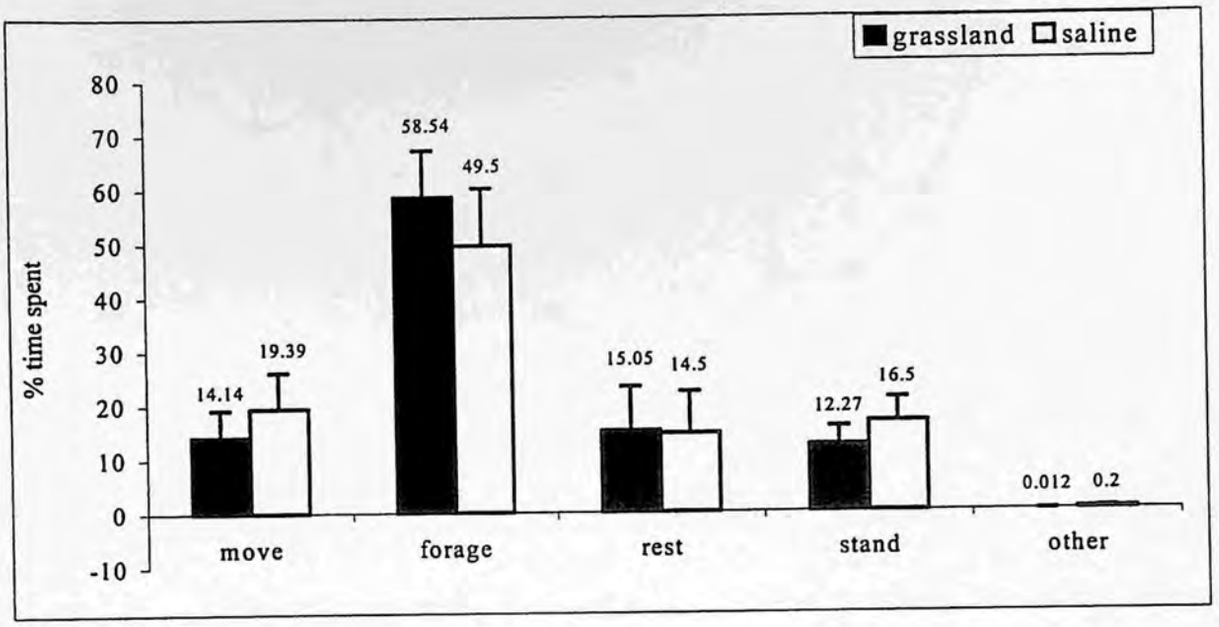


Table 3.1: **Comparison of student t test and bootstrapped t test for blackbuck mixed herds in grasslands and saline habitats during winter.**

Behaviour	Students t test			Bootstraped	
	t value	Df	p value	t value	p value
Moving	-5.59	5	0.001	5.9412	< 0.01
Foraging	2.18	5	0.072	2.1368	< 0.1
Resting	1.28	5	0.249	1.2286	> 0.05
Standing	–1.27	5	0.253	1.2898	> 0.05

Figure 3.2: Temporal variation in foraging & resting patterns of mixed black buck herds in grasslands during winter

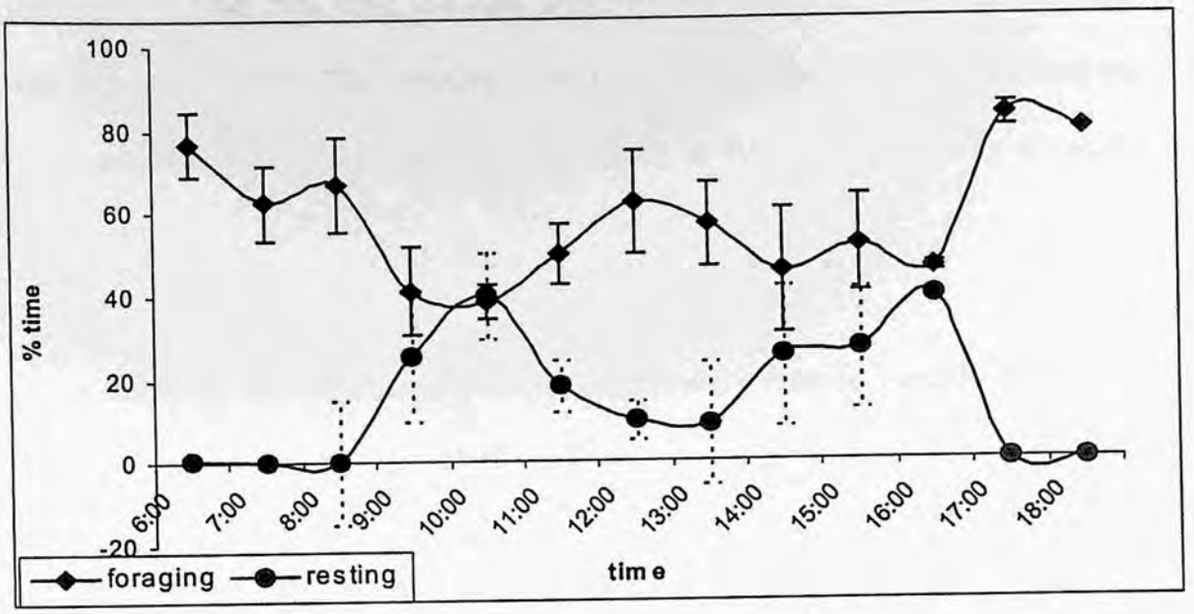
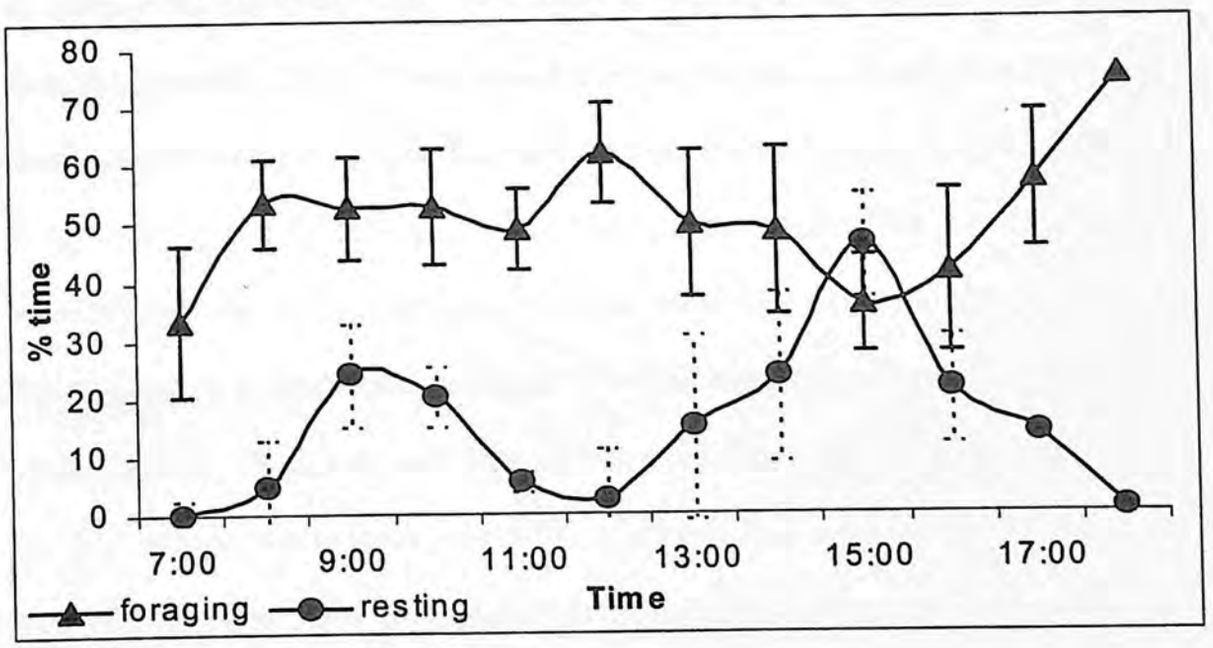


Figure 3.3: Temporal variation in foraging & resting patterns of mixed black buck herds in saline habitats during winter



time (Fig. 3.4). The foraging pattern in males was found to show three prominent peaks, with the morning peak being greater than 65% and the mid afternoon and evening peak being greater than 80% (Fig. 3.2 And 3.5). Females had a similar pattern but a smaller mid day peak (<70%). The females in general showed less intensities of foraging, with the amplitudes varying much less, 80% foraging to 40%, while in males it ranged from 90% to 30%.

Foraging activity was found to be significantly more in bachelor herds ($p=0.029$, Table 3.2) while standing ($p=0.049$) and moving activities were found to be more in mixed herds ($p=0.078$).

3.1.3 Comparison of seasonal differences in blackbuck

In summer the percentage time spent foraging was 49.25%, with moving, resting and standing occurred 17% to 15% of the time. Other activities occurred only 0.49 % of the time in summer (Fig 3.6). The daily temporal pattern of foraging in summer had three foraging peaks at approximately 0700, 1100 and 1600 hours (Fig 3.7). The peaks had approximately the same magnitude of about 60% time spent in foraging time. The foraging pattern in winter had prominent (70-80% time) early morning and late evening peaks (Fig 3.2). Though the total time spent in resting activity was not different between the two seasons, the temporal allocation of resting time was different. In winter, the resting period seems to be more equally distributed than in summer with herds in summer having a single prominent resting peak (approximately 60%) around 0900 hours than those in winter (Fig 3.2 and 3.7).

Figure 3.4: **The percent time spent in different activities between blackbuck mixed herds in grasslands during winter and blackbuck bachelor herds in grasslands during winter.**

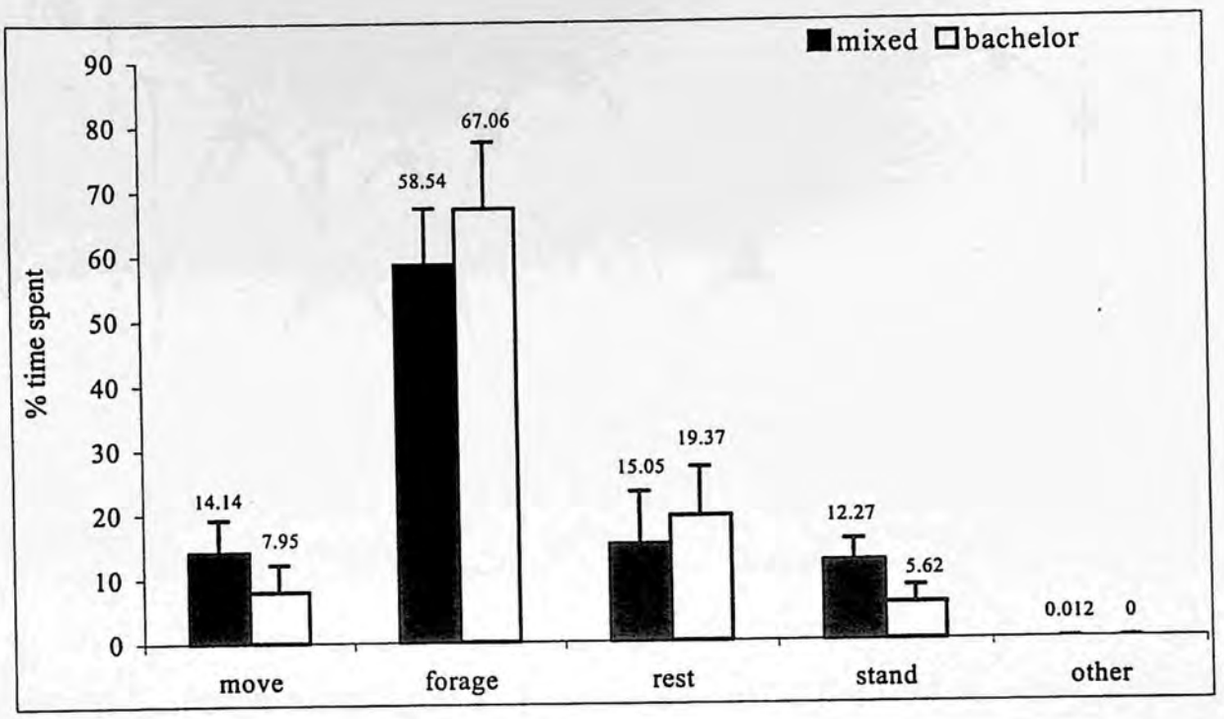


Table 3.2: **Comparison of the student t test results and bootstrapped results for blackbuck mixed herds and bachelor herds in grasslands during winter.**

Behaviour	Students t test			Bootstrap	
	t value	Df	p value	t value	p value
Moving	-2.21	4	0.078	2.2136	< 0.1
Foraging	3.04	4	0.029	3.0398	< 0.05
Resting	–0.40	4	0.70	0.4036	> 0.05
Standing	-2.59	4	0.049	2.5925	< 0.1

Figure 3.5: Temporal variation in foraging & resting patterns of male blackbuck herds in grasslands during winter

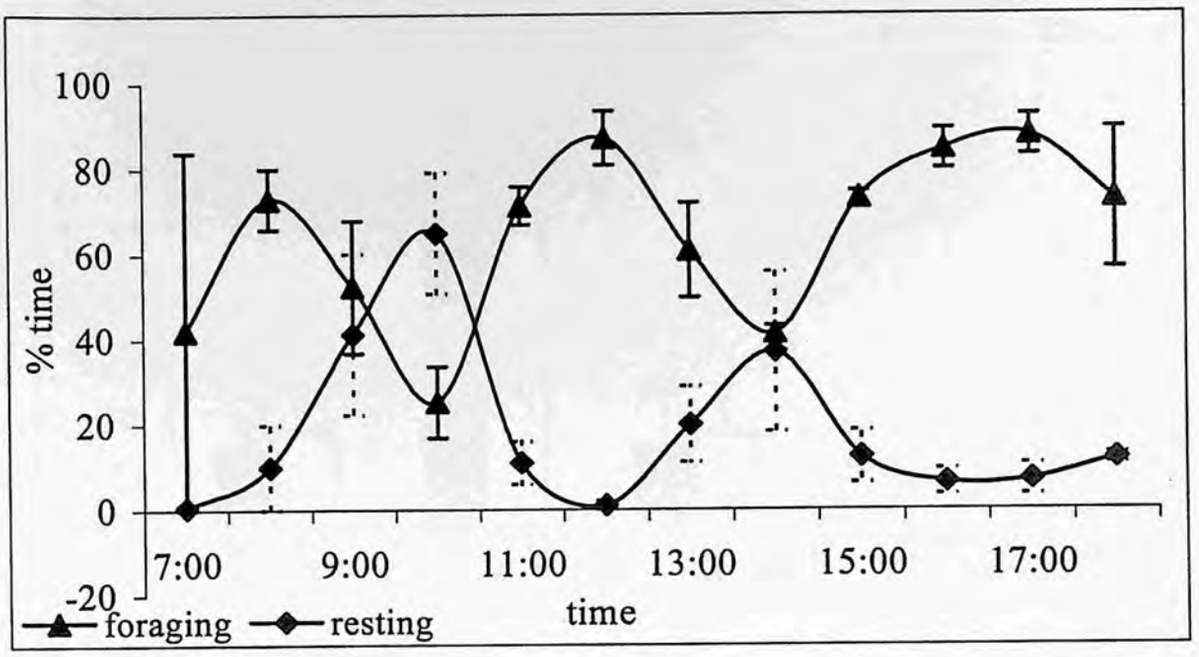


Figure 3.7: Temporal variation in Foraging & resting patterns of mixed black buck herds in grasslands during summer

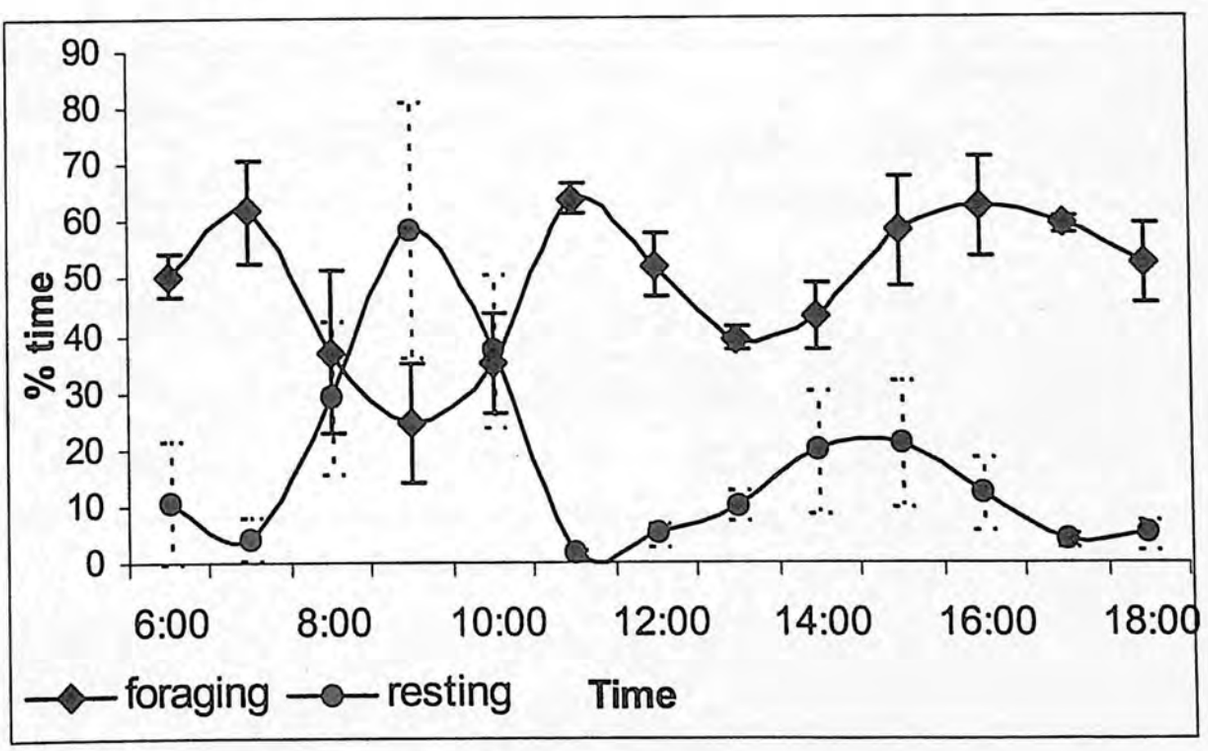


Figure 3.6: **The percent time spent in different activities between blackbuck mixed herds in grasslands during winter and summer.**

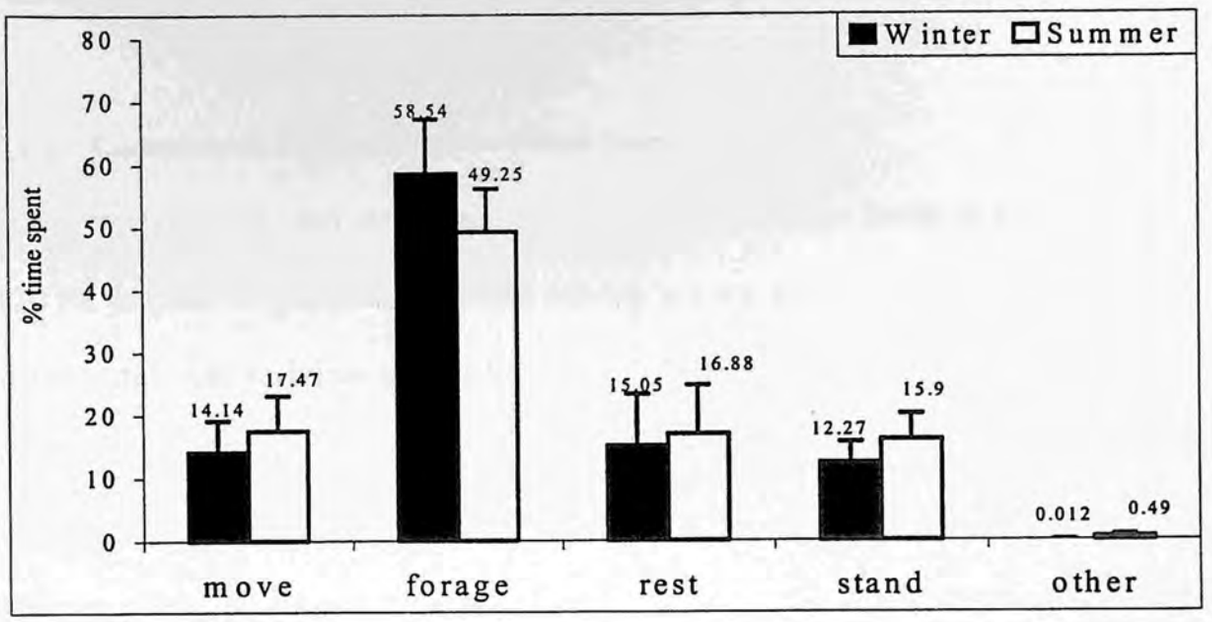


Table 3.3: **Comparison of the student t test results and bootstrapped results for blackbuck mixed herds during winter and summer in grassland habitats.**

Behaviour	Students t test			Bootstrap	
	t value	Df	p value	t value	p value
Moving					
Foraging	–2.09	4	0.091	2.0893	> 0.1
Resting	–1.46	4	0.20	1.4552	> 0.1
Standing	1.56	4	0.232	1.5623	> 0.05

The results showed that in mixed herds foraging activity in winter was significantly more than in summer (p= 0.091 Table 3.3). The other activities such as moving and resting were similar between the two seasons.

3.1.4 Comparison of differences between sexes in Nilgai

The percentage time spent in foraging activity by mixed nilgai herds during winter was 43.71% and 26.72 % in resting. While moving activity occurred 15.69 % of the time, standing and other activities occurred less than 15% of the time (Fig 3.8). Nilgai bachelor herds foraged 49% of the time and rested 32.04% of the time. All other activities occurred less than 10% of the time (Fig 3.8). Though the total percentage foraging and resting between males and females were not different, the temporal allocation of time differed (Fig 3.9 and 3.10). In males, a higher intensity foraging peak occurs (approximately 90%), which gradually decreases down at around 1130 hours while in females the foraging peak (65%) suddenly decreases at around 0900 hours. The resting period in females is one large block with three minor resting peaks at 1000, 1200 and 1600 hours with approximately 40% time spent, while in males of the three peaks one peak is highly prominent (approximately 80%).

Nilgai groups did not differ in the proportional diurnal time allocated to various activities between mixed herds and bachelor herds (p> 0.05, Table 3.4).

3.1.5 Comparison of seasons in Nilgai

Nilgai in summer spend 55% of their time foraging and 16.52% of the time in resting and 15.66% of the time standing, and 12.36% moving (Fig 3.11). Compared with winter, nilgai spent 43.71 % foraging time, 26.72% resting and 15.69% moving

Figure 3.8: **The percent time spent in different activities between nilgai mixed herds and nilgai bachelor herds in grasslands during winter.**

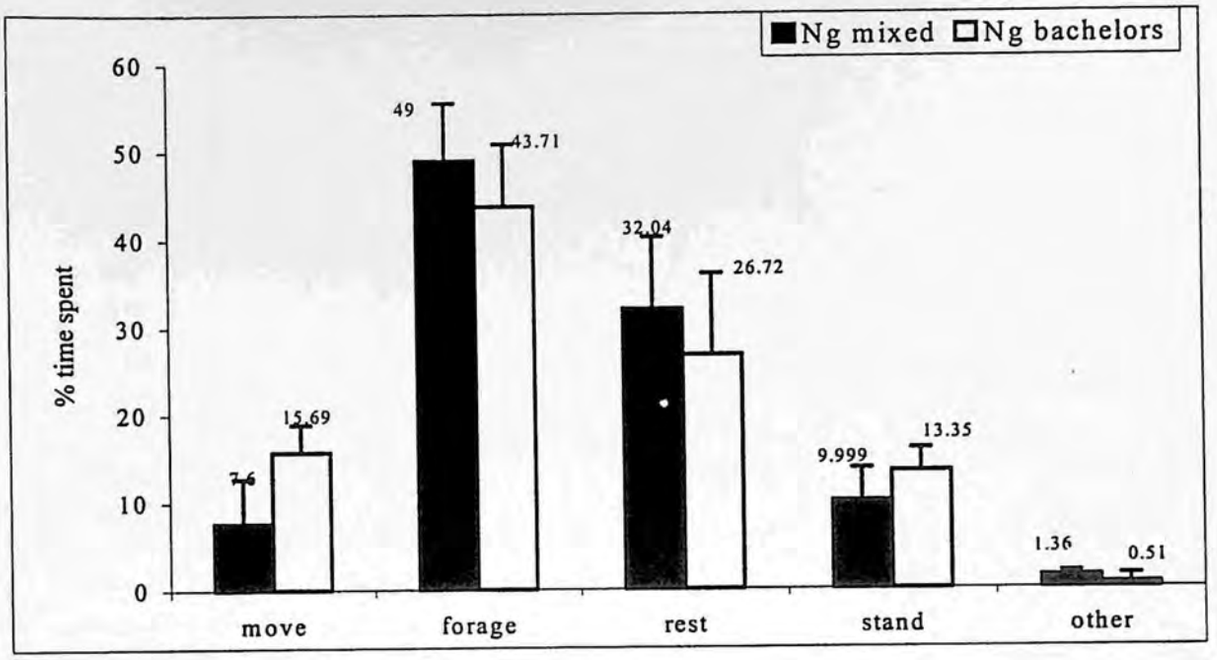


Table 3.4: **Comparison of the student t test results and bootstrapped results for nilgai mixed herds and bachelor herds in grasslands during winter.**

Behaviour	Students t test			Bootstrap	
	t value	Df	P value	t value	p value
Moving	1.61	6	0.152	2.0773	< 0.1
Foraging	–1.74	6	0.126	1.7259	>0.1
Resting	-0.29	6	0.78	0.3805	> 0.1
Standing	1.51	6	0.174	1.8454	> 0.1
Other	-0.75	6	0.478	0.6378	> 0.1

Figure 3.9: Temporal variation in Foraging & resting patterns of male nilgai herds in winter

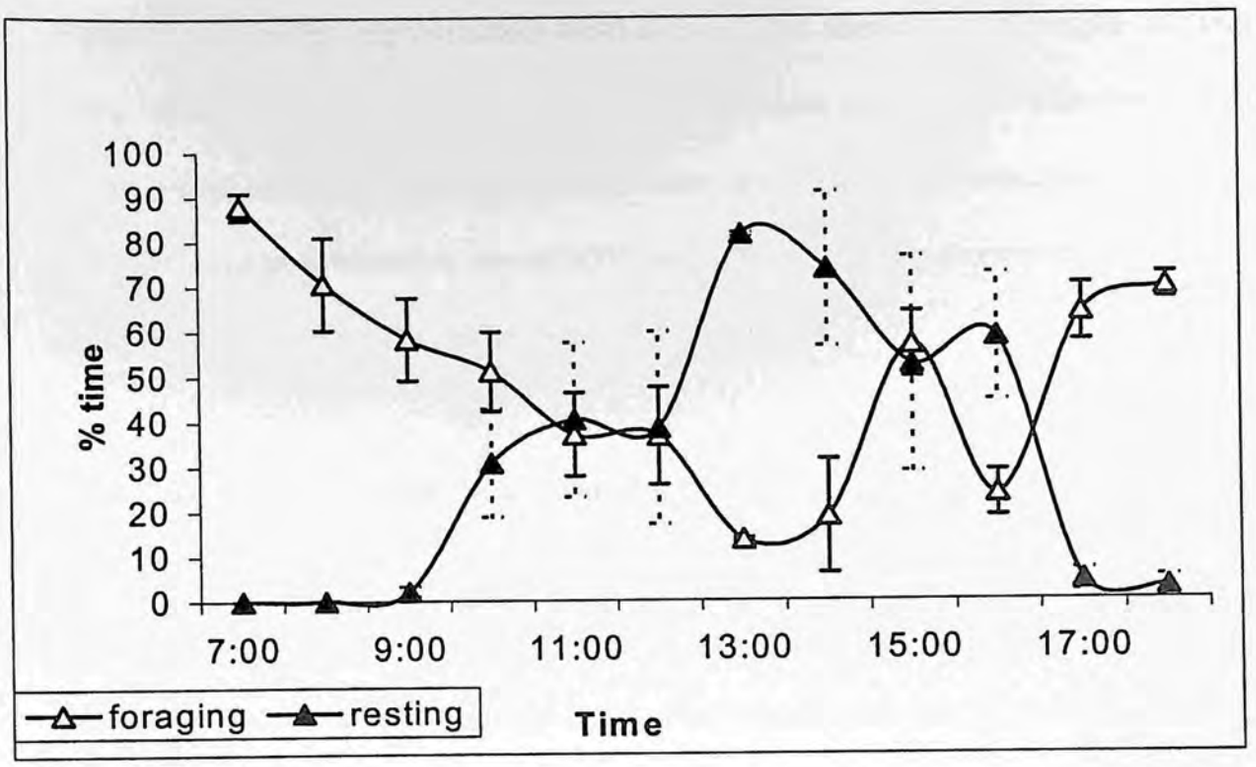
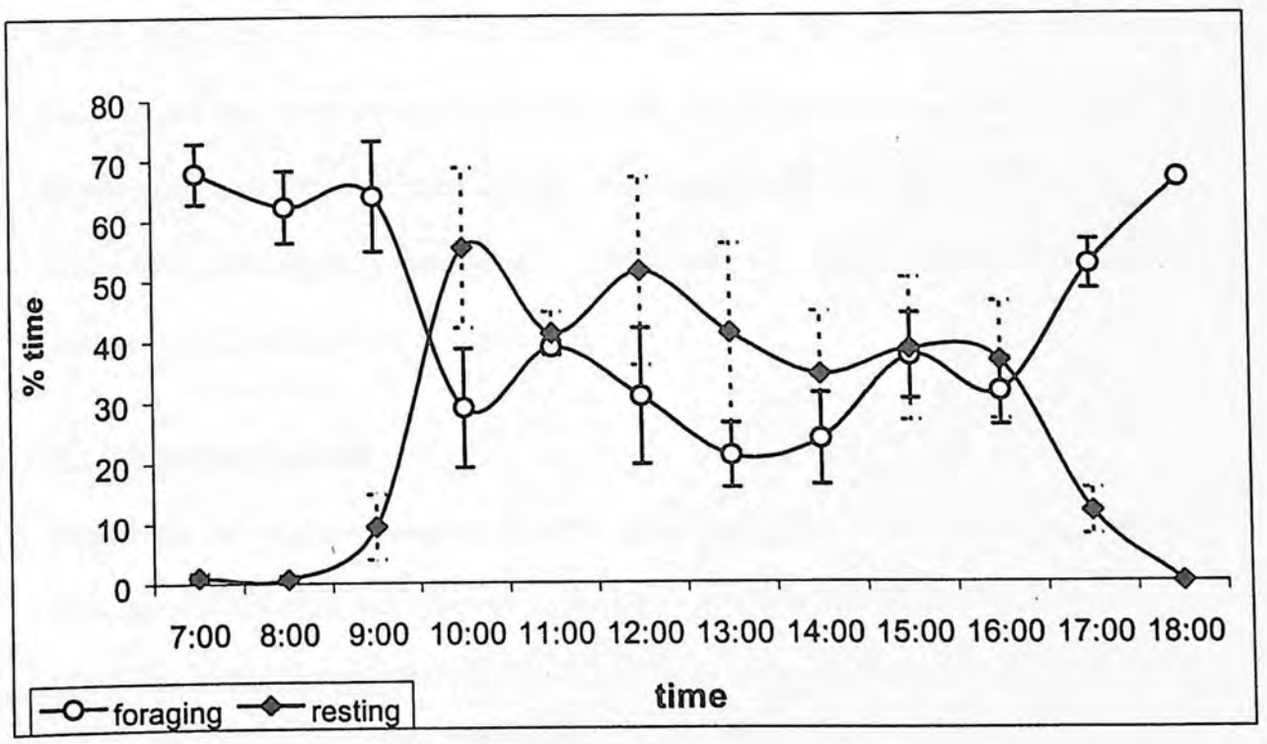


Figure 3.10: Temporal variation in Foraging & resting patterns of mixed nilgai herds in winter



(Fig 3.11). The temporal allocation of time to foraging between winter and summer was not highly different as well (Fig 3.10 and 3.12). Only the early morning foraging peak in winter is much higher (approximately 90%) and of longer duration, extending up till 1000 hours. While the morning peak in summer (80%) extends up to around 0830 hours. The resting period culminate in one peak in summer at around 1400 hours, than in winter, where the main peak occurs at around 1000 hours. Thus foraging activity in summer was significantly more than in winter ($p=0.042$, Table 3.5).

3.1.6 Comparison between Nilgai and Blackbuck

3.1.6.1 During winter

Blackbuck spent 58.5% of its time foraging, while nilgai spent 43% (Fig. 3.13). Resting activity was shown more in nilgai (26.72%), than in blackbuck (15.05). Moving (15.69%, 14.14%) and standing activity (13.35%, 21.27%) was similar in nilgai and blackbuck respectively (Fig 3.13). Other activities were shown less than 1 % in both species. The temporal variation in foraging and resting was very different between blackbuck and nilgai (Fig. 3.2 and 3.10). While blackbuck has three prominent peaks foraging peaks, interspersed by two prominent resting periods, nilgai have two prominent peaks foraging peaks with one large resting period. The percentage of time allocated to different activities in both species was the same ($p>0.05$) except foraging, which was significantly more in blackbuck ($p= 0.009$, Table 3.6).

3.1.6.2 During summer

Blackbuck in summer foraged 49.25% as compared to 55.08% in nilgai (Fig. 3.14). Resting and standing activities were the same in nilgai (16.88%, 15.9%) and blackbuck (16.52%, 15.66%) respectively (Fig. 3.14). Both temporal daily activity patterns in both species showed a more sustained feeding pattern through out the day (Fig. 3.7 and 3.12).

Figure 3.11: **The percent time spent in different activities between nilgai mixed herds in grasslands during winter and nilgai mixed herds in grasslands during summer.**

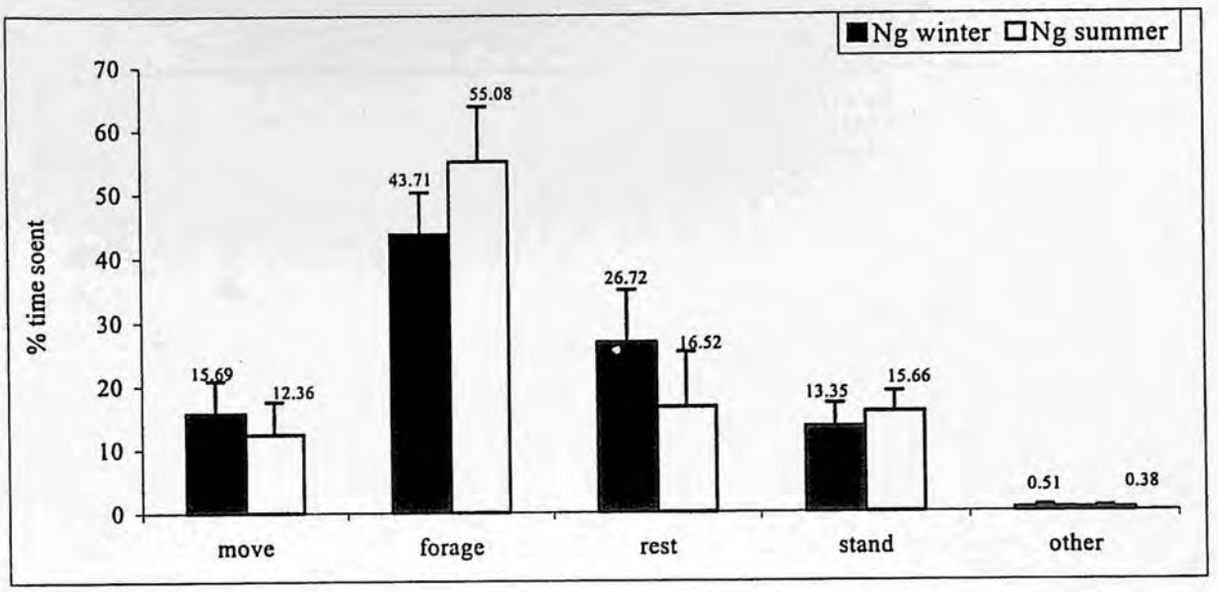


Table 3.5: **Comparison of the student t test results and bootstrapped results for nilgai mixed herds and in grasslands during winter and summer.**

Behaviour	Students t test			Bootstrap	
	t value	df	P value	t value	p value
Moving	0.712	6	0.50	0.7375	>0.1
Foraging	–2.48	6	0.042	2.8766	<0.05
Resting	1.18	6	0.276	1.3747	> 0.1
Standing	–1.47	6	0.184	1.7969	> 0.1

Figure 3.12: Temporal variation in Foraging & resting patterns of mixed nilgai herds in summer

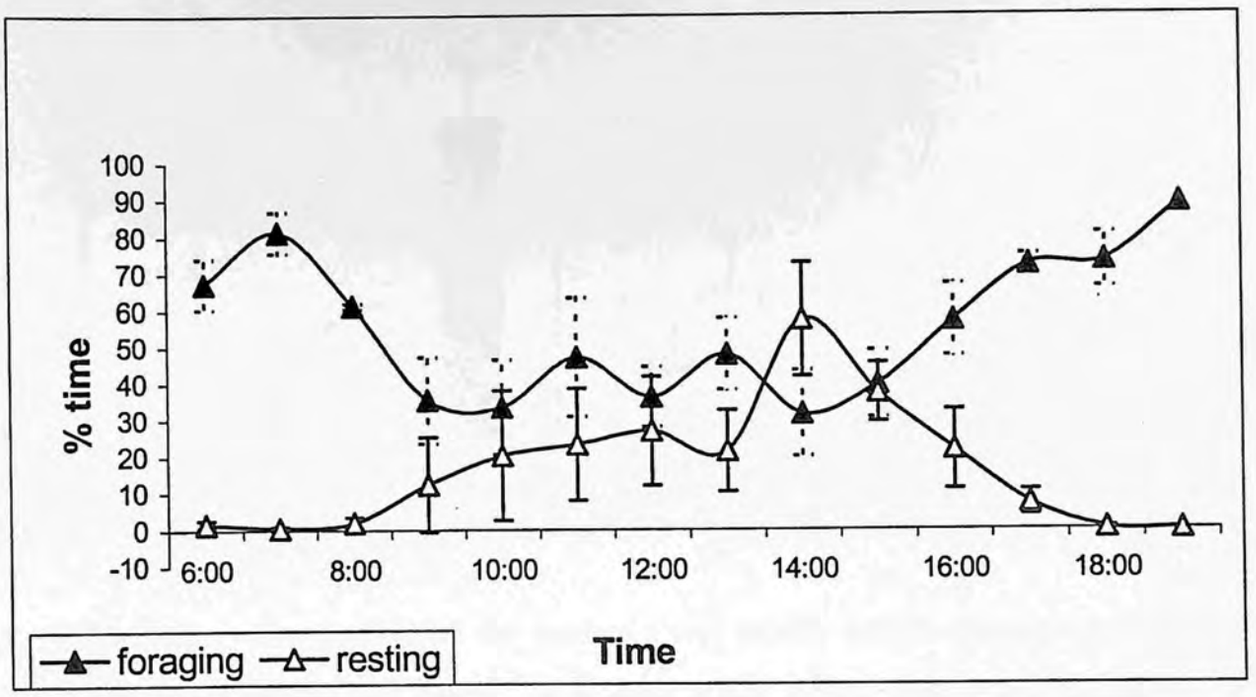


Figure 3.13: **The percent time spent in different activities between blackbuck mixed herds in grasslands during winter and nilgai mixed herds in grasslands during winter.**

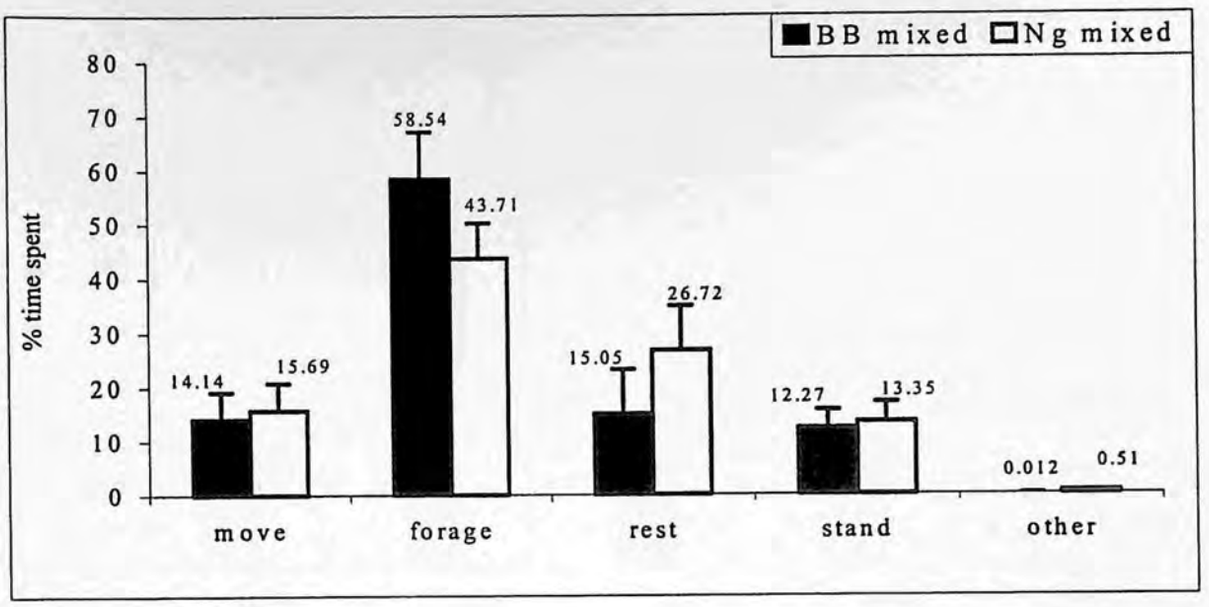


Table 3.6: **Comparison of the student t test results and bootstrapped results for blackbuck mixed herds and nilgai mixed herds and in grasslands during winter.**

Behaviour	Students t test			Bootstrap	
	t value	df	P value	t value	p value
Moving	1.17	6	0.28	1.5128	> 0.1
Foraging	-3.60	6	.009	3.9222	< 0.01
Resting	1.23	6	0.259	1.5302	> 0.1
Standing	0.31	6	0.766	0.3581	> 0.1

Figure 3.14: **The percent time spent in different activities between blackbuck mixed herds in grasslands during summer and nilgai mixed herds in grasslands during summer.**

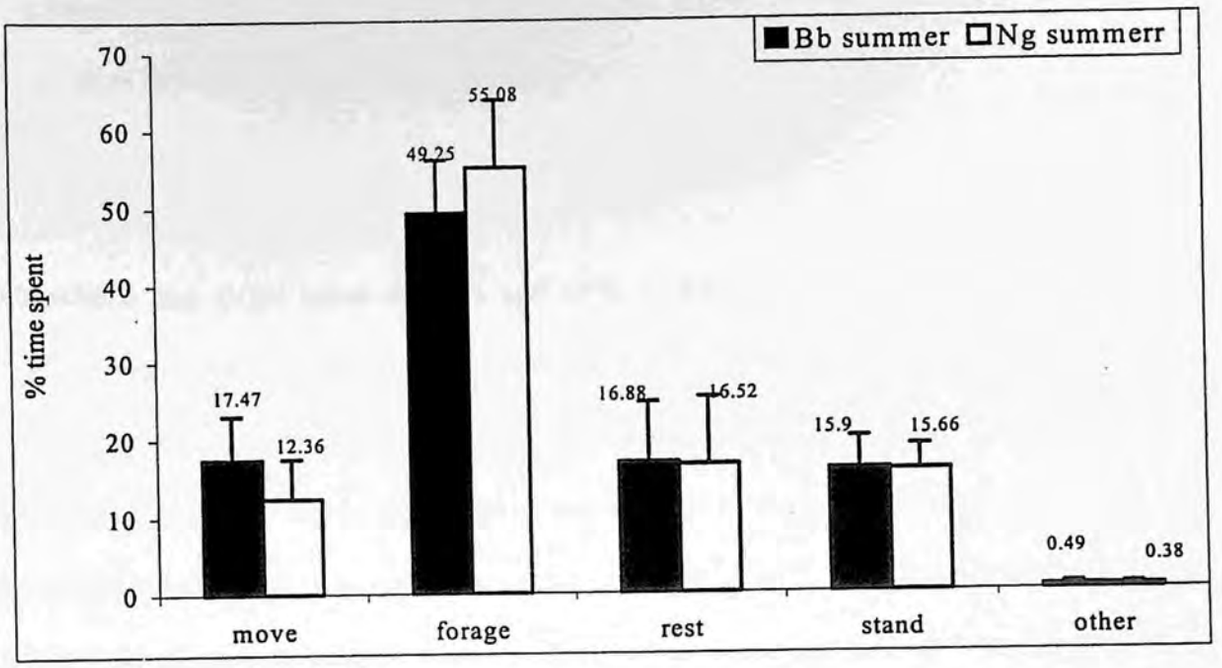


Table 3.7: **Comparison of the student t test results and bootstrapped results for blackbuck mixed herds and nilgai mixed herds and in grasslands during summer.**

Behaviour	Students t test			Bootstrap	
	t value	Df	P value	t value	p value
Moving	0.40	4	0.703	0.4041	>0.1
Foraging	–1.55	4	0.181	1.5541	>0.1
Resting	0.00	4	1.00	0.000	> 0.1
Standing	2.71	4	0.042	2.7136	< 0.1

The resting patterns in both were similar in the fact that both have a one major resting peak, at 0900 hours in blackbuck and 1400 hours in nilgai (Fig. 3.7 and 3.12). There was no significant difference between percentage of time spent in different activities in blackbuck and nilgai during summer, except for standing activity, which was more in nilgai than in blackbuck (p=0.042, Table 3.7).

3.1.6.3 Between Bachelors

Blackbuck and nilgai spent 67.06% and 49% of their time foraging (Fig 3.15). Nilgai (32%) spent more time resting than blackbuck (19.37%). Both spent the same amount of time moving (7.9% and 7.6%). Standing and other activities occurred less than 10% of the time (Fig. 3.15). The temporal allocation of time to foraging differed with blackbuck having three high intensity foraging periods (>75%) at 0800, 1200 and 1700 hours (Fig. 3.5), while nilgai males have a more gradual decrease and increase in foraging (Fig. 3.9). There was no difference in percentage time spent in different activities between males of both species except for resting activity, which was found to be significantly more in nilgai bachelor herds than blackbuck bachelor herds (p=0.010, Table 3.8).

3. 2 RESOURCE USE PATTERN

3.2.1 Ranging Patterns

Blackbuck across all the various classes and social groups traveled a mean distance of 3.5 km through out the day (Fig. 3.16, Table 3.9a,b). Blackbuck herds in summer traveled an average distance of 1.82 km from sunrise to sunset (Fig. 3.18). Nilgai herds in winter and summer traveled a mean distance of 3.76 and 3.88 km, per day (Fig. 3.17, Table 3.9a,b). Nilgai bachelor herds traveled an average of 4.12 km per day (Table 3.9a,b). Daily ranging patterns or the total diurnal distance traveled between blackbuck and nilgai, between habitats, sexes and seasons showed no differences (p=0.166).

Figure 3.15: The percent time spent in different activities between blackbuck bachelor herds and nilgai bachelor herds in grasslands during winter.

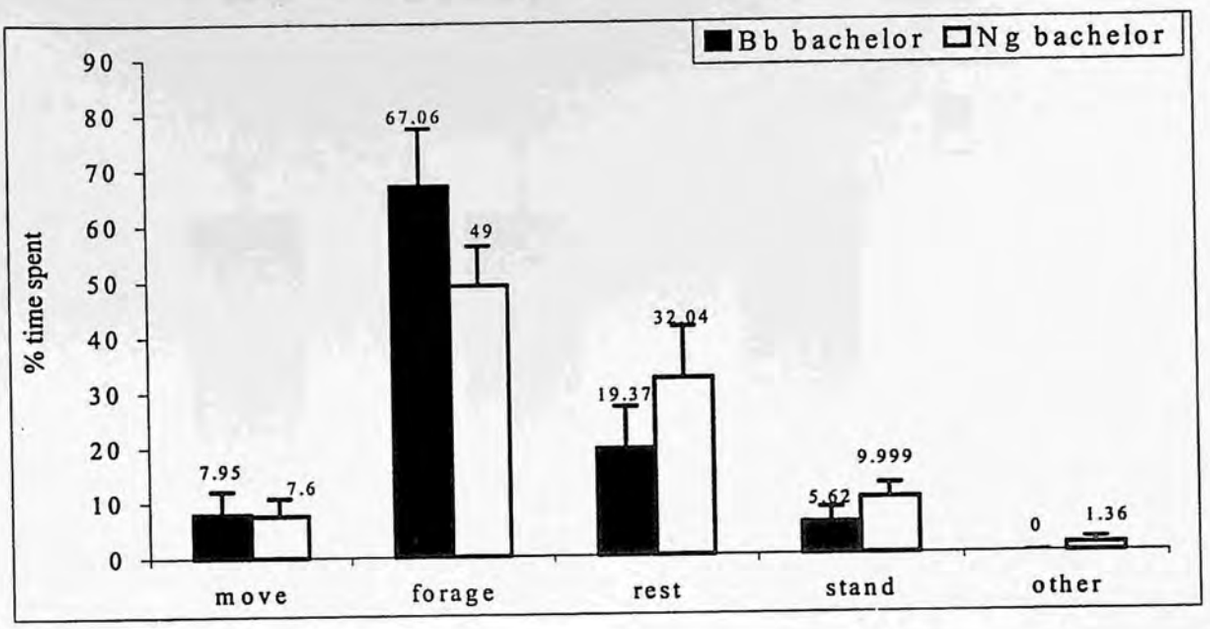


Table 3.8: Comparison of the student t test results and bootstrapped results for blackbuck bachelor herds and nilgai bachelor herds in grasslands during winter.

Behaviour	Students t test			Bootstrap	
	t value	Df	P value	t value	p value
Moving	–1.34	4	0.239	1.3363	>0.1
Foraging	–1.57	4	0.177	1.5714	>0.1
Resting	4.00	4	0.010	4.00	<0.02
Standing	–1.81	4	0.130	1.8091	>0.1

Figure 3.16: The mean length of grazing circuits of black buck in summer & winter

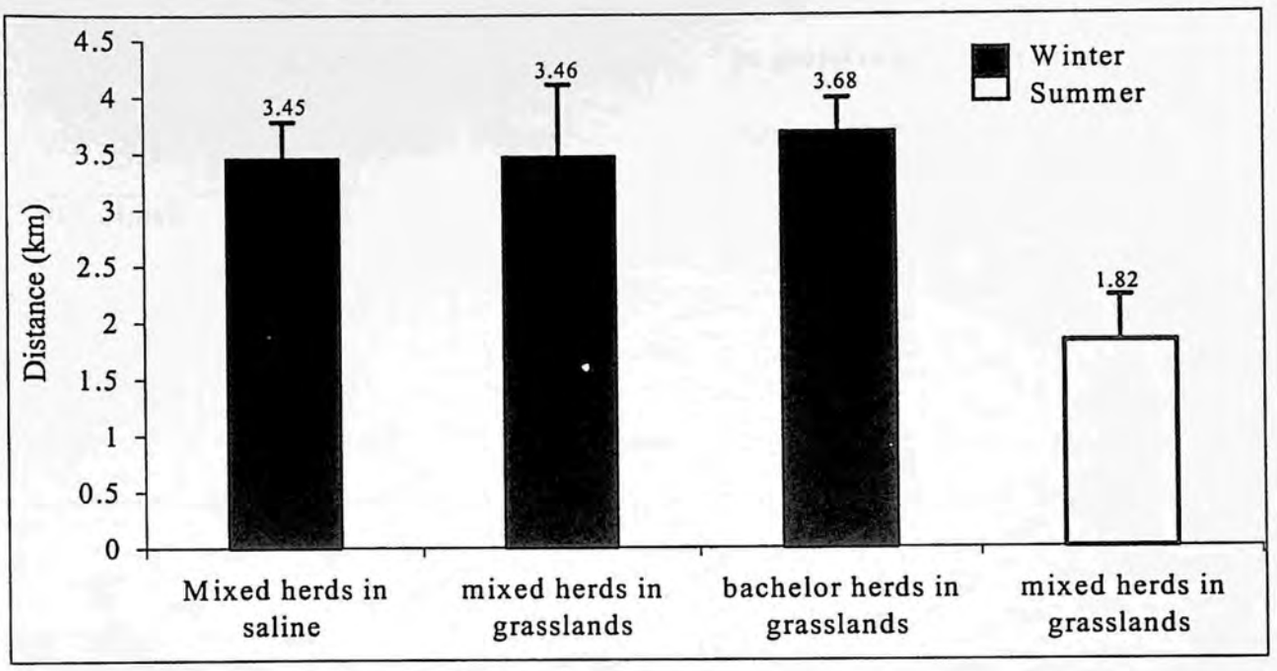


Figure 3.17: The mean length of grazing circuits of nilgai

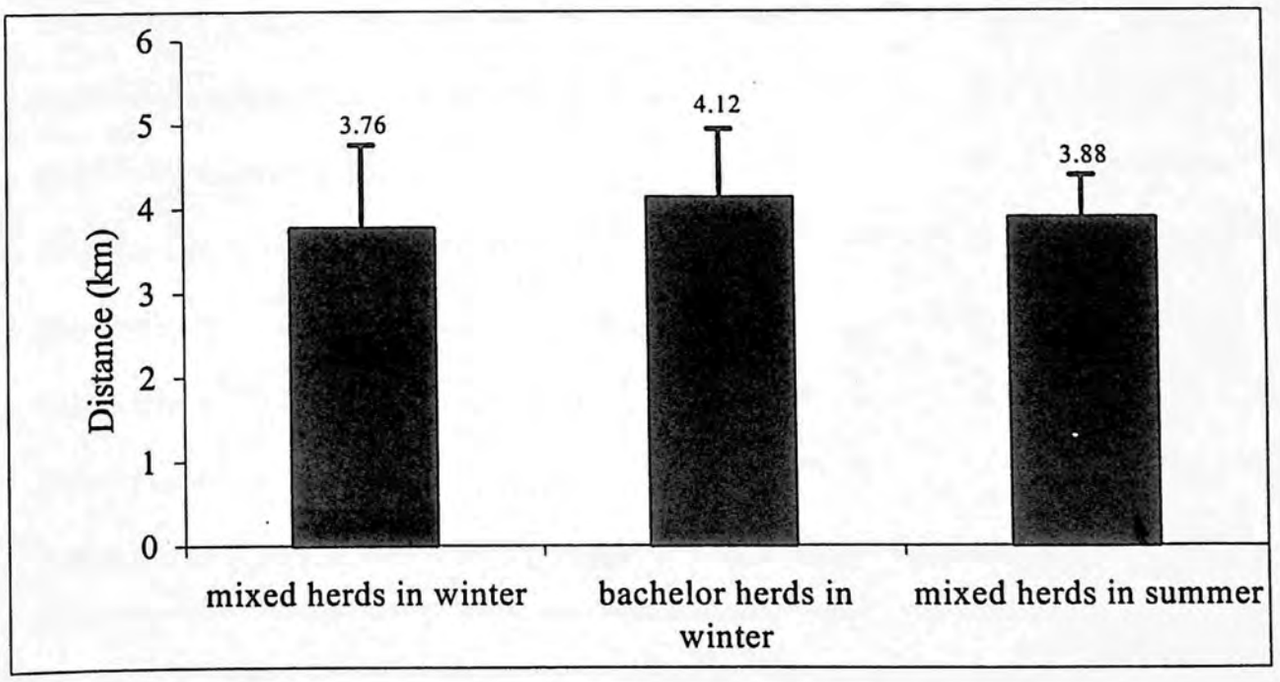


Table 3.9a: Comparison of the average distances moved by blackbuck and nilgai under different conditions

Distance (km)	Mixed herds in grasslands during winter	Mixed herds in saline during winter	Bachelor herds in grasslands during winter	Mixed herds in grasslands during summer
Blackbuck	3.46	3.45	3.68	1.82
S.E	0.643903	0.333339	0.304091	0.399035
Nilgai	3.76	-	4.12	3.88
S.E	0.990717	-	0.817315	0.505106

Table 3.9b: Student t test results of comparisons of grazing circuits of blackbuck and nilgai herds.

Animal category	T value	Df	P value
Blackbuck grassland Vs saline	0.13	6	0.90
Blackbuck mixed groups Vs bachelor groups	-0.39	6	0.709
Blackbuck winter Vs summer	1.67	6	0.139
Nilgai mixed herds Vs bachelor herds	-0.28	4	0.790
Nilgai winter Vs summer	-0.25	4	0.814
Nilgai mixed herds Vs blackbuck mixed herds	0.76	6	0.47
Nilgai summer Vs blackbuck summer	-3.21	4	0.024
Nilgai bachelor herds Vs blackbuck bachelor herds	0.08	4	0.936

3.2.2 Habitat Utilization

The study area vegetation was classified in to eleven types (Table 3.10). Blackbuck herds in different habitats, social groups, and across seasons showed significant differences in vegetation selection (Table 3.11). Mixed nilgai herds, bachelor herds, herds in summer were also found to exhibit a choice in habitat selection (Table 3.11). Comparisons between nilgai and blackbuck mixed herds, bachelor herds and summer herds were also significantly different showing that a selection was made. ANOVA results also found animals to be significantly different from each other in their habitat usage (p=0.0001).

The results of compositional analysis ranked the selection of habitat types in order of selection (Table 2.2, 3.13). There was no significant difference between summer and winter habitat use patterns in blackbuck (Table 3.12, 3.14). Nilgai males and females herds and nilgai winter and summer herds showed similar patterns of habitat use. No differences in patterns of habitat utilization were shown by blackbuck mixed herds and nilgai bachelor herds (p= 0.541) and blackbuck bachelor herds and nilgai mixed herds (p=0.635).

3.2.3 Nutritional index

The mean available nutrition in the whole study area for blackbuck was 472 units (SD: 357). The utilized nutrition ranged from 560.5 to 778.4 units in the various groups of blackbuck (Figure 3.18, 3.19). For nilgai the mean availability was determined to be 515.1 units while the mean utilized nutrition 796, 803.6 and 802.3 units.

Table 3.10: **The percentage area and nutrition value (crude protein/ lignin) of the different vegetation classes in Velavadar National Park**

Vegetation classification	Percentage area	Crude protein / Lignin
Agricultural fallow	20.13503	0.4
P. juliflora dense and moderate	3.198091	0.19
P. juliflora sparse	28.51307	0.19
Saline sparse vegetation	4.695004	0.34
Sueda & chloris communities	14.49199	0.34
Savanna : *P. juliflora, sporobolus madraspetensis S.virginicus*	2.685087	0.214
S. virginicus & S.madraspatensis	4.797917	0.27
Dicanthium annulatum & S.madraspatensis	4.422129	0.37
D.annulatum & S. virginicus	3.486559	0.25
S. virginicus , S.madraspatensis & D.annulatum	9.151438	0.334
D.annulatum	3.706418	0.21

Table 3.11: Chi square test values for habitat use for each category

Categories	χ^2 Value	P value
Blackbuck mixed herds in grasslands during winter	286.68	< 0.001
Blackbuck mixed herds in saline during winter	36.43	<0.025
Blackbuck bachelor herds in grasslands during winter	315.61	< 0.001
Blackbuck mixed herds in grasslands during summer	130.95	< 0.001
Nilgai mixed herds during winter	155.79	< 0.001
Nilgai bachelor herds in winter	257.85	< 0.001
Nilgai mixed herds in summer	211.55	< 0.001

Table 3.13: **The preference ranking of different vegetation classes as determined by compositional analysis for the various blackbuck and nilgai categories.**

	Prosopis dense and moderate	Saline sparse	Sparse *Prosopis*	Sueda & chloris	Savanna	*S.v & S.m*	*D.a & S.m*	*D.a & S. v*	*S. v , S.m & D.a*	*D.a*
Blackbuck males	2	4	1	1	3	6	5	7	7	9
Blackbuck mixed saline herds	3	7	0	9	6	6	1	3	8	1
Blackbuck mixed winter grassland herd	0	1	2	4	6	9	8	5	7	4
Blackbuck mixed summer grassland	3	0	2	1	4	8	5	7	9	6
Nilgai male	2	1	0	4	3	9	8	7	6	5
Nilgai winter	2	4	0	5	7	9	8	6	5	1
Nilgai summer	6	3	4	3	7	8	9	9	4	1

Savanna community of *Prosopis juliflora*, *Sporobolus madraspetensis S.virginicus*; *S.v - S.virginicus*; *S.m. - S. madraspetensis* ; *D.a. - Dicantium annulatum*

Table 3.12: The results of ANOVA for habitat use of blackbuck and nilgai

	Type III Sum of Squares	df	Mean Square	F	Sig.
ANIMAL	393.795	6	65.632	6.930	.000
HABITAT	1227.475	9	136.386	14.400	.000
ANIMAL * HABITAT	1176.241	54	21.782	2.300	.000

Table 3.14: Habitat groups obtained from ANOVA multiples range test (Duncans) for the different animals groups.

ANIMAL	N	Subset				
		1	2	3	4	5
Blackbuck saline	30	-3.008				
Blackbuck summer	30	-2.13143	-2.13143			
Blackbuck grasslands/winter	50		-0.98287	-0.98287		
Nilgai bachelors	30			-0.52348	-0.52348	
Nilgai summer	30			-0.47708	-0.47708	
Nilgai winter	30				0.775504	0.775504
Blackbuck males	30					1.141522
Significance		0.255922	0.136598	0.540899	0.112014	0.635231

Figure 3.18: The mean available nutrition and utilized nutrition index values by the black buck groups (Index crude protein/ lignin x NDVI)

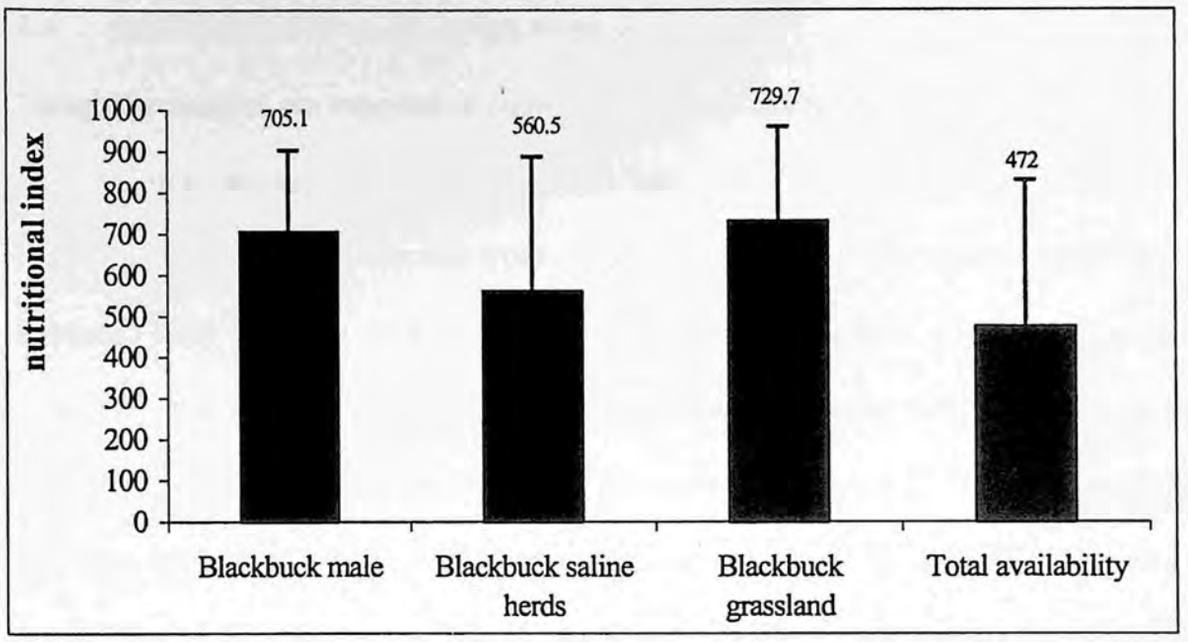
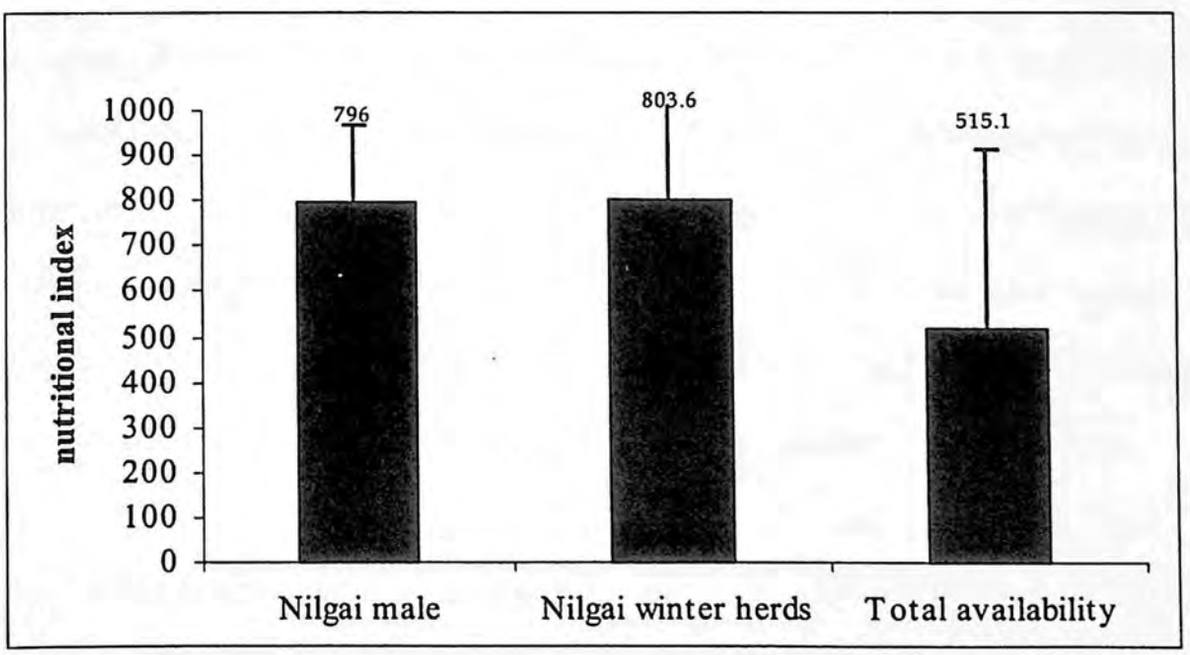


Figure 3.19: The mean available and utilized nutrition index values by the various nilgai groups



CHAPTER 4

DISCUSSION

4.1 DIFFERENCES IN HABITAT USE BY BLACKBUCK

Foraging strategies are expected to change in different habitat types, and in semi arid and arid conditions animals are expected to select their habitats in relation to food distribution (Lawes and Nanni 1993). The two types of habitats in question were grasslands and saline habitats. They differed in the dispersion of resource patches. Grasslands were a continuously distributed resource, with different species forming different communities. Saline areas were relatively patchier, with resources being more clumped and separated by large bare areas. Within a clump several species were present. In this situation availability of resources were more dispersed in the saline region and thus more difficult to obtain relative to grasslands.

There were two choices that could be made depending on the specific blackbuck situation. One could be the distance traveled variable keeping the time spent foraging constant (time minimisers). Another could be the foraging time variable keeping distance traveled constant (energy maximisers) (Shoener 1971). If the first condition is true, distance moved is expected to be more in saline regions due to the dispersal of forage. If the second is true, foraging activity is expected to be more in grasslands, with perhaps more searching or moving behaviour exhibited in saline habitats.

The results show exactly the same trend with moving activity being significantly more in saline habitats than in grasslands. And foraging activity was higher in grasslands than that in saline habitats (Fig 3.1). The total distance traveled by blackbuck was not

different between herds in grasslands and saline, but the difference in movement behaviour was more within a feeding patch. The average distance traveled in a day (3.45km) might have been constrained by distance to water and other crucial resources. Buck blackbuck has been known to have an average home range of about 7.6km^2 (Prasad 1982). The percentage of movement behaviour does suggest that more searching at a micro scale had occurred.

Daily temporal variation in foraging patterns was found to be different between the two habitats as well (Fig. 3.2, 3.3). This is possibly due to the fact that foraging intake is not limited by quantity at a given time period, but is limited by the gut capacity and rumination. While for the saline habitat herds the foraging intake is limited by the amount of forage at a given time period. Thus animals would need to forage continuously to maintain the daily requirement. Since foraging is not intensive at any given time period, activities such as rumination can occur along with foraging and possibly accounts for the less prominent resting periods.

The habitat use pattern of blackbuck mixed herds in grasslands and saline were seen to be different from that of random availability, showing that a choice is being exerted. The grassland and saline herds habitat use patterns were different in reference to the various vegetation classes (Table 3.12, 3.14). When examined closely (Table 3.13) the most selected grass communities for herds in grasslands were *S. virginicus* and *S. madraspatensis* communities and *D. annulatum* and *S. madraspatensis* communities with a crude protein/lignin ratio of 0.27 and 0.37 respectively. While in the saline habitat herds the most selected communities were *Sueda* and *Chloris* communities and *S. virginicus, S. madraspatensis* and *D. annulatum* communities with *Sueda* spp. and *Chloris* spp. having a crude protein/ lignin ratio of 0.80 and 0.33. Thus the crude protein/ lignin ratio is higher

in the saline habitat than in grasslands (Table 3.10). This means that nutrition wise the saline region is more nutritious (Fig. 2.7). The nutritional index of the overall nutrition of the grassland is higher than in the saline (Fig.2.4 and 3.18), but this is simply an outcome of the difference in biomass (Fig. 2.3). Thus in the grasslands the resource is continuous, abundant but not very nutritious, while in the saline habitat it is very patchy and widely dispersed, of low abundance, but very nutritious. Thus this could to an extent make up for the higher foraging levels and larger group sizes in grassland herds, as blackbuck are adapted to surviving on low nutrition communities (pers. comm Y. V. Jhala). Another possible cause is, because of the lower nutrition levels in the grasslands, animals are being more selective and thus spending more time foraging. Of consideration is the large herd sizes varying from 70-300 on average in the grasslands, while much smaller herd sizes of 6-30 animals are found in the saline region. The larger herd sizes in the grasslands are mainly due to the higher abundance of forage, and thus lesser intraspecific competition. Predation pressure should also to a certain extent influence larger groups to form in the grassland herds. Less abundant and very patchy and widely distributed forage would not allow the herd size to be large, though the forage is highly nutritious. Plus predation pressures would be higher in smaller herds, especially in such open and patchy habitats, so vigilance would occur at the cost of foraging. While in the larger grassland herds, lesser time would need to be devoted to vigilance, allowing more time for foraging.

On the whole the foraging time spent by blackbuck herds in saline in less than that spent in grasslands. This is an outcome of a number of factors, such as the dispersion of vegetation in the saline region, cover, nutrition levels in grasses, smaller herd sizes and predation. Overall blackbuck has shown different foraging strategies for resource intake in grasslands and saline habitats.

4.2 DIFFERENCES BETWEEN SEXES IN BLACKBUCK AND NILGAI

Greater feeding time in female ungulates has been attributed to accommodate increased lactation costs (Herman 1977). Or lower feeding time in males to tending females (Clutton-Brock *et al.* 1982, Jarman and Jarman 1973). But red deer were found to spend more time grazing in winter after the rut (Clutton-Brock *et al.* 1982). Examining male and females foraging times without the complication of reproductive costs Bunnell And Harestad (1983) determined that males ungulates on average occupied lower nutritional areas (Barboza and Bowyer 2000), spent less time foraging than females and less time foraging per unit metabolic weight. During the non breeding season male foraging times is 71% of that of females and falls more during the breeding season, but right afterwards its higher than that of females, a recovery period (Bunnell And Harestad 1983). Differential usage of habitats by red deer were slight, difference being mainly in the habitats heavily used by hinds (Clutton-Brock *et al.* 1982).

4.2.1 Blackbuck

In this light, examining the result that males spent more time foraging than that in females, it is possible to speculate that males were preparing for the up coming rutting season. Male costs in lekking are said to be a costly affair (Gosling *et al.* 1987). There are two breeding periods, one in early April and the other in late October. And these males in VNP hardly feed during the lekking season and lose condition quickly (Kavitha Isvaran pers comm).Thus this particular season sampled for males, from January to beginning of March, was in the 'peak' of the body building condition, after the lekking season in October, and before the April season. It is possible that for this purpose males forage more than females.

A point to be considered is that males have been shown to show lower efficiency in foraging based on its allometric relationship to the incisor arcade, female bite sizes were found to be smaller but the bite rate higher (Illius and Gordon 1990, Perez-Barberia and Gordon 1999, see literature review). The feeding intake in blackbuck showed similar rates for males and females (Hudson 1985, Appendix 3). This dimension to male and female allometric relations indicates that females intake could possibly be higher than that indicated in a comparison of foraging time.

The habitat use pattern between bachelor herds and mixed herds were found to be significantly different in terms of use of different vegetation communities (Table 3.13 and 3.12). With males feeding more on *D. annulatum* based communities with crude protein/ lignin ratios (CP/L ratio) of 0.21, 0.33 and 0.24 and females feeding more on *S. virigicus* and *S. madraspatensis* communities with CP/L ratios of 0.27 and 0.37. Overall the nutritional index values were slightly higher in females than in males (Fig. 3.18). Thus females maybe foraging more selectively than males. Possibly this higher selection could effectively reduce the foraging time spent in females.

Bachelor herds were found to be foraging significantly more than mixed herds. But when the utilized nutritional level was examined the amount of nutrition utilized by mixed herds was slightly more than in bachelor herds (Fig. 2.5, 2.7). A number of possible reasons exist for the differential habitat selection of males, compared to females. One is related to dimorphism in blackbuck. Where larger bodied males are able to forage on coarser forage, as their rumen capacity in larger and therefore allows longer retention and greater utilization of fiber for energy (Barboza and Bowyer 2000). Possibly this effect coupled with more selectivity due to coarser forage, could be responsible for triggering

increased rates of foraging in bachelors. Another reason affecting male habitat selection in Velavadar National Park is predation. Male blackbuck are predominantly predated upon (Jhala 2000). Male activity is concentrated near habitation where wolf activity is less, to avoid predation to an extent (pers comm. Y. V. Jhala). Above all the upcoming rutting season could be one of the main reasons responsible for the difference in foraging time between male and female blackbuck.

4.2.2 Nilgai

In nilgai as mentioned above, trends showing female foraging time to be higher was expected. Nilgai being dimorphic in body size, their foraging time was found to be different (Table 4.1). But the results showed no significant differences between males and females. This could just be attributed to the difference in social organisation. Nilgai are known to have a linear heirachy or harem formations, with a rutting season from December to February in Texas (Sheffield *et al.*1983) and October to February in India (Bohra *et al.* 1992, Schaller 1967). Thus the breeding strategy in nilgai is different than in blackbuck in Velavadar National Park, which follow mainly a lekking system. Due to linear hierachy, most males in a bachelor herd do not get the opportunity to mate, and a single male dominates. And from my observations in Velavadar National Park only one or a maximum of two females in a herd were courted at one time. Which could indicate that only one to two females came into oestrus at a time in a herd. This would allow for one male to monopolise a female. Thus for the dominant male, breeding costs might be high, but would not reflect in the activity of the bachelor herd. Females are expected to show more percentage foraging time taking in to consideration the body size hypothesis (Hudson 1985, Bunnell and Gillingham 1985, Owen-Smith 1988). But on the whole the observed pattern, in terms of percentage activity or temporal variation in foraging does not fit the expected pattern.

Table 4.1: Value for the various foraging related activities of nilgai and blackbuck. Equation Y= aW^b was used to derive the values for the following categories for nilgai and blackbuck.

		male nilgai	female nilgai	Male blackbuck	female blackbuck
foraging time	% 24hr	37.2073	36.01976	32.23859	31.50511
Foraging +ruminating time	% 24hr	85.15739	82.10586	72.47509	70.62269
Foraging radius	km	17.91078	15.22923	8.746897	7.79612
Home range	ha	615.9469	407.3148	99.0442	73.85697
Feed intake	kg/d	4.651542	3.362978	1.109369	0.881302
Ruminating capacity	g ell wall/min	4.8	3.2	0.8	0.6

Source of equation and 'a' and 'b' values: Hudson 1985;

Source of nilgai male and female body weight: Sheffield *et al.* 1983.

Source of blackbuck male and female body weights: Y. V. Jhala pers. comm.

The grazing circuits of male (4.12 km) and female (3.76 km) nilgai showed no difference (Table 3.9). The habitat use patterns between male and female nilgai showed no difference, with both mainly selecting *S .virginicus* and *S. madraspatensis* communities and *D. annulatum* and *S. madraspatensis* communities (Table 3.14). When the nutritional utilization was examined females were found to be slightly more selective than males (Fig. 3.19). This could also be attributed to the larger body size in males and the ability to forage on coarse more fibrous forage (Barboza and Bowyer 2000). Overall there was no significant difference in either foraging behaviour or in habitat usage amongst nilgai males and females.

A fact to be kept in mind is the fact that nilgai are intermediate feeders, more browser than grazer. In the *Bhal*, nilgai are known to raid crops consistently. But the present study was conducted, during an ongoing two year drought. Most crop fields were fallow except a few small plots of *Sorghum* spp., which were mainly meant for domestic cattle feed (A. Aiyadurai pers comm). It is possible that due to the sheer scarcity of resources and low protein content, that the species itself is foraging at the minimum required level.

4.3 SEASONAL DIFFERENCES IN BLACKBUCK AND NILGAI

Seasonal differences bring in the question of resource scarcity. Considering the on going drought in the land and that the growth period after monsoon might have been minimal. In red deer grazing time is longer when food is less in winter. This was associated with a reduction in ingestion rates (Clutton-Brock *et al.*1982)

4.3.1 Blackbuck

The data shows that only foraging behaviour was significantly less in summer. Blackbuck were also found to move considerably less (1.82 km) in summer than in winter (3.46 km) (Table 3.9). Moving activity was slightly higher, in summer (Fig. 3.6), but since total distance moved was less, thus showing that in summer searching behaviour was more. According to Jhala (1991) blackbuck in Velavadar National Park considerably decrease their total forage consumption as it becomes more and more unprofitable to process with crude protein levels falling to 3.6% in summer, resulting in them losing more proteins than what it gains. Seasonal lows in forage quality become even more pronounced during droughts, together with limiting grazing areas (Jhala 1997). Thus these results are in accordance with that study.

The habitat use patterns for blackbuck in winter and summer were not found to be different (Table 3.12, 3.14). Summer herds selected *S.virginicus, S.madraspatensis* and *D.annulatum* communities, *S.virginicus, S.madraspatensis* communities and *D.annulatum* and *S. virginicus* communities (Table 3.13) with crude protein levels of 3.44, 3.73 and 3.28 respectively. But the crude protein/lignin levels were found to be 0.15, 0.16 and 0.19, which is much lower as compared to the winter CP/L ratios of 0.27 and 0.37. Thus lower foraging levels would indeed mean that blackbuck are less selective, and thus conforming to the above hypothesis.

Overall the foraging behaviour has decreased in summer but the pattern of habitat use was not changed between winter and summer, most possibly affected by the change in strategy as mentioned above.

4.3.2 Nilgai

Winter and summer habitat utilisation patterns were found to be the same in nilgai (Table 3.13 and 3.14). No change in selection was observed in both seasons. Foraging time was found to increase in summer (Table 3.11). It is possible that though the nutrition level of the forage decreased in summer, the proportional decrease would be the same. Therefore, it should still be higher than in other vegetation types. *P. juliflora* pods were borne in March-April (pers. obs.). And this could help overcome the low forage nutrition, and explain why there was no differential habitat usage. The increase in foraging time, could be attributed to more selection. It is also possible that nilgai has not become more selective as the resources became more and more scarce. It is possible that for nilgai the maximal nutrition utilization levels was already reached in winter. Nilgai, foraging mostly on browse, this sort of situation could be highly constrained by quality. More selectiveness would be necessary, with decreasing nutrition, thus the observed increase in foraging time.

4.4 DIFFERENCES BETWEEN BLACKBUCK AND NILGAI

The different strategies of the two species have various implications for foraging behaviour. Nilgai, would classify as an intermediate feeder and blackbuck would fall in the category of small bodied selective roughage feeder (Jarman 1974, Hoffman and Stewart 1972). Selective feeders are faced with a more patchy resource, while intermediate feeders are faced with a relatively more continuous resource (Jarman 1974). The fact that blackbuck is a small bodied antelope and nilgai is much larger brings the body size hypothesis in to the picture as well. (see literature review). Another factor to be kept in mind is that large sized animals such as nilgai are least constrained by predators and also due to their higher energy requirements tend to be more active over 24 hours than smaller bodied animals.

4.4.2 Mixed herds and bachelor herds

When blackbuck and nilgai mixed herds were compared foraging behaviour was found to be more in blackbuck than in nilgai. Blackbuck are coarse bulk feeders, and they are adapted to poor resource conditions. Thus their foraging level is adapted for the prevailing drought conditions. But they could possibly be increasing their selectivity, as shown by their increased foraging time. Meanwhile nilgai are browsers/intermediate feeders, who need a more qualitative diet. Thus they are probably unable to consume larger amount of coarse forage. It is possible that they could be restricting themselves to minimal amounts of necessary forage and supplementing their diet with *P.juliflora* pods. This could explain why they are spending less time foraging. Blackbuck bachelor herds and nilgai bachelor herds showed no difference in foraging time of any consequence.

The temporal variation of foraging time between blackbuck and nilgai is insightful, showing the different constraints that act upon the animals (Fig 3.2 and 3.10). The basic blackbuck foraging pattern has three foraging and two resting peaks. This corresponds with its gut capacity, since it is a small bodied animal (Demment 1982, Demment and Van Soest 1985). Thus blackbuck would be constrained by the amount of intake, after which it must ruminate and empty its gut, to be able to forage again. Nilgai, are much large bodied with a larger gut, which explains their ability to have feeding sessions of much longer duration, and therefore the resting/ruminating periods has to be of longer duration. Interestingly previous studies have found blackbuck to have two foraging peaks, one in the early morning till late morning and the second in the evening, going past sunset (Bohra *et al.* 1992 and Pandey *et al.* 1986).

There was no difference in habitat use patterns between the two species. When the nutritional utilization was compared it was found to show that nilgai were more selective than blackbuck. Nilgai bachelor herds and blackbuck mixed herds were found to show no difference in their selection of different habitat types (p=0.54). And blackbuck bachelor herds and nilgai mixed herds also showed no difference in their usage of different vegetation types (p=0.635). The utilized nutritional level in nilgai male and females was much higher than the respective overlapping blackbuck category, even though the vegetation type selection was similar (Fig. 3.18 and 3.19). This confirms that the qualitative requirement for nilgai is much higher than that of blackbuck, and that they are maximising on nutritional than on total amount of forage.

4.4.3 Seasonal differences

During summer there was no significant difference between nilgai and blackbuck. This is possibly attributable to the fact that blackbuck are foraging less than they were in winter. And nilgai, foraging at their minimal requirement, are being more selective due to the further decrease in forage quality, thus increasing the overall foraging time. The temporal distribution of foraging time shows a more consistent foraging curve, with more animals foraging at any given time than in winter (Fig. 3.12).

The habitat use patterns of the two were significantly different. Blackbuck were utilizing more *S.virginicus, S. madraspatensis* and *D. annulatum* mixed communities and *S. virginicus* and *S. madraspatensis* comunities while nilgai were using more *D.annulatum* and *S.viginicus* communities along with *D. annulatum* and *S. madraspatensis* communities. The crude protein values, were 3.44 and 3.73 for blackbuck and 3.28 and 3.26 for nilgai, and were not very different from each other. But the crude protein/ lignin ratios were 0.15 and 0.16 for blackbuck and 0.19 and 0.216 for nilgai. Thus nilgai were utilizing more nutritious forage. The difference for the two species is

that blackbuck are adapted to lower quality forage and have devised a strategy of foraging less than in winter (Jhala 1997). While in nilgai the problem is one of quality, as they are mainly browser-intermediate feeders. Thus they are selectively foraging on more nutritious less coarse forage.

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* not referred to in original.

Appendix 1

Percentage utilization of difference vegetation classes by blackbuck and nilgai from November 2000 to April 2001in Velavadar National Park.

	2	3	4	5	6	9	10	12	13	14
Blackbuck male	5.218392	0.001	1.74013	0.001	0.002	0.001	7.826087	2.608695	9.565217	47.82609
Blackbuck male	0.002	0.001	12.001	0.001	0.002	0.001	0.001	0.001	13.33333	28
Blackbuck male	0.654595	0.001	0.002	0.001	7.843137	0.001	22.87582	16.33987	10.45752	20.26144
Blackbuck saline	15.50488	0.001	18.60465	0.001	19.37985	1.550387	13.17829	0.775194	0.001	31.00775
Blackbuck saline	15.001	0.001	37.77778	0.001	31.11111	4.444445	5.555555	0.001	0.001	6.111111
Blackbuck saline	16.07143	0.001	27.38095	3.571429	32.7381	2.380952	3.571429	0.001	1.785714	12.5
Blackbuck summer	3.334333	0.001	0.002	0.001	0.002	0.001	23.33333	0.001	6.666665	51.66667
Blackbuck summer	10.7448	0.001	0.827446	0.001	0.002	0.826446	15.70248	3.305784	10.7438	47.10744
Blackbuck summer	2.565102	0.001	0.002	0.001	0.002	0.001	23.07692	8.974359	10.25641	50
BB winter grassland	10.05391	16.93122	2.646503	2.116402	3.703703	1.058201	6.349206	1.587301	23.80952	30.15873
BB winter grassland	7.774852	0.001	18.0222	0.001	9.540636	0.001	1.06007	0.001	0.353357	38.5159
BB winter grassland	5.295118	0.001	2.648059	0.588235	14.70588	4.705882	34.70588	14.70588	5.294118	16.17647
BB winter grassland	17.92553	0.001	2.831188	0.001	0.002	0.001	8.490566	1.886792	12.26415	54.71698
BB winter grassland	7.459563	0.001	0.553486	0.828729	4.42089	9.668508	33.70166	19.61326	4.41989	18.78453
Nilgai male	2.420354	0.001	0.002	0.001	2.420354	0.001	36.29032	20.16129	8.870968	22.58065
Nilgai male	7.246377	0.001	8.695652	0.001	11.5942	1.449275	21.73913	26.81159	9.42029	13.04348
Nilgai male	14.55224	3.358209	17.91045	2.61194	14.1791	2.238806	14.1791	6.343283	4.104477	12.68657
Nilgai summer	1.734104	0.001	3.469208	0.001	16.76401	4.046243	29.47977	28.90173	10.40462	5.202312
Nilgai summer	6.016038	0.001	7.518797	0.001	23.30827	10.52632	34.58647	9.022556	0.001	9.022556
Nilgai summer	4.317547	0.001	5.03597	0.719424	10.79237	9.352518	33.09352	15.82734	11.51079	9.352518
Ng winter grassland	3.376527	29.53586	24.05163	5.063291	5.063291	2.531646	3.375527	10.12658	10.97046	4.64135
Ng winter grassland	1.124595	5.05618	0.002	1.685393	2.808988	7.865169	24.7191	25.8427	20.78652	10.11236
Ng winter grassland	6.141351	0.001	4.385964	0.001	6.140351	9.649122	38.59649	20.17544	12.2807	2.631578

1-*Prosopis* dense and moderate;2-Saline sparse; 3-Sparse *Prosopis;* 4-Sueda & chloris 5-Savanna:*Prosopis juliflora, sporobolus madraspetensis sporobolus virginicus*; 6- *S.virginicus*; *S. madraspetensis* 7- *Dicantium annulatum & S. madraspetensis* ; 8- *Dicantium annulatum & S.virginicus*; 9- *S.virginicus*; *S. madraspetensis & Dicantium annulatum* 10- *Dicantium annulatum*

APPENDIX 2

Log transformed percentage utilization of difference vegetation classes by blackbuck and nilgai from November to April in Velavadar National Park.

	2	3	4	5	6	9	10	12	13	14
Blackbuck male	0	-8.55994	-1.09823	-8.55994	-7.8668	-8.55994	0.405273	-0.69334	0.605944	2.215382
Blackbuck male	0	-0.69315	8.699598	-0.69315	0	-0.69315	-0.69315	-0.69315	8.804875	9.546813
Blackbuck male	0	-6.48402	-5.79087	-6.48402	2.483378	-6.48402	3.553819	3.217347	2.77106	3.432459
Blackbuck saline	0	-9.64891	0.182257	-9.64891	0.223079	-2.30265	-0.16258	-2.9958	-9.64891	0.693083
Blackbuck saline	0	-9.61587	0.923604	-9.61587	0.729448	-1.21646	-0.99332	-9.61587	-9.61587	-0.89801
Blackbuck saline	0	-9.6848	0.532805	-1.50408	0.711496	-1.90954	-1.50408	-9.6848	-2.19722	-0.25131
Blackbuck summer	0	-8.11203	-7.41888	-8.11203	-7.41888	-8.11203	1.94561	-8.11203	0.692847	2.74054
Blackbuck summer	0	-9.28218	-2.56383	-9.28218	-8.58903	-2.56504	0.379396	-1.17875	-9.3E-05	1.478009
Blackbuck summer	0	-7.84975	-7.15661	-7.84975	-7.15661	-7.84975	2.196835	1.252373	1.385905	2.970025
BB winter grassland	0	0.521197	-1.33472	-1.55824	-0.99863	-2.25139	-0.45963	-1.84593	0.862124	1.098513
BB winter grassland	0	-8.95865	0.84071	-8.95865	0.204666	-8.95865	-1.99256	-8.95865	-3.09117	1.600177
BB winter grassland	0	-8.57454	-0.69296	-2.19741	1.021462	-0.11797	1.880124	1.021462	-0.00019	1.116773
BB winter grassland	0	-9.79398	-1.84553	-9.79398	-9.10083	-9.79398	-0.74727	-2.25135	-0.37955	1.115948
BB winter grassland	0	-8.91725	-2.60102	-2.19736	-0.52316	0.259377	1.50805	0.966709	-0.52338	0.923537
Nilgai male	0	-7.79167	-7.09852	-7.79167	0	-7.79167	2.707637	2.11985	1.29887	2.233179
Nilgai male	0	-8.88826	0.182322	-8.88826	0.470004	-1.60944	1.098612	1.308333	0.262364	0.587787
Nilgai male	0	-1.46634	0.207639	-1.71765	-0.02598	-1.8718	-0.02598	-0.83035	-1.26567	-0.1372
Nilgai summer	0	-7.45825	0.693436	-7.45825	2.268743	0.847298	2.833214	2.813411	1.79176	1.098612
Nilgai summer	0	-8.70218	0.222977	-8.70218	1.354379	0.55945	1.749034	0.405299	-8.70218	0.405299
Nilgai summer	0	-8.37044	0.153919	-1.79199	0.916152	0.772958	2.03665	1.299051	0.980598	0.772958
Ng winter grassland	0	2.168757	1.963355	0.405169	0.405169	-0.28798	-0.0003	1.098316	1.178359	0.318157
Ng winter grassland	0	1.503188	-6.33203	0.404576	0.915401	1.945021	3.090153	3.134605	2.916881	2.196335
Ng winter grassland	0	-8.7228	-0.33664	-8.7228	-0.00016	0.451822	1.838117	1.189421	0.692984	-0.84746

1-*Prosopis* dense and moderate;2-Saline sparse; 3-Sparse *Prosopis;* 4-Sueda & chloris 5-Savanna:*Prosopis juliflora*, *sporobolus madraspetensis sporobolus virginicus*; 6- *S.virginicus*; *S. madraspetensis* 7- *Dicantium annulatum & S. madraspetensis* ; 8- *Dicantium annulatum & S.virginicus*; 9- *S.virginicus*; *S. madraspetensis & Dicantium annulatum* 10- *Dicantium annulatum*